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PLC BASED FLEXIBLE AND SCALABLE VACUUM CONTROL AT THE ARGONNE TANDEM LINEAR ACCELERATOR SYSTEM (ATLAS)*

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Abstract

The beamline sections of an accelerator and different ion sources require a vacuum system capable of providing pressures down to 10^{-10} Torr. To control, monitor, and provide interlock protection of the vacuum equipment, a PLC-based vacuum control system was developed and tested at the Argonne Tandem Linear Accelerator (ATLAS). This system was designed to be highly flexible and scalable to meet the variety of equipment and configurations at ATLAS. The current FPGA-based system is reliable and fast, but is very difficult to maintain and upgrade. Particular attention was paid to the signal distribution to promote standard cable connections, minimize the usage of terminal blocks, and reduce the time to troubleshoot problematic channels. The system monitors the status of fast acting relays for interlock or control purposes, and utilizes RS-485 communication to gather lower priority information such as pump speeds or vacuum pressure readouts. The vacuum levels are monitored to interlock the high voltages of some beam instruments to protect against sparks as the Paschen minimum is approached. This paper mainly presents work on hardware interface to various vacuum devices.

INTRODUCTION

ECR (Electron Cyclotron Resonance) and EBIS (Electron Beam Ion Source) ion sources are used at ATLAS to generate beams along with other sources. There are two ECR (ECR2 and ECR3) sources and one EBIS here.

Paschen's law is an equation that describes the breakdown voltage between two electrodes in a gas as a function of pressure and gap length [1]. As shown in Fig. 1, the breakdown voltage drops dramatically when the vacuum condition of the system gets worse from high vacuum level. Without any protection, some beam instruments such as beam extractor, puller may generate high voltage (HV) sparks which could damage themselves or other beam components. So it is very important to interlock the HV bias of those beam instruments to the related vacuum levels to prevent HV sparks related to bad vacuum.

We have some aged in-house custom built vacuum hardware used for some other beam sections. It combined analog logic control circuitry and outdated FPGA (Field Programmable Gate Array) devices to control some specific vacuum devices. There are different revisions depending on their original intended purposes. For example, some chassis don’t provide a remote vacuum pressure reading and some don’t support a separate turbo pump, causing additional effort to integrate into the control system [2].

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A new PLC (Programmable Logic Controller) based vacuum control system was proposed after communication with operators, engineers and management people. Then it was developed. The prototypes which were developed before finalized design requirement due to project schedule have been utilized in EBIS and ECR3. ECR3 is a newly developed ion source. The modified final design has been finished and will be deployed into other areas of ATLAS. The new system is highly flexible and scalable. The details are discussed below.

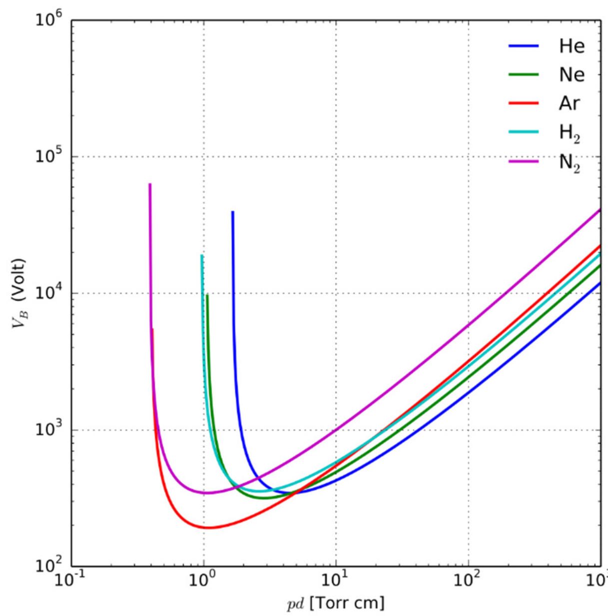

Figure 1: Paschen curves obtained for different gases.

DESIGN AND IMPLEMENTATOIN

The conceptual structure of the PLC based system is shown in Fig. 2. The PLC system used contains Modicon M340 system with Ethernet, RS-485 and some I/O modules, such as BMXDDI6402K and BMXDDO3202K. The PLC system communicates with the PLC interface, distributing output control and grouping input status signals. The interface chassis also provides RS-485 path for the PLC to collect pressure readout and other information. Then the valve and pump stations connect to the individual vacuum devices for controlling, status information collecting and RS-485 communication. Standard D-sub cables are used as much as possible to reduce the label time of making custom cables and costs. Most of the cables to the specific vacuum devices are also standard D-sub cables with one end re-terminated to the device’s configuration.

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For future purchase of vacuum devices, we also published recommendation of allowed vacuum devices list to avoid too much complexity. Unless a vacuum device is really required by the projects and no alternative, it is not recommended to buy if it is not on the allowed list.

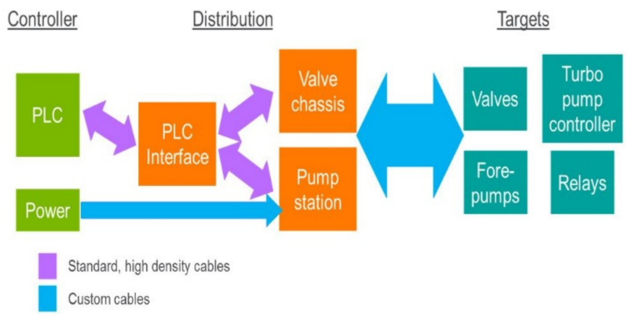

Figure 2: A conceptual structure of PLC based vacuum control system.

We looked our existed vacuum devices carefully and grouped them by required I/O numbers. Table 1 shows the configuration of typical vacuum devices. For example, a VAT gate valve has two status relays and one 24V DC type solenoid to open/close the valve. A NORCAL gate valve is in the same group as the VAT gate valve for the valve station design though the end connectors are not the same. All pumps can be daisy chained together with different addresses if they only need RS-485 communication.

Table 1: Typical Vacuum Devices

Device Model	Type	Relay	24V	RS-485
VAT Gate Valve	Valve	2	1	
NORCAL Gate Valve	Valve	2	1	
GP-275 Mini CV Gauge	Gauge	2	1	1
GP-390 Micro-Ion Gauge	Gauge	3	1	1
Edwards nXDS-15i	Pump	1		1
Anest Iwata ISP-500C-SV-D1	Pump			1
Leybold EcoDry 65+	Pump			1
Leybold Turbovac 361 (TD20)	Pump	2	1	1

An example of circuitry for 3 relays, one 24V control signal and RS-485 device (GP-390) is shown in Fig. 3. Because some devices may have an open collector output (or other voltage such as 10V) instead of a relay, so there is a solid state relay SSR10 to convert this output to 24V output signals as a right input signal to PLC. Pin 11 and 12 of D-sub connector J6 for RS-485 communication. Pin 9 is a PLC output signal controlled 24V to provide controlled power. Pin 10 can also be a 24V power but not controlled by PLC.

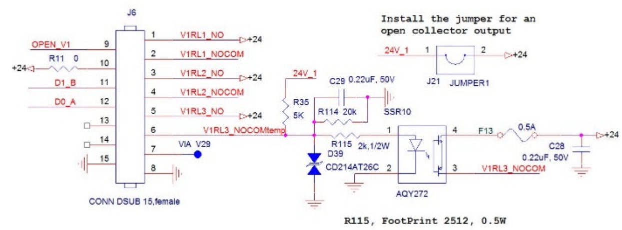

Figure 3: An example of circuitry for GP-390 gauge.

Fig. 4 shows a test stand with valve station, pump station and dual-channel 24V power supply. LEDs on front panels of valve or pump stations indicate the status of some interested signals. Fig. 5 shows a back panel of valve station as an example.

Figure 4: Front sides of valve, pump stations and power supply.

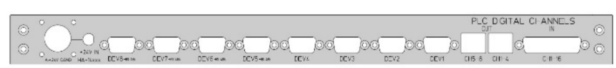

Figure 5: Back panel of valve station using D-sub and RJ-45 connectors for signals.

The threshold of the status relays of the gauges are set for monitoring the vacuum levels. The vacuum levels of some critical positions are monitored and also interlocked to the related HV power supplies.

For example, as for ECR3 PLC vacuum control system, one of the IG1A (GP-390 Ion Gauge) relays is set to monitor the vacuum level at certain level. If the vacuum level drops to below this threshold, then the relay will trip to open the interlock relay of HV power supplies of the source beam extractor and puller. Another gauge IG2 (GP-390 Ion Gauge) is also configured to interlock the platform HV supply of the source deck. PLC also records the incidents and drops the control voltages when trips happen.

The GUI interface is shown in Fig. 6. The actual pressure reading from different gauges are obtained through RS-485 communication from PLC to/from the specific devices.

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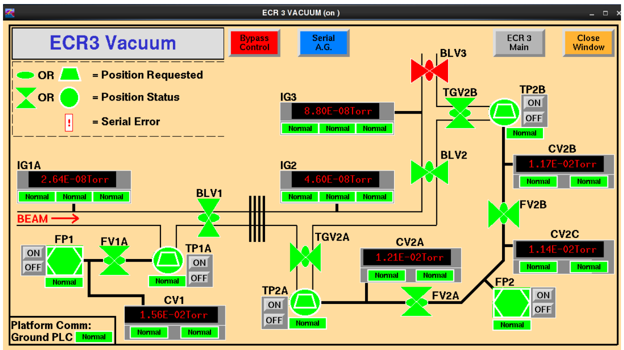

Figure 6: ECR3 PLC vacuum control system GUI.

CONCLUSION

The work of developing a PLC based vacuum control system for the beam devices and beam line have been conducted at ATLAS, the prototype system serves well for vacuum control and is providing vacuum level related HV interlock protection to the critical beam devices. Some finalized products are also built and ready to be deployed to other areas.

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