Maximize Operator Effectiveness:

High Performance HMI Principles and Best Practices

Part 1 of 2

A PAS White Paper
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Bill Hollifield
Principal Alarm Management and HMI Consultant, PAS

Hector Perez
HMI Product Manager, PAS
### Table of Contents

Introduction and Overview ...................................................................................................................... 1  
HMIs Past and Present ................................................................................................................................. 3  
Justification for HMI Improvement ........................................................................................................... 5  
Proper Graphic Principles .......................................................................................................................... 6  
Show Information Instead of Raw Data ...................................................................................................... 7  
Proper Use of Color .................................................................................................................................. 9  
Elements and Depictions of HPHMI .......................................................................................................... 10  
Depicting Process Values ........................................................................................................................... 10  
Depicting Alarms ....................................................................................................................................... 11  
Depicting Profiles of Temperature or Pressure ....................................................................................... 13  
Depicting Dynamic Equipment .................................................................................................................. 13  
Bars vs. Pointers ........................................................................................................................................ 14  
Depicting Level Indication .......................................................................................................................... 14  
Depicting Control Valves and Shutoff Valves ............................................................................................ 14  
Depicting Equipment Commands .............................................................................................................. 15  
Use of Trends ............................................................................................................................................. 16  
Depicting Tables ........................................................................................................................................ 16  
Depicting Advanced Process Control (APC) .............................................................................................. 17  
Depicting Shutdown Activation .................................................................................................................. 17  
Depicting Interlock Functionality ............................................................................................................... 18  
Startup Map ............................................................................................................................................... 20  
Navigation and Command Buttons ......................................................................................................... 20  
Display Layout and Faceplate Handling ..................................................................................................... 21  
Avoiding “Blob” Graphics ......................................................................................................................... 23  
Display Hierarchy ....................................................................................................................................... 23  
Level 1 - Operation Overview ..................................................................................................................... 24  
Level 2 - Unit Control ................................................................................................................................. 25  
Level 3 - Unit Detail .................................................................................................................................... 26  
Level 4 - Support and Diagnostic Displays ............................................................................................... 26  
Conclusion of the Part 1 Document ........................................................................................................... 27  
About the Authors ....................................................................................................................................... 28  
References ................................................................................................................................................... 29
Introduction and Overview

The process control and automation industry has spent billions on improving process safety via complex, instrumented systems. Yet, we continue to frequently see industrial incidents, accidents, and fatalities in the news. The causes are generally not the failure of such automated systems, but are instead the result of a wide variety of human errors. PAS firmly believes that addressing the causes of human error and the improvement of *Operator Effectiveness* is of the highest importance. The proper use of such technologies as High Performance HMI and Alarm Management can actually save lives and prevent injuries. Detailed information on these should not be withheld, and that is why we offer this and other white papers freely. They can also significantly lessen process upsets, improve process efficiency, and increase productivity.

The human-machine interface (HMI) is the collection of screens, graphic displays, and other technologies used by the operator to monitor and interact with the control system (typically DCS or SCADA). Several major accidents, such as the Texas City refinery explosion in 2005, have cited poor HMIs as a significant contributing factor. The design of the HMI plays a critical role in determining the operator’s ability to effectively manage the operation, particularly in quickly detecting and resolving an abnormal situation, which is the most important task of an operator. A poor HMI can actively *interfere* with this ability.

For several reasons, the current designs and capabilities of most HMIs are far from optimal for running the kinds of complex operations we have in industry. Most HMIs consist simply of schematic or P&ID style graphics covered in numbers. Such displays provide the operator large amounts of raw data, but almost no real information. They are difficult to interpret and provide inadequate situation awareness to the operator.

Since we published *The High Performance HMI Handbook* in 2008, improving HMI has become one of the hottest topics in the automation industry. In that book, we explained exactly why most current HMI practices were poor, and we put forth the proper principles and details for making graphics significantly better. Many companies have adopted those principles and have completed migrations to improved graphics. Many more have such efforts currently underway.

This two-part paper provides a history, justification, and detailed plan of action for the improvement of a process control HMI. Here is an overview of the contents.
Part 1

**Examples:** We provide typical examples of common but poor HMIIs, along with highly detailed depictions of improved methods that provide for much better operator situation awareness and control.

**Principles:** We cover the most important aspect of High Performance HMI™ (HPHMI), the display of information to the operator rather than raw data. Many other necessary graphic principles including the correct way to use color are provided. Depictions of detailed graphic elements are included.

**Hierarchy:** HPHMI graphic designs must reflect a proper hierarchy - the exposure of additional detail as needed. We include examples of graphics that illustrate this hierarchy, along with the work processes used to design such graphics.

If your facility utilizes a process control system with a computer-based HMI, you will find this information useful. This white paper augments the detailed content in *The High Performance HMI Handbook*.

Part 2 (Separate Document)

**Case Studies:** Since the publication of our 2008 book, many projects have provided for the development of real-world case studies. We include two such studies in this paper. The first was conducted by the Electric Power Research Institute (EPRI), but is applicable to all types of process operations. The second shows how a major company has improved performance and significantly lowered costs via company-wide adoption of standardized High Performance graphics. This has led to a major HPHMI product innovation for the power industry: PowerGraphiX®.

We also provide an example as to how “out-of-the-box thinking” can address HMI issues, in the discussion of a Pipeline System Overview Display.

**Standards Review:** Two standards documents available on HMI are discussed, including the ISA-101 HMI Standard released in August 2015.

**HPHMI Work Processes and Implementation Guidance:** The work process for HMI improvement is described. We also address the most common issues encountered in HMI improvement, and cost effective ways to transition to High Performance graphics.
HMIs Past and Present

Before the advent of sophisticated digital control systems, the operator’s HMI usually consisted of a control wall concept such as Figure 1.

The control wall had the advantages of providing an overview of the entire operation, key trends, and a limited number of well-defined alarms. A trained operator could see the entire operation almost at a glance. Spatial and pattern recognition played an important role in the operator’s ability to detect burgeoning abnormal situations.

These systems had several disadvantages. They were difficult to modify, the addition of incremental capabilities was problematic, and the ability to extract and analyze data from them was almost non-existent. In the 1980s-1990s, the modern electronic control systems (DCS/SCADA) replaced them for such reasons.

When the modern systems were introduced, they included the capability to create and display graphics for aiding in the control of the operation. However, there were no guidelines available as to how to create effective graphics. Early adopters created graphics that mimicked P&ID or schematic drawings, primarily because they were readily available. The limited color palette was used inconsistently, and screens began to be little more than crowded displays of numbers on a P&ID.

Graphics such as Figures 2 and 3 were developed over 20 years ago and remain common throughout the industry. Indeed, inertia, not cost, is the primary obstacle to the improvement of HMIs. Engineers and operators become accustomed to this style of graphic, and are resistant to change.

Figure 1: Example of a Control Wall

Figure 2: An Early Graphic Showing Many Problematic Practices
As a result, industries that use modern control systems are now running multi-million dollar operations from primitive HMIs created decades ago at a time that little knowledge of proper practices and principles was available.

As control system hardware progressed, the manufacturers began to develop very flashy example graphics which were used for marketing purposes. While fit for that purpose, they were quite ineffective for actually controlling a process. Many companies and projects, however, began to create graphics similar to those examples. The results were displays that are actually suboptimal for operators.

To illustrate this point, Figure 4 is an example of flashy design taken from a power generation facility. The graphic dedicates 90 percent of the screen space to the depiction of 3-D equipment, vibrantly colored operation lines, cutaway views, and similar elements. However, the information actually used by the operator consists of poorly depicted numerical data, which is scattered around the graphic, and only makes up 10 percent of the available screen area.

There are no trends, condition indicators, or key performance elements. You cannot easily tell from this graphic whether the operation is running well or poorly. That situation is true for more than 90 percent of the graphics used throughout industry today because they were not designed to incorporate such information. Instead, they simply display dozens to hundreds of raw numbers lacking any informative context.
Justification for HMI Improvement

Poorly performing HMIs have been cited time and again as significant contributing factors to major accidents. Yet, our industry has made little significant change in HMI design. There is another industry that learns from its accidents and has made phenomenal advancement in HMI design based on new technology. That industry is avionics. The resulting improvement in pilot situation awareness is one of the largest contributing factors in the decades-long decline in aviation accidents.

Modern avionics feature fully-integrated electronic displays as shown in Figure 5. These depict all of the important information, not just raw data, needed by the operator (i.e., pilot). Position, course, route, engine diagnostics, communication frequencies, and automated checklists are displayed on moving maps with built-in terrain proximity awareness. Real-time weather from satellite is overlaid on the map. Detailed database information on airports is available with just a click. Situation awareness and abnormal situation detection is far improved by these advances. This capability - impossible even a dozen years ago in multi-million dollar airliners - is now standard on even the smallest single engine aircraft.

There have been tests involving actual operators running realistic simulations using traditional graphics vs. High Performance ones. PAS participated in such a test at a large power plant, sponsored by the EPRI and detailed later in this paper. The results were consistent with a similar test run by the ASM® (Abnormal Situation Management) Consortium on an ethylene plant. The test showed the High Performance graphics provided significant improvement in the detection of abnormal situations (even before alarms occurred) and significant improvement in the success rate for handling them. In the real world, this translates into a savings of hundreds of thousands of dollars per year.

Since safety is significantly improved with modern HMIs, it is only logical that we would want all operators to have access to them. Yet most companies have done little to upgrade.
Proper Graphic Principles

Ineffectively designed graphics are easy to find. Simply search the internet for images under the category “HMI.” Problems with these graphics include:

- Primarily a schematic or P&ID representation
- Lots of displayed numbers
- Few or no trends
- Spinning pumps/compressors, moving conveyors, animated flames, and similar distracting elements
- Brightly colored 3-D equipment
- Highly detailed equipment depictions
- Attempts to color code piping with contents
- Long, cryptic tag names shown on the screen
- Brightly colored liquid levels displaying the full width of the vessel
- Lots of crossing lines and inconsistent flow direction
- Inconsistent color coding
- Bright colors on dark backgrounds
- Misuse of alarm-related colors
- Limited, haphazard navigation
- A lack of display hierarchy

Ineffective graphics encourage poor operating practices, such as operating by alarm. By contrast, High Performance graphics have:

- A generally non-schematic depiction except when functionally essential and at Level 3
- Limited use of color, where color is used specifically and consistently
- Gray backgrounds to minimize glare and reflection issues
- No animation, except for specific alarm-related graphic behavior
- Embedded, properly-formatted trends of important parameters
- Analog representation of important measurements, including their value to normal, abnormal, alarm, and interlock conditions
- A proper hierarchy of display content providing for the progressive exposure of detailed information as needed
- Simple and straightforward depictions in 2-D not 3-D
- Consistent flow depiction and layout to minimize crossing lines
- Embedded information in context (via right-click menus or similar methods) such as alarm documentation and rationalization, standard operating procedures, and more.
- Logical and consistent navigation methods
- Techniques to minimize operator data entry mistakes
- Validation and security measures
Show Information Instead of Raw Data

A primary difference of High Performance graphics is the underlying principle that, wherever possible, operational values are shown in an informational context and not simply as raw numbers scattered around the screen.

*Information is data in context made useful.*

As an example, consider this depiction of a compressor shown in Figure 6. Much money has been spent on the purchase of instrumentation. Yet, unless you are specifically trained and experienced with this compressor, you cannot tell if it is running at peak efficiency or is about to fail.

The mental process of comparing each number to a memorized mental map of “what is good” is a difficult cognitive process. Operators have hundreds (or even thousands) of measurements to monitor. Thus the results vary by the experience and memory of the operators, as well as how many abnormal situations they have personally experienced with this particular compressor. Training new operators is difficult because the building of these mental maps is a slow process. Adding more numbers to a screen like this one does not aid in situation awareness; it actually detracts from it.

By contrast, a bank of analog indicators, as in Figure 7, can represent these numbers much more effectively. Analog is a powerful tool because humans intuitively understand analog depictions.

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**Figure 6: All Data, No Information**

**Figure 7: Analog Depiction of Information**
We are hard-wired for pattern recognition. With a single glance at this bank of properly designed analog indicators, the operators can tell if any values are outside of the normal range, by how much, and the proximity of the reading to both alarm ranges and the values at which interlock actions occur. Analog depictions such as these moving analog indicators are a key element of HPHMI.

In just a second or two of examination, the operator knows which readings, if any, need further attention. If none do, the operator can continue to survey the other portions of the operation. In a series of short scans, the operator becomes fully aware of the current performance of their entire span of control.

The knowledge of what is normal is embedded into the HMI itself, making training easier and facilitating abnormal situation detection – even before alarms occur, which is highly desirable.

Similarly, depiction of PID controllers is accomplished with the addition of easily scanned setpoint, mode, and output information, as in Figure 9. If the final control element has a position feedback signal, deviation is easily and effectively shown on the output scale. Mechanical deviations are prime causes of abnormal situations, and they should be made easy to spot.

The subtle, slight gradients and shadows are intended to increase prominence of the live elements. Images in printed form are often significantly different than images shown on a screen. For that reason, other modifications to increase printed visibility have been made on some depictions in this paper. Actual design of HPHMI elements concerns their appearance on the screen.

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**Figure 8:** Further Explanation of Moving Analog Indicators
Proper User of Color

Color must be used consistently. People have several types of common color-detection deficiency (e.g., red-green, white-cyan, green-yellow). For this reason, the most important rule for color is this:

*Color, by itself, is never used as the sole differentiator of an important condition or status.*

Most graphics throughout the world violate this principle. A color palette must have a limited number of distinguishable colors used consistently. Bright colors are primarily used to bring or draw attention to abnormal situations, not normal ones. Screens depicting the operation running normally should not show brightly saturated colors, such as bright red or green pumps, equipment, valves, and similar items.

When alarm colors are chosen, such as bright red and yellow, they are used solely as an aspect of the depiction of an alarm-related condition, and for no other purpose. If color is used inconsistently, then it ceases to have meaning. Figure 10 is a workable HPHMI color palette, and the example figures in this paper generally follow it. There should not be very many colors, and all colors must be easily distinguishable.

Graphics with color-neutral gray backgrounds on LCD screens are effective. They also enable the lights in the control room to be turned back to bright – where they should be. Poor graphics began with dark backgrounds and bright colors due to 1980s-90s CRT hardware limitations. This scheme resulted in major glare and reflection problems, which were addressed by dimming the control room lights. For operator alertness, the control room lighting should actually be brighter than a typical office, all day and all night.

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*Figure 9: Analog Depiction of PID Controllers and Position Feedback*
Elements and Depictions of HPHMI

This section shows many of the common situations that a process graphic must depict, and how to accomplish those depictions by following High Performance HMI principles.

Depicting Process Values

The display of live values on the screen should be shown in a different way than static text:

- The choice of a bold, dark blue is a good choice with the gray background, and differentiates live values from static text done in black or dark gray as in Figure 11.
- Leading zeros are not displayed, except on fractional values (e.g., 0.27). Values are shown only to the precision needed by the operator.
- In tables or columns, generally align numbers on the decimal point.
- Units of measurement are displayed in non-bold text near the value.
- Point names should not be shown on the screen by default. It should never be necessary for an operator to have to type in a point name in the entire HMI.
- Process values can have a variety of diagnostic conditions. Figure 11 shows a clear, concise, and visible way for depicting those. Color coding is not recommended.
- When items are “selected”, that status should be indicated. Surrounding the selected item with a white outline is a good practice.

### Depicting Alarms

Proper alarm depiction should also be redundantly coded based upon alarm priority (color / shape / text). Alarm colors should not be used for non-alarm related functionality.

When a value or object comes into alarm, the separate alarm indicator appears next to it, as shown in Figure 12. The indicator flashes while the alarm is unacknowledged (one of the very few proper uses of animation) and ceases flashing after acknowledgement, but remains visible as long as the alarm condition is in effect. People do not detect color change well in peripheral vision, but movement such as flashing is readily detected. Alarms thus readily stand out on a graphic (and on multiple screens) and are detectable at a glance.

Figure 12 shows that the most common methods of alarm indication are a direct violation of the basic rule of color use, as they are different solely by the use of color.
It is highly beneficial to include access within the HMI to the alarm rationalization information contained in the Master Alarm Database as shown in Figure 13. If these terms are unfamiliar, you are advised to read the ISA 18.2 standard for Alarm Management in the Process Industry, or read the API RP-1167 Alarm Management Recommended Practice if you are in the pipeline industry. PAS offers free white papers explaining both documents.

![Figure 12: Depiction of Alarms](image)

![Figure 13: Linked Alarm Information](image)
Depicting Profiles of Temperature or Pressure

Consider these alternative distillation column temperature profile displays. When only numbers are shown, even an experienced operator may easily miss a suboptimal condition. Additionally, a new operator will find it difficult to build a mental map of a proper profile. The desire is for all operators to recognize normal and abnormal profiles at a single glance.

A correct profile can be seen at a glance as a straight line.

Depicting Dynamic Equipment

So what about the paradigm of using bright green to depict “on” and bright red for “off” (or vice versa in the power industry)? This is an improper use of color. The answer is a depiction such as Figure 15.

The relative brightness of the object shows its on-off status, as does the use of a process value word next to it. Equipment items brighter than the background are on (think of a light bulb inside them). Items darker than the background are off. If equipment has no status that is sensed by the control system, but is desired on the graphic anyway, it is shown as transparent to the background color. The status word can indicate several conditions, as shown. Remember, if any of those are also alarm conditions, the separate alarm indicator will appear next to the equipment when it is in an alarmed state.

Figure 14: Measurement Profile

Figure 15: Depicting Status with Redundant Coding and Proper Color Usage
Bars vs. Pointers

Attention to detail is important. It is typical to use bar graph elements to show relative positions and values. While this may be better than simply showing numbers, it is inferior to the use of moving pointer elements, since the bar disappears as the bar’s value gets low. The human eye is better at detecting the presence of something than its absence. And, the low condition may be more important than the high condition and should have equal visual prominence. The example in Figure 16 is superior in showing relative values, besides the color improvement.

Figure 16: Bars vs. Pointers

Depicting Level Indication

Vessel levels should not be shown as large blobs of saturated color. A simple strip depiction showing the proximity to alarm limits is better. A combination of trend and analog indicator depictions is even better such as Figure 17. The right-hand edge of the trend replaces the pointer and provides context.

Figure 17: Vessel Levels

Depicting Control Valves and Shutoff Valves

Control valves turn out to be one of the more complicated items to depict. The tendency is to want to cram too much data into a small space. Traditionally, we depict a control valve (throttling, variable position) with a domed head depiction and an automated block valve (only on-off) with a rectangular head depiction.
In keeping with equipment depictions, the valve body is filled darkly for closed and brightly for open. This also follows the P&ID paradigm for block valves. The same method can depict the state of three-way valves. The solenoid and position switch statuses can also be shown if desired.

**Figure 18:** Control and Automated Block Valves

### Depicting Equipment Commands

When DCS/SCADA points are built that indicate equipment state, the control engineer can usually decide which words to display to represent the current state. The choices they make are often poor. The most common example is “RUN” and “STOP.” Do these represent the equipment’s status, or a command to it? “RUNNING” and “STOPPED” are much better status indication words. “STOP” and “START” are commands, not statuses.

Similarly, the graphics need to differentiate clearly between status indications and command possibilities. In general, the graphic indicates the current state, and faceplate interactions are used to command changes to that state. It is common to have a point type that includes both a switch-type (binary) output command and binary status feedback, commonly called a Digital Composite Point. Figure 19 shows a compact graphic presentation of those statuses. Selecting the graphic element would call up the faceplate for the actual interaction.

**Figure 19:** Digital Composite Point Depiction
Use of Trends

The most glaring deficiency in HMI today is the general lack of properly implemented trends. Every graphic generally has one or two values on it that would be far better understood if presented as trends. However, the graphics rarely incorporate them.

Instead, engineers and managers believe vendor claims that their operators can easily trend any value in the control system on demand with just a click. This is incorrect in practice; a properly scaled and ranged trend may take 10 to 20 clicks/selections to create, and usually disappears into the void if the screen is used for another purpose (like calling up a different graphic).

This deficiency is easily provable; simply walk into the control room and count how many trends are displayed. Our experience in hundreds of control rooms is that trends are vastly underutilized and situation awareness suffers due to that.

Trends should be embedded in the graphics and appear, showing proper history, whenever the graphic is called up. This is generally possible, but is a capability often not utilized. Trends should incorporate elements that depict both the normal and abnormal ranges for the trended value. There are a variety of ways to accomplish this as shown in Figure 20. The range indicator could also indicate the alarm and interlock ranges (see the later Level 1 Overview Example; Figure 33).

Depicting Tables

Even tables and checklists can incorporate proper principles as shown in Figure 21. Consistent colors and status indication can be integrated. The intent is to make the abnormal stand out.
Depicting Advanced Process Control

Advanced Process Control (APC) is also known as Multi-Variable Control. It is the method by which a sophisticated computer program monitors the process and adjusts controllers in real time to continually optimize performance.

Not all controllers are “touched” by the APC system, and it is useful for the operator to see which ones are, and what the APC system is doing with them. Small indicators next to the affected controllers are useful for this. Figure 22 shows this with an alternative, non-analog PID controller representation that is useful in some circumstances.

A Level 2 or 3 screen showing overall health and functionality of the APC system itself is desirable.

Depicting Shutdown Activation

Operators must have the ability to shut down operating equipment manually and quickly. However, when an important action with significant consequences is based upon operator input, the input should have a confirmation mechanism that avoids inadvertent activation. The “cancellation” option should be consistently implemented.

It should never be possible to make a single selection on a screen that results in an inadvertent shutdown. A “Shutdown button” should call up at least one and perhaps two layers of confirmation before it is possible to actually cause such a significant event.

The “defaults” of such mechanisms should be on the safe option. Always consider what an inadvertent “ENTER” will do and label screen items with full clarity.

Major process upsets have occurred by mistyping an input (for example, opening a slide valve to 47 percent instead of 4.7 percent). Older DCSs using membrane keyboards are particularly susceptible to this type of error. Error checking methods should be used to require confirmation of numerical entries that seem inappropriate.
Depicting Interlock Functionality

Interlocks are functions whereby normal control actions are overridden by predetermined process conditions. An example would be to override a steam valve to the closed position if the equipment temperature or pressure is too high. There are several HMI-related issues to be addressed for interlocks, and these must be handled regardless of whether the interlock is implemented in the DCS or in a separate Safety Instrumented System.

Interlocks are implemented using logic structures – usually “blocks” or “points” or “ladders.” These are usually complicated and cryptic to understand, when displayed using the native capabilities of the DCS (e.g., logic point detail). They may activate infrequently, since they are usually designed to protect against an abnormal situation. Due to this, the operator may not encounter them for months. When they activate, the operator may not remember being told about “the new column interlock” implemented a year ago, and have no idea why he cannot start feed to the column. If this occurs at 2 a.m. on a Saturday night, then the engineer is (deservedly) likely to get a phone call and production may be delayed.

Therefore every interlock, when activated, needs to indicate that activation on the appropriate Level 2 and 3 display. The strategy may be different for those displays.

For Level 2 displays, a small bank of interlock symbols can be created, with functionality as shown in Figures 24 and 34. An element next to it can indicate the interlock action conditions. When an interlock becomes active, any element that it is affecting (such as a pump or control valve) should have the interlock symbol appear next to it. In this manner, the operator can clearly see which interlocks are in effect and what items they are affecting.
For Level 3 displays, a more detailed view of the interlock can be shown such as in Figure 26. When active, the specific interlock symbol can be displayed next to each initiator signal and affected output. For Level 3 displays, an interlock diagnostic element should be created, clearly showing the possible initiators and possible actions taken by the interlock. This does not have to be complicated; a table such as the following can often suffice.

When an interlock shuts down a piece of equipment, a first-out indication is often desirable since some of the other initiators may activate after the shutdown trip occurs. Figure 27 is a simple example of a Shutdown “First Out” Table:

![Figure 26: Interlock Diagnostic Table](image1)

![Figure 27: Shutdown Initiator Table with First Out](image2)

Shortly after the compressor shuts down due to high vibration, the oil pressure also drops, which produces another shutdown initiator. As a result of equipment isolation, the suction pressure may also drop sufficiently to activate another shutdown initiator. Thus by the time the diagnostic graphic is consulted, three separate shutdown causes are present and the question is – which is the original culprit? Two are a consequence of the immediately prior shutdown, and the actual cause of the shutdown is shown via the “First Out.” The vibration reading depicted is “currently” much less than the shutdown limit (since it quits shaking after the shutdown), thus the high vibration indication (the “X”) needs to be latched until reset.
Startup Map

Interlocks are functions whereby normal control actions are overridden by predetermined process conditions. An example would be to override a steam valve to the closed position if the equipment temperature or pressure is too high. There are several HMI-related issues to be addressed for interlocks, and these must be handled regardless of whether the interlock is implemented in the DCS or in a separate Safety Instrumented System.

Navigation and Command Buttons

Multiple methods of navigation should be provided. The operator should be able to go up and down through the hierarchy, side to side through the process, and call related details, trends, and shutdown status displays from any graphic. This navigation capability should work with all available methods provided by the DCS vendor – mouse or touch screen target selections, keyboard keystrokes, context sensitive menus, or others.

Every screen (particularly Level 2) should have navigation targets to the most likely other screens that the operator would access. When a P&ID depiction is used, any process line entering or exiting the screen should contain a navigation link to the relevant graphic. Navigation buttons or targets should be consistent and simple (and not look identical to command buttons). Most control systems provide pre-made navigation button objects, including many that are inappropriately colored, needlessly 3-D, and overly intrusive.

The system and graphics should be configured so it is never necessary for the operator to type in a point name or graphic name. Some DCSs have arrays of programmable keys, which can be assigned to call up certain displays or combinations of displays. For systems that do not, programmable key arrays are inexpensive on the computer accessory market.
Implementing an entire navigation structure in a single windows-type pull-down hierarchical menu (i.e., one with “sub-menus” that pop-out of the side) is generally not recommended, particularly a structure more than two levels deep.

**The Main Menu:** It is desirable for the operator to have two-click access from any graphic to any other graphic, to supplement any other navigation method used. Every graphic should have a consistently placed “Main Menu” navigation button. It opens a simple text screen, logically and hierarchically arranged, with one-click navigation links to all graphics.

**Display Layout and Faceplate Handling**

Displays need a consistent “look and feel.” Different DCSs have unique embedded structures and paradigms around the location and type of navigation abilities, faceplates, “change zones,” programmable keys, and similar items. These features should be implemented in such a way as to comply with the principles of High Performance displays.

It is important to use these built-in abilities to their maximum potential. It is inadvisable to attempt to make a “Brand XYZ” DCS look like a “Brand ABC.” The results will usually be far from optimum.

Layout for a typical screen is shown in Figure 30. Screen layout usually includes these elements:

- A top menu and status area shows a variety of information, such as screen and alarm controls. This element is provided by the DCS manufacturer, is often mandatory, fixed in size, and usually configurable in several ways.
- A bottom “status line” area, usually optional, depicts information about a selected object, a command, or similar condition.
- A process depiction area is where the graphic is created.
- A reserved area for faceplates is provided. (This reserved area is a High Performance practice.)

![Figure 30: Typical Screen Layout](image-url)
When screen objects are selected, additional information about them should be shown. This is typically in the form of a faceplate popup. If the operator can interact with or manipulate the object, the interface for that interaction is contained in the faceplate. A reserved area in which the faceplate appears is important. It is undesirable for a faceplate to appear randomly on the screen, obscuring the primary graphic, and then requiring it being manually dismissed or moved. Reserved areas should be a rectangular area on the upper or lower right side of the screen, or a narrow strip across the bottom or right-hand side.

The size of the reserved faceplate area is determined by the brand of DCS. Ideally, faceplates are tall and narrow. This provides for placing them adjacent to the right-hand edge of the graphic, leaving a large, contiguous, mostly rectangular area for the process depiction. But, some DCSs have faceplates that are large, square, clunky, and poorly organized, making a reserved area for them difficult to accomplish. If you own such a system, encourage the manufacturer to move into the 21st century and modify their standard faceplates.

Only one item on a screen should be selectable at a time. Any new selection on the screen should replace any prior faceplate from a prior selection, without any manual “closing” of the prior faceplate needed. On a few screens, it might be desirable to enable more than one faceplate at a time.

Faceplates are usually supplied as standard elements by the DCS manufacturer. It may or may not be possible to alter them, and they may not follow some of the principles you desire for your HMI, such as proper and consistent use of color. However, rebuilding or replicating dozens of standard faceplates from scratch to correct minor consistency issues may not be worth the effort, since future vendor software upgrades may override that work.

The faceplate should show the point name and description, since point names should not normally be shown on a graphic. Exposing even more configuration information (i.e., Level 4 “point detail” or configuration data) about the point should be possible from the faceplate element. Faceplate interaction should not be modal (i.e., preventing other graphic action until the faceplate is closed).

We have seen a presentation advocating that faceplate functionality (altering setpoints, outputs, modes, states, etc.) be incorporated into the graphics themselves, and the use of the standard faceplate interaction eliminated. Now, as you can imagine, we are always open to evaluating new ideas, but not every new idea is a good one! The claim is made that “it is speedier and the operator might save fractions of a second per interaction that way, which will add up to maybe several hours saved per year.” This is a bad idea, because huge amounts of additional custom coding and its upkeep are needed and significant layout and consistency problems must be addressed. Stick with faceplates.
Depending on DCS HMI capabilities, other methods for point information manipulation are possible, such as right-click menu access.

**Avoiding “Blob” Graphics**

Some places have carried the gray-scale principle too far and created extremely low-contrast “blob” graphics shown in Figure 31. These are gray-on-gray, typically without even thin black boundary lines defining the various elements. These are a bad idea; we have seen many operators squinting at these to figure out what is happening. Graphics should be clear and unambiguous, and blob graphics are not recommended. The key is to provide easy visibility of elements, but to reserve emphasis for abnormal situations.

**Display Hierarchy**

Displays should be designed in a hierarchy that provides progressive exposure of detail. Displays designed from a stack of P&ID schematic designs will not have this; they will be “flat” like a computer hard disk with one folder for all the files. This does not provide for optimum situation awareness and control. A four-level hierarchy is desired.

![Figure 32: High Performance HMI Display Hierarchy](image-url)
Figure 33: Example Level 1 Display

This is a single graphic showing the operator’s entire span of control, the big picture. It is an overall indicator as to how the operation is running. It provides clear indication of the current performance of the operation by tracking the Key Performance Indicators as in Figure 33.

Level 1 Overview graphics are usually not designed for making control interactions (i.e., no faceplate zone).

The Figure 33 example is from a large power plant. We often hear “But it doesn’t look like a power plant!” Correct! Does your automobile instrument panel look like a diagram of your engine surrounded by numbers? The display is designed so that it is easy to detect if the plant is running well or poorly, and that important abnormal conditions and alarms stand out clearly.

The Level 1 graphic is ideal for display on a large, perhaps off-console monitor. Many have purchased such large screens with little idea of how to make the best use of them.
Level 2 – Unit Control

Every operation consists of smaller, sub-sectional unit operations. Examples include a single reactor, a pipeline segment, a distillation train, or a compressor station. A Level 2 graphic exists for each separate major unit operation. It is designed to contain all the information and controls required to perform almost all operator tasks associated with that section, from a single graphic as shown in Figure 34.

Figure 34: Example Level 2 Display of a Reactor

Notice how the analog indicators and controllers are lined up for easy scanning, rather than being scattered all around a P&ID depiction. Ease of abnormal situation detection is an important HPHMI design consideration.

When properly designed, most operator actions will occur at Level 2, and the Level 3 graphics will be used only for more detailed troubleshooting.
Level 3 – Unit Detail

Level 3 graphics provide all of the detail about a single piece of equipment. These are used for detailed diagnosis of problems. They show all of the instruments, interlock status, and other details. A schematic or P&ID type of depiction is often desirable for a Level 3 display.

The Figure 35 example shows what could be created “from scratch” as a Level 3. Besides the P&ID depiction, other HPHMI elements are included. In existing systems, most graphics are actually Level 3. See the “HPHMI Implementation on a Budget” section in the Part 2 document for guidance about this.

Level 4 – Support and Diagnostic Displays

Level 4 displays provide the most detail of subsystems, individual sensors, or components. They show the most detailed possible diagnostic or miscellaneous information. A “Point Detail” display is a typical example. The dividing line between Level 3 and Level 4 displays can be somewhat gray.
Conclusion of the Part 1 Document

The principles of High Performance HMI are specifically developed to deal with the needs of today’s operators regarding the complex systems they manage. A High Performance HMI is designed to be the best tool for operator interaction with the process control system. It is designed to maximize operator situation awareness and abnormal situation detection and response.

In the separate Part 2 document, we provide case studies supporting that a High Performance HMI accomplishes these goals. In addition, there is discussion of a major HMI-related advance in the power industry, a review of HMI Standards, and an example Table of Contents of HMI Philosophy and Style Guide documents.
About the Authors

**Bill R. Hollifield, PAS Principal Alarm Management and HMI Consultant**

Bill is the Principal Consultant responsible for the PAS work processes and intellectual property in the areas of both Alarm Management and High Performance HMI. He is a member of the American Petroleum Institute’s API RP-1167 Alarm Management Recommended Practice committee, the ISA SP-18 Alarm Management committee, the ISA SP101 HMI committee, and the Engineering Equipment and Materials Users Association (EEMUA) Industry Review Group.

Bill has multi-company, international experience in all aspects of Alarm Management and HMI development. He has 28 years of experience in the petrochemical industry in engineering and operations, and an additional 12 years in alarm management and HMI software and services for the petrochemical, power generation, pipeline, pharmaceutical, and mining industries.


Bill has authored several papers on Alarm Management and HMI, and is a regular presenter on such topics in such venues as API, ISA, and Electric Power symposiums. He has a BSME from Louisiana Tech University and an MBA from the University of Houston. In 2014, Bill was made an ISA Fellow.

**Hector R. Perez, PAS High Performance HMI Product Manager**

Hector oversees the High Performance HMI business line at PAS. He is a chief designer of High Performance graphics intended to facilitate situation awareness in a variety of industries. At PAS, Hector oversees PAS software directions to improve product design and capabilities.

Prior to working with PAS, Hector was a senior engineer at Schlumberger. His strength in design contributed to his success in creating new and improved HMIs for reservoir evaluation services and interfaces for business Key Performance Indicator tracking.

In addition to his expertise in High Performance HMI, Hector has widespread experience in all aspects of Alarm Management. He has facilitated numerous Alarm Management workshops, conducted alarm rationalization projects, and developed Alarm Philosophy documents for a wide range of clients in the petrochemical, power generation, pipeline, and mining industries.

Hector has authored technical articles on High Performance HMI. In 2009, he and Bill collaborated with the Electrical Power Research Institute (EPRI) on a comparative research study evaluating High Performance graphics and operator effectiveness. Hector holds a Bachelor of Science in Chemical Engineering from Rice University.
References


About PAS

PAS Global, LLC is a leading provider of software solutions for process safety, cybersecurity, and asset reliability to the energy, process, and power industries worldwide. PAS solutions include industrial control system cybersecurity, automation asset management, alarm management, high performance HMI, boundary management, and control loop performance optimization. PAS solutions are installed in over 1,000 facilities worldwide with more than 40,000 users.

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