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HMI FIELD GUIDE TO BEST INTERFACE RESOURCES

There's a jungle lot of information out there about how terrific many human-machine interfaces are, but precious little wisdom about how to select and implement the best HMI for your application. Well, *Control's* editors and contributors have beaten the bushes, and found some of the best resources and experts for doing just that, including Dave Strobhar and Ian Nimmo.

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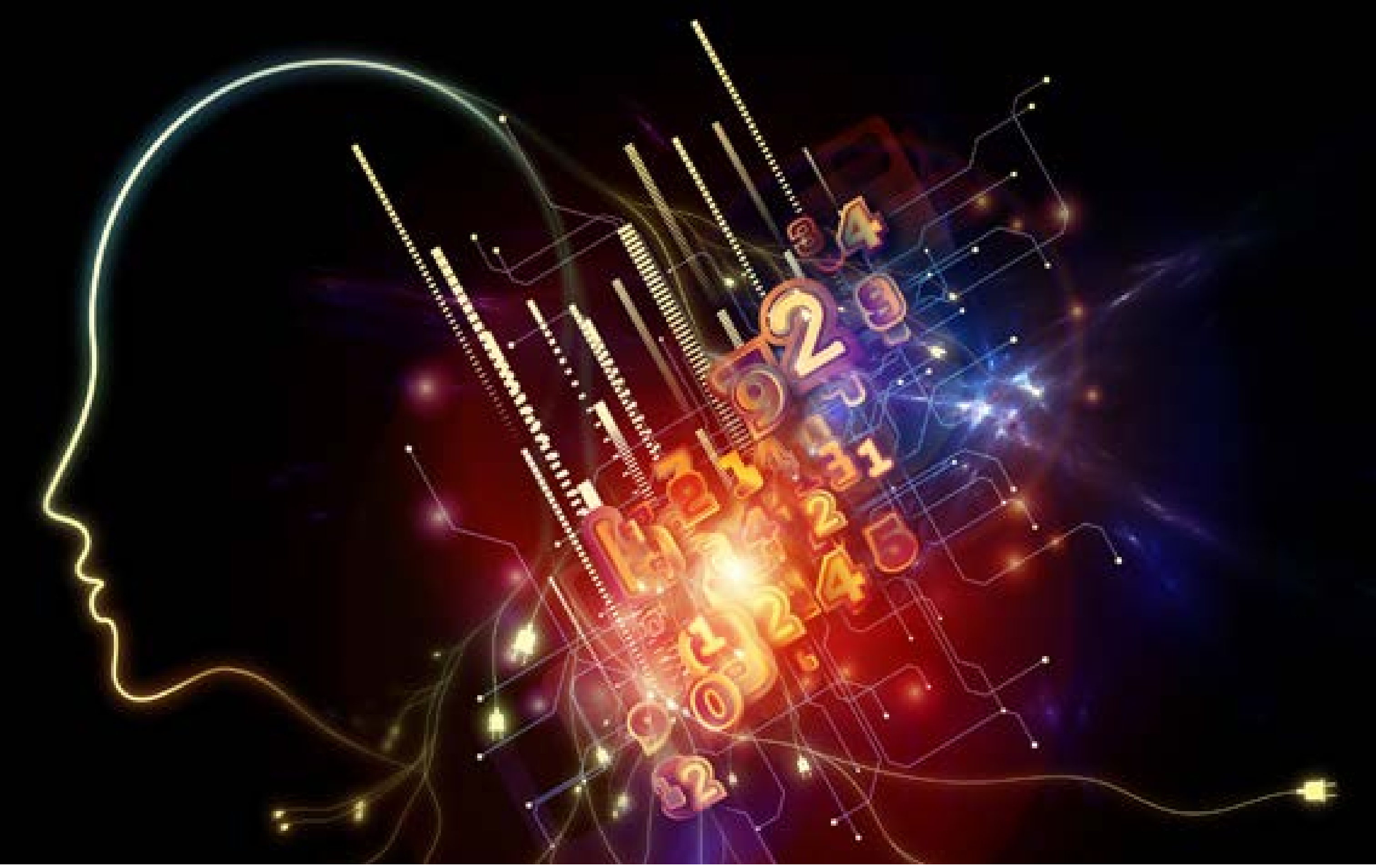

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Here's what to look for in operator displays

Use the 4-second rule: can an HMI tell you what you need to know in 4 seconds?

Mike Bacidore, chief editor, *Control Design*

A fundamental responsibility for any operator is identifying whether a process is OK. And making that determination should take no longer than 4 seconds, according to David A. Strobhar, PE, author of "Human Factors in Process Plant Operation" and principal human factors engineer at Dayton, Ohio, based Beville Engineering, a member company in the Center for Operator Performance.

"To be able to do that in 4 seconds, an operator needs a display that gives them that information," Strobhar told the crowd during his presentation on a different way of approaching interface designs at ABB Automation & Power World in Houston.

Based at Wright State University in Dayton, the Center for Operator Performance, is a collaboration of operating companies and distributed-control-system (DCS) companies that research ways to improve operator performance.

Strobhar prioritized the factors of good display design, in order, as content, organization, layout and formatting, symbols/shapes, color coding, number and size of monitors, and background color.

"Background color is the least important," he explained. "That is almost trivial. Why is it this way? Rethink what a graphic display is about. It's about information transfer. You're trying to transfer information about the process to the operator."

How do you maximize that information transfer in the best form to the individual who needs to have it?

"You should always think about how the information is being transferred," he said. "You can't overcome missing content."

Information is a reduction in uncertainty, explained Strobhar.

"Anything that reduces uncertainty is information," he said. "If it doesn't reduce uncertainty, then it's not information. Any time you're looking at a display, does it help you make a decision? If not, it's just noise."

Strobhar encouraged the audience to think about displays in terms of bits per square inch. "What is the rate of information transfer on the screen?" he asked. "If you're thinking about a movie you've seen or a book you've read, it's about the plot over the prose. That's what you want from your interface. All the fancy colors and animations are not going to make up for a lack of making good sense. Display design should be good storytelling. The problem with a lot of graphics is they are just streams of consciousness. There is no coherent structure that brings them together. You want the information grouped together so it makes sense. What are you trying to convey?"

He advised designers to spend time thinking about what they want to tell operators or convey to them. Often, less is more, said Strobhar, noting that typically it takes more time to write a short, well-organized letter than it does to write a long, rambling one.

Content, then organization

"Once you have content, the second step is organization," he said. "How do you organize the information? What you want is some organization that matches the system. Anticipate what summary information the operator needs and organize accordingly. The primary purpose is to have an overview. In the organization, it is critical to have higher-level displays. You don't want to organize around P&IDs. You want to focus on what the operator is doing."

In the data structure, you need to define the content underneath the structure, Strobhar explained.

"You're looking down from above on the structure, so you can see the organization of the sections," he advised. "What's important in each of these sections? What it looks like is still not important yet."

Once you have the content and organization, then you can go into the layout and formatting.

"This is the prose that goes with the story," said Strobhar. "How am I going to say it? You want to convey the maximum amount of information in the smallest amount of space. Rarely does static information qualify as reducing uncertainty. Get to the point. You want to be succinct and tell them what they need to know. It's not that the color has no importance. It's just not as important."

Strobhar offered an example of a large greenfield project, which was starting from scratch.

"One of my first questions was: Do you have a hierarchy?" he said. "Just because someone creates a hierarchy, it doesn't mean it makes sense. But if you have a starting point, you can look at it and decide not to build all of the graphics or figure out how to combine and consolidate. As you're looking at the graphics and interface, look at organization and content first."

Sometimes you want prose, and sometimes you want tables to convey the information, said Strobhar.

"In an exothermic reaction, I want to know if one of my beds is deviating. But that's just one bit of information. By structuring it and organizing it, the operator can check his display and make the determination within four seconds whether his process is OK. I can focus on what is really important content, but I can provide more bits per square inch if I use symbols."

Color coding is easy to address, he said.

"If you're going to have a color code, each color should only mean one thing," Strobhar advised. "Don't let the same color have two different meanings associated with it."

Strobhar said the Center for Operator Performance is an open group and is currently creating guidelines for large displays.

"We're conducting a survey right now on large-screen usage," he said, encouraging any interested parties to participate in the survey by visiting the organization's website.

"You don't want to organize around P&IDs. You want to focus on what the operator is doing." David A. Strobhar, PE, of Beville Engineering explained how to design operator interface with information as the focal point at ABB Automation & Power World.

HMI Design Basics

CG1505 CD HMIpresentationIn this presentation, Dave Stobhar, Center for Operator Performance, discusses the fundamentals of HMI design display, and answers commonly asked questions on content, layout and formatting, color coding, symbols and shapes and the importance of each factor for the machine designer. Watch the presentation now. ●

HMI experts show interface advice

In the February 2015 Resources column, *Control*'s editors provide the latest educational materials on HMIs

BUILDING AN HMI THAT WORKS

When a process plant suffers a catastrophic failure that costs lives, where does the blame lie? With the operators who may have been among the casualties and can't speak for themselves? Or the HMI that failed to show the operators a system out of control at a time when they could still do something about it? What about the less spectacular failures that cost time and money and waste raw materials and energy? This white paper, "Building an HMI that Works," explores best practices to build an HMI that can deliver crucial production information to inform operators in a clear and timely manner. Download the white paper.

Opto 22

SCADA BASICS

This brief, free tutorial provides an overview of the basics of typical SCADA systems. Subjects covered include hardware and software architectures, including communications and interfacing, application development, product evolution and development roadmaps, engineering and types of systems from various vendors, such as Schneider Electric and GE Fanuc, including Intellution and iFix systems. Access the tutorial.

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BETTER DATA = BETTER PROCESSES

The modern factory runs on information. The more you have—presented in a usable, actionable fashion—the better you can run your processes and your overall operations. This presentation by manufacturing consultant Charlie Gifford discusses the data collection process for manufacturing intelligence, and explores how to build operations, business intelligence and KPI knowledge for shop-floor understanding. It's free but registration is required. Watch the presentation.

Maple Systems

PLC/HMI TUTORIAL, THE VIDEO

This 7-minute YouTube video shows good practices for accessing PLC data and I/O from HMIs for optimized performance, reliability, maintainability and portability using RSLogix 500. Watch the video.

Rohtek Automation

VISUAL BASIC FOR HMI APPLICATIONS

This free PDF explores the technical issues to be addressed when providing information delivery from plant floor devices to the enterprise in HMI applications using Visual Basic technologies. Issues include PLC and control system connectivity, database connectivity, recipe download, logging, trending and alarming. The paper explores how off-the-shelf technologies based on specifications such as COM, ActiveX and OPC can be used with applications developed in Visual Basic to address these issues and provide flexible, cost-effective information delivery systems. The intended audience is the control systems engineer with little or no experience with Visual Basic, but who is familiar with PLCs, is comfortable using a PC running the Windows operating system, and may have created HMI applications in the past using other tools. Download the PDF.

Software Toolbox

HMI TUTORIAL MARATHON

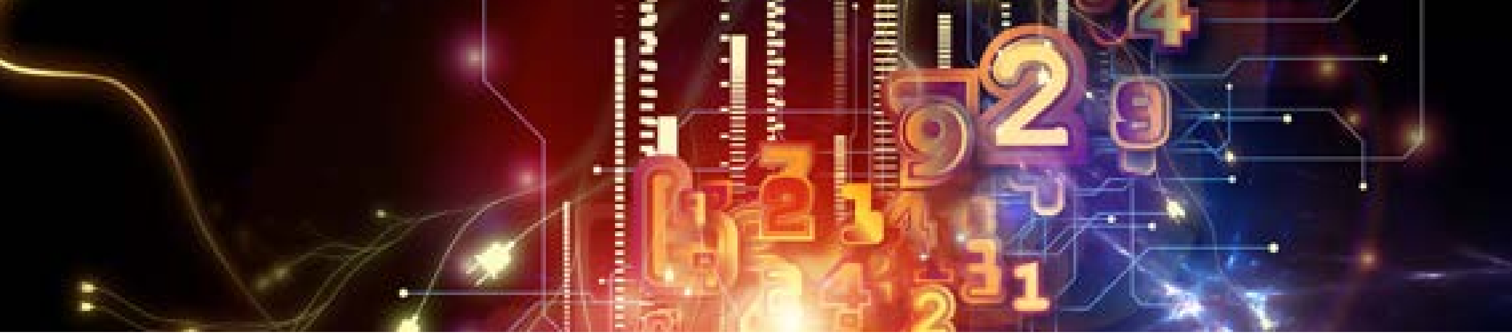
This is a collection of three video tutorials on the general subject of "Screen Designing and Interfacing with a PLC." The three videos are "Momentary and Maintained Buttons," "Display Elements, Meter, Bar Pipe" and "Set Constants, Increment and Decrement in HMI." Each is about 15 minutes long. All are free, but popcorn is not included. Watch all three videos.

NFI Industrial Automation Training Academy

USER-CENTERED HMI INTERFACES

This 21-page, free PDF tutorial introduces the underlying principles of good user-centered HMI design. The target audiences are engineers and designers with an interest in meeting end users' wants and needs, and individuals who have heard about usability of user-centered design and would like to find out more. Topics covered include why usability is important, basic principles of engineering a user-centered HMI, measurable HMI targets, the usability engineering lifecycle, requirements gathering and rapid prototyping, usability evaluation, and relevant international standards. Access the PDF.

International Engineering Consortium



HMI everywhere

There's a difference between monitoring and interacting or controlling. Effective control requires an HMI.

By Ian Verhappen

Last month, I talked about how RFID and IPv6 make "lick-'n-stick" sensors possible, driving the adoption of real-time measurements, such as energy usage, in the consumer market. Though not yet mainstream, there are simple sensor products on the market today that allow you to remotely monitor conditions in such places as a boat, a hot tub, pool or other parts of your home, including your IP-based security systems, over your smart phone or tablet. (See Opto22's Groov—ed.)

However, there is a difference between monitoring and interacting or controlling. Effective control requires an HMI. Now that most HMIs are web-based, the power of open standards is once again being demonstrated in the industrial sector.

The critical open standards defining today's web browser are continuing to evolve with development and adoption of revised standards, such as CSS3, SVG and HTML5, that support scalable graphics in any browser, solving an important piece of the future HMI puzzle.

What will these new standards bring to the scalable HMI equation?

Cascading Style Sheets (CSS) is a style sheet language used for describing the look and formatting (presentation semantics) of a document written in a markup language. Its most common application is to style web pages written in HTML or XHTML, but it can also be applied to any kind of XML document.

Scalable Vector Graphics (SVG) is an XML-based vector image format for two-dimensional graphics that includes support for interactivity and animation. SVG defines the image's behavior in an XML text file.

HTML5, as the name implies, is the fifth generation of HyperText Markup Language (HTML) used for structuring and presenting content for web pages. HTML5 is intended to subsume not only HTML4, but also XHTML (eXtensible HTML) 1.1 and Document Object Model (DOM) Level 2 HTML.

HTML5 includes detailed processing models to encourage more interoperable implementations. Many features of HTML5 have been built to run on low-powered devices such as smart phones and tablets.

In particular, HTML5 adds many new syntactic features designed to make it easy to include and handle multimedia and graphical content on the Web without having to resort to proprietary plugins and APIs. Other new elements are designed to enrich the semantic content of documents. HTML5 also defines in some detail the required processing for invalid documents, so that syntax errors will be treated uniformly by all conforming browsers and other user agents.

A recent ARC report cites nine automation industry technologies to watch. These are intelligent devices and the Internet of Things; predictive analytics for big data; cloud computing and services-based solutions; virtualization; 3D simulation and augmented reality; mobility-enabled applications and "wearable" technologies; bring your own devices (BYOD); remote operations/asset management; and additive manufacturing/3D printing.

Notice that all of these imply more openness, tighter integration of control and business networks, and access to any data, anywhere, anytime. To deliver on this promise obviously requires security and, I believe, the associated move to HMI on a broad range of platforms (BYOD). Moving to smaller screen sizes makes following principles of high-performance HMIs more important than ever.

The recent announcements by Apple of its new iPhones and the unveiling by Samsung of the Galaxy Gear smart watch reinforce how easy it is for us to always remain connected and to access the Internet, thus increasing the pressure to further open the enterprise to beam us data on demand when, where and how we want it.

What is the high-performance HMI?

Operators learn to live with design flaws and often take the easy way out and live with the less-than-perfect systems they grew up with

By Ian Nimmo

The industry today is in a state of confusion regarding basic process control systems' (BPCSs) human-machine interfaces (HMIs). The industry has about 40 years experience with man- or human-machine Interfaces in one form or another. With the evolution of the BPCS, the HMI has evolved over a period of 50 years and has transitioned from physical lights, switches and annunciator panels with analog gauges and trend displays to electronic simulations and finally to computer interfaces.

But, the computer interfaces were designed with little knowledge or science added into the design, and many issues still remain because of this. To help understand the issues and the proposed solutions, we need to understand the current state of the industry. What specific problems we are trying to eliminate?

A quick survey of the current state of the HMI design using a strengths, weaknesses, opportunities and threats (SWOT) analysis reveals that the industry has fully adapted to the current state, and, in spite of known problems and limitations, is reluctant to change. This is mainly because change requires commitment to learn a new system, which involves design, implementation, testing, documentation and training.

Process control operators learn to live with design flaws, and often take the easy way out and continue to live with the less than perfect systems they grew up with. The strength of the existing system is that it evolved from panels to electronics to a first-generation faceplate equivalent and finally to a crude, graphical interface based on plant design.

The HMI many people have been using evolved from a hard panel to group faceplate displays and then to P&ID graphics-integrating faceplates. This has been an easy solution, first taking the controllers from the panel and placing them into groups on a computer display, and then using the faceplate live values within a P&ID graphic.

The black backgrounds and bright, fully saturated colors were not designed. They were more a symptom of the technology, one that the vendors did not mind because bright, fully saturated colors are aestheticly pleasing to the eye, even though they may be 180° from the best practices learned from the science of using color. The vendors still sell their systems based on this premise, rather than on the science of using color correctly.

This statement can be proved by looking at automation vendors' websites and viewing the examples they use to promote

WHY USERS LIKE THE CURRENT SYSTEM

A SWOT analysis reveals the strengths of current HMI graphic systems and reasons why many users are reluctant to rethink their design:

- They evolved slowly over time; the paradigm remains unchanged.
- Easy and comfortable. Staying the same requires little or no effort.
- Familiar.
- Provide context.
- Vendor-supported.
- Aesthetically pleasing.

WEAKNESSES OF THE CURRENT SYSTEM

In spite of being in many users' comfort zone, the design of many current HMI graphics have many flaws:

- Lack hierarchy, causing navigation issues.
- Design is inconsistent.
- Require the use of too many screens.
- Have readability issues.
- Use of high-contrast color causes eyestrain.
- Lack functionality.

their systems. Even though they may have policies supporting the new ASM Consortium-promoted graphics, grey-scale does not sell systems.

As we examine the weakness or problems that are created by this solution, we can read of multiple accident/incident reports that identify the HMI as a contributor to these incidents. We also discover that operators struggle with tracking information or getting overloaded with information because their graphics are not task-based, and information is scattered by the P&ID design. The old groups were faster, as they were assembled based on tasks.

Problems with the Old Way

We see navigation issues caused by lack of hierarchy, in which everything is designed at the same level with no overview. We also see inconsistencies in design because no structure was anticipated by the design. We also see operators trying to get around this issue by requesting more screens. I have actually seen a single operator with more than 24 screens, even though the new standards and guidelines recommend only four process control screens per operator based on short term memory (STM) issues and the limitations on the operator's ability to track more screens.

In addition, ergonomic design principles also help us understand that main screens should be within a 30° and 60° design.

These kinds of graphics have basic readability issues during "normal operations," let alone when data is moving fast during both abnormal operating conditions (AOCs) and emergency operations. These have been categorized as issues with clarity, consistency, too much variety, overload, visual noise and luminance contrast.

Many operators complain of eye-strain because of high-contrast color usage and the use of >3:1 contrast ratio for colors, such as extremes of brightness from yellow-on-black backgrounds.

The eye has to adjust to light and dark continuously, especially with the extremes of light and dark in the environment. Most control rooms with these style graphics are kept dark to reduce glare issues. However, windows, task lights, ceiling lights and windows all create problems in these types of environments.

Graphics designed in this way suffer from poor or lacking functionality. They create an environment that supports human error. For example, they exacerbate short-term memory issues. These can include operators forgetting they've made a manual move, such as opening a drain valve or bypassing an alarm. This system also generally creates high levels of cognitive workload as operators try to diagnose problems by searching for information, all the while keeping an eye on the operation. In the past, we have experienced many data entry problems, which often happen when the operator is several moves ahead of display updates.

The bigger issue with human error is one I've described as situation awareness issues. These touch on some of other areas, such as salience or misplaced salience, data overload and at-

THE OLD, FAMILIAR PANEL WALL.

Figure 1. The panel wall is the starting point of the evolution to the current HMI design used in most process automation operations.

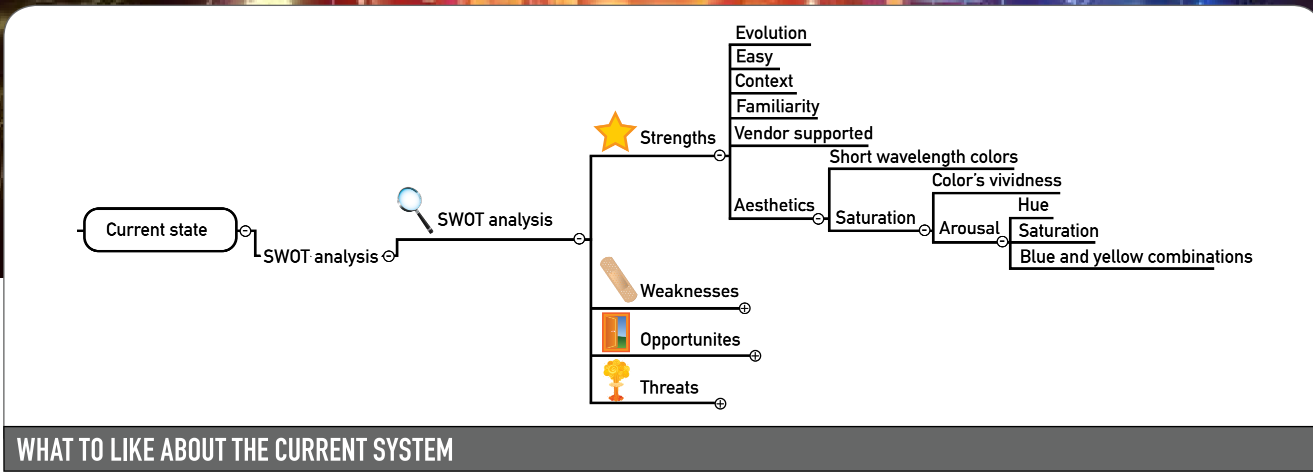


Figure 2. This strengths, weaknesses, opportunities and threats (SWOT) analysis outlines the capabilities of common HMI designs.

tention tunneling. Each of these deserve a white paper of its own. Other issues include distractions, communication breakdowns, out-of-loop syndrome, complexity creep, workload, fatigue, and working with the wrong mental model due to use of P&ID style.

Some quick fixes are available, and include reviewing existing graphics against a formal philosophy and style guide, addressing issues around consistency, and only making graphics pop for important information. You can improve readability by addressing text font and character size or height, and by controlling color and following strict coding rules. Apply similar rules for lines and graphic objects. Address visual clutter, and follow rules regarding how much white space should be left and how many screens each operator should be following. Develop of a hierarchy of graphics views—overview, unit view, detail view and diagnostic view—instead of just using a flat P&ID view. P&IDs normally live down at the detail view. Also, training, management of change and documentation practices often need to be added to a graphic enhancement project.

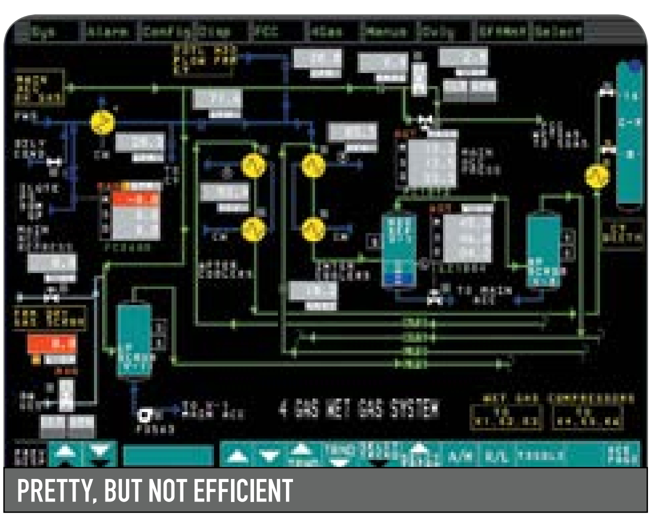


Figure 3. Current designs may be aesthetically pleasing, but they ignore basic color science best practices.

All or Nothing?

Some of the biggest questions I'm often asked are, "Is it all or nothing? Can we do anything to our existing graphics without throwing away what we have? Or, do we have to redesign them totally?" Those are great questions.

I view improvement as an iterative process. Often it all depends on what else is happening. If you're going through an automation replacement, it makes sense to redesign the graphics to today's new standards. Many parts of a current design—the good parts—can be kept, but chances are the new techniques will require something that does not exist in the present design. Many of our customers testify that the new design techniques often result in a significant reduction in the number of graphics or schematics.

The important thing is to have a roadmap, in the form of a philosophy and style guide, which will ensure that the designer and users understand the rules for designing and building graphics, and address the issues of consistency, clarity, variability, etc.

In addition, the greatest lesson that designers and users need to understand about BPCS graphics is that they need to be layered. The background layer should be for fixed reference information, the next layer for variable information, then notifications, then alarms, and finally safety-critical alarms.

The pop-outs at the very front are controlled by color, thickness, brightness, contrast, etc. This allows different priorities to catch the operator's attention, provides improved situational awareness, and allows the graphic to work with the alarm system, rather than being a competitor for the operator's attention.

Finally, new graphics should be designed to the new life-cycle model promoted by ISA-101 draft standard, and follow Human Factor/Ergonomic rules outlined in the ISO 11064-5 standard.

HMIs evolve in process control

New HMI technology is putting a whole new (inter)face on how operators view control systems information, while at the same time driving human error out of systems and improving safe work practices.

By Ian Nimmo

The process control industry's understanding of human machine interfaces (HMI) has evolved. In the early days of automation, the pneumatic panel became the first process industry HMI. These panels *(See Figure 1 below)* were well planned and broken down into task-specific sections, optimizing the panel operator's performance. Without incorporating task analysis and forethought into the optimal instrument layout, the panel operator would have had to run backward and forward and up and down the panel.

Early panels allowed operators to manage specific equipment, such as a boiler or a furnace, from one position with clear understanding and separation of controls. For example, a fuel gas system and boiler feed water were grouped into a logical concentration. The ignition system also was in a logical location with appropriate alarms and interlock mechanisms within easy reach. These panels often had an overview mimic of the process, which was very comprehensive, but often out of date.

In the 1970s, this panel was replaced with an early DCS which didn't have an overview feature, and only allowed the operator access to a group of eight controllers *(See Figure 2 below)*. This initial DCS had many pages of these groups, and operators managed to memorize which controller was on which page. Less familiar operators relied on special keyboards to navigate to relevant groups. Plus alarms within a group caused the keyboard button to annunciate the alarm.

Each controller was a software representation of the pneumatic or electronic equivalent controller located on the panel. The group was configured based on layouts on the panel, and no new task analysis was done. So, sometimes due to the limit of only eight controllers per page, a necessary grouping was lost, and operators had to navigate other pages to make appropriate moves to resolve an abnormal condition. Though operators lost the trend that was with the controller, they could

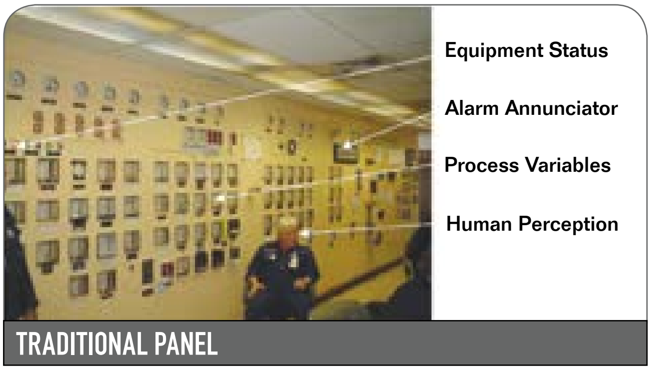


FIGURE 1: Early control panels only indicated equipment status (lights at left), annunciated alarms (two-deck component at right), displayed process variables (windows at center), and relied on human perception (operator in foreground).

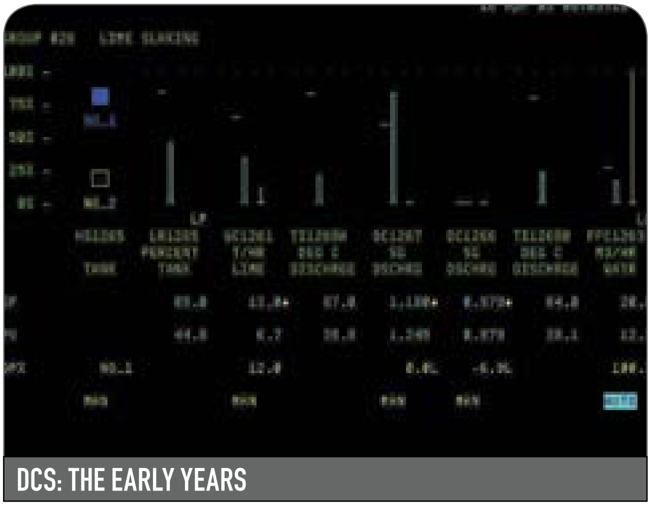


FIGURE 2: Originally, DCSs didn't have an overview feature, and only gave operators access to a group of eight controllers.

navigate to a detail display to retrieve this information. This was only done during the diagnostic process, so normal operation lost a valuable insight to changing variables and direction of change. The big picture provided by the mimic panel soon became outdated, leaving operators with only a keyhole view to the process. The only overview the system provided was an Area and Unit overview display, which provided a summary of the group display.

The discipline of task analysis was also lost in this transition, and the operator became adept at finding information, but often suffered from tunnel vision. Hence, the need for additional alarms was conceived, and DCS vendors applied software capability to the solution. Though the system had some minimal trending provision, it was difficult to use and not always user friendly, so operators became reluctant to use the trending system. Some managers tried to reuse some independent trending equipment, but because there was no dedicated person to service the trending equipment, they too became superfluous.

The next DCSs came with powerful capabilities, and allowed any single point the ability to configure multiple alarms per controller. Unfortunately, without any disciple or management of change, the plants' alarms went from 75 hardwired alarms to 24,000 alarms with some duplication. A single event could initiate several of these functions such as level, plus rate of change, and sometimes bad process variable as the transmitter went out of range.

This generation of DCSs *(See Figure 3 below)* also provided simple graphical representations of the process. These early graphics were crude and fairly low resolution, and their design was based on simple segregation of the plant P&ID. This was the control engineers' perception of the process, and how they related to it. Before long, operators complained about the graphic or schematic designs because they didn't reinforce the operator's mental model of the plant, and the loss of task organization needed the operator to redesign the graphics.

The redesigned graphics improved, but were still problematic because they went from a logical interpretation of the P&ID to an ergonomist's worst nightmare. They had major human-factor issues, too many colors, and multiple uses of color. Rather than reserving colors like red and yellow purely for alarms, all color in these graphics was high intensive. The objects had unnecessary detail; object sizes and position on layout weren't consistent with relative importance; the direction of flow was inconsistent for feeds and products; symbols and lines were poorly implemented; text and numbers were small; and fonts were difficult to read. Numeric format also was difficult to read, some variables had inappropriate levels of detail, and engineering units were inconsistently applied, especially as a space-saving exercise to cram more information on the screens.

STICK FIGURES

FIGURE 3: Initial, DCS-based process representation graphics were crude and fairly low resolution, and their design was based on simple segregation of the plant P&ID.

Operating Display Problems

Graphical shortcomings have contributed to human errors and incidents, some with severe consequences. For example, regulatory inspectors identified several HMI-related issues as contributing to the July 1994 explosion and fire at the Texaco Pembroke refinery in Wales, U.K. Under the fluid catalytic cracking unit (FCCU) control system that existed on the day of that incident, any imbalance in liquid flow through the FCCU could lead to liquid accumulation. Therefore, it was important that any imbalance in liquid flow be detected, so the mass flow of the unit could be returned to a balanced position. The plant was well equipped with alarms, which showed where liquid was accumulating, but it was more difficult to assess the relative flows through the vessels and the overall mass balance of

the unit. The process of fractional distillation requires that one raw material be divided into many fractions.

While it was easy to assess the unit feed rate, the various outputs of the process were spread over five product streams. This caused a practical problem because the accumulated outputs of the system may be spread across several different control display units, and the overall output of the unit wouldn't be readily apparent unless the control system were configured to meet this need.

Unfortunately, this need reportedly wasn't met at Texaco Pembroke. There were no displays providing an overview with an appropriate time scale on the FCCU. Therefore, it was difficult to obtain a complete picture of the whole or large sections of the process. In a mostly display-screen-based operating system, the provision of good overview displays is especially important because the operator doesn't have a continuously available set of panel indicators.

During the incident, no one from the operations department had a complete picture of the FCCU. The actual FCCU graphics on the operating displays weren't best designed or configured to help operators control the process. The operating graphics on the FCCU contained limited amounts of process data per graphic, and didn't use color and intensity to highlight process data. Some graphics contained details of the internal structure of plant items. However, displaying the structure of plant items is only useful if measurements or derived information, such as pressure, temperature and flow, also are displayed to give the operator information relevant to plant status. At times, the text was unnecessary in the FCCU graphics. Text takes up large amounts of space on a graphic, and there were instances where the same information could have been better indicated by color change, according to U.K. Health and Safety Executive (HSE) investigators, reporting on the disaster in "Investigation into the Explosion and Fires on the Pembroke Cracking Co.'s Plant at the Texaco Refiner."

The HSE investigators' recommendations on human factors are of immediate interest in designing HMIs, especially the report's Recommendation #3: Display systems should be configured to provide an overview of the condition of the process including, where appropriate, mass and volumetric balance summaries.

Other studies into these types of human errors have identified that 30% of errors are attributed to the operator not becoming aware of an abnormal situation due to information overload, vague or misleading information, inappropriate levels of detail and operator vigilance decrement. Further research identified that an additional 20% of errors were attributed to the operator's inability to identify the root causes in a timely manner due to insufficient knowledge, lack of operator experience, conflicting priorities, inaccurate labeling or information presentation, and excessive mental tasks. Many of these issues can be resolved by a well designed HMI.

Many of these traditional problems were initially introduced by poor guidelines from DCS manufacturers and even worse project implementation practices by vendors. Fortunately, vendors have continued to evolve the DCS, and now the graphics are high resolution, and are becoming web based. Unfortunately, the vendors again haven't invested in human factor education *(See Figure 4 below)*, and now promote 3-D objects that take over 60% of the screen. This means that 60% of the screen's fixed data is unfortunately in the foreground, while real data useful for detecting

HMI DESIGN MISTAKES REDUX

FIGURE 4: A lack of human factor education had led HMI makers to promote 3-D objects that fix more 60% of a screen's data in the foreground, while real data useful for detecting and diagnosing abnormal situations shoved into the remaining 40% of the graphic's background.

and diagnosing abnormal situations is shoved to the remaining 40% of space in the graphic's background.

Ergonomics Can Resolve Operator Errors

In addition, the process industry hasn't responded to the human error problem by following guidance that's now available for alarm management. EEMUA, the organization that produced the well known "Alarm Management Guidelines," Publication 191, has also produced a similar guideline for graphics called "Process Plant Control Desks Utilizing Human-Computer Interfaces: a Guide to Design, Operational and Human Interface Issues," Publication 201. This document hasn't had the same publicity or exposure, and needs further detail, but it's a great start to improving the standards and current HMI or HCI practices. As knowledge and papers available on this subject are examined, a researcher will discover it's not that information is lacking.

Other industries, such as the nuclear field, have good guidelines for HMI developers, and many of these are directly relevant to the process industry. Likewise, ISA has produced recommended practices for Fossil Fuels on HCI and task analysis, which appeared in the organization's RP 77.60.05-2001 report, "Fossil Fuel Power Plant HMI Task Analysis."

In fact, the latest recommended practices for developing graphics includes starting with, not just a task analysis as was done 50 years ago for the control panel layout, but more in-depth analysis using a variety of techniques. These formats include:

- Hierarchical task analysis
- Tabular task analysis
- Timeline analysis
- Link analysis diagram
- Human error analysis tabular

Better Graphics

Some of the latest practices associated with HCI development directly address these human factor issues by first providing a good graphic style guide. Many of these practices are identified in the EEMUA 201 document.

The background of HMI graphics also has changed from the traditional black to a grey background to mitigate glare. Most lighting schemes will produce glare and contrast issues when first delivered through glass VDUs. This problem was dramatically reduced as technology changes allowed LCD screens to be implemented. Black backgrounds facilitated operators turning the control room lights out, but use of multiple bright colors on these black backgrounds added to their complexity.

Graphics also have become easier to read as developers moved to brighter grey backgrounds, and reduced use of added colors by using high and low-intensity hues. Glare and reflection were reduced, but potential problems can still arise. Moving to brighter background color can introduce new problems if a control room's lights are still turned out. Ideally, the control room should be designed to facilitate operator vigilance, especially with 12 hour shifts, by illuminating the control room between 500 and 800 LUX.

As mentioned above, the practice of using grey on grey for lines and vessels has allowed developers to put the fixed information into the background of the graphic, and place the variable information in the foreground.

Reserving colors and limiting color adoption in the graphic enables easier identification of off-normal or abnormal operation using grey on grey as normal and color as an attention getter. When a high-priority alarm annunciates on these displays, it becomes very visible on the graphic. And when the alarm is acknowledged, the color intensity is reduced to half, making the alarm still visible, but not the highest attention. This allows priority to become part of the graphic design.

Some investigations have been done about using graphical analog instruments, rather than just using digital numbers. Level and flow gauges are easier to read and make estimates of than relying on purely digital information. The aircraft industry mixes digital and analog data to provide good situational awareness, and uses analog indicators and accuracy where needed with its digital data. These new graphic systems use objects to represent mathematical solutions, such as mass energy balance and polar star techniques to represent change, and how it impacts other physical variables. This provides a better understanding of how to correct problems.

The technology now allows integration of information outside the DCS, such as Microsoft Word and Excel documents to be integrated into the graphic. By using pull-down menus, one

of these IT based documents can be launched to provide calculations, lookup tables, procedures, and diagnostic information. This may include alarm information, stating the purpose for the alarm, typical problems that initiate the alarm, what corrective action is expected, consequences of no action, and other supporting information that would be useful to the operator.

As the HMI or HCI world continues to change, we have the power, but we need the discipline and knowledge of how to use this technology. We need to recognize that the problem we're solving is called "situation awareness," and alarms, trends and graphics are an integral part of the awareness solution.

This solution requires a true overview display, one that allows operators to monitor the important equipment within their scope of control, and provides clear indication of the highest level of alarms. The display needs to provide production information that will help the operator monitor the most important key performance indications (KPIs). Some solutions may include a graphical bar chart showing normal, the ± off-normal indication, and relevant alarm data.

The graphic system of the future will have trending embedded into the displays, operators again will use trends to predict off-normal, and they'll be less dependent on alarms. The new system will exploit new navigation techniques, such as hierarchical navigation, which moves from overview to unit view to detail view, and finally down to diagnostic views and controller change zones. This form of navigation allows use of yoking techniques. This will allow automatic screen setup based on selecting a point, and populating the other displays with the relevant information associated with that point from overview to unit to detail to trend and alarm data.

Recent graphic projects also have exploited large overview screens and video walls, which reduce the amount of glass required at the console, and can significantly reduce the cost of the console because fewer workstations are required.

Another anomaly with HCI development is that graphics should be developed before the console, and the console should be developed before the control room. Unfortunately, we do this in reverse order, which causes problems with the flow and concentration of information.

Consequently, the future of the process industry should be driven by standards organizations such as ISA. Industry needs to free up and encourage engineers to address this topic. Research should be done first to identify what has worked well during this evolutionary process, looking back at how operators and supervisors used the panel, as well as how operators adapted to group displays and the new transition to cool graphics that provide good situation awareness. As an industry, we also need understand the research and knowledge that the nuclear, fossil fuels and aircraft industry have identified as best practices in HMI development.

The final solution will not be driven by operators or control engineers, but by a management team that understands the issues with the existing culture, is brave enough to follow the leaders in industry, and invest in good task management and up-front project loading. Investment is needed in graphical style guidelines suitable for all DCS vendors systems and project-specific requirement specifications. This specification is a how-to guide to implementing the style guide on a specific system and/or project. Investment in graphical object libraries is also required to provide more than traditional valve, pump, and compressor objects, so the new systems will have diagnostic modules that help the operator understand more advanced information, such as material mass and volumetric balance.

Driving human error out of systems and improving safe work practices is a management responsibility, but so far management still lacks knowledge and experience to prevent those errors. They have a poor understanding of human factors, and are complacent to the needs of their operators. The control engineer can do a service to his company by raising awareness of this topic at the highest levels in an organization, and pursuing best practices on the control system upgrade projects.