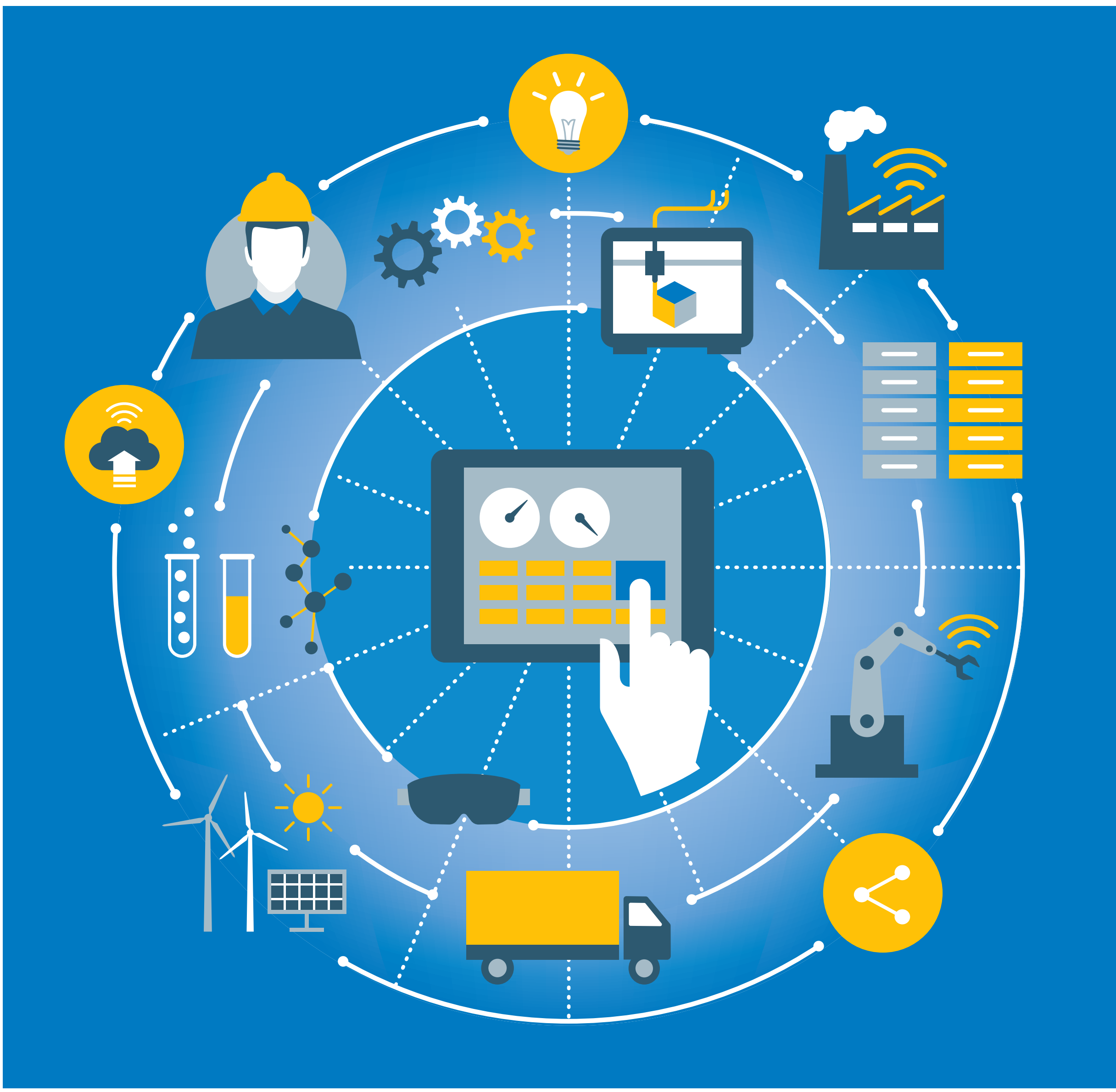
TECHNOLOGY REPORT

Advances in HMI



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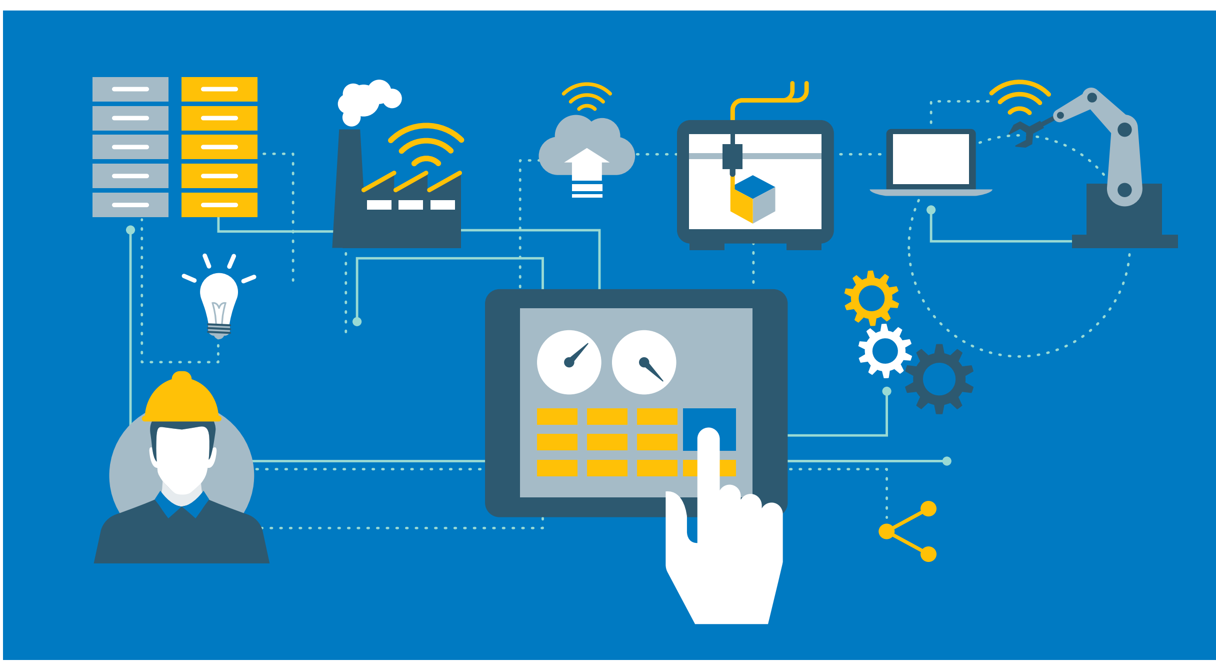


You might have HMI design backward

Did you know background color is the least important element?

By David A. Strobhar, PE, Center for Operator Performance

I've heard many comments and discussions in the past few years regarding the color grey. Is that even a color? I'm not talking about the 50-shades-of variety. The use of a grey background on process graphics has become all the rage, or rage-inducing, depending upon with whom you are talking. Is background color on a display so powerful that it can, by itself, radically improve operator performance?

There are other elements of HMI design, so where do they fit in? If you rely on more than five decades of human performance research, I would argue that the order of importance for the elements of HMI design would be as follows, with background color the least important of them:

1. content
2. organization
3. layout and formatting
4. color coding
5. symbols/shapes
6. number and size of monitors
7. background color.

Many people would likely have ordered this list the reverse of what I have. Their upside-down view of which elements are important in HMI design likely stems from a misperception of what HMI design is all about. People often think display design is fundamentally a visual issue. It's not. HMI design is about information transfer: transfer of information from the process to the operator at the console. As such, the key concern needs to be how to transfer information, not visual representation of objects.

An easy way to think of this is storytelling, an analogy put forth by Don Norman, one of the pioneers in human factors. In telling a story, you're trying to transfer some information. There are a variety of mediums for doing this—verbal, print, movie, play. While the medium can aid the transfer, it doesn't in itself result in the transfer. The best prose, pictures or visual effects do not a great story make. Similarly, the best shapes, dynamos and color do not a great HMI make. Fundamentally, the success of the transfer depends upon the content.

This focus on content was emphasized in one of the first projects funded by the Center for Operator Performance, which is a collaboration of operating companies and DCS suppliers based at Wright State University in Dayton, Ohio. In conducting a project on color usage, Dr. Jennie Gallimore pointed out that, while poor color coding can hinder performance, it is proper content that is essential to performance. If the correct content is present, albeit with poor presentation, the task can likely still be performed. However, if the content is absent, task failure is almost guaranteed regardless of the presentation.

Many people would say that the content for the HMI is determined by the I/O of the process. It's not. The I/O constrains the content, just as the events in your life constrain your biography. However, a biography that contained every event in your life presented with equal weight and detail would be both very long and very dull. Similarly, a good HMI design entails selection and organization of those I/O relevant to the tasks required. This selection and organization can and should be the longest part of the HMI design process. It not only is necessary to ensure good HMI design, it speeds the subsequent display design efforts and minimizes rework.

If done correctly, this process will yield a far more compact and efficient HMI than one designed in a stream of consciousness approach, simply drawing graphics starting from the beginning of the process to the end. Keep in mind a famous quote attributed to Abraham Lincoln, among others—"I am sorry to have written you such a long letter, but I didn't have time to write you a short one." Optimizing information transfer requires upfront thought and effort.

So should I just ask the users what information they need? While user input is essential, we often don't know what we really need. Just because we know how to do something doesn't mean we have analyzed how we do it and with what information. Most adult Americans can drive a car, but few have taken the time to determine the information processing and skill required to do it. Many a process plant operator has asked for an interface that replicates what they have, often because they know they are successful in using it. However, that can lead to either replicating a negative design or failing to produce a superior design.

For example, at one plant the operators wanted the hardwired firing panel for a boiler duplicated on screen, failing to realize that the panel did not have the necessary fuel flow and pressure controls needed to operate the firing panel. They failed to realize the need since those controls were relatively close on the hardwired panel. Once on an HMI, they would be on another screen. The operator would need two screens to perform the task rather than one. Obviously the operator knew how to perform the task; he just hadn't analyzed what it actually took to accomplish it.

Once the information that is needed is known, it must be organized and structured. Hopefully in writing your autobiography—the transfer of information about your life—you would take the time to organize the events in some structure. While a chapter for each year would cover your life, it would likely be a poor way to transfer the information, just as a display for each piece of equipment is a poor HMI. Organization of the information into a hierarchy is a good approach for a variety of reasons. As you move down the hierarchy, greater detail is provided. The pinnacle of the hierarchy is those variables needed for an overall assessment of the process to maintain situation awareness—the big picture—and avoid tunnel vision. This pinnacle, the overview display, should reflect the hierarchy underneath it.

Now comes the point which most people think of as HMI design, the layout of the displays. Is that not simply a reflection of the equipment itself? No, that is a flaw called naïve realism. HMI design is about information transfer, and information is the reduction in

Many a process plant operator has asked for an interface that replicates what they have, often because they know they are successful in using it.

uncertainty. Showing me the level in a vessel reduces my uncertainty about that level. Evaluation of any display or display element should entail an assessment of how it reduces uncertainty. Does showing all the trays in a tower reduce uncertainty? Not if I already knew how many trays were there. If it does reduce uncertainty, does the display element do so in the most efficient manner? This should be thought of in terms of bits/in2, the information transfer for a given area of the display. If you want to convey the status of a pump, then maximum information transfer will occur using a symbol sized just above the threshold for readability. Anything larger is less bits/in2: the same information divided by a larger area is worse information transfer.

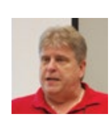
Coding is a useful human-factors tool in that it enables more information to be transferred in a smaller space and in parallel with the other information, if it is done correctly. There are four major types of codes: color, shape, position and alphanumeric. The first two have the greatest use in HMI design. Color coding is simple in concept, each color used for coding has a unique—one and only one—meaning associated with it. If red means warning, then it cannot also mean "closed." Since we humans are limited in our perceptual abilities, only about seven colors can be effectively utilized for coding. For shape coding, the goal is to transfer the information in as small and simple of a way as possible. A study by the U.S. Navy showed strong preference for symbols that looked just like the real aircraft, but performance was 70% better when simple triangles were utilized.

Of little importance is the number and size of the monitors the operator uses. This is due to the limitations of how we humans perceive our world. First, our conscious processing is limited to about seven chunks of information. So, even if each monitor could be processed as a chunk, which is unlikely, more than six monitors are likely to be unused. Second, the primary visual field for people is a 28-in diameter circle at normal viewing distance. Placing information outside that circle will exponentially reduce its usability. Adding more monitors will add little value. While many an operator has maintained that they do use all their monitors, it is surprising how often you will find the same display on multiple monitors.

Finally, the background color of the graphics needs to be set. What color? It doesn't really matter, as long as the contrast ratio with the foreground colors is maintained. Operators have been told that grey background is best, yet grey includes everything from almost black to almost white. One plant switched only the background on their graphics from black to light grey. The cyan (light blue) process variables were almost unreadable. Grey, blue and tan are all viable background colors, as long as the contrast with the foreground colors is adequate.

Hopefully, if you're in a conversation on HMI design, you'll now be able to focus the discussion on the key elements. The key to effective HMI design is maximizing the transfer of information. This will require upfront effort to define that information and organize it. The result, though, will be better performance by the user and, hopefully, superior process performance, as well. ◻

ABOUT THE AUTHOR



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Combine Control and Operator Interface

The upsides and downsides of controller-display combo units

By Dan Hebert, contributing editor

A combo controller and operator interface can save big compared to separates.

As the miniaturization of electronics continues its relentless march across the personal-consumer-device landscape, it's only natural for it to proceed apace in machine and robot automation systems. One consequence is the combination of what were once separate components into a single housing, as with a machine controller and an operator interface device.

Although relatively new on the scene, these combo units have seen significant adoption by machine builders because they are less expensive than separates, require no wiring or integration between the controller and the operator interface, and take up less panel space.

For many applications, these benefits more than negate disadvantages, which include a single point of failure for both control and operator interface and a lack of the highest-end functionality, particularly for basic units.

These combo units come in two main flavors. The first combines a PLC with an operator interface terminal (OIT) to create a unit designed for basic machines. The second marries a PC-based controller to a full-featured HMI, creating a unit capable of providing control and operator interface for the most complex machines.

Combo PLC-OIT units were initially introduced with limited features and functions, but more recent products have upped the ante by adding more sophisticated capabilities. "The newest addition to our FT1A Touch micro programmable controller series of combo HMI+PLC units is the FT1A Touch 14 I/O, with new features making it suitable for advanced analog monitoring and control," says Don Pham, a product manager at IDEC.

"The FT1A Touch 14 I/O provides up to 158 discrete and analog inputs and outputs, using FT1A controllers as remote I/O slaves, PID control, Ethernet communications and a built-in 3.8-in touchscreen HMI in a compact package costing less than $500," adds Pham.

This is obviously an attractive price point, one hard to match by purchasing a separate PLC and an OIT, particularly when the cost of wiring, integrating and installing two separate units is taken into account.

A bit higher up the scale in price and performance, staring at about $1,000, is the Perspecto CP TV line of combo units from Wago. These units feature five sizes of TFT touchscreens: 3.5, 5.7, 10.4, 12.1 and 15 in. "Performance is optimized with scaled processing power up to 1.6 GHz processor, 256 MB of RAM and 128 MB of Flash memory," notes Charlie Norz, the product manager for WAGO I/O Systems.

"Our combo units are programmed using CoDeSys software, providing advanced programming tools, support for all the IEC 61131-3 programming languages and an easy-to-use graphic editor," notes Norz. These units also have multiple interface ports, including CAN bus and Ethernet, and a built-in Web server that allows remote users to view and control the graphic screens using any browser.

These combo units can be a good fit for machine builders not requiring large HMI-type screens, hundreds of I/O points or advanced control functionality. For applications requiring those features and functions, the next step up the line are combo PC+HMI units.

Readers over 40 years old may have not-so-fond memories of the sheer size, bulk and weight of older PC-based control systems. Not only was the CRT-based screen a monster, so was the industrial PC. Add, in some outboard I/O, the entire package was cost- and size-prohibitive for all but the most high-end applications.

But times have changed, and new units simply tack a PC-based controller onto the back of a flat-panel screen, creating a slim panel-mount package with reasonable weight and not much more depth than a monitor alone.

Combo PLC-OIT units were initially introduced with limited features and functions, but more recent products have upped the ante by adding more sophisticated capabilities.

A pioneer in this area is Beckhoff Automation with its panel PCs. "Rather than recommending a multi-component solution with separate PLC and HMI hardware, we offer customers an all-in-one approach combining an industrial PC and HMI, packaged as a streamlined panel PC," explains Reid Beilke, the industrial PC product specialist at Beckhoff.

"These units offer multicore processing performance, available multi-touch functionality and customizable housings. When running our TwinCAT software, one multi-tasking panel PC can handle the work of multiple PLCs, while also performing motion and robotic control," adds Beilke. ◻

PLC+HMI enables critical stress testing

AeroSpec's medical device test system simulates actual use to verify reliable operation of critical components

By Bryan DeCelles and Zach Marinella, AeroSpec

Medical devices used in hospitals and clinics around the world must undergo a series of rigorous tests to evaluate their reliability before coming into contact with patients. With the high stakes involving patient health, sometimes life-or-death situations, there is no room for mistakes or faulty devices. Each tool in a medical staff's arsenal must function flawlessly every time. With these demanding requirements in mind, AeroSpec, a custom equipment manufacturer in Chandler, Arizona, developed its medical device test system (Figure 1).

This system is designed to perform endurance tests on new medical devices to ensure high-quality performance when met with load and stress from actual use. The system helps medical device manufacturers run extensive tests to ascertain optimal designs, verify reliability and ensure robust products.

AeroSpec started as a machine shop more than 30 years ago and quickly evolved into a full-service custom equipment supplier for a variety of industries including automotive, semiconductor, medical and others. AeroSpec's OEM equipment provides customers with low-cost and efficient methods to verify their medical devices have been tested and are ready for use in the field, whether these devices will be used in a walk-in clinic or an operating room.

INITIAL DESIGN

The AeroSpec medical device test system is a cost-effective, predesigned solution based around the IDEC FT1A PLC+HMI controller and operator interface unit. Versatility is a strength of the system, as it can be adapted to run tests on a wide variety of medical devices.

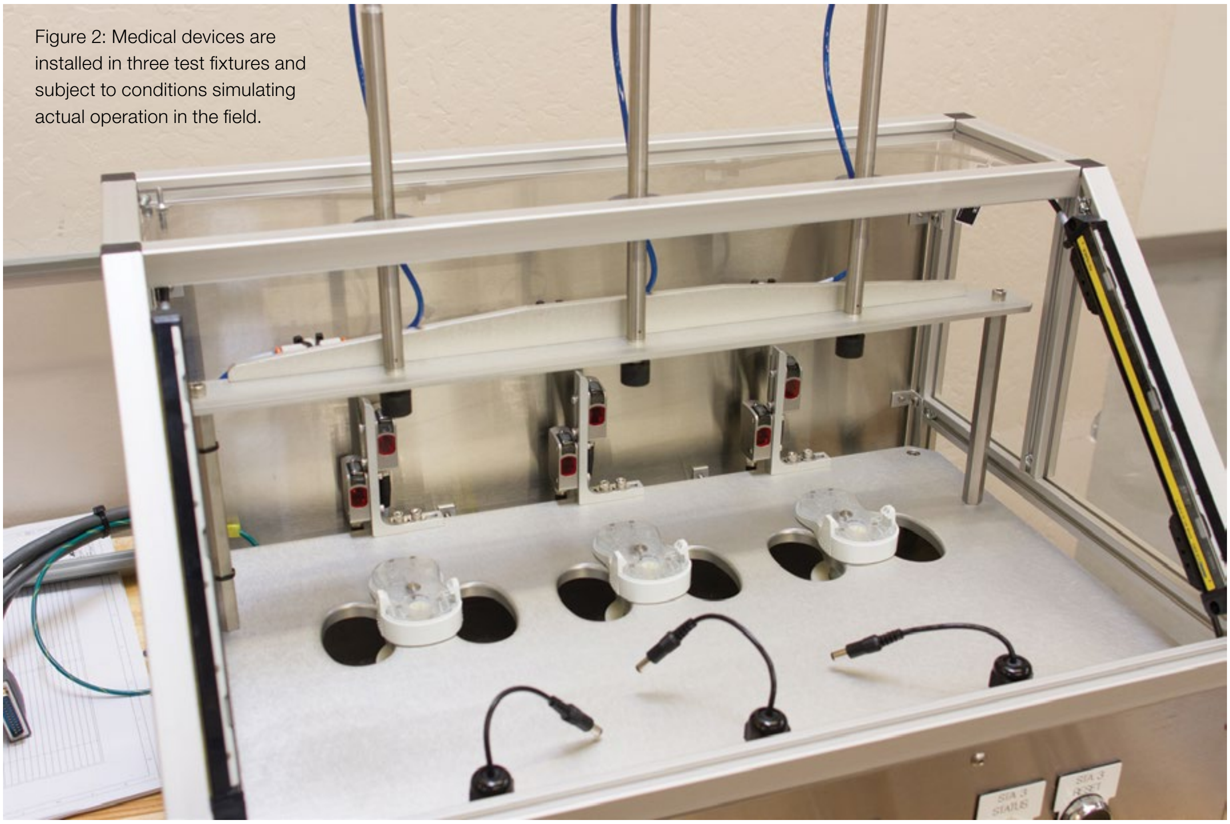
Using the PC-based programming software supplied with the PLC+HMI unit, AeroSpec developed a powerful program to control the unit, and a key feature of this design is the test system's ability to operate lean assembly and testing fixtures.

AeroSpec began work on the test system based upon client-requested specifications. Their client needed a system to run endurance tests on the new product, a cosmetic surgery device used for cellulite reduction, with the ability to simulate the load on the product and measure the stress endured by the device.

Initially, the request was for a test system that would measure current draw through the power cable of the tested device, but the client changed direction on the product to move to a wireless model, making the original request obsolete.

Figure 1: The heart of this medical device test system is the PLC+HMI, which performs control and monitoring of the system and provides operator interface.

Figure 2: Medical devices are installed in three test fixtures and subject to conditions simulating actual operation in the field.



To comply with client requirements, AeroSpec opted to add an rpm sensor to measure and chart the change in velocity of the motor in the device. The rpm sensor would also provide the client's engineers with critical data verifying the device could withstand real-world usage. This system was designed to allow AeroSpec's client to run tests with wired devices, determine an optimal running current and copy that model to the wireless versions of the devices to continue testing.

FUNCTIONALITY AND FEATURES

The test system is designed to execute endurance tests that assist medical-device manufacturers in the development of new products. The test system accomplishes this by simulating actual operating scenarios and by measuring the stress on the devices installed in the text fixtures to gauge how they perform (Figure 2).

The test system has three channels running in parallel with each other. When testing the endurance of medical devices, the test system controls and monitors three pneumatic actuators, three high-speed sensors that gauge rpm on the motor modules and three electromagnetic brakes. The brakes are used to simulate a load on the device, and the pneumatic actuators are used to activate and deactivate the devices.

The test system provides two main fault-condition alerts. The first condition—failed to activate part—occurs when the test system attempts to switch a device on and observes that the rpm reading from the motor module is not increasing. When this occurs, the test system tries to reactivate the device. If it fails to activate a device three times in a row, the test system provides a fault message. The second fault condition—failed to deactivate part— occurs when the test system attempts to turn off a device and doesn't observe the rpm dropping to an acceptable level.

For both fault conditions, the test system flashes a red light for the station that failed to activate or deactivate a device. In a situation where one of the stations fails, or if the user attempts to initiate a cycle with the part incorrectly secured, the HMI screen will also display an alarm.

Hundreds of alarms can be recorded in the PLC+HMI unit alarm log file. Each alarm is accompanied by a brief description to inform the operator of the nature of the fault, and by a time and date stamp. The operator can select a particular alarm and click on the help button, and the PLC+HMI unit will open an alarm help screen where more information and helpful tips will be provided. This makes the process of troubleshooting different faults intuitive and enables the user to take corrective action promptly.

To reset the test system, the operator simply pulls the device out of the test fixture and then reinsert it, or press the reset button. In both cases, this will reinitiate the test cycle.

COMBO PLC+HMI

AeroSpec's medical device test system is responsible for critical product testing, and it's powered by IDEC's FT1A Touch, a combined PLC+HMI in a single housing.

Figure 3: The HMI screen is configured to show all of the test parameters of interest and to guide the operator through the test procedures.

AeroSpec felt the IDEC unit was the best option for its test system as it allowed AeroSpec to attain design goals with a compact form factor unit at a competitive cost.

Another reason for selecting the unit is that the PLC part of the FT1A Touch provides the intelligence and logic needed to control the test processes as it's a 32-bit-based controller with built-in arithmetic, trigonometric, exponential and logarithmic functions to handle the required high-level mathematical calculations.

The PLC has Modbus RTU and TCP ports, with TCP used in this application to communicate between the two PLCs: the master PLC and the slave PLC, which was used as a distributed I/O block. It also has a USB port to allow AeroSpec's customer to download programs to the unit for control and monitoring of the test system. The PLC has sufficient memory to allow the program to expand and to cover the depth of the logic needed for the test procedures.

The HMI part of the FT1A Touch has all the features needed for executing tests and for observing results visually and efficiently. The HMI provides the test system with the graphical capabilities required to set up the tests and displays the current cycle and test number for each station (Figure 3).

The HMI sets the parameters used to run the tests, including minimum and maximum test cycle times, number of tests performed and simulated load amounts. There is a screen for each station that displays an active trend of the rpm and the current test cycle. Located to the right of the screen are options to navigate to the parameters for each station including a histogram of the rpm, test cycles, use-life cycles and torque set points. The test system requires very little training for an operator to use it effectively. An operator simply places the device in a test fixture, and, with no further input from the operator, the machine automatically cycles and tests the device.

When testing is complete, a green light for that station begins blinking, and the operator removes the tested product. The entire process is fast and efficient, and an operator can be trained in less than five minutes to perform these functions.

Due to the nature of the testing, the cycle time can be high, but it is also completely variable. Since the machine possesses three stations, the operator can test three devices simultaneously, tripling the number of devices that can be tested.

TEST SYSTEM SPECS

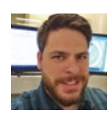
The entire test system is compact enough for desktop operation. Despite its compact size, the system houses impressive capabilities. It continuously logs each station's test data, such as rpm, electromagnetic brake force and station count, at a sample rate of about 500 ms. Data is logged for the duration of the test cycle, which is typically 10 minutes with 25 tests per cycle.

The test system is offered at prices starting at $5,000 and can be made to order in five to six weeks. In addition to the above-mentioned control and monitoring features, the test system includes the electromechanical components required to secure and test products. The test system can be expanded to include features such as thermal and vibration readings.

The test system includes:

- a PLC with up to 24 discrete inputs, 12 discrete outputs, six analog inputs, four analog outputs and four high speed counters
- an HMI touchscreen
- test fixtures
- three variable-force electromagnetic brakes capable of supplying forces from 0.01 Nmm to 20 Nmm with 0.01 Nmm resolution
- pneumatic and solenoid valves
- other components as required for testing a wide variety of medical devices.

This initial implementation of the test system is only the beginning. Several of AeroSpec's customers are currently working with them to adapt the system to meet specific medical-device test requirements. This flexibility of the test system, powered by the PLC+HMI unit, makes these types of adaptations feasible and allows for new implementations to meet customer demands.



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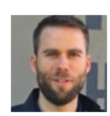

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SPONSOR-SUPPLIED CONTENT

Boiler control system uses advanced PID algorithm

System integrator uses automation system to control complex boiler installations used in hotels, hospitals and other large facilities

By Jack Heiser, Diverse Devices

Founded in Los Angeles in 1946, Parker Boiler manufactures hot water and steam boilers used in manufacturing, wastewater treatment, heating large buildings ranging from hospitals to hotels, and other facilities worldwide.

In 2017, Parker Boiler worked with system integrator Diverse Devices to develop a PLC-based control system using an advanced PID algorithm to sequence multiple boilers. Rather than implementing one large boiler to service the needs of their clients, one or more smaller boilers are often used to minimize downtime, simplify maintenance, and provide regulatory compliance (Figure 1). These and other boiler control applications often require remote access for alerts, adjustments, maintenance and troubleshooting.

Diverse Devices chose an IDEC MicroSmart FC6A PLC and a 10" HG3G HMI to fulfill the needs of Parker Boiler. Diverse Devices migrated from the IDEC FC5A to the MicroSmart FC6A PLC in 2017 because the newer IDEC product had all the features they needed at an attractive price/performance ratio.

Some of the most important new features for this and other applications include a built-in, real-time clock and calendar; Modbus RTU and Modbus TCP IP communication protocols, embedded Ethernet, and data logging capabilities. Other key features needed in this application were data and alarm logging onto a removable SD card, the ability to download logged data via a USB flash drive, and a small footprint for the PLC and HMI.

ADVANCED PID ALGORITHM IMPROVES CONTROL

The IDEC PLC is not involved in the safety controls for the boiler, but is instead used to modulate the firing rate of the boilers, along with control of other functions. If one boiler is not sufficient to meet the heat demand, additional boilers are brought online, and their firing rates are controlled and coordinated by the PLC.

This is accomplished either through Modbus RTU communication or by a 4-20mA analog output signal, depending upon the Parker boiler type. Water temperature (or steam pressure) is measured by the PLC, and then using the PID algorithm, the firing rate is adjusted up or down as required to keep the temperature (pressure) constant. Water temperature is typically the process variable of interest in hydronic heating applications, and steam pressure typically the process variable of interest in industrial processes. Hydronic heating systems use tubing to run a hot liquid beneath floor, along base board heaters, or through radiators to heat commercial buildings and other facilities.

"Setting up the PID function in the PLC using IDEC's PID with Derivative Decay (PIDD) instruction is very easy, and the PIDD controller has a very fast reaction time," says Noel Shamoon, chief programmer at Diverse Devices. "Tuning is quick and intuitive, and multiple changes can simultaneously be made to the PIDD parameters. This new PIDD function has helped eliminate undershoot and overshoot of set points in this and other systems."

Figure 1: Modular systems from Parker Boiler provide improved performance as compared to one larger boiler, as with these four smaller boilers.

REMOTE ACCESS AND OPERATOR INTERFACE

Through the HMI interface, the control system is connected to the internet, providing browser-based access to the boiler system from any internet-connected device such as a laptop, PC, tablet or smartphone. This access allows alarms and alerts to be sent to local or remote personnel via text or email.

Another provision is the ability to remotely monitor, diagnose and upgrade the PLC program—accomplished primarily over a cellular network for purposes of convenience and security. Program maintenance, troubleshooting assistance, and feature upgrades are all handled remotely by connecting a cellular modem installed inside the enclosure.

Cellular was chosen over a wired internet connection to improve security, and to eliminate reliance on the end user's IT network. Alarms generated by the built-in functions of the PLC and HMI are pushed out as e-mails over the cellular network. "We have systems deployed all over the United States, and in a few foreign countries, and we never have to leave the office to support the controller," says Shamoon. "IDEC has made it easy for us to connect remotely, and the ability to connect to a faraway system saves us and our customers substantial amounts of money, while also providing much quicker response."

The HMI was programmed with accessible graphics and menus to make the Parker system easy to set-up and monitor, with virtually no

Figure 2: The HMI interface provides intuitive control and monitoring of the boiler system.

operator training required (Figure 2). The screens are self-explanatory, and Parker keeps certain screens password-protected so an operator does not inadvertently change a critical setting. The alarm log, data log and trend display features of the HMI are all utilized to provide information needed for trouble-

Figure 3. The entire control system including the PLC, the HMI and other ancillary components is housed in a small enclosure, saving money and space.

shooting and preventive maintenance. The entire automation system for control of up to eight boilers is housed in a 16-by-16-by-8-inch enclosure (Figure 3).

CONCLUSION

Diverse Devices has had extremely good reliability with IDEC PLCs and HMIs, finding them to be compact and simple to use, but with the advanced programming features they need. The company has used IDEC PLCs and HMIs for machine and motion control applications. They like the straightforward interface provided by the Automation Organizer suite of programming tools, and appreciate that the tools are maintained and upgraded frequently at no charge.

Parker Boiler has sent a number of their employees to IDEC training classes to become familiar with PLC and HMI programming so they can support the control systems. "The nearby classes have provided tremendous value for us," says Greg Danenhauer, VP of Engineering for Parker Boiler. "We are now supporting our control systems and doing our own programming in-house. The ability to connect remotely has saved us thousands of dollars by minimizing the need to fly technical personnel to job locations."

The end result is a simple yet powerful control system that can be maintained and supported by Parker Boiler. ◻

AUTHOR BIO

Jack Heiser is the president of Diverse Devices, a system integrator located in Orange County, California and specializing in the design of solutions for connecting machines and processes to the internet. Prior to founding Diverse Devices, Heiser worked for various industrial firms in a variety of engineering and management roles. He holds a bachelor's degree in environmental/environmental health engineering from the University of California Irvine, and has also done graduate studies in lighting at Rensselaer Polytechnic Institute.