ALBA HIGH VOLTAGE SPLITTER - POWER DISTRIBUTION TO ION PUMPS

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Abstract

High Voltage Splitter (HVS) is an equipment designed in Alba that allows a high voltage (HV) distribution (up to +7kV) from one ion pump controller up to eight ion pumps. Using it, the total number of high voltage power supplies needed in Alba's vacuum installation has decreased significantly. The current drawn by each splitter channel is measured independently inside a range from 10nA up to 10mA with 5% accuracy, those measurements are a base for vacuum pressure calculations. A relation, current-pressure depends mostly on the ion pump type, so different tools providing the full calibration flexibility have been implemented. Splitter settings, status and recorded data are accessible over a 10/100 Base-T Ethernet network, none the less a local (manual) control was implemented mostly for service purposes. The device supports also additional functions as a HV cable interlock, pressure interlock output cooperating with the facility's Equipment Protection System (EPS, ref: [1]), programmable pressure warnings/alarms and automatic calibration process based on an external current source. This paper describes the project, functionality, implementation, installation and operation as a part of the vacuum system at Alba.

INTRODUCTION

Alba's vacuum system contains 458 7kV ion pumps, 392 of them were selected to be supplied by HVS-s, it means that 392 HV outputs had to be distributed in the different positions of the machine, in the most efficient way and reducing costs for the HV cables. The best installation topology was designed and finally 83 HVS units were produced and installed, “20x8channel” supplying the booster and “63x5channels” supplying the storage ring, front ends and linac.

High Voltage Splitter was a collaborative project between Q-Lambda company [4] which developed a current measuring solution (sensor) under the high voltage, Vacuum Section in Engineering Division which provided necessary theoretical assumptions and calculations, R&D Section in Engineering Division which managed mechanical design, Electronics Section in Computing Division [2] which developed the project, managed a HV current sensor evaluation, upgrades and troubleshooting, and Control Section in Computing Division which developed a TANGO control system.

IMPLEMENTATION

HVS contains two systems: low voltage electronics which manages data processing, control, communication, and high voltage electronics which supplies ion pumps, splits the high voltage and measures the current consumption of ion pumps.

A typical HVS application is presented in Figure 1. The standard arrows show an Ethernet data flow, while a user records pressure measurements each second. The big arrows depict the high voltage distribution from one high voltage power supply to eight ion pumps. The checked arrows provide a basic implementation storing time related data into a database.

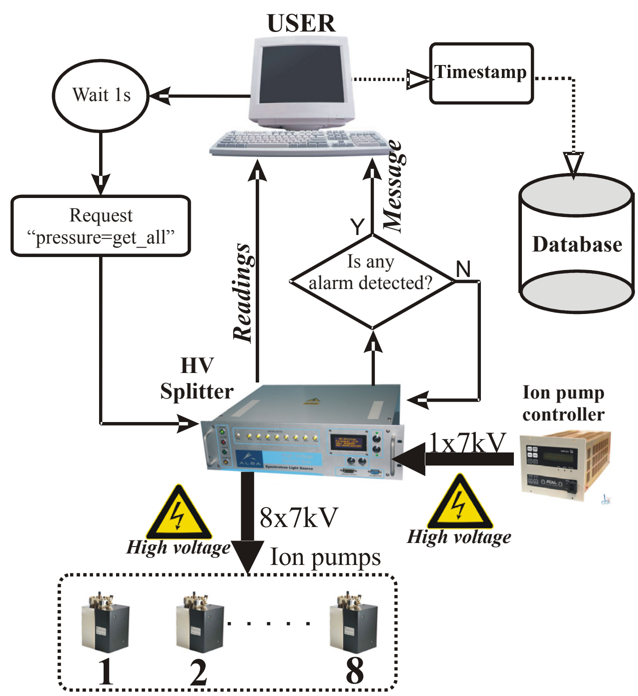

Figure 1: Typical application.

During this process, the current drawn by each HV channel is measured independently.

PRESSURE MEASUREMENT

Extensive performance evaluations under high voltage conditions have been done to proof the functionality. The pressure measurement involves a current consumption conversion into a pressure reading under constant conditions which are configured and predefined by a user, and determined by a high voltage value and ion pump model.

Theory

A real correlation example current-pressure describing 25[lps] noble diode ion pump supplied with constant high voltage U=7kV is presented in Figure 2.

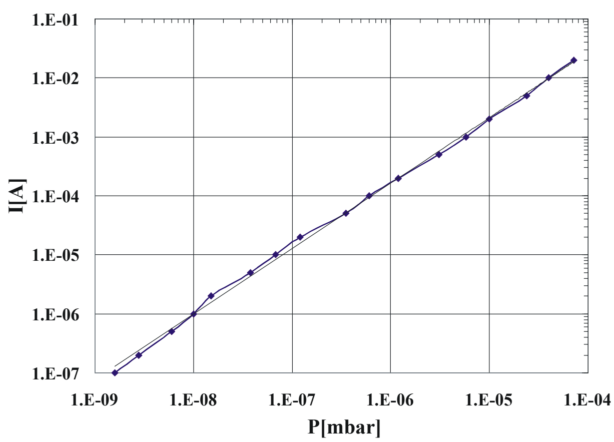

Figure 2: 25lps noble diode ion pump, Uconst=7kV.

The characteristics is almost linear and can be described by Equation 1. The chart, equation and related theoretical support were provided by Gamma Vacuum [3]-manufacturer of ion pumps. Generally all other pump models (25, 75, 150, 300, 500[lps]) strongly correlate with the theoretical formula.

$$P[\mathrm{mbar}]=\frac{0.08778*\frac{5600}{Voltage[\mathrm{V}]}*Cal_{Factor}*I[\mathrm{A}]}{IonPump_{Speed}[\mathrm{l/s}]}$$

Equation 1: Default pressure implementation.

The HVS current measurements are based on Q-Lambda sensors [4]. The sensors are current-to-voltage converters which provide a linear voltage output (0-8V) related to a logarithmic current input (10nA-10mA). A real conversion is presented in Figure 3, the characteristic "V=f(I)" shows a difference in current readings acquired under low voltage using a current source reference and high voltage (7kV) supplying ion pumps.

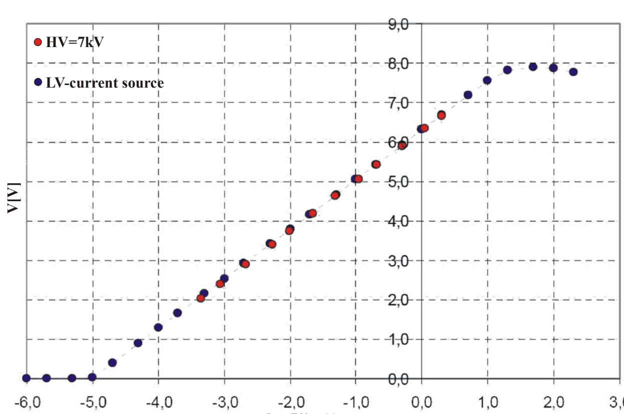

Figure 3: Current measurements "V=f(I)" under high and low voltage conditions with a Q-Lambda current sensor.

The output voltage dispersions are almost negligible, lower than 5%, so tests and calibration issues can be performed under low voltage without any quality risk.

Current Calibration Process

HVS integrates an automatic calibration process based on a Keithley 2611A source/meter working as a current generator/reference. The implementation is presented in Figure 4.

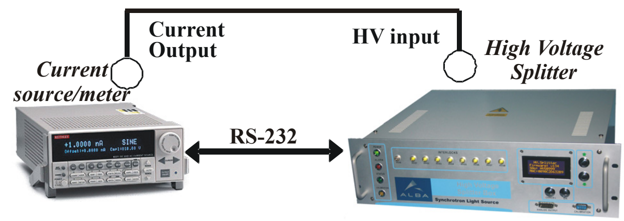

Figure 4: High Voltage Splitter calibration.

The Keithley current source is able to set a fixed current with an error lower than 0,001%. Two connections are necessary between those two instruments to execute the calibration: the serial RS-232 link and current link connected to a splitter channel under the calibration. Once the process is executed, HVS takes a control over the Keithley source sweeping all the current ranges and completing the process. For some specific ranges, HVS needs some time in order to compensate internal thermal drifts. This process is completely transparent for a user and assures 5% accuracy inside the range 10nA up to 10mA. The calibration data are fully available remotely for backup purposes.

Pressure Reading Implementation

A user can bind a pressure value to a current one making a set current-pressure, once the set is prepared, can be applied to any channel determining calculations of the final pressure readings (e.g. like in Figure 2, blue line). It means, a user can adjust HVS pressure readings with a full flexibility (even nonlinear characteristics), in total 13 sets can be programmed: one per each ion pump model (25, 75, 150, 300, 500[l/s]) and 8 independent ones. One set has to be tied to one channel, by doing it this way, a user can adjust the pressure readings of a channel for his particular real installation determined by real measurements, experience, or other gauge instruments, and not being fixed purely to the theory. If those sets has not been inserted, the default configuration is applied based on Equation 1 which gives very accurate readings as well.

ALARMS & PROTECTIONS

Pressure Alarms

Two different pressure alarms can be configured with two independent thresholds for each channel. If the pressure reading of any channel exceeds the first threshold level, a warning message is visible in the splitter front panel and also the control system is informed with a proper warning event over Ethernet. The second pressure alarm activation provides the same warning/alarm messages, plus opens a dry contact output informing Alba's Equipment Protection System [1].

Equipment Protection System

An exceptional vacuum loss scenario is indicated with the dry contact EPS output. As this trigger shuts down the accelerator, a redundant activation mechanism has been implemented. It is possible to set up to 8 different EPS alarm configurations which contain alarm conditions for different ion pumps (channels). One particular configuration example is presented in Table 1, it shows that the machine will stop if the second pressure threshold is exceeded in the channels: Ch2,Ch3 and Ch8.

Table 1: EPS Alarm Configuration Example

	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8
EPS Config		X	X					X

HVS has also an external interlock input. Its purpose is to combine the EPS alarm with any other external interlock e.g. provided by any ion pump controller etc.

Cable Interlock

In order to increase security during the instrument operation, a cable interlock system has been implemented. An ion pump controller provides a cable interlock security mechanism which generates a 5V high impedance signal to interlock circuitry inside a high voltage cable. A functional diagram is depicted in Figure 5.

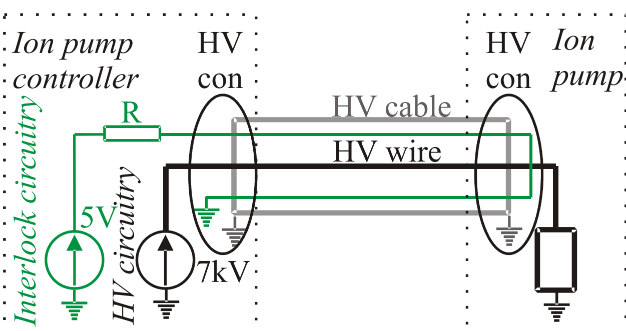

Figure 5: HV cable diagram for one ion pump controller and one ion pump.

When a high voltage cable is connected to an ion pump, a shortcut is applied to the interlock circuitry. In this way, the controller senses the high voltage cable status. If a low level is detected, it means that the high voltage cable has been correctly connected and the high voltage output can be enabled.

In case of HVS, a cable interlock distribution system has been designed to preserve this security protection. Internally all interlock signals are connected in series. It means that all high voltage cables connected to their splitter have to be correctly connected to ion pumps, otherwise the high voltage will not be enabled by a supply controller as the cable interlock protection will prevent that. HVS also detects which is a cable that is unconnected (failing) and reports it on its display and remotely. The HVS interlock distribution is depicted in Figure 6.

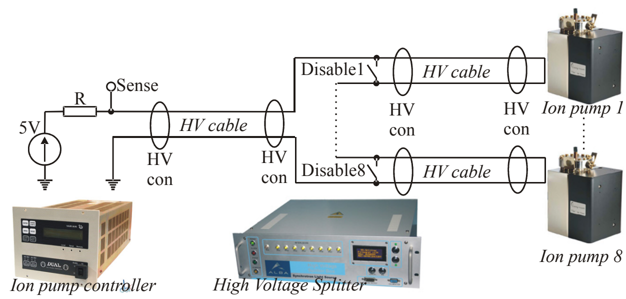

Figure 6: Cable Interlock diagram for one ion pump controller, HVS and 8 ion pumps.

CONTROL & OPERATION

Local Control

The local control is based on a keypad which allows to navigate between two submenus:

- "Measurement menu" - shows actual measurements.
- "Settings menu" - allows to change configurations.

Remote Control

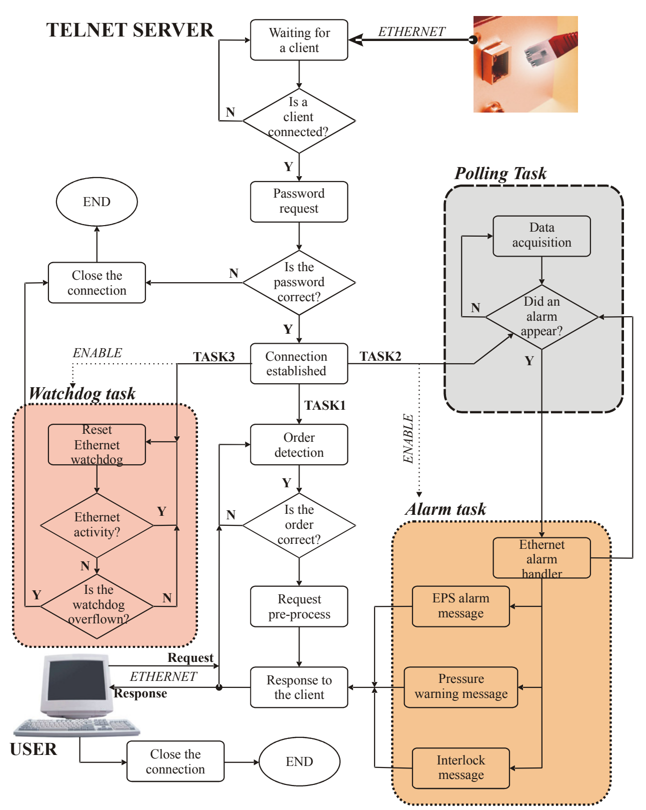

Figure 7: Telnet server – block diagram.

HVS provides its settings, status, measurements and records over Ethernet network. A DHCP protocol applies an automatic IP configuration and Telnet provides a bidirectional interactive text-oriented communication. Over 80 different string commands are available giving a full flexibility for any kind of implementations, plus an event based system informs a control room about any exceptional situations. The remote workflow is presented in Figure 7.

Operation Modes

HVS has two operation modes: commissioning and secure. In the commissioning mode, a user has unrestricted access to configuration settings using the local control menu. In the secure mode, the access to the configuration settings are limited only to Ethernet commands. A change from one mode to another can be done only remotely, so via the control room.

HVS is aimed to work in the secure mode. It assures that there is no accidental action done with the local control which could generate some alarms in the machine.

CONCLUSIONS

High Voltage Splitter has been a collaborative in-house project between many different sections: Vacuum, Mechanics, Electronics and Controls at Cells. The project development and tests took around one year, and first units were applied in first vacuum installation of the booster. From that point on, HVS-s have been fully working for more than 2 years also supplying the storage ring, front ends and linac. In total, 83 units were installed which made HVS a key instrument in Alba vacuum system.

Full implementation flexibility, complete integration to Alba's TANGO based control system, diagnostic purposes and cost efficiency make this project a great solution and improvement of synchrotron technologies.

REFERENCES

[1] D. Fernandez-Carreiras et al., "Personnel Protection, Equipment Protection and Fast Interlock systems. Tree different technologies to provide protection at three different levels", ICALEPCS'11.

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[3] Gamma Vacuum, “High and Ultra High Vacuum Products”, http://www.gammavacuum.com/.

[4] Q-Lambda, Getingevägen 46, 222 41 Lund, Sweden