Automated Virtual Instrumentation and Imaging System for Production Testing of Gas Pressure Regulators

To maintain leadership among gas regulator suppliers, Victor Engineering of Denton, Texas needed to improve the quality control and production speed of their pressure regulator and gauge manufacturing line. While many test systems employ bus interfaces, electrical signals, or serial protocols to control devices or acquire data, interfacing with gas regulators requires the test system to simulate human interaction while testing a manually-operated device: turning a hand-screw to adjust delivery pressure and visually noting pressure levels from mechanical gauges.

A robust and cost-effective semi-automated test system was developed using LabVIEW™ for controlling test sequence and machine states and for acquiring data using National Instruments data acquisition and imaging hardware. A machine vision board tracks movement of pressure gauge needles installed in dials of various colors, sizes and spans. Data acquisition boards and signal conditioning control vacuum chambers, motor torque, pressure measurement, and encoder counting. Control and monitoring of a helium leak detector is accomplished through RS-232 serial communication. The semi-automated test system included a flexible user interface controlled through a touch-screen.

The Challenge

To develop semi-automated software and hardware systems to test gas regulators in production - providing a flexible user interface to operators and technicians, and improving quality control and production speed.

The Solution

Use LabVIEW for controlling test sequence and machine states and for acquiring data using National Instruments data acquisition and imaging hardware.

Introduction

High Tech Services of Richardson, Texas hired G Systems, Inc., a National Instruments Alliance member located in Dallas, Texas to develop a software and hardware system to automate gas regulator production testing for Victor Equipment. Victor is a leading supplier of high-quality gas regulators and uses semi-automated testing in their production lines for increased throughput and product quality. G Systems integrated the test system using National Instruments data acquisition hardware, IMAQ vision hardware and LabVIEW graphical programming environment. In many respects, the test stand control and acquisition elements are similar to other production test stands with basic machine control functions, data acquisition and storage, and graphical user interface. However, the feature that differentiates this system from others is its simulation of human interaction with the device under test. These interactions include basic motion control to set outlet pressures and image acquisition to “read” regulator gauges.

Graphical user interface for Victor Equipment gas regulator production testing shows status of two simultaneous tests. Software was developed by G Systems in LabVIEW using IMAQ Vision toolkit.
Background

Gas pressure regulators are devices that “step down” a high-pressure source to a desired level. They come in all shapes and sizes with control options ranging from preset, fully-sealed packages with fixed output pressure to sophisticated, microprocessor controlled systems. Perhaps the most common gas pressure regulator style is a hand-screw controlled model which has a mechanical pressure gauge indicating the “high” side, or inlet pressure and another gauge indicating “low” side, or outlet pressure. Simply turning the hand-screw clockwise or counterclockwise yields a higher or lower pressure on the outlet side which is reduced from the inlet pressure. These types of regulators are used in virtually every production environment, laboratory, shop, and industrial setting. They are relatively low-cost, low-tech and are produced in high volumes. However, they are control and measurement devices which will be placed in applications depending on their performance and reliability. Therefore, Victor Equipment ensures their quality by testing each unit before it leaves the factory.

Testing Requirements

Verifying the integrity of a gas pressure regulator requires a variety of tests. As one might expect, most tests are related to pressure control and measurement – investigating regulator attributes such as gross leaks, maximum outlet pressure, delivery pressure while flowing, pressure drop from no-flow to flowing, static pressure creep over time, and others. More sophisticated tests include placing the regulator in a vacuum environment while charging it with helium to perform hermetic leak tests. And finally, visual tests are used to verify operation of the mechanical gauges. Throughout the pressure test procedures, the regulator hand-screw must be rotated to place the regulator in the required state. While many test systems employ bus interfaces, electrical signals, or serial protocols to control devices or acquire data, interfacing with gas regulators requires the test system to simulate human interaction: turning a hand-screw to adjust delivery pressure and visually noting pressure levels from the mechanical gauges.

Reading Regulator Gauges

Victor regulator gauges are similar in that they all have a full swing of 270 degrees from zero pressure to full span, but models vary in size, range of operation and face color. The regulators are mounted in vacuum chambers during testing to facilitate leak testing during the test process. Therefore, visual access to the gauges is accomplished by a thick quartz window in the chamber wall. Illumination of the gauge face is provided by a light outside the chamber. The hardware solution for this machine vision system includes an IMAQ frame grabber board connected to a Sony XC-75 high-resolution, black-and-white video camera. Custom software for acquiring and processing the image was developed with LabVIEW and the IMAQ Vision toolkit. The program tracks movement of the gauge needles on both sides of the regulator.

There are two main requirements for this vision application. The first requirement is that the background exhibit some reference points which locate the image coordinates. For example, on each dial face are rivets which may be used to reference the image location. The centerline of the gauge needle spindle is another reference. The regulator’s position is fixed by its mounting inside the vacuum chamber. Therefore, the image plane location for the center of each regulator size can be stored in a configuration file. Nonetheless, searching the image plane for major features is possible with IMAQ without prior knowledge of their location.

The second requirement for this vision system is that the needle boundary contrast highly against the gauge dial face. The quartz window complicates the image acquisition because it introduces
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conditions such as first surface reflections. However, anti-reflection coatings help alleviate this effect. To eliminate other anomalies in the image, lighting intensity and contrast may be adjusted to improve image quality. In this application, because a black-and-white camera is employed, it resides behind a selectable filter mechanism with filter colors corresponding to the color of the dial face under test. For instance, when a red-faced gauge is under test, a red lens filter dampens the face color spectra so that the camera effectively distinguishes a black needle against a white background. Another complicating factor for the application is that the camera axis is not directly perpendicular to the gauge face. This arrangement is necessary to prevent glare off of the gauge face from the exterior illumination. Viewing the circular faces at an angle yields an elliptical image of the gauge. Nevertheless, the IMAQ-based software is able to process the image accurately.

Automatic Regulator Pressure Control

As mentioned earlier, the second significant challenge for simulating human interaction with the regulator is adjusting the delivery pressure using the hand-screw. To adjust the pressure setting while mounted inside the chamber, a DC motor rotates six “fingers” arranged in a circular pattern that straddle the regulator handle. All control of the system resides in the program developed in LabVIEW. As described earlier, the position of the hand-screw determines the delivery pressure from the regulator. When the hand-screw is turned fully clockwise, or “jammed,” the regulator delivers maximum output pressure. When the hand-screw is turned fully counterclockwise, the regulator is closed – the delivery pressure and flow are zero. At various points during the test sequence, the LabVIEW program adjusts the setting of the regulator.

Two challenges were overcome while developing this basic motion control system. First, the position of the hand-screw is not known by the machine when the regulator is installed for testing. The regulator may be fully open or closed. The logical decision is to home the hand-screw position by rotating it until it “jams” – rendering the regulator fully open. Yet, if the motor turns the hand-screw too far clockwise, the DC motor torque will strip the regulator threads and scrap the entire unit. The second challenge is that turning the hand-screw too far counterclockwise will cause the hand-screw to disengage from the regulator housing threads and fall out of the regulator. Mechanical restraints do not exist to prevent the hand-screw from falling out of the regulator housing. This does not necessarily harm the regulator, but delays testing on the production line while an operator corrects the problem.

The solution to the first problem is to tap the motor controller card and read the tap within the LabVIEW program. The tap outputs a voltage proportional to motor current. This signal is routed to a National Instruments plug-in DAQ board and monitored repeatedly as the motor is turned clockwise. When the program recognizes a sudden rise in motor current caused by the screw reaching the jam point, the motor is turned off.

The solution to the second problem is to use an encoder wheel on the motor shaft to count hand-screw revolutions relative to its jam point. After homing the hand-screw, the number of revolutions can be tracked to prevent backing the screw out too far. Most of the regulators are fully closed after three and one-half turns counterclockwise from the jam point. The closed position for particular models is noted in a configuration file so the LabVIEW program can command the motor to turn a specified number of revolutions to reach a closed state.

Victor channel configuration panel allows operator to configure signal locations for various digital lines on the test stand on-the-fly. This interface looks similar to the actual SSR backplane arrangement in the test stand DAQ enclosure.

Victor image data entry screen allows operator to change or add test parameters for various regulator models.
Other Solutions for Testing Gas Regulators

This test system also includes digital handshaking for sharing common equipment between test stands such as a mass spectrometer for identifying trace gas leakage. In addition, coupled with a bar code scanner for reading regulator models and operator information, a touch screen user interface eliminates the need for a mouse or keyboard on the production test stand.

Summary

National Instruments software and hardware solutions enabled G Systems and High Tech Services provide a robust and cost-effective semi-automated test system for Victor Equipment. Significant challenges were overcome to simulate human interaction while testing a manually-operated device. This commitment to rigorous testing helps Victor Equipment maintain leadership in the gas regulator market.

Products Used

LabVIEW
AT-MIO16E-10
IMAQ PCI-1408
PCTIO-10
PC-DIO-24
AT-DIO-32HS
SSR

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