

Pipeline SCADA Displays

API RECOMMENDED PRACTICE 1165
SECOND EDITION, DECEMBER 2022



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Pipeline SCADA Displays

1 Scope

This recommended practice (RP) focuses on the design and implementation of displays used for the display, monitoring, and control of information on pipeline supervisory control and data acquisition (SCADA) systems. The primary purpose is to promote the success of the controller to safely operate pipeline systems and to document industry practices that provide guidance to a pipeline company or operator who wants to select a new SCADA system, or update or expand an existing SCADA system, and for guidance throughout the SCADA system display lifecycle. The pipeline industry and stakeholders have determined that well-designed displays can contribute to safe operations and prevent or mitigate pipeline incidents. Using established human factors considerations in display design can promote the safety performance of a pipeline operator.

This RP assists pipeline companies and SCADA system developers in identifying items that are considered best practices when developing human-machine interfaces (HMI). Design elements that are discussed include, but are not limited to, hardware, navigation, colors, fonts, symbols, data entry, and control/selection techniques.

A secondary purpose is to provide guidance to SCADA display designers and developers to use industry experience to promote safety, efficiency, and reliability during the display lifecycle.

It is recognized that each operator has unique philosophies and SCADA systems; therefore, not all elements of this RP may be applicable.

For example:

- some pipeline control centers are a combination of several different SCADA systems;
- some of these SCADA systems may not have the developer tools necessary to implement the RPs;
- some operators may have existing display techniques that utilize unique operating philosophies.

This RP is not all-inclusive. It is intended to cover best practices and provide examples for display techniques only, not dictate operational control philosophy or overall SCADA system functionality. Examples included in this RP are not prescriptive and are provided to illustrate representative practices.

This RP complements but does not replace other procedures and effective display techniques or industry standards that are used for software development and implementation. Regulatory and individual company standards are not addressed in this publication.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

API Recommended Practice 1168, *Pipeline Control Room Management*, Second Edition, 2015

Endsley, M.R. and Jones, D.G. (2016). *Designing for Situation Awareness: An Approach to User-Centered Design*, Second Edition. Boca Raton, FL: CRC Press.

McCormick, E.J. and Sanders, M.S. (1993). *Human Factors in Engineering and Design*. Seventh Edition. New York; London; McGraw-Hill

ISO 11604-4 1, *Ergonomic design of control centres—Part 4: Layout and dimensions of workstations*, 2019

¹ International Organization for Standardization, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, www.iso.org.

ISO 11604-6, *Ergonomic design of control centres—Part 6: Environmental requirements for control centres*, 2005

3 Terms, Definitions, and Abbreviations

3.1 Terms and Definitions

For the purposes of this specification, the following terms and definitions apply.

3.1.1

animation

Dynamic changes in size, shape, color, orientation, and movement of an object because of point changes.

3.1.2

button bar/toolbar

A row of buttons used to navigate.

3.1.3

client server architecture

The structure of a computer network in which many clients (remote processors) request and receive service from a centralized server (host computer).

3.1.4

coding

The method of discriminating data on a display via the use of color, shape, text, and sound attributes.

3.1.5

condition

A normative assessment applied to a state.

3.1.6

control center

pipeline control room

An operations center staffed by personnel charged with responsibility for remotely monitoring and controlling entire or multiple sections of pipeline systems.

3.1.7

controller

pipeline controller

An individual who remotely monitors and controls the operations of entire or multiple sections of pipeline systems via a SCADA system from a pipeline control room and who has operational authority and accountability for the daily remote operational functions of pipeline systems.

NOTE For purposes of this document, the term “qualified” means an individual has been evaluated and can perform assigned covered tasks and recognize and react to abnormal operating conditions (AOCs).

3.1.8

data attributes

Data attributes are metadata (data about data) of a point. Data attributes improve controller situation awareness by fully describing the state of a point.

3.1.9

dialog box

A window on the screen that contains a set of choices whenever the executing program needs to collect or provide information.

3.1.10**display****SCADA display**

The visual presentation of text and objects used for pipeline system operation on a monitor, from a SCADA system.

3.1.10.1**display call-up time**

The display call-up time is the elapsed time between the controller call-up request and rendering of all display graphics and data on the monitor.

3.1.10.2**display refresh rate**

The display refresh rate is the elapsed time between a change external (field change or via input controller) to the SCADA server (including FEP if equipped) and complete rendering of changed data and/or graphics.

3.1.11**display hierarchy**

A structure of display types, arranged in levels, where each lower level reveals successively more operating detail than the related level above it.

3.1.12**display levels**

The unique categories of a display hierarchy.

3.1.13**equipment tag**

A text string and/or image attached to a database point that indicates some relevant detail about the point such as equipment identifier.

3.1.14**gestalt psychology**

Theories of visual perception and behavior to describe how people tend to organize visual elements into groups or unified wholes.

3.1.15**hidden text**

Information that is not visible (in background) to the controller until a specific event occurs, at which time the text becomes visible (in foreground).

3.1.16**hot spot****navigation buttons****poke points**

An area, symbol, or text on a display that, when selected, provides navigation to some predefined display, opening of a new window, or other commands.

3.1.17**human factors engineering****HFE**

The science of designing systems that are safe, comfortable, effective, and usable.

3.1.18**human-machine interface****HMI**

A user interface that allows the controller to interact with the system.

3.1.19**informational tag**

A text string and/or image indicating a dynamic attribute associated with a database point.

3.1.20**input device**

A hardware device, such as a keyboard or mouse, used to interact with the system.

3.1.21**invalid**

An indication of a point state that is undefined, out of range, or otherwise unknown.

3.1.22**layers**

Organizations of the graphic objects of a display by function or purpose.

3.1.23**monitor****display device**

The hardware used to present SCADA displays to the controller.

3.1.24**navigation**

The controller activity of ascertaining their position within a process or the pipeline system and planning and following a route through menus and displays.

3.1.25**navigation object****button bars****navigation button**

A graphic object that allows controllers to choose where they want to go within a display, within the display hierarchy and/or within the menu system.

3.1.26**navigation scheme**

Allows the controller to traverse “horizontally” across each display within a level as well as “vertically” between levels.

3.1.27**object dynamics**

Graphic object properties used to depict the condition of equipment or data that can have multiple states.

3.1.28**off-scan**

A point that has been intentionally deactivated from updating the SCADA display.

3.1.29**operator**

A company that monitors and controls a pipeline system.

3.1.30**overlay**

Covering a window with another window.

3.1.31**point**

A physical or calculated value stored in the SCADA database.

3.1.32**poke point**

Part of a display in which a mouse-click results in an action, such as a pop-up, dialog box, or navigation to another display via an input device action.

3.1.33**pop-up**

A temporary display that provides details related to its parent display(s).

3.1.34**remote**

A field device, such as a process control system, remote terminal unit (RTU), programmable logic controller (PLC), or flow computer.

3.1.35**salience**

The state or quality by which an object stands out from neighboring objects.

3.1.36**SCADA controllable**

A device or point that is controllable through SCADA.

3.1.37**situation awareness**

Controllers:

- a) perceiving deviations from the expected state of the process,
- b) comprehending the current state, deviations, and trajectory, and what could be done to address the deviations, and
- c) projecting the future state of the process and the expected impact of any commands they may issue.

3.1.38**state**

The objective status of equipment, process, or system.

3.1.39**static**

A term used to describe a point or object that does not change.

3.1.40**supervisory control and data acquisition****SCADA**

A computer-based system that collects information about a pipeline facility, generates alarms, and provides a structured view of the pipeline system with the capability to control the pipeline operation.

**3.1.41
symbol**

An image or character used as a conventional representation of an object, function, or process.

**3.1.42
usability testing**

Evaluation to assess the effectiveness, efficiency, and satisfaction of the HMI using observational, performance, or other techniques.

**3.1.43
workspace**

Monitors and/or areas of monitors that are interacted with rather than reserved solely for displaying data.

**3.1.44
yoking**

The practice of contextually linking together related displays that contain varying degrees of detail.

3.2 Abbreviations

AOC	abnormal operating condition
EOC	emergency operating condition
FEP	front-end processor
GUI	graphical user interface
HFE	human factors engineering
HMI	human-machine interface
MOC	management of change
MOP	maximum operating pressure
OQ	operator qualification
PC	personal computer
PLC	programmable logic controller
RTTM	Real-time Transient Model
RTU	remote terminal unit
SCADA	supervisory control and data acquisition
STM	short-term memory

4 Human Factors Engineering (HFE) Considerations in Display Design

4.1 General

4.1.1 Displays

Display design refers to the way information is arranged and presented on a monitor. It can vary extensively, depending on the function of the display. Display design requirements may be unique for each display, depending on the display's primary function.

Displays should be designed to provide optimum transfer of information to the controller. Information should be presented simply and consistently, in a well-organized manner, and in expected locations. Displays should have an orderly and clutter-free appearance, a simple way to navigate through the system, and obvious indications of interrelationships.

A controller task analysis should be performed to identify activities the HMI should support. Sources to help identify controller tasks that should be supported in the HMI include:

- operating procedures,
- control room management plan—roles and responsibilities,
- operator qualification (OQ) plan—covered tasks.

Because of the wide variety and importance of SCADA systems in managing and performing pipeline operations, SCADA system design is critical to safe operations. Examples of tasks performed using the SCADA system in pipeline control rooms include:

- start a pipeline;
- stop a pipeline;
- redirect flow to and from sources and destinations based on product characteristics or volume;
- perform a midline delivery or injection;
- verify open and correct flow path;
- monitor for unexpected changes in pressure and flow;
- recognize abnormal operations;
- operate equipment (pumps, compressors, open/close valves, control valves, etc.);
- coordinate operational activities with field personnel;
- determine pump/compressor to use to achieve desired flow rate and maximize efficiency.

SCADA displays and inputs should be designed to reflect the tasks they are expected to perform.

4.1.2 Human Factors

Humans have certain basic capabilities and limitations. Strengths includes powerful pattern recognition and selective attention, the capability to learn, the ability to store and retrieve large amounts of information, reason, adapt, and draw from past experiences to make decisions (McCormick and Sanders, 1982). Humans have

limitations in short-term memory (STM), information access, and information processing. Technology should be used to support human capabilities and overcome limitations.

4.1.3 Situation Awareness

A central concept in HFE is that of situation awareness. Simply stated, situation awareness is knowing the state of the world relative to the work and tasks to be performed and what must be done as a result. Situation awareness involves perceiving information in the work environment, comprehending what that information means in the context of work activities and responsibilities, and being able to predict what the future system state will be if specific action is taken, or not taken, and in what timeframe. An accurate mental model of the work system and task requirements is required for good situation awareness, and an accurate mental model is developed by training, experience, and by the accuracy and design of the HMI.

In terms of human performance related to situation awareness, human performance strengths include powerful selective attention, powerful pattern recognition, the capacity to learn, and the ability to apply expertise to new, novel situations. Features of complex systems interact with human information processing systems to threaten situation awareness. These factors, or situation awareness demons (Endsley and Jones, 2012), are attentional tunneling; requisite memory trap; workload, anxiety, fatigue, and other stressors; data overload; misplaced salience; complexity creep; errant mental models; and out-of-loop syndrome. The implication of these factors is that controllers can be overwhelmed by data overload, complexity creep, and taking over when automation fails.

An important aspect of situation awareness for the pipeline industry is flow path alignment and validation. Controllers must be able to easily perceive, understand, and correctly control flow paths to prevent serious operational issues, including overpressure and product contamination. Methods to assist controllers in the prevention and detection of incorrectly aligned flow paths include valve status salience, task panels, dynamic presentation of piping, and pressure and flow rate indications. A combination of methods may be employed to promote flow path error prevention, detection, and mitigation.

Knowledge of human performance strengths and weaknesses should inform effective HMI design and is the basis for the HMI design RPs in the subsequent sections.

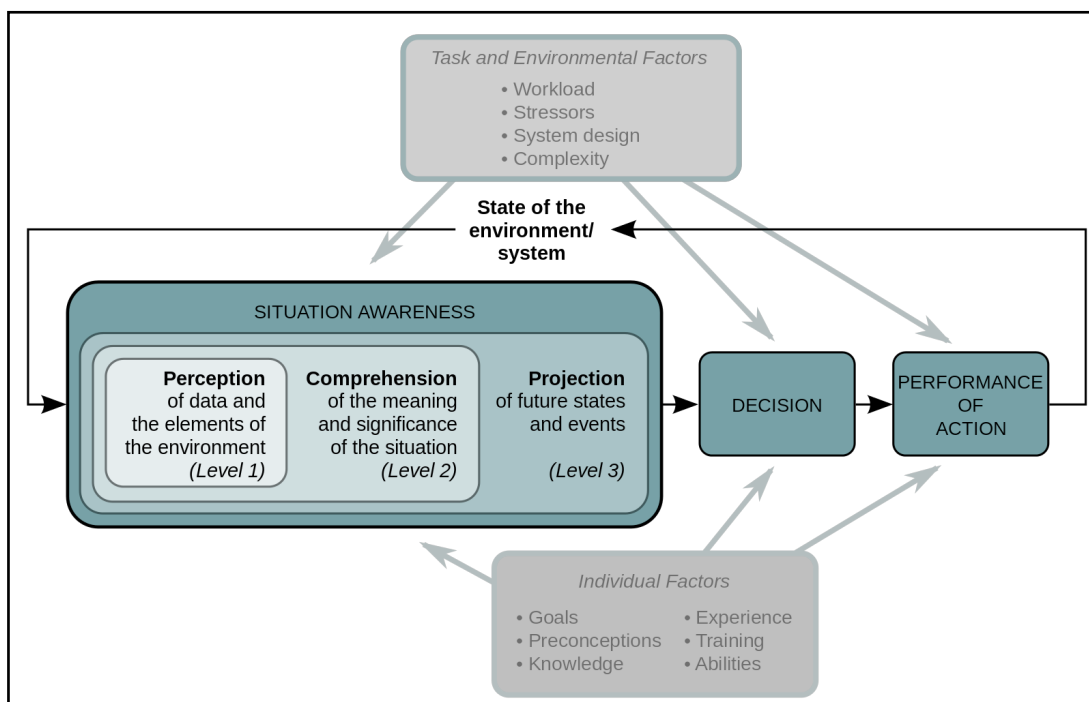


Figure 1—Endsley Situation Awareness Model

In Figure 1², the phases of perception, comprehension, and projection form a continuous and ongoing mental process for controllers. The HMI can support controllers in these phases, analogous to HMI support for operational tasks. Each phase may benefit from different HMI elements to optimize situation awareness, for example:

- perception: rate of change indicators, complex objects, embedded trends, user-defined alerts, or in the case of abnormal operations, alarms;
- comprehension: alarm and event summaries, user-modifiable trends, other historical reports, task panels, efficient navigation;
- projection: user-defined trends, countdown timers, and warning messages for automated actions, results of calculations and logic.

4.1.4 SCADA Systems and HMI

Operators make trade-offs when developing displays. Common trade-offs include:

- call-up time vs high-performance content;
- consistency vs specialized requirements;
- complexity vs uniformity;
- flow path awareness vs other considerations, such as signal-to-noise or use of color.

Operators should consider the methodology under which trade-offs are made and document variances from their established practices. Variances should be made based on risk.

4.1.5 Automation and Human Control

Many functions that were manually controlled are now largely automated. Operators should be aware of their critical automated processes and how they are communicated to controllers. Controllers should be made aware of automated processes and their activities under their scope. Many automated processes are not included on displays but are important to controller responsibilities.

Changes to automated processes should be communicated to controllers if it impacts their responsibilities.

Refer to API 1168 for further details about change management.

4.1.6 Human Visual Deficiencies and SCADA Displays

4.1.6.1 General

A critical dimension of human performance and the perception stage of situation awareness in the control room environment is human visual attention, which relates to both selective attention and pattern recognition. Various aspects of the visual environment can capture a controller's attention. These aspects, such as motion, brightness, and color may be outside of the controller's ability to manipulate on the screen. If these visual cues are misapplied, they can incorrectly capture the controller's visual attention at the wrong time and either creates a distraction or increases the controller's workload to overcome the distraction. If properly applied, these aspects of visual attention can be used to improve situation awareness and controller performance. If done well, properly applied visual coding techniques should improve the controller's performance during

² Lankton, Peter Dr., Endsley Model of SA. 2007-05-20, 2008-02-17. This work has been released into the public domain by its author, Dr. Peter Lankton at English Wikipedia. Dr. Peter Lankton grants anyone the right to use this work for any purpose, without any conditions, unless such conditions are required by law. <https://commons.wikimedia.org/wiki/File:Endsley-SA-model.svg>

higher workload or stressful situations. Some controllers may have a form of color-vision deficiency, using color alone as the only coding technique may lead to poor performance and is not recommended.

4.1.6.2 Proximity

The human perception system tries to organize objects into groups if they are near each other in space. Proximity can be used to address issues like signal-to-noise ratio.

If two objects are related operationally, bringing them close together in one display assists with STM, particularly under stress.

In the pipeline example in Figure 2, the charge pumps are located more closer together in (b), rather than equally spacing all three pumps as shown in (a); this creates better visual separation from the booster pump. In the table example in Figure 3, the related columns and rows are closer together to assist in visually parsing the array of data in the table.

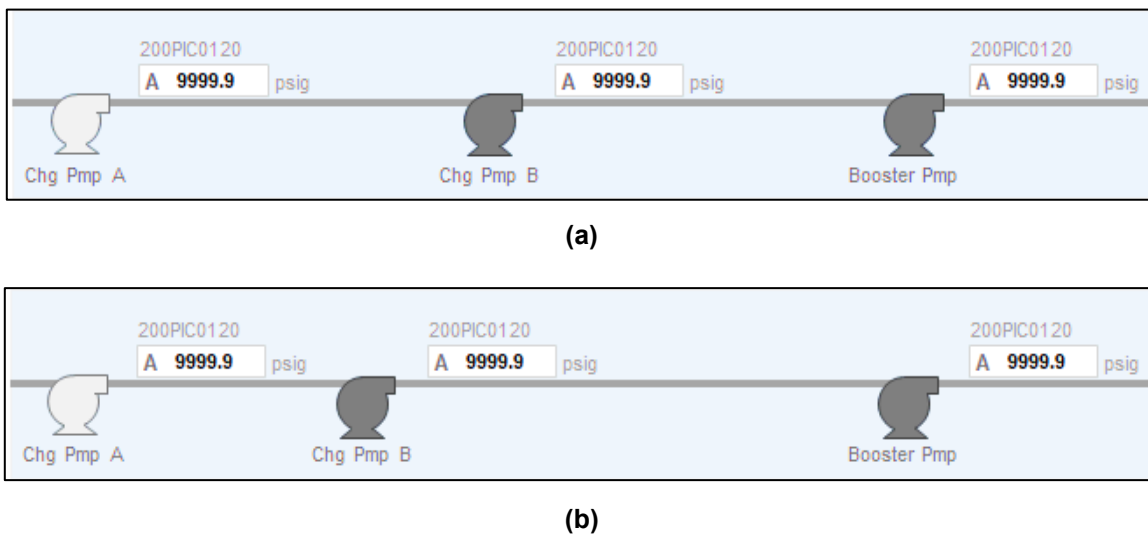


Figure 2—Proximity Example 1: Pipeline Example Where Proximity (a) Has Not Been Applied and (b) Has Been Applied

	Pressure		Temperature	
	Suct	Disch	Suct	Disch
Unit 1A	9999.9 psig	A 9999.9 psig	9999.9 F	9999.9 F
Unit 1B	9999.9 psig	A 9999.9 psig	9999.9 F	9999.9 F
Unit 2A	9999.9 psig	A 9999.9 psig	9999.9 F	9999.9 F
Unit 2B	9999.9 psig	A 9999.9 psig	9999.9 F	9999.9 F

(a)

	Pressure (psig)		Temperature (F)	
	Suct	Disch	Suct	Disch
Unit 1A	9999.9	A 9999.9	9999.9	9999.9
Unit 1B	9999.9	A 9999.9	9999.9	9999.9
Unit 2A	9999.9	A 9999.9	9999.9	9999.9
Unit 2B	9999.9	A 9999.9	9999.9	9999.9

(b)

Figure 3—Proximity Example 2: Table Example Where Proximity (a) Has Not Been Applied and (b) Has Been Applied

4.1.6.3 Similarity

Objects are perceived as related if they visually share common properties, such as size, color, orientation in space, or brightness.

The similarity example in Figure 4 supports perceiving all the non-pipeline shapes as valves because of the similar “butterfly” feature, even though there are three distinct types of valves present in the example.

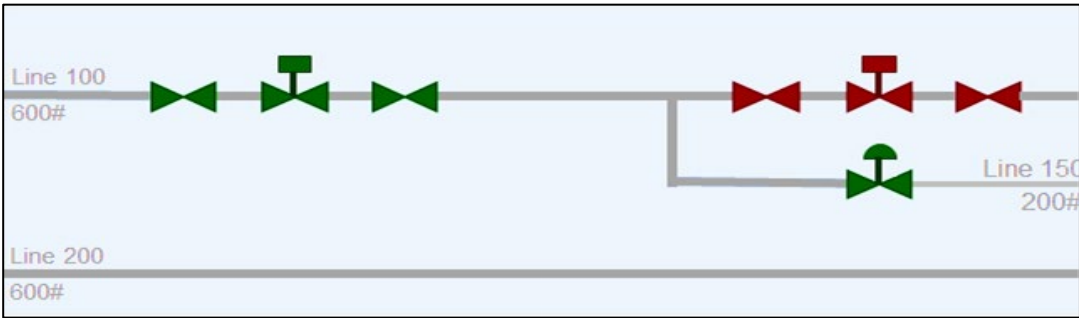


Figure 4—Similarity Example: All Valves Are Recognized as Valves Because of the Similar “Butterfly” Property

4.1.6.4 Closure

The human eye tries to complete figures and establish meaningful wholes. Incomplete objects or symbols can then be perceived as complete or whole.

The closure example in Figure 5 illustrates how a pipeline with line breaks—which are used to segment the pipelines' multiple crossing intersections—is seen as the same pipeline despite the line break (which is "closed" visually when scanning the line past a given break).

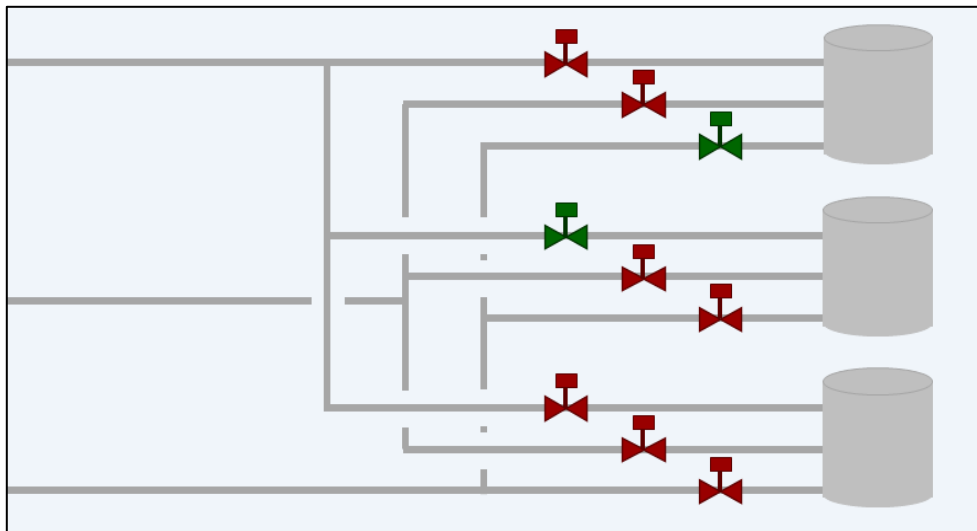


Figure 5—Closure Example: Line Breaks Are Closed Visually when Scanning a Given Pipeline with the Break

4.1.6.5 Balance

Humans prefer stability in the perceived visual environment. The presentation of materials at right angles and in virtual rows and columns is easier to process visually than curved or angled visual images.

The balance example in Figure 6 shows the pipelines as balanced coming in from the left as well as balanced going to each respective tank, where the valves for a given pipeline share the same virtual column.

NOTE The closure example might be a preferred layout if the top pipeline typically supplies the top tank and if the bottom pipeline typically supplies the bottom tank. The balance example might be a preferred layout if any line-up is equally likely.

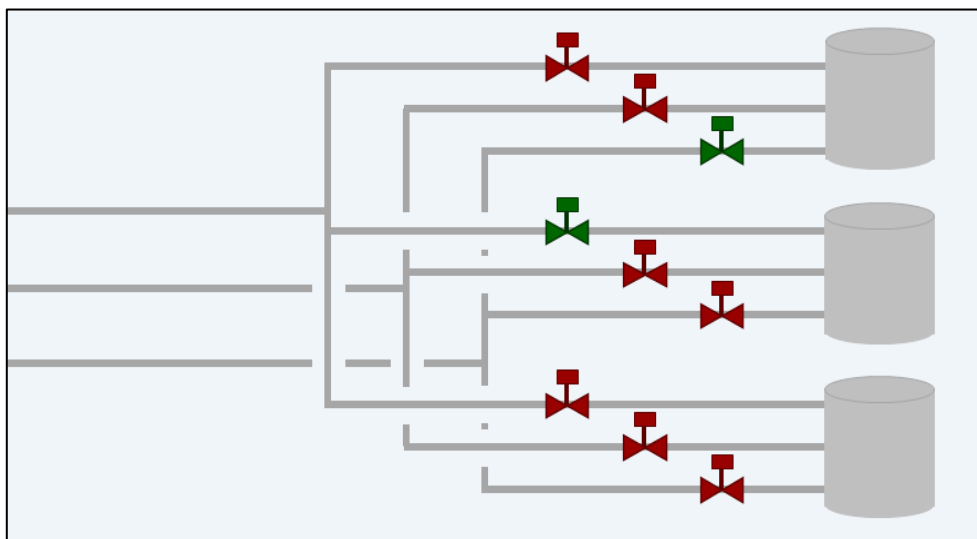


Figure 6—Balance Example: Line Breaks Are Closed Visually when Scanning a Given Pipeline with the Break

4.1.6.6 Figure/Ground

The relationship between an object and its background is based on positive space and negative space. The eye separates elements of focus in a design from the background of that design.

The figure/ground examples in Figures 7 and 8 present data elements of a numerical indicator so that increasingly important information is presented more and more to the foreground. Similarly, the proximity examples in Examples 1 and 2 also illustrate figure/ground principles, where the pressure valve value is the strongest foreground element, followed by the running pump status, followed by flow path of the pipeline, then the controller mode, then equipment name, tag ID, and engineering units.

As shown in Figures 7 and 8, figure/ground can be applied to display indicators to align the visual processing of elements consistent with their relative importance (e.g. pressure valve values are more visually prominent in the foreground than the indicator box outline).

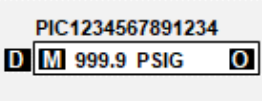
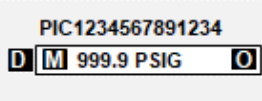
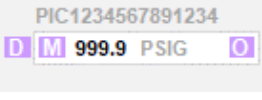
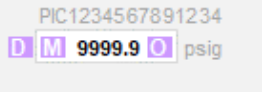
Salience Coding of Data Elements		
	Color-coding alone	Color- and Size-coding
Figure = Ground		
Figure > Ground		

Figure 7—Figure/Ground Example: Salience Coding of Data Elements

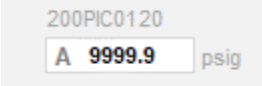
Condition			
	Normal	Alarm	Off-normal
Figure > Ground			

Figure 8—Figure/Ground Example: Figure/Ground Examples for Different Potential Conditions Based on the Salience Coding Shown in the Example Above

These principles are often called gestalt principles, in reference to the field of psychological research. In addition, display design should incorporate the general principles of HFE discussed in the next sections.

4.2 Short-term Memory

4.2.1 General

An overriding principle in display design is the limitation of the human STM. STM is the place in the human information processing system where all conscious processing of information occurs. Studies have shown that STM can process seven, plus or minus two blocks of information. A block of information is any meaningful cluster of data (e.g. a word, a phrase, a number). If this information is not transferred to long-term memory, it will be forgotten.

The STM limitation does not mean that only seven, plus or minus two, points or symbols should be on a display. The STM limitation cannot be erased, but techniques of salience and visual representation should be used to allow the controller to treat numerous points as one block. For example, demarcating related groups, using methods such as shaded boxes, and use of closure by putting values inside figures all facilitate processing of those elements as a block. Figure 9 shows an example of related flow and volume information grouped together. The general principle is that related information should be grouped together, but large groups of information should be broken up into subgroups. Related information is determined by what tasks are required to be performed by the controller and by the controller's perceptions of the information requirements.

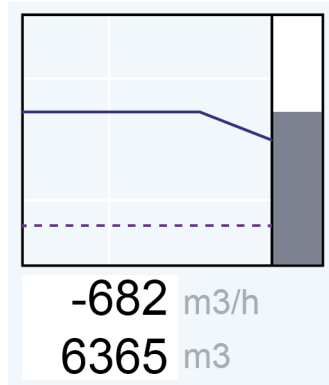


Figure 9—Example Flow and Volume Information

STM can also be supported using complex objects by displaying current process values combined with related information such as alarm limits or previous values (e.g. trends).

4.2.2 Spacing of Items

Item spacing may contribute to the impression of clutter and impair controllers' ability to process information. Relative spacing of items in a display rather than using an equally spaced array also helps the grouping process.

Using equal (but closer) spacing within a local area (e.g. a set of charge pumps) vs a greater distance to the next set of booster pumps down the line (where the booster pumps have the same equal but closer spacing as well) may help visually separate the two sets of pumps. Where the pumps are equally spaced in the display, they might be seen as all being part of the same "group."

Enumerating or presenting information in numeric, alphabetic, or chronological order also helps controllers to mentally associate groups of information. STM also has implications on the number of displays to be created. If a controller must compare information on two different displays, then STM requirements are higher than if the same information were on a single display. STM limitations pose strong arguments for a minimal number of displays with well-grouped data.

4.3 Signal-to-Noise Ratio

Talking with someone in a crowded room is often difficult since words are difficult to distinguish as the background noise increases. The signal (the words) is masked by a noise similar in intensity and characteristics (the surrounding conversations).

As more items are added to the display, it becomes increasingly difficult to locate the signal or target on the display. Anything that is not a signal is noise and will make location of the signal more difficult. When designing a display, each element on the display should be examined with respect to how it impacts controller performance.

All items on a display should have a purpose. Display design principles indicate that information necessary to complete the task should be put on each display, but items not relevant to the current tasks should not be included.

Using principles such as salience and grouping can allow for more information to be added to a display design without adding to the difficulty of identifying a signal.

4.4 Eye Scan Pattern

4.4.1 General

Display design should lead controllers to important functions and information. Important information should be emphasized, while less critical information should be de-emphasized.

The location of objects on a display, as well as object size, color, and other attributes, determine their relative importance to the controller. Larger objects and objects placed on the top and the center of the display tend to draw attention first. Studies have shown that the initial eye scan pattern of the monitor tends to concentrate on certain areas of the display. The information that is important to the controller and needs to be picked up on the initial scan of the display should be in the upper left and lower right of the display. This does not mean that data placed elsewhere on the display will be missed by the controller. After the initial eye scan, the controller will look at the entire display.

Experienced controllers develop habits and expertise that supersede the typical scan pattern.

4.4.2 Displays Containing Text or Tabular Data

Tabular displays present data in rows and columns. They allow for a controller to have a summary of information and reduce the need to move between displays. Not all tabular displays exclusively use numerical data, and many have functional elements. Controllers generally scan tabular displays from the left to right of the screen. An example of a tabular display is shown in Figure 10.

Tank Summary

Quick Filters Location ☒ XX ☐ YY ☐ All Filter by Query

Status ☐ Active ☐ Inactive ☐ All Manual Selection ☒

	Tank		Location	Flow Rate m3/hr	Current Volume m3	Target Volume m3	Volume to Target m3	Time to Target hr:min	Avail Space m3	Avail Prod m3	Current Level mm	Temp deg C	Density kg/m3	Prod Type
1	123	3	XX	1000	2544	3154	-610	02:12	6342	8521	16954	12.9	927	AA
2	124		XX	1000	26541	12540	14001	00:01	112	21001	22002	10.0	828	ZZ
3	125		XX	-	16421	11601	4820	-	2451	121	14652	12.2	912	ZZ
4	126		XX	-	15681	34621	-18940	-	68541	240	15520	9.8	859	BB
5	127	L	XX	-	12421	15412	-2991	-	24	1202	11200	9.5	818	BB
6	128		XX	1000	1452	3215	-1763	20:01	32541	21210	1223	7.0	824	CC

Figure 10—Example Tabular Data Display

Means to improve controller scanning in tabular displays include row shading, color, placement, and font.

4.4.3 Graphic Displays

Graphic displays present an integrated representation of data. They are frequently modeled around a depiction of assets such as a simplified map or pipe schematic and are generally customized to each function and location. Because graphic displays have a wide and customized appearance, there is no single eye scan pattern that can be assumed. An example graphic display is shown in Figure 11.

Means to communicate critical information in a graphical display include weight, curvature, color, iconography, and size. Dynamic objects are frequently employed to assist the controller. Controller scanning can be directed by modifying object salience.

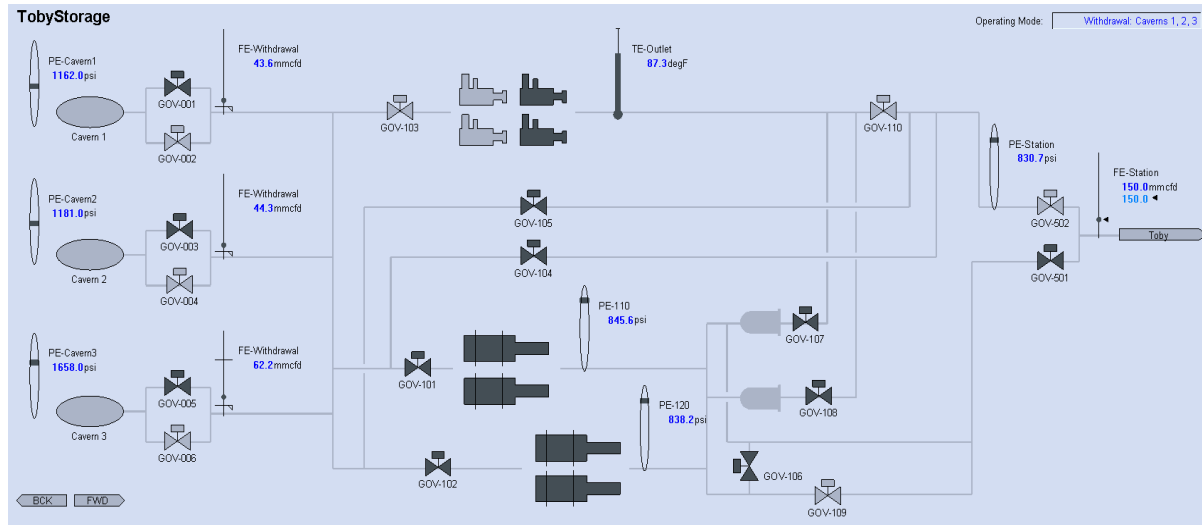


Figure 11—Example Graphic Display

4.4.4 Multi-display Consoles

Modern SCADA consoles typically have multiple monitors to communicate information to a single controller. Additional non-SCADA screens and telecommunication are frequently also placed in workstations. An example of a multi-display console layout is shown in Figure 12.

The most critical controller functions should be displayed in the center of the controllers' range of vision to prevent fatigue and increase controller's capacity to recognize information. Less critical data should be placed on the peripheral screens.

For more information about ergonomic design considerations in workstations, refer to ISO 11604-4:2013.

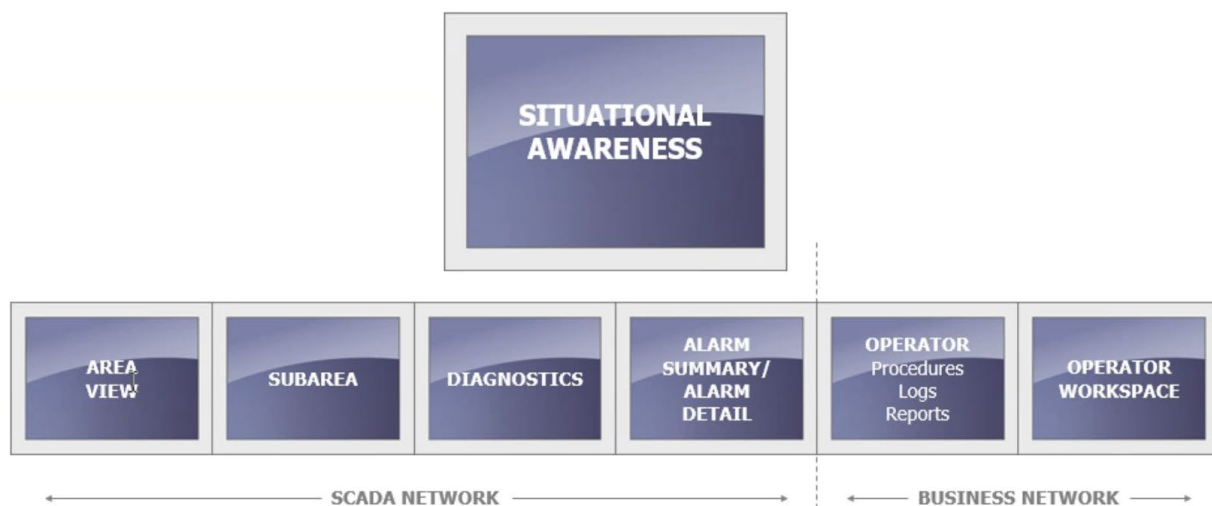


Figure 12—Example Console Layout

4.5 Consistency

4.5.1 General

Consistency is essential to display design, especially if controllers are managing multiple monitors or cross-trained on multiple consoles. Documenting HMI standards early in the design phase promotes consistency. These standards include shape, color, presentation, and placement of both static and dynamic objects and text. Consistency facilitates rapid controller response since it helps the controller know where to look for pertinent data and how the data appears.

4.5.2 Consistent Objects

Static text and objects do not change state and should stay consistent. Dynamic text and objects update based on the condition of the system; therefore, specific attributes change to draw attention to the update.

Figure 13 shows an example display where static objects are displayed consistently.

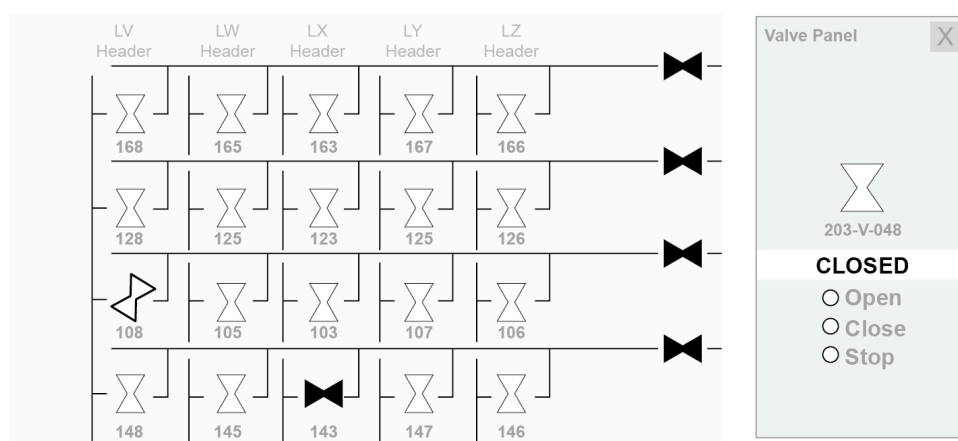


Figure 13—Example Static Object Consistency

4.5.3 Consistent Text

The presentation of text within categories should vary as little as possible. For example, display title formats should be consistent but do not require consistency with engineering units. Text formatting should be part of overall salience considerations.

Static text, such as labels, should be consistent, but dynamic text changes attributes to draw attention.

On-screen language should be clear and concise. Avoid local jargon unless it is commonly accepted terminology for the controllers and facilitates quicker understanding of the system for all controllers.

Figure 14 shows an example display where static text is displayed consistently.

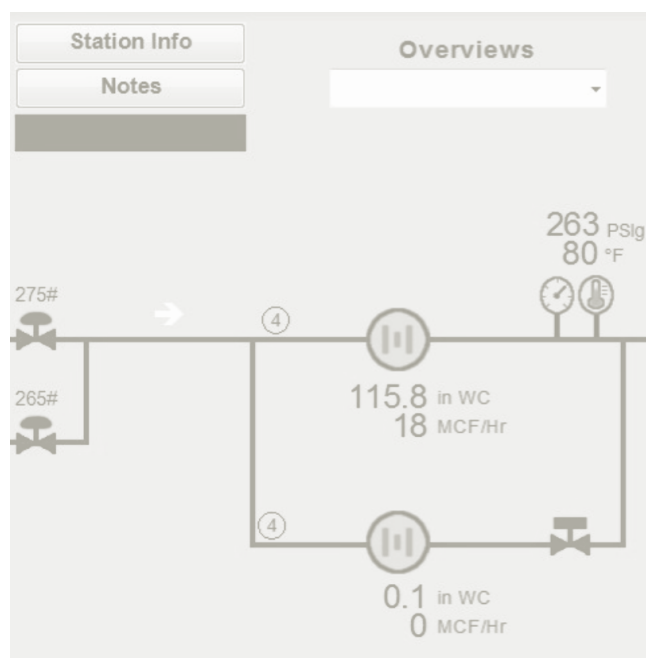


Figure 14—Example Static Text Consistency

4.6 Coding

4.6.1 General

Coding is the assignment of meaning to a display object. Examples of information that is frequently visually coded include normal/abnormal conditions or shape-coding of device symbols such as pumps, valves, and meters.

Visual coding allows more information to be conveyed in a smaller space. For example, rather than adding the word “emergency” next to an alarm, an icon with a unique shape, color, letter, or number indicating priority would occupy less space. Another benefit of visual coding is that it helps bypass some of the STM limitations. Color is processed prior to conscious processing, allowing information to be transferred even if the STM system is overloaded.

Auditory coding captures the controller’s attention when they are not looking directly at a display. For example, alarm tones indicate issues of concern to a controller.

It is important to develop a visual coding scheme prior to designing displays. The total list of attributes for which codes should be developed should be defined before deciding on coding options. This applies to the major methods of visual coding used in SCADA displays:

- 1) layout and position (see Section 6),
- 2) color (see 8.2),
- 3) shape (see 8.3),
- 4) animation (see 8.4),
- 5) alphanumeric or text (see 8.5).

Exercise caution not to overuse coding, as it can then lose its effectiveness.

4.6.2 Coding Traits

The following traits should be kept in mind.

- Detectable—The controller should be able to detect the stimulus. For example, blink rates should be within human thresholds for detection.
- Discernible—The controller should be able to differentiate the code from the background or other codes. Use of alternating colors, where blue-yellow-blue means one thing and yellow-blue-yellow means something else, would not be a good coding technique.
- Compatible—The code should have natural associations where possible, such as associating filled/empty for inventory/no inventory.
- Meaningful—If the code does not have an impact on controller behavior, there should not be a code. Coding for aesthetics of information or because things are different is not a reason to use a code.
- Consistent—The code should be used the same way throughout the system and whenever appropriate. This is the best way to develop the desired response to a code.
- Redundancy—Multiple coding techniques can increase effectiveness. An example of this is a stop sign; it employs several coding techniques: color (red), shape (octagonal), alphanumeric (“stop”), and position (right side of road).

Overloading coding may impair controller actions and responses. Care should be taken to maintain context to allow for effective decision-making.

Figure 15 shows an example valve object and the coding of its traits.

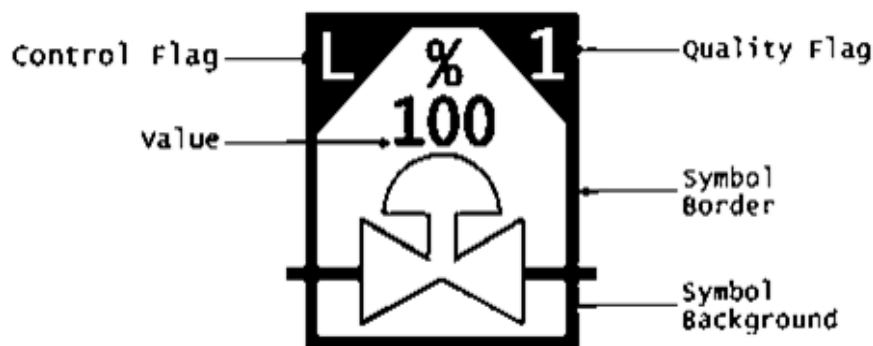


Figure 15—Coding for Object Traits

5 Display Hardware

5.1 General Considerations

SCADA systems typically use local network connected computers and workstations for the primary HMI subsystem. This technology has been proven to be cost effective, scalable, and easily upgraded as needs change.

5.2 Display Devices

5.2.1 Display Device Types

Information is presented to the controllers on a video monitor.

5.2.2 Number of Monitors per Controller Console

Controller consoles and workstations are typically equipped with multiple monitors of the same technology. The exact number should be chosen based on expected controller span of control, the number of displays to be viewed concurrently, and how much information can be clearly presented on each monitor. The ability of the display subsystem software to show multiple displays on the same monitor may also influence the size and quantity of monitors. Controller consoles with multiple monitors are typically positioned horizontally in front of or around the controller. Stacking of two rows of horizontally oriented monitors is also a common arrangement. Larger monitors with very high resolution may be utilized instead of stacking monitors. Vertical and horizontal viewing angles and distance are important ergonomic considerations to provide controllers with optimal line of sight and legibility.

For more information about ergonomic design considerations in workstations, refer to ISO 11604-4.

Consideration should be given to the consistency between the number, size, and type of monitors at the primary control room and a backup control room, if one exists. Consideration may also be given to having spare consoles or workstation to manage peak workload, or additional modes of operation.

5.2.3 External or Remote Display Devices

Some control rooms or external operating environments may lend themselves to having display devices other than the monitors at the controller workstations. These devices may range from large monitors or display projection systems to laptop or handheld personal computers (PCs).

In control rooms, large monitors can provide a means where a wide audience can see the same data simultaneously. These large monitors are typically driven by one of the controller console computers and may be configured to mirror single monitors on the console or present content specifically developed for the dimensions and usage of the display.

A handheld display device may be used within a control room or at an external location and may include mobile phones, tablets, and desktop or laptop computers. These devices use application software to interface with a SCADA process control system via wireless networking technology. Safety, integrity, and security are the primary concerns with any remote or handheld SCADA device interface, especially when allowing remote access using wireless technology. Display hardware should complement and support effective cybersecurity programs.

Remote presentation of data should be consistent with what is displayed in the main control center. See Section 11 for more information.

5.3 Display Response

Display subsystem response is a function of both hardware performance and software design. In modern SCADA systems that use client server architecture, both the host (server) and HMI computer (client) can affect the initial display call-up time and data refresh rate. Once installed, display response times should be periodically reviewed.

The richness of display content vs call-up time may be trade-offs to consider in display design, depending on other factors such as bandwidth. Reasonable display call-up times should be expected in any SCADA system design to avoid controller frustration and to support STM. Display call-up times of between 2 to 3 seconds or less are desirable while the SCADA system is under a normal processing load.

Some strategies to manage time necessary to call up information may include the following.

- Ordering the sequence of information called up within a display (e.g. trends last).
- Caching displays in memory.

- Displays that are persistently open or “pinned” such as Level 1 displays (see Section 6) may have richer content (trends, complex objects). Longer call-up time for these displays is acceptable due to the infrequent need to call them up (typically only on system start-up).
- Planned hierarchical navigation to reduce controller need to call up displays.

Strategies to support continuity and uninterrupted monitoring during shift change may include the following.

- Dual workstations to stage login/logoff.
- Avoiding display shutdown by providing adequate provision for cybersecurity and record-keeping of transfer of control

Display refresh by updating all data fields displayed vs updating individual fields as they change is a software design issue; either scheme should provide changed data to be visible in a reasonable time. Data refresh rates may be selectable with respect to the type of data (status, analogs, accumulators, etc.) being updated and the speed of data acquisition from the remote field devices. Often it is desirable to refresh the data on a display as quickly as possible after it has been received and processed by the SCADA host computer.

5.4 Controller Input Devices

5.4.1 General

A controller input device (peripheral) is any component that attaches to a computer. Examples of input devices used for entering information into a computer include keyboard, mouse, track ball, touch-sensitive screen, control-grip and joystick, graphics tablet, and voice recognition device.

The standard computer keyboard and mouse or trackball are the most widely used input devices on SCADA systems.

A dedicated input device per monitor is not typically used in larger control centers. Console workstations typically have a keyboard and mouse or trackball that are used to perform input on multiple monitors.

5.4.2 Training and Controller Devices

Consider how training and trainer controllers interact during on-the-job training when determining input device availability. In some cases, Trainers may be expected to interact with the SCADA system without disrupting the training controller's activities (e.g. on a separate console or workstation). When two separate workstations are available, software applications can be used to determine if a single input device or two input devices are necessary.

Spare input devices and a means for controller swapping are desirable.

6 Display Layout and Organization

6.1 General Considerations

To promote situation awareness and avoid confusion, display layout conventions should be planned and documented in the design process. For display design, the design/development team should first decide what and how to display the information. Deciding what information to display depends on the purpose of the display and the tasks it supports. An important step in this decision is the review of the display by the controllers who will use the display. Displays that model the real-world process and structure are easier for the controller to recognize and react to normal and abnormal situations. Duplicating every component of the field piping and equipment (i.e. drain piping, locally operated equipment, etc.) may create clutter on the display. The level of detail should be appropriate for the purpose of the display.

Pipeline information can be displayed in either a graphical or tabular format. Generally, graphical displays work well when physical pipeline configuration details are important. Tabular displays are best used for text or numeric summaries, such as event logs, alarm summaries, ticket details, proving reports, or displays used to total numbers from various locations that are not necessarily geographically near one another.

On a graphical display, the flow of the pipeline system and information should be consistent, with left to right, top to bottom being the most prevalent direction. Geographical orientation (north—top of screen; south—bottom of screen) is not commonly used on tabular or graphical displays; however, it may be used for diagnostic purposes or for field communication. Overview type graphics (e.g. a pipeline overlay on a topographic map) typically display the flow of information geographically. Bidirectional station displays could be managed by the addition of dynamic directional indicators. On tabular displays, flow or location information should also be consistent, with top to bottom being most prevalent.

6.2 Display Hierarchy

6.2.1 General

SCADA systems typically consist of multiple levels or types of operational displays, where each level presents additional detail. This hierarchical structure helps to minimize the number of displays a controller is required to work with and serves to group information in a logical manner that is easy to locate. An example of an organized four level system is outlined in the subsections below.

6.2.2 Level 1 Situational Awareness Overview/System Overview

The purpose of Level 1 displays is to present a qualitative overview of all the pipelines systems operated by a controller. They enable the controller to quickly understand the current operating conditions of the system(s) they are controlling.

Consideration when designing a Level 1 display may also be given to including system information not controlled from the console or information from connected facilities to promote shared situation awareness. Level 1 displays are a critical tool to address the potential for cognitive tunnel vision, while allowing controllers to focus on areas of concern.

This display may be designed with hot buttons for access to individual pipeline overview displays.

Operation of controllable field devices is normally not allowed from this display.

Effective Level 1 overview displays have taken the form of maps, trends, tables, among others.

Figures 16, 17, and 18 show example Level 1 displays.

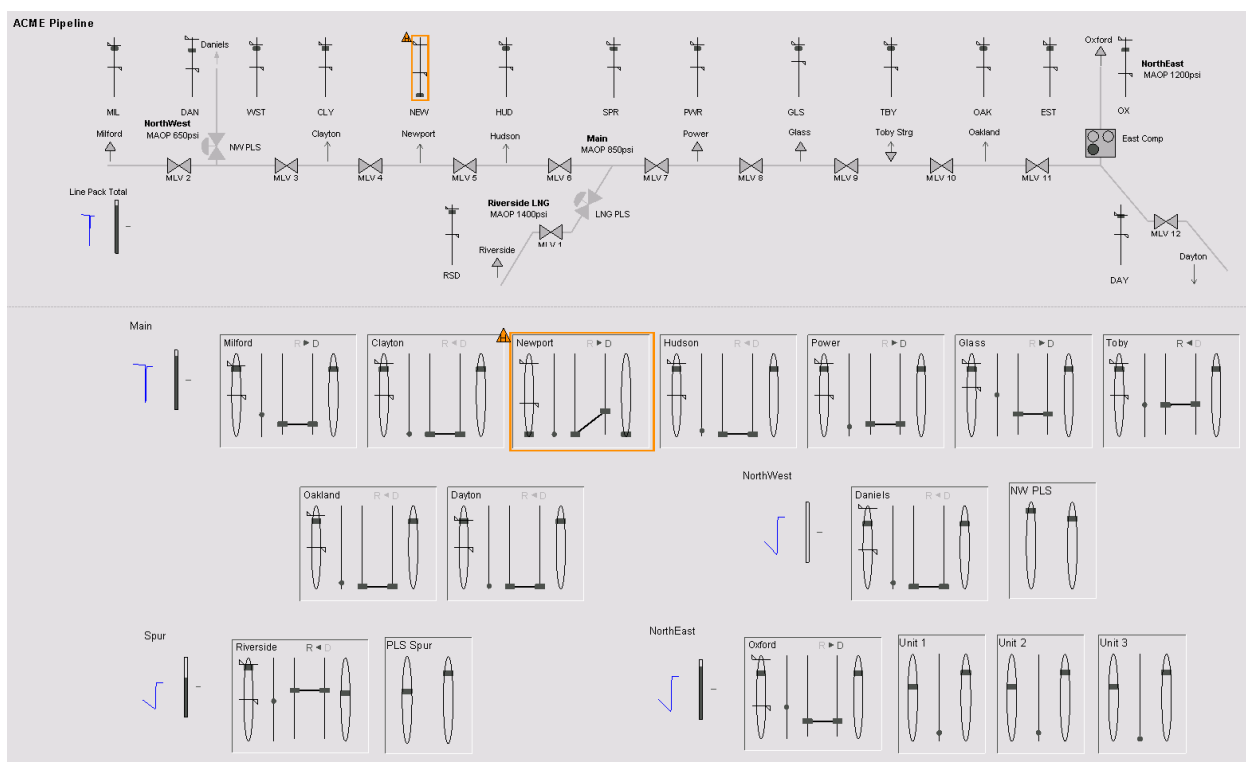


Figure 16—Example Level 1 System Overview A

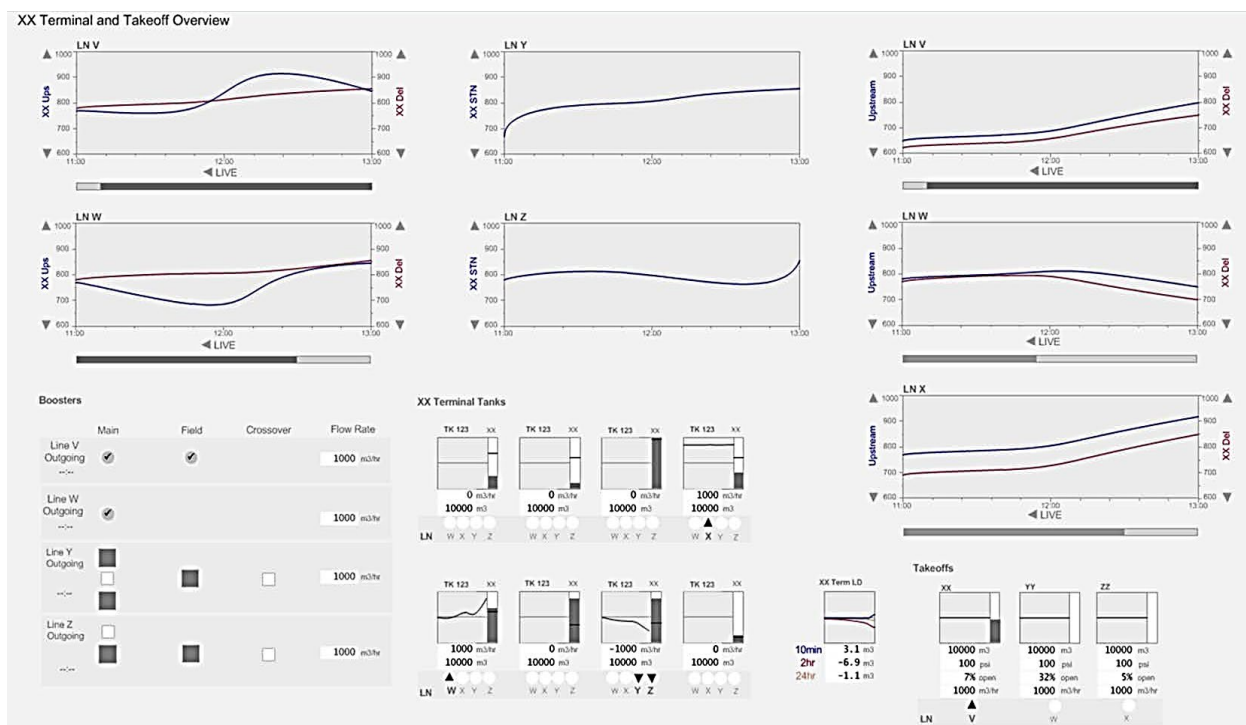


Figure 17—Example Level 1 System Overview B

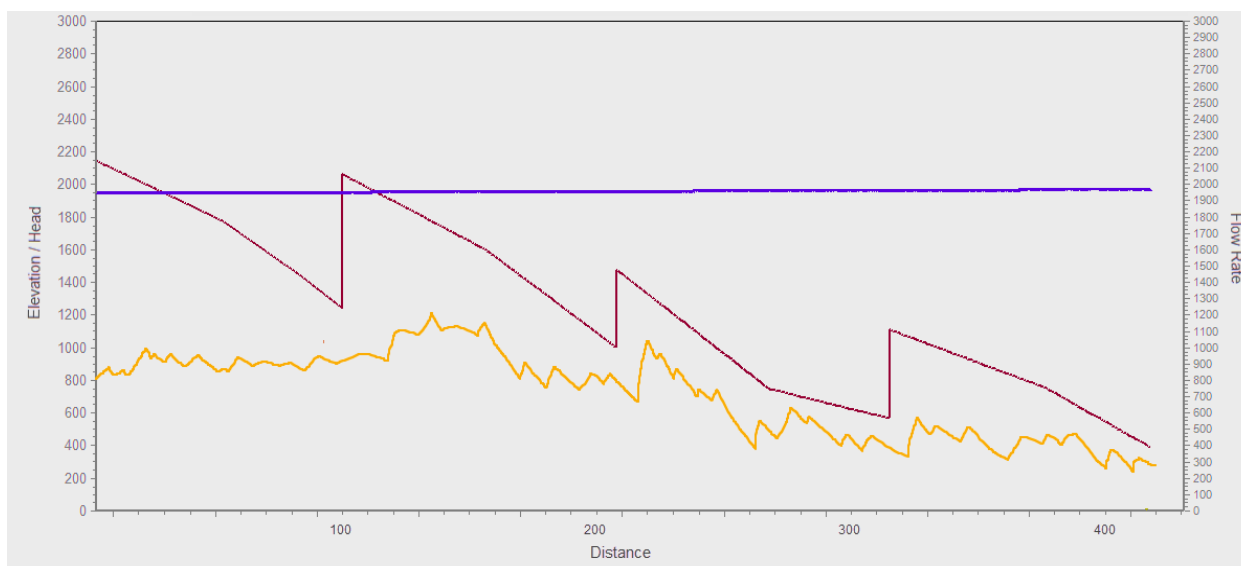


Figure 18—Example Level 1 Trend Display

6.2.3 Level 2 Operational Overview Displays, Site Overviews, or Task Centric Displays

A Level 2 graphical or tabular display presents a defined system or operation. This display may be designed with hot buttons for access to individual station displays.

Displays developed for specific tasks (e.g. start-up, switches) may also be included at this level.

Operators may utilize Level 2 displays to control field devices.

Figures 19 and 20 show example Level 2 displays.

OVW_ODORIZER1 16:12:21 7/17/2019

Overviews Maps

1 2 3 4 5 6 7 8

Odorization Monitor Page 1

Nav Menu Dismiss Legend System

Division	Station	Fault	Inject Rate LB/MMCF	Flow Rate MCF/H	Inject Rate LB/MMCF	Flow Rate MCF/H
Division 1						
Station A						
Station B	D H		1.00	2		
Station C	D H		1.00	2		
Station D	D H		1.00	1184		
Station E	D H		1.00	736		
Station F	D H		1.01	5		
Station G	D H		1.00	16		
Station H	D H					
Station I	D H		1.00	335		
Station J	D H		1.03	257		
Station K	D H		1.00	142		
Station L	D H		1.21	0		
Station M	D H		1.00	0		
Station N	D H		0.99	3621		
Station O	D H		1.01	590		
Station P	D H		0.97	2		
Division 2						
Station Q	D H		0.60	0		
Station R	D H		1.00	89		
Station S	D H		1.03	43		
Station T	D H		0.99	11		
Station U	D H		1.00	18		
Station V	D H		1.00	249		
Station W	D H		0.89	2		
Station X	D H		0.76	0		
Station Y	D H		0.99	2		
Station Z	D H		1.00	328		
Division 3						
Station AA	D H		1.00	76		
Station BB	D H		0.96	12		
Station CC	D H		1.00	0		
Station DD	D H		1.00	0		
Station EE	D H		1.03	15		
Station FF	D H		1.00	1		
Station GG	D H		0.99	104		
Station HH	D H		1.00	0		
Station II	D H		1.00	0		
Station JJ	D H		1.00	1275		
Station KK	D H		0.98	33		
Station LL	D H		1.01	796		
Station MM	D H		1.00	0		
Station NN	D H		0.96	2		
Station OO	D H		1.00	0		
Station PP	D H		0.97	2		
Station QQ	D H		1.00	1003		
Station RR	D H		0.99	3		
Station SS	D H		1.03	9		
Station TT	D H		1.00	0		
Station UU	D H		1.00	234		
Station VV	D H		0.97	5		
Station WW	D H		1.00	965		

Figure 19—Example Level 2 Tabular Display A

LINE F T COMM PCV HLDY MON RSS RMS SPT SUC SUC THR/ DISC DISC RMD FLW UNITS LD LGT HVY UP STN

V AA 75% 50 100 60 200 300 100 1000 45 816 816

BB 3% 50 100 200 300 100 1000 1 914

CC 100% 50 100 200 300 100 1000 15

DD 88% 101 50 1000 39 917 909

W AB 100 200 300 1000 753

222 100

333 100

444 398 726

X AC 91% 50 74 75% 200 300 100 1000 24 814

456 200

567 200

AD 100% 50 283 200 300 100 1000 1 831 810

578 200

678 200

777 246 200

AE 72% 50 128 29 200 300 200 1000 33 810

789 200

AF 84% 50 185 31 200 300 100 1000 33 812

889 200

910 50 125 200

ZZ 22% 147 50

Y BA 65% 127 50 127 60 200 300 100 1000 29 920

555 298

567 216 1000

678 149

789 127 200

BB 61% 50 50 57 200 300 100 1000 74 920

BC 82% 74 50 200 300 100 1000 916

Z CC 9% 73 50 127 200 300 100 1000 29 875

333 176

CD 4% 255 50 1000 917 916

Line Control

Stop Line

Apply Comm-out Limits

Remove Comm-out Limits

Apply Transition SPT Standards

Apply Steady SPT Standards

Enhanced ALD Monitoring

Apply Multi-Discharge SPT

Apply Multi-Suction SPT

Task Stop Line

From AA-X

To ZZ-X

Execute Cancel

Figure 20—Example Level 2 Tabular Display B

6.2.4 Level 3 Station Displays or Subsystem Displays

This display graphically presents a single station and location or group of locations. Greater attention to detail in station piping and field devices is present. This display illustrates detailed functionality for a specific station, including equipment status and analog data. This display could be designed with navigation buttons for access to detail displays.

Operation of controllable field devices is typically allowed from this display.

Figure 21 shows an example Level 3 display.

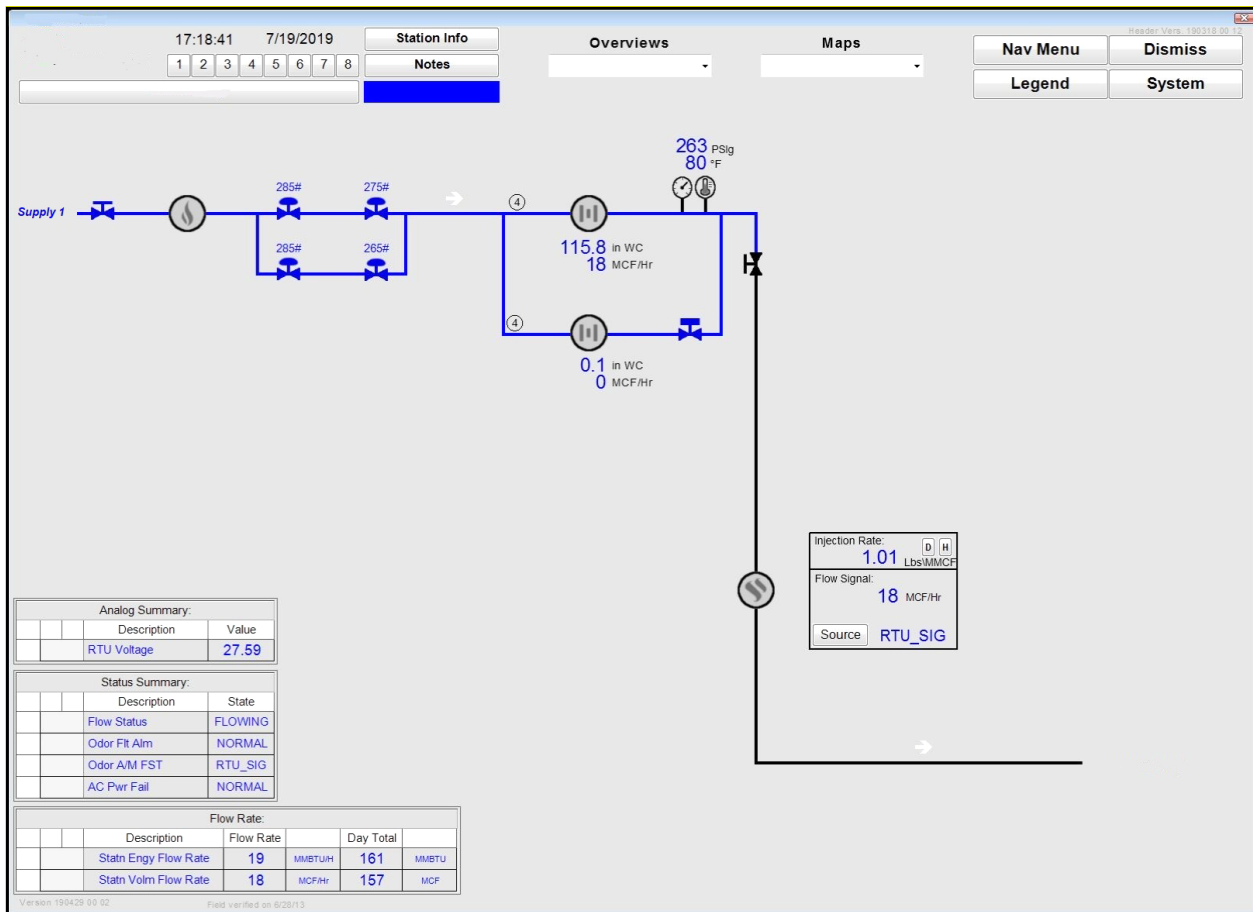


Figure 21—Example Level 3 Display

6.2.5 Level 4 Detailed Diagnostic and Operational Configuration Displays

A Level 4 display presents greater equipment detail and additional operational or point information and may contain control elements.

Examples include control displays and informational displays as well as pop-ups.

Control displays are typically pop-up type, parent/child in nature, and may contain in-depth information for a specific data point including ranges, alarm limits, remote name, and current value. Some Level 4 control displays are predetermined as well.

Informational displays may include summaries for database information, event logs, and trends.

In some cases, Level 4 displays incorporate control elements along with detailed information about a device. In other cases, the control element is not included in the Level 4 display.

Figures 22 and 23 show example Level 4 displays.

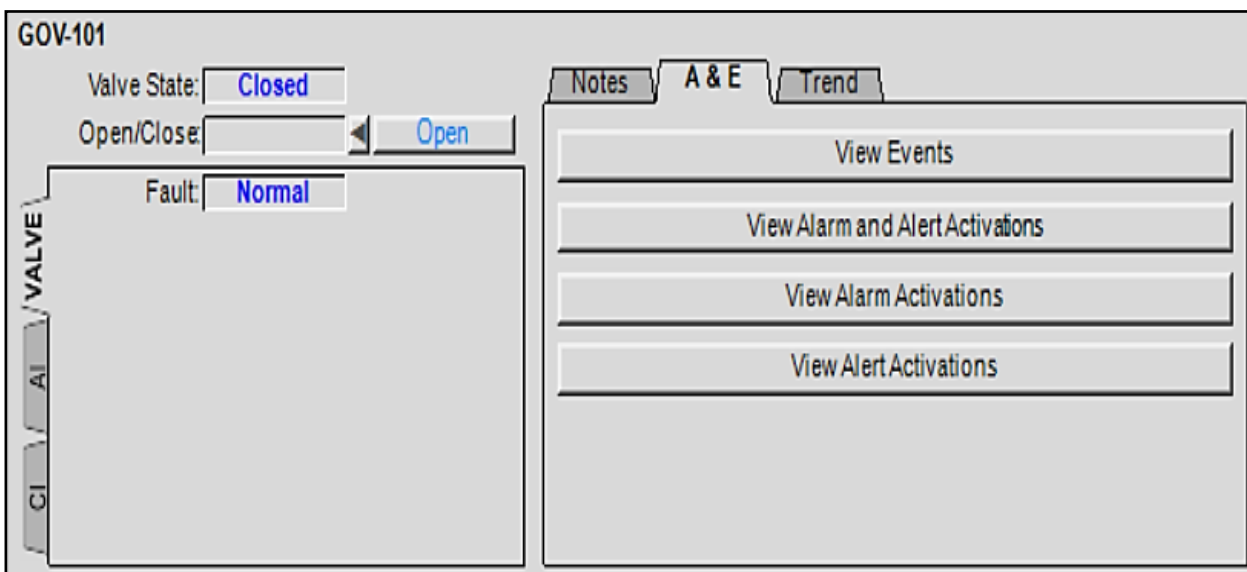


Figure 22—Example Level 4 Predetermined Control Display

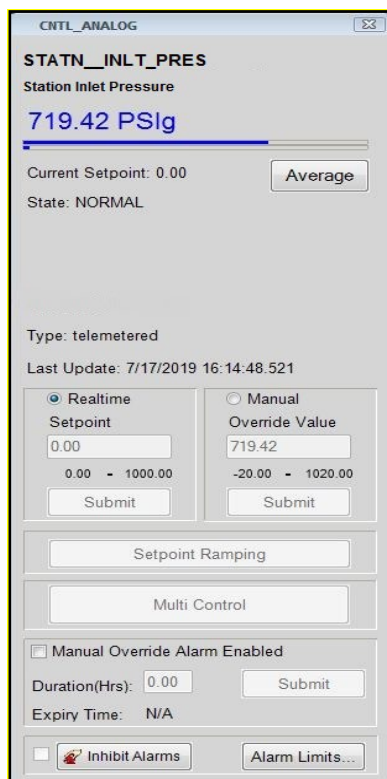


Figure 23—Example Level 4 Pop-up

6.3 Window Management Considerations

6.3.1 General

Window management issues are an important consideration in the design of the HMI. Issues to be considered when creating the display layouts may include the maximum number of open windows, window sizing, window locations, whether a new window replaces an existing one, and how windows are closed, minimized, moved, or resized.

6.3.2 Number of Open Windows

6.3.2.1 General

Open window management can take several forms.

6.3.2.2 Limited Windows

One widely used technique to consider in the management of open windows is to limit the maximum number of open windows per monitor, regardless of the type of display. Only associated pop-up control windows, layers, and overlays would be allowed to open for a given parent window and remain open until closed or the parent window is closed. Child windows would be configured for movement on top of the parent window. Secondary windows would be permitted to overlay the main window; they should be designed with a close button that would return the controller to the main window.

Benefits of the above technique include:

- maintaining system performance,
- simplifying the controller HMI with the computer system.

Risks of the above technique include:

- limiting controller flexibility and may force the use of multiple monitors to achieve an appropriate level of visible windows.

Mitigations of those risks include:

- maintaining contextual awareness between open main windows and other associated windows.

For example:

- pop-up panels clearly showing the relationship between panel and device;
- associating displays with the overall system, e.g. with display label matching object label on overview.

6.3.2.3 Unlimited Windows

A second, less desirable technique of managing the number of open windows is to place no limit on the maximum number of windows.

Benefits of the above technique include:

- increasing the controller's ability to manage the interface with the computer system, providing almost unlimited use of monitor space and computer functionality.

Risks of the above technique include:

- creating the possibility of overloading the computer's resources making the system unstable,
- increasing the possibility of the controller losing the location of an important window when it is overlaid by other windows,
- breaking any link between the current visible window and other associated windows,
- different controllers arranging displays in unexpected ways.

Mitigations of those risks include:

- training controllers on display management,
- issuing a notification based on system performance degradation or based on display workstation resource thresholds,
- pop-up listing of all open displays to bring desired displays to top.

6.3.2.4 Predetermined Window Positions

A third technique is a mix of predetermined monitor positions for pinned displays, typically Level 1 displays and alarm displays, with additional monitor positions that allow controllers to invoke Level 2 and Level 3 displays as desired.

Benefits of the above technique include:

- facilitates management of resource requirements,
- balance between predictability and flexibility.

Risks of the above technique include:

- losing contextual awareness,
- inefficiency in opening displays.

Mitigations of those risks include:

- clear labeling,
- favorites/bookmarks, screen sets, frequently used, back/forward buttons, recent (historical) displays, etc.

6.3.3 Sizing

6.3.3.1 General

Window size refers to the dimensions of a display and not to the monitor resolution or aspect ratio to maintain the same size of objects across monitor resolutions.

6.3.3.2 Fixed Window Sizes

Ideally, window sizes are fixed to promote situation awareness by making display characteristics predictable and repeatable.

Benefits of the above technique include:

- optimizing the use of screen real estate,
- maintaining legibility,
- navigation efficiency,
- managing system performance.

Risks of the above technique include:

- constrains controller ability to manage scope of open displays in real-time.

Mitigations of those risks include:

- using task analysis and usability assessment to optimize display design.

6.3.3.3 Variable Window Sizes

In some cases, software may not support fixed window sizes.

Benefits of the above technique include:

- allowing for controller flexibility.

Risks of the above technique include:

- data may be truncated if a window is resized smaller than the initial rendering. For example, alarm name, time stamp, and alarm message should always be visible without scrolling;
- reducing legibility.

Mitigations of those risks include:

- using window scaling to prevent clipping or truncating data, if legibility is maintained;
- training controllers on display management.

6.3.4 Location

Window locations should be consistent for similar display types.

- If alarm summary is not pinned, it should appear in a consistent location.
- Level 1 displays should appear in predictable locations.

6.3.5 Overlaying

New windows can be designed to either replace or layer on top of others when rendered. Navigation to a main map or menu should always be accessible to the controller. Alarm windows should never be minimized and should remain “on top” of the stack if layering is utilized. Overlaying for large windows that may obstruct Level 1, 2, or 3 displays is not recommended. Overlaying is commonly used for temporary pop-ups.

Tabs are preferred to overlaying because open windows are not dismissed. However, information may be covered by switching to a different tab. This risk can be mitigated through controller training.

6.3.6 Windows Spanning Multiple Monitors

SCADA system display capabilities differ based on operating system, software, and hardware types. Some SCADA HMIs function with multiple monitors configured as one workspace, and others function independently. Either method is acceptable. A benefit of the one workspace method is the ability to see more detail on a complex display by stretching the window across multiple monitors; however, portability to single monitor HMIs is compromised.

6.3.7 Screen Savers and Lock Screens

Screen savers should not be used on controller workstations that are constantly active. Automatic screen locks should not be utilized. Manually activated login screens with passwords should be used on any SCADA workstations in an unsecured location or where unauthorized persons could gain access to the console.

7 Display Navigation

7.1 General Considerations

Navigation design is critical to the successful use of the SCADA system. Significant planning is required based on the capability of the software and operating requirements of the pipeline system. A good navigation approach provides quick access to the most frequently used displays and infrequently used but safety-critical displays, with easy access to secondary or associated displays. Navigation should be intuitive and aligned with the hierarchy and process relationships existing in the pipeline that the SCADA system controls.

Navigation efficiency can be optimized by giving special consideration to the number of moves required to transition between screens—specifically, the number of:

- clicks,
- keystrokes,
- moves (reorienting) between mouse and keyboard.

Refer to ISO 9241-11 for further information on navigation design.

7.2 Navigation Techniques

7.2.1 General

Navigation techniques are the various ways a controller can interact with the SCADA displays. One key element in designing navigation schemes is to provide multiple methods of accessing any display. Examples of navigation techniques include, but are not limited to, menus, button bars, hot spots, and navigation buttons. Sometimes the mouse buttons are used to perform different functions based on the navigation techniques used. Keyboard keys can be used in a similar manner.

The controller should be able to access necessary displays with a minimum number of keystrokes, mouse-clicks, and reorientations with a goal of no more than two clicks/strokes/reorientations between any two screens, with appropriate exceptions for detailed or diagnostic displays. Consideration should be given to providing the ability to navigate through displays using a single input device. For example, when navigating through hierarchical displays, a single action (e.g. mouse-click) could permit the user to navigate to another display level. A single action could also permit the user to toggle between the last two displays.

7.2.2 Direct Display Call-up

7.2.2.1 General

Displays that are called up should open in a predictable location that complements the current information being displayed and should not overlay areas of the screen the controller uses to monitor or control operation.

Tabs or buttons are a direct display call-up method for navigating the display hierarchy. They can be used to navigate to various aspects of an object, different displays of a similar type, or other cases.

Figure 24 shows an example tabbed control panel.

NOTE Figure 24 is discussed further in A.4.33.

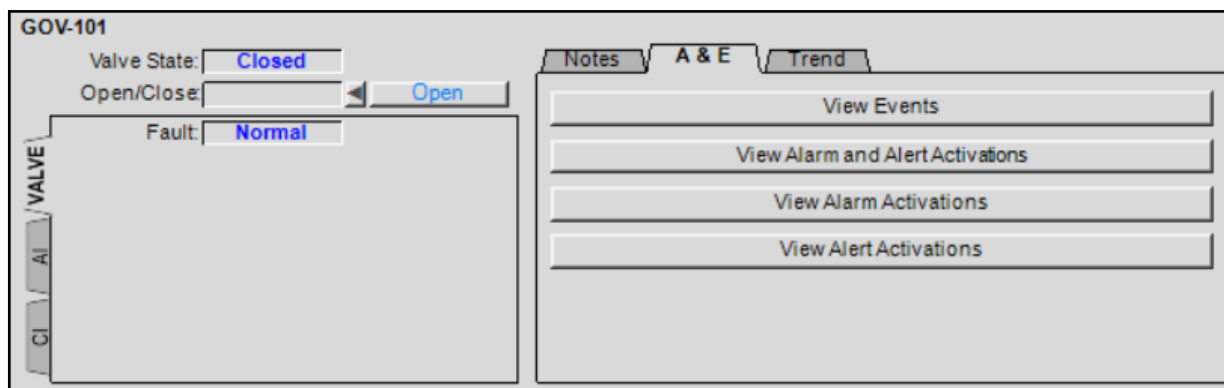


Figure 24—Example Tabbed Control Panel

Menus are another method used to navigate to various displays. Menus should be consistent in terminology and order structure. They should be designed and sorted in a logical order to minimize scanning and search time. Menu sorting by frequency of use, related display types, or geographic areas are typical examples.

The number of menu options influences the number of menu levels required. If more than one level is required, grouping should be logical to the controller. If many levels are necessary, a help field or preview that looks ahead to options at the next level could be beneficial.

Menus are typically used to navigate between pipeline systems, pipeline stations, and SCADA applications. Types of menus might include pull-downs, pop-ups, button bars, and dedicated display menus.

Pull-down menus, also called “drop-down menus” or “pop-down menus,” are a common type of menu used with a graphical user interface (GUI). A menu title is displayed that, when selected by clicking it, causes the menu to drop down from that position and be displayed. Items are selected by highlighting the line in the menu and either clicking it or letting go of the mouse button.

Figure 25 shows an example navigation menu with a series of pull-down menus.

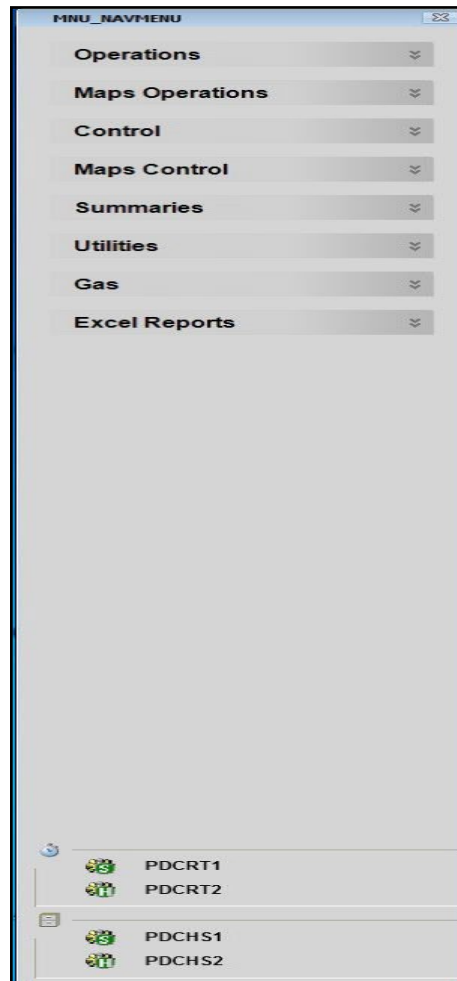


Figure 25—Example Navigation Menu

Button or ribbon bars can be used to place fixed links between a series of displays or to provide links to submenus. Figure 26 shows an example ribbon bar.

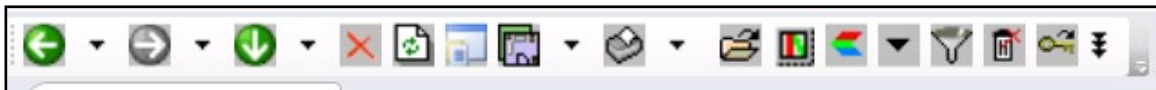


Figure 26—Example Ribbon Bar

7.2.2.2 Pop-up/On-demand Panels

Pop-up locations are best located in the following categories:

- a dedicated space on current display,
- a dedicated place in the overall display layout,
- adjacent to the object being controlled.

Consideration should be given to deliberately positioning pop-up panels that are opened such that they do not diminish the controller's ability to operate.

If Bullet 3, consideration should be given to methods to limit hidden information, including:

- dismissing pop-ups automatically after command execution,
- auto-dismissing after predetermined duration,
- limiting size of the pop-up,
- avoiding covering other controls or menu bars.

7.2.3 Hot Spots and Navigation Buttons

Hot spots and navigation buttons refer to an area, symbol, or text on a display that when selected provides navigation to some predefined display. Hot spots may or may not have a visible indication that it provides navigation; operators should be instructed as to the use of this method. A navigation button is an image of a button on a computer screen that simulates being “pushed” when clicked by the mouse and provides navigation to some predefined display.

Implementation of navigation buttons and hotspots should be intuitive, predictable, and consistent throughout the system. For example, on long pipelines with multiple stations, the individual station displays could be fitted with navigation buttons to access both previous and next station displays so the controller can navigate from one end of the pipeline to the other, one station at a time. Hot spots could be used on a pipeline system overview map to navigate to individual station displays using the station name as the hot spot.

Hot spots, including poke points and buttons used for navigation, should be consistent and distinct from hot spots used for other purposes such as object dynamics.

Types of navigation implemented can include the following.

- Upstream/downstream arrows—for traversal across a level in a hierarchy level (e.g. traversal along a flow path between stations).
- Hierarchical (up and down the levels).
 - Traversal navigation may be configured to open on the same screen position, and hierarchical on different screen positions.
- Recently viewed and/or back/forward (i.e. web browser-like).
- Bookmarks/favorites.
- Hot spot—opens additional details (e.g. faceplate/trend/additional navigation).
- Display yoking.
 - Opens appropriate Level 2 and Level 3 displays from a Level 1 object.
 - Context-sensitive yoking (depending on operational mode—operating mode/alarm state/default).

Consideration should be given to alarm navigation:

- opens Level 2 and/or Level 3 displays from an alarm message/banner;
- alarm rollup with navigation to greater detail of associated alarming subsystems (downward in hierarchy), e.g. opens appropriate Level 2, Level 3, and/or Level 4 screens from a Level 1 object showing an active alarm animation;

- navigation from summary to detail quickly, e.g. to “home” display and downward, or aggregated object and downward;
- navigation (or pop-up) to procedures, alarm response information, etc.

7.2.4 Mouse and Keyboard

Using the mouse or other pointing device to place the cursor over hot spots and buttons is the most common navigation technique. Although the number of mouse buttons is limited, additional navigation may be possible dependent on the functionality associated with the mouse button. For example, left clicking the mouse might call up a specific station display, while right clicking the mouse might navigate to the display associated with the most recent alarm.

Dedicated keyboard keys can be used to navigate displays. Keyboard sequences are not intuitive and can be confusing. The controller should not be required to use a keyboard to perform navigation.

7.2.5 Zoom, Pan, and Overlays

Consideration should be given to the density of information and/or number of symbols on a graphic display to allow a controller to easily see what is going on. When display density gets too high, the use of pan, zoom, layering, and overlay techniques can be considered for certain types of displays such as maps and trends. These techniques allow a controller to choose a level of detail based on their needs. Pan and zoom features are typically assigned to a mouse button, while layers and overlays are called by buttons. Trend displays are a typical example of the benefit of zooming because of the quantity of data available. Zooming in on trends improves the controller's ability to interpret the trend.

Pan and zoom should be avoided on displays where critical information could be hidden.

8 Object Characteristics

8.1 General Considerations

8.1.1 General

On SCADA displays, objects are defined as any type of symbol or text that relays information to the controller. Each object has attributes or characteristics such as color, size, shape, fill, etc. that are used to enhance or fortify the meaning to the controller. The careful design and planning of a good set of displays should incorporate these different types of objects in a manner that supports situation awareness, particularly as controllers orient to operating conditions, and evaluates impacts and next steps.

There should be a distinct difference between objects that are controllable and non-controllable remotely by the controller. This may be done with color, borders, fonts, highlights, symbols, text style, data attributes, etc. These indications may be dynamic if controllability changes according to permissions at the SCADA level (multiple consoles with ability to transfer control of facilities), field level (if a local technician can turn off remote control), or local logic level (control permissives/inhibits based on conditions).

8.1.2 Display Space Consideration or “Every Pixel Matters”

Weigh space considerations carefully, especially when objects will be re-used, because wasted space may be multiplied across multiple displays.