MULTIPURPOSE VACUUM CHAMBER - AUTOMATION, INTERLOCK-SYSTEM AND SELF-OPERATING VACUUM ROUTINES

R. M. Caliari*, H. G. P. Oliveira, G. L. M. P. Rodrigues, C. H. Tho,
Brazilian Synchrotron Light Laboratory, Campinas, Brazil

Abstract

The LNLS' Beamlines Engineering Group is developing new technologies for SIRIUS Beamlines. To validate and test those technologies, the group has previously worked in a Multipurpose Vacuum Chamber (MPVC). This chamber has a powerful pumping system, several viewports, feedthroughs, RGA and a cryocooler system installed. This configuration delivery a very flexible test environment and relative short pump time to achieve UHV conditions, essential to reduce the test and validation time.

This paper will detail the MPVC automation structure, presenting the state machines, interlock logic and other diagrams that exemplify the automatic routines concepts. Operations like pumping from atmospheric pressure to HV, ionic pump flash and ventilation routines are automatic.

The automated system was developed in LabVIEW, using a cRIO and Touch Panel interface. Based in Ethernet connection and published shared variables, the system has a friendly user interface and archiving for the main variables.

The system was developed in a multi user collaborative ambient. The paper will show the advantages and disadvantages we faced working with LabVIEW as multiuser development tool.

INTRODUCTION

This work presents de project of a multipurpose vacuum chamber for the beamline engineering group at LNLS, dedicated for new beamlines projects for Sirius, the new Brazilian 4th generation synchrotron [1, 2]. Monochromators [3], KB Mirrors, Front Ends [4] and many others. The first experimental results were already presented on previous conferences [5].

SYSTEM PURPOSE AND DESIGN

The Beamline Engineering group started the mechanical design on early 2015, aiming one flexible environment, with some principal characteristics:

- Ultra-high vacuum (UHV) environment (target: 10-11 mbar with backing procedure and 10-8 mbar without baking);
- Low vibration environment;
- View ports in different angles, to make it flexible to implement optical instrumentation from outside the chamber;
- Low diffraction coefficient viewport from VAb Vakuum-Anlagengau, for interferometer characterization from outside;
- Many power, signal and temperature feedthroughs;
- Cryogenic support system;
- Residual Gas Analyser;
- Complete automation operation;
- Safety system;
- Low electrical noise environment;
- IPS protection for main components.

Those characteristics were obtained as foreseen requirements for the future development projects, for the new Sirius beamlines, their prototypes and concept proves. The automated routines are the base for a pump station under development, which's mechanical sketch shall be similar to some published works [6].

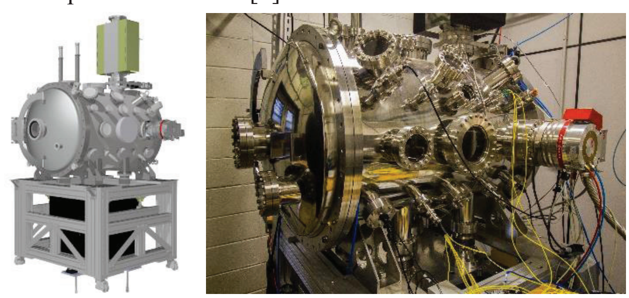

Figure 1: 3D model and actual picture of the Multipurpose Vacuum chamber, a flexible environment for the beamline engineering group.

The detailed design was made, and the 3D model can be seen in Figure 1. The group experience conducted the project for a big UHV chamber (800 mm diameter and 1000 mm depth), and simulations were made to ensure a robust low vibration environment Figure 2.

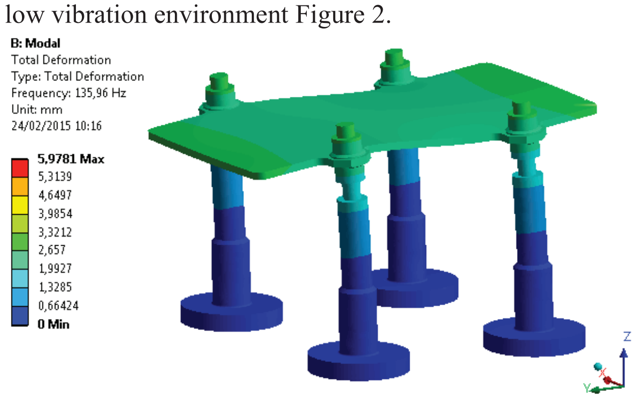

Figure 2: Modal Analyses to guaratee the low vibration environment (first vibration mode).

With the requirements and mechanical projects set, the final release, with hardware, software and interfaces solutions are presented on this text.

* ricardo.caliari@lnls.br

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HARDWARE

Vacuum Instrumentation

The selected vacuum pumps and instruments are:

- Mechanical pump: Pfeiffer ACP 40
- Turbomolecular pump: Pfeiffer HiPace 7000
- Ionic pump: Agilent 500 L/S-VACION PLUS 500
- Titanium sublimation pump: Agilent TSP
- Getter pump: SAES Getter NexTorr D2000
- Vacuum sensor: Vacom MVC3-BM
- RGA: Standford Research RGA 200

With the selected system, the pressure level of 10^{-3}mbar can be reached in about 8 minutes (with mechanical pump), that should be enough for the cryogenics preliminary evaluations, for example. The final pressure of about 10^{-8} mbar can be reached in about 8 hours with turbomolecular pumping. The Ionic system can be used for low vibration operation in UHV.

Control Hardware

Hardware and software solutions from National Instruments were chosen for this system. The previous experience of many group members on LabVIEW programing and the hardware flexibility were essential for this choice.

The cRIO platform with FPGA was elected (Figure 3). The FPGA card was used to implement an interlock safety routine and an Ethernet based application run the end user interface. The I/O's and platform specifications are:

- NI 9148: Ethernet controller with integrated FPGA
- NI 9871: RS-485 serial interface 4 Ch module
- NI 9477: 60 V, Sinking Digital Output 32 Ch module
- NI 9425: 24 V, Sinking Digital Input 32 Ch module
- NI 9215: ±10 V Analog Input, 16 bits, 4 Ch module
- NI 9217: RTD PT100, 4 Ch module

In order to make a robust interface between the platform and the instrumentation, two break-out-boxes were projected by the Electronics Support Group, in LNLS. One was installed inside the electronic rack and the other directly by the chamber. Robust cables and connectors were chosen to make the interface. Feedthroughs from MDC Vacuum and Accu-glass make the insertion of those signals into the UHV chamber.

AUTOMATION SYSTEM

Interlock and Safety Routines

To guarantee a safety operation, an interlock routine was implements into the FPGA card presented on the main controller. This is the last hardware layer before the instruments I/O's. The really high speed processing (40 MHz clock) and real parallel characteristics of the FPGA ensure the safety operation, with really small event time response.

The FPGA programming was much easier using the LabVIEW user interface. An easy logic between the most important I/O's was defined to look for every input. This routine deals with problems like: safety button interface, energy power lost, pressure levels watch (to guarantee safety operation of turbomolecular, ion, titanium and getter pumps).

Data Logging and Tends

The data logging is one of the most important features for the future tests. Using the pressure sensors, the analog input and the RS-485 interface, the system can save the pressure data with a resolution of some mili-seconds. Some pumping data can be seen in Figure 4.

Figure 3: Schematic representation of the interface hardware, using NI cRIO with FPGA card, NI LabVIEW in virtual machine, data bank in central Storage System and NI Touch Panel for final user interface.

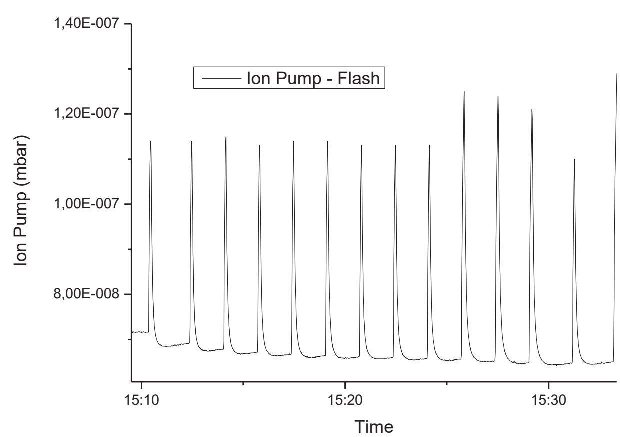

Figure 4: Ion pump pressure over time, using automated routine.

Project Structure

The program was implemented based on Ethernet communication, using the LabVIEW Shared Variables. The NI Distributed System Manager was an essential tool during debug phase, to verify the integrity of all variables. Figure 5 shows the project structure in LabVIEW Project.

The program works with different Sub-VI's running in parallel with the main program, at the host PC. These VI's coordinates the RS-485 communication with each controller. Suppliers have its own protocol and most of them were not available for LabVIEW. The implementation library was developed in this project and a stable version was updated on the NI Forum community.

The Hardware is used in a hybrid mode, were part of the chasis is running in FPGA mode and part using the Scan Interface. This solution was chosen to keep just the critical

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I/O’s running on the FPGA target and being processed at the safety routine. The lower speed I/O’s (temperature sensors, for example) communicates directly with the host.

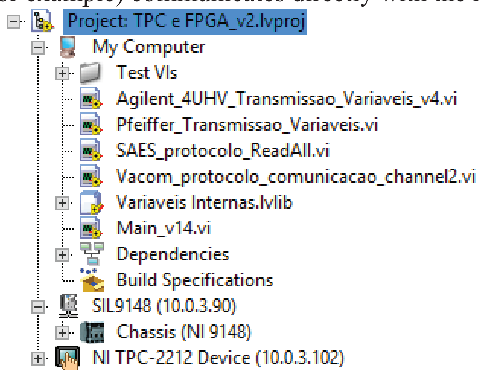

Figure 5: LabVIEW project structure, showing the VI's parallel running on the control computer, the control chassis, containing the FPGA interlock routine and the Touch Panel Controller, with the user interface.

Vacuum Automatic Routines

The main used vacuum pumping routines were automated. Those procedures were implemented to make the day life of the test engineers and technicians easier at the test shop. Another purpose of this implementation was the automation prototype for the future automatic pump stations for the Sirius beamlines. Those stations are already under development.

The automated routines are:

- Pumping: taking the system from atmospheric pressure to high vacuum level (10^{-8}mbar).
- Venting: take the system from any vacuum level to atmospheric pressure.
- Ionic pump flash: start the ionic pump operation, flashing it before the continuous operation.

Those routines were implemented in the high level application, using LabVIEW. They are always watched for the safety system and make the interface with the pump controllers.

One result can be seen in Figure 4, were the ion pump flash routine is shown. Figure 6 shows the user interface for the Touch Panel, installed at the control rack.

LESSONS LEARNED

The cooperative development using LabVIEW was really difficult to manage. About three people worked together on the software development. LabVIEW provided a really poor platform for parallel development. Therefore, the programmers should work in different sub-Vis and merge the code by their own.

The project operation relies in almost 100 shared variables, the use of the NI distributed system manager was essential at the debug phase. The non-initialization of these variables generated many issues and strange errors.

The National Instruments local support and Internet Forum community were once more fast and helpful to solve the doubts during the development phase.

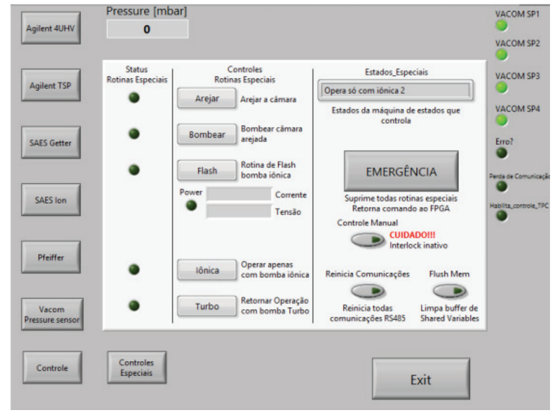

Figure 6: User interface, with the automated routines and special controls view.

RESULTS

Many results were already obtained using this test facility. A historic behaviour of the residual gas (example, Figure 7) into the chamber, over the performed tests, can indicate any kind of contamination and also perform specific vacuum compatibility characterization tests.

Formal outgassing analysis were made based on CERN procedures [7], the results were compared with NASA open databank [8] and the internal procedures validated.

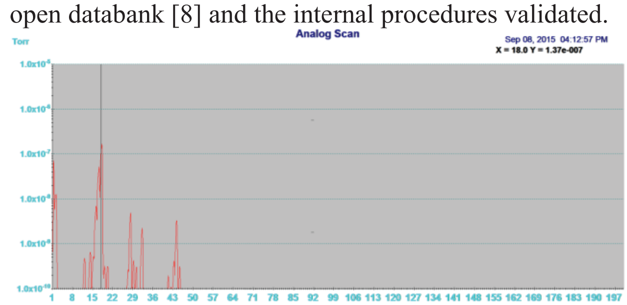

Figure 7: Analog scan using the RGA at a total pressure of about 10^{-7}mbar.

CONCLUSIONS

The system was successfully implemented and tests are being conducted on a stable environment. A beta version started the operation for vacuum experts on October 2015 and the first stable version was set at the really end 2015. Since then, about three big improvement maintenances were already conducted and the system could be really improved. The automated routines are working fine. The implemented logic is under revision and shall be the base for the automated pump station for Sirius Beamlines.

Over the past months, many tests were conducted and a historical database is now populated. Those data provide a much better comparison tool for future tests and an incremental quantitative evaluation for subsystems, like the first high-dynamics DMC prototype.

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