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PLC OPERATED PLUG AND PLAY VACUUM GAUGE FUNCTIONALITY AT THE ARGONNE TANDEM LINEAR ACCELERATOR SYSTEM*

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Abstract

ATLAS (Argonne Tandem Linear Accelerating System) accelerator at Argonne National Laboratory is upgrading the vacuum control system from hardware-based, embedded controllers to modern flexible PLC-based controllers. This PLC (Programmable Logic Controller) system includes additional fail safes and a new remote operation feature. As part of this upgrade, enabling easy vacuum equipment replacement became apparent, specifically the vacuum gauges which are interfaced using serial communications. We developed a solution to remotely program the gauges, which offers more options for gauge control than the hardware-based controllers. Expanding on this, we added a process to initialize and restore the configuration for replaced gauges. This simplifies the process and eliminates the need for a system expert for these tasks.

INTRODUCTION

The ATLAS accelerator is located at the United States Department of Energy's Argonne National Laboratory in the suburbs of Chicago, Illinois. It is a National User Facility capable of delivering ions from hydrogen to uranium [1] for low energy nuclear physics research to perform analysis of the fundamental properties of the nucleus.

The accelerator requires pumps to create a vacuum in the beamline to prevent collision of the beam with air particles. Most of the vacuum control system uses custom built hardware-based chassis (Figure 1) that provide static vacuum interlock logic. The interlock logic largely relies on the set points of vacuum gauges to determine when safe operating conditions have been exceeded so that pressure-sensitive pumps can be isolated or stopped. The set point values can be locally adjusted from the gauge controllers. These systems are connected to a CAMAC (Computer Automated Measurement and Control) Serial Highway [2] to provide basic vacuum information to the control system such as: absolute vacuum pressures, pump status, and valve status.

Since 2019, ATLAS has been replacing the hardware-based vacuum monitoring system with flexible Schneider Electric PLC-based systems. The new systems enable remote vacuum control (Figure 2), flexible logic and vacuum hardware additions, and fully automated vacuum systems; all of which were cumbersome with the hardware-based system [3].

A goal of the ATLAS vacuum upgrade is to integrate vacuum automation. Since safety checkpoints are programmed in automated vacuum systems, there is less knowledge required to operate the system. At the same time, the new vacuum upgrade should have all the features of the hardware-based system. In this paper we will focus on seamless gauge replacement and set point configuration.

HARDWARE DESCRIPTION

The existing ATLAS vacuum system includes many obsolete vacuum gauges which feature manual set point adjustments from a gauge controller. The replacement devices largely include faster responding vacuum gauges with larger vacuum ranges, more features, and remote communication interfaces. To minimize the upgrade efforts and to keep all the former features in place, the obsolete vacuum gauges are being replaced by modern Granville-Phillips (GP) 275 and 390 gauges as the sectioned PLC upgrades take place. The modern gauges are modular and have integrated controllers. Therefore, when a gauge is replaced, all programmed information from the old gauge must be sent to the new gauge.

SOFTWARE DESCRIPTION

The PLC used for this vacuum upgrade features RS232 and RS485 serial communication natively. This is important since the majority of the new GP vacuum gauges require RS485 serial communication as their only interface to program the gauge, and read vacuum pressures. The default factory serial communication settings for all gauges are the same and will not be changed for use with the PLC.

Figure 1: Hardware-based vacuum Control Chassis with adjustable vacuum set point switches.

Gauge Addressing

Each GP vacuum gauge has a manual, 16-position adjustment of 0-F for device addressing. In addition, there is a programmable address offset that can be changed to a value of 0, 10, 20, or 30 (HEX). For PLCs with more than 16 gauges, the address offsets will be required to prevent duplicate addresses. With address offsets, a maximum of

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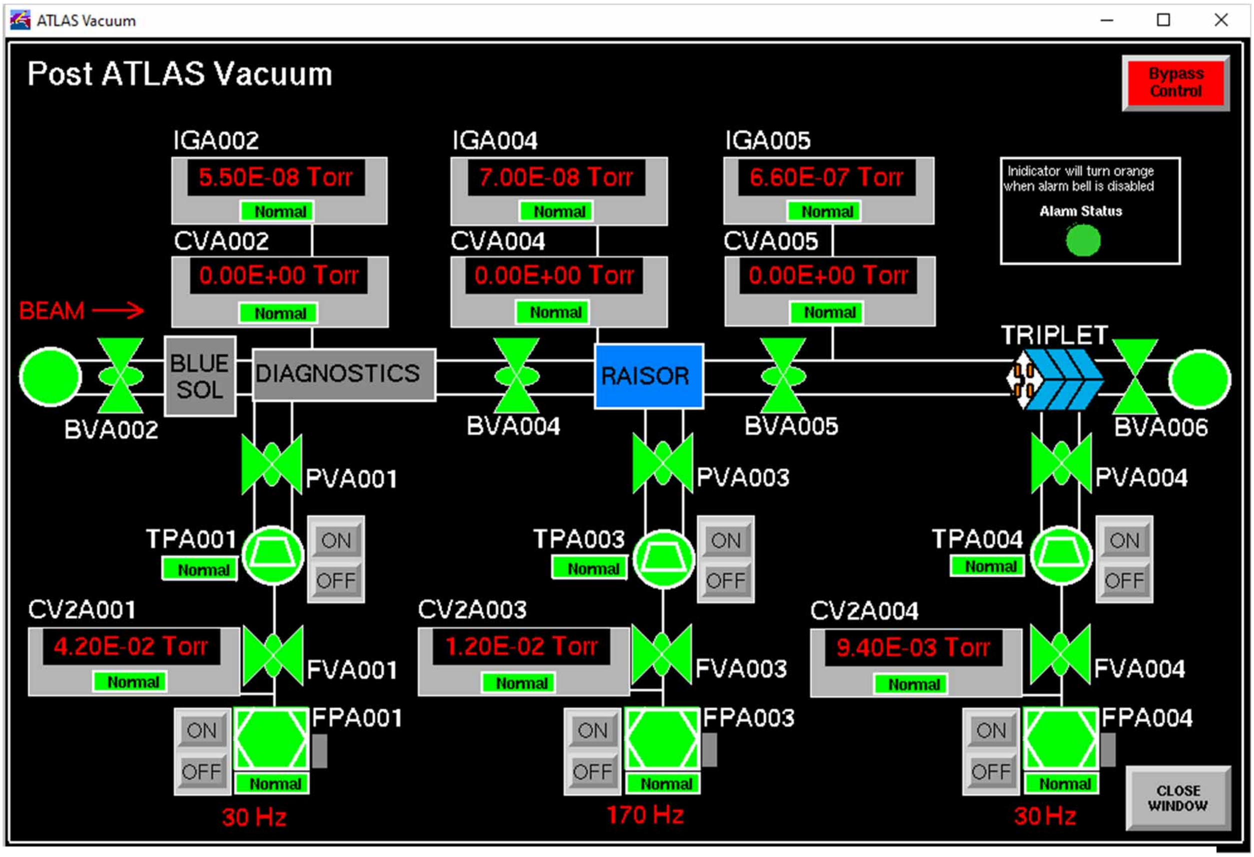

Figure 2: A typical ATLAS PLC-controlled vacuum display using Vista-Controls [4] VDraw feature.

64 devices are possible. However, addresses 0-F (where the address offset is zero) will be reserved for uninitialized devices. Meaning, that if a gauge needs to be replaced, the process will be to set the manual external switch on the new gauge to match, then let the PLC update the address offset over serial. This system, then limits our available addresses to 48 per PLC since the remaining 16 addresses are reserved for uninitialized devices. To change the address, some GP gauges require the toggle lock command to be sent. To get the address to take effect, GP requires that the gauge be powered off, or receives the reset command.

Required Serial Description

To duplicate the features of the hardware-based system on all GP gauges, the following command descriptions are needed: read vacuum pressure, reset module, toggle lock, read set point, and write set point. With the new system, technicians can update 1 set point at a time from a remote display interface. After every set point change, the appropriate set point value is updated in the PLC. After replacing a broken gauge, a gauge reinitialize button must be pressed to reset all the set points of a gauge. This differs slightly from the old system since the set points were originally set by front panel knobs on the gauge controller.

Figure 3 demonstrates the order of programming requests that the PLC will send to the vacuum gauge. The PLC operates using a state machine, which means that the serial communication will take several PLC cycles to complete, while the critically important interlock logic is processed during every PLC cycle. After the user requests a gauge to initialize using the display in Figure 4, the PLC first sends all the set points to the new gauge. At this point, the PLC sends a request to a gauge with the uninitialized address (the manual dial address only). If no gauges respond to this request, the PLC will then send a request to the initialized address (the manual dial address with the address offset). After several failed attempts at both addresses, the PLC will report an error.

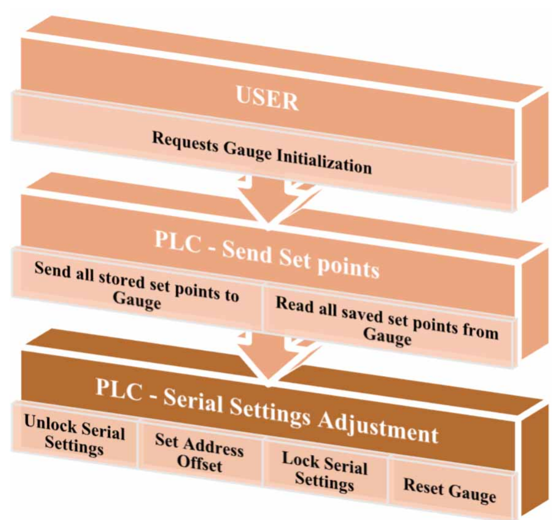

Figure 3: The order that a GP gauge is programmed by the PLC after a user requests an initialization.

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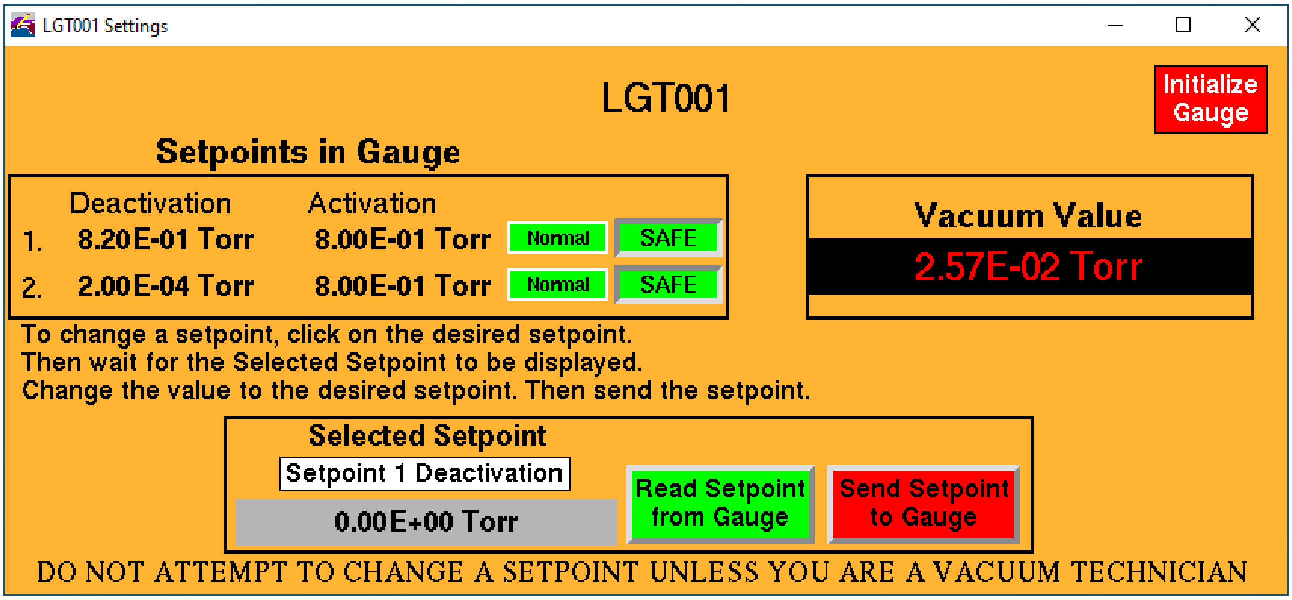

Figure 4: A Vista-Controls [4] concept display that features working set point adjustments and gauge initialization.

If the PLC finds a device with either address, it moves on to send the set point values to the gauge. Then, if the PLC is using the uninitialized address, the PLC will send the requests needed to add an address offset and force the gauge to apply the new address. All later requests to the initialized gauge will use the initialized address.

SETPOINT STORAGE

As mentioned, there is a copy of the set points that exist in the PLC and in each of the gauges. There is no way to save the set points in the PLC after a power bump except to purchase an expensive PLC-compatible SD card. The set points that are stored in the gauges, however, are non-volatile. Therefore, the PLC was designed to prioritize the set points in the gauges. At startup, the PLC will read every set point from each gauge to store them locally and display the value to technicians. If a gauge needs replaced, and an initialization is performed on the gauge, the saved set points in the PLC are sent to the gauge. With this system, there is a low chance the PLC power cycles before a gauge can be replaced; In which case the set points for the gauge will be manually entered again.

USER EXPERIENCE

As mentioned previously, there are plenty of advantages of PLC-based vacuum control over the existing hardware-based method. One important advantage is that the PLC-based method allows for remote control and monitoring of all vacuum devices. Each of these control displays can be accessed from any control system display computer at ATLAS. For select individuals, the control displays can also be accessed from outside the lab.

FUTURE PLANS

Automated gauge configuration is currently in the testing phase and will be installed with a new vacuum upgrade section during this winter's accelerator shutdown. After this install, it would be ideal to create a system that prevents the vacuum set points from being lost, should this become an inconvenience to the operations staff.

With the new setup, each GP gauge is required to be factory reset by a control system expert when there is a chance that it re-enters service. New gauges are already at a factory reset state, but if gauges are removed from the beamline, they will still be programmed to their previous service settings. Before the gauge enters service again, the address offset should be reset to allow the initialization algorithm to function properly. To match the theme of building systems that allow all of this to be done by technicians, a device could be built that will send the factory reset command to all possible serial addresses.

CONCLUSION

The purpose of this work is to provide vacuum technicians the same functionality as the previous hardware-based vacuum control system. The new system will also offer the advantage of full gauge replacements and remote control of vacuum gauges that was otherwise impossible. Though the newly upgraded system is not installed yet, small scale test of this system have proved effective. Ultimately, this upgrade will provide ATLAS with a complete feature replacement of the previous hardware-based system as well as lay the groundwork for future state-of-the-art vacuum automation.

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