NEXT-GENERATION SCADA HIGH PERFORMANCE HUMAN MACHINE INTERFACES

Configuring HMIs to Display “Operator-centric” Information

Ryan Kowalski, PE; Ed Kowalski, PE
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Today’s Presenter

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Learning Objectives

• Recognize key components of a plant or facility **Human Machine Interface (HMI)**

Define **situational awareness** as it relates to SCADA systems and identify common HMI pitfalls working against it

• Describe how High Performance HMI (HPHMI) **concepts** serve to enhance situational awareness

• Identify how **methodologies** such as ANSI/ISA 18.2 alarm management approach support HPHMI and are critical to SCADA system success

• Outline how to **benchmark and measure** the performance of HPHMIs and related alarm management systems
Introduction

Automation and SCADA systems are fundamental to water resource plant operations.

Operators struggle with massive amounts of alarms, increasing screen counts and I/O.

Information is presented in ways that may not enhance situational awareness.
Agenda

1. Background of HMI Engineering
2. Situational Awareness
3. “High Performance” HMI
4. Examples of Implementing HPHMI Engineering
5. Alarm Management – An integral part of HPHMI
1. BACKGROUND OF HMI ENGINEERING
HMI Components

Enterprise Systems
Remote Site Telemetry
HMI/OIT Controllers
Packaged Vendor Systems
VFDs/Actuators
Field Instruments

HMI - Human Machine Interface – The collection of displays (hardware and software) that allows an operator to “see and hear” the process.
The Plant Control Room

- Monitors
- Computer Screens
- Graphics
- Console Stations
- Mouse & Keyboard
- Portable Devices
- Alarm Lights
- Audible Devices
History of HMIs: …80s, early 90s
History of HMI: 90s/00s

Computerized SCADA systems

Control engineer prepares Process and Instrumentation Diagrams (P&IDs)

HMI software provides toolkits, features, objects, colors

Contractor/System Integrator configures HMI based on P&IDs and specifications
Typical Current HMI Screens
2. SITUATIONAL AWARENESS
Situational Awareness (SA)

Situational awareness (SA) is the **perception** of environmental elements with respect to time or space, the **comprehension** of their meaning, and the **projection** of their status after some variable has changed, such as time, or some other variable, such as a predetermined event.
Situational Awareness (SA)

“The relationship between the operator's understanding of the plant's condition and its actual condition at any given time”

- (International Society of Automation (ISA))
<table>
<thead>
<tr>
<th>HMI Impacts to SA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance shaping factors:</td>
</tr>
<tr>
<td>“Attention tunneling”</td>
</tr>
<tr>
<td>Reliance on Short-term Memory</td>
</tr>
<tr>
<td>Physical and mental stress</td>
</tr>
<tr>
<td>Too much data</td>
</tr>
</tbody>
</table>

“Too much data” “Increasing Complexity”

Too many alarms
Too many options
Easy to configure
Built-in alarms for analog
Custom graphics development

Configured Alarms per Operator

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“Attention Tunneling” “Loss of View”
“Misplaced Emphasis” “Too much data”

Where is the alarm?

ALM: 02_UA1002 DWP#304 PMPBR FAILTRP#12
3. “HIGH PERFORMANCE” HMI
High Performance HMI

Terms:
• “High Performance”
• “High Impact”
• “Next Generation”
• “Situational Awareness”

HPHMI - Providing an interface to the process that is operator-centric, and focuses on human factors, the operator’s mental model, and enhancing the operator’s situational awareness.
Vision

Source: HMI Handbook
Vision

Display

- Contrast
- Repetition
- Alignment
- Proximity

Graphic Development

- Use of Color and Shape
- Use of Patterns
- Use of Trends

Source: Stock Photo
Use of Color and Shape

Use color and shape to focus attention

- Muted Background (Gray)
- Avoid Run/Stop/Open/Close Color, use contrast instead
- Indicate alarms with both color and shape

Source: The High Performance HMI Handbook (Hollifield et al., 2008).
Use of Patterns and Analog Indicators

- “At-a-Glance”
- Analog Indicator
- Pattern Recognition Objects (PROs)
  - Profile Displays
  - Radar Plots

Source: The High Performance HMI Handbook (Hollifield et al., 2008).
Use of Analog – Car HMI Example

Useful to the driver (operator)?
Use of Trends

- Enhanced use of trends
- Embedded “road-map” trending

Features:
- Alarm and shutdown levels
- Setpoints
- Time interval

Tank 1

Level: 20.2 ft

2 hr
Hearing

Ability for humans to distinguish sounds is exceptional.

**Example:** Car HMI unique sounds:
- Driver opens the door with keys in the ignition
- There is low tire pressure
- Outside temperature falls below 3°C (37°F)
- The windshield washer fluid is low

Source: Stock Photo
High Performance HMI
ISA Standard 101 – HMI Lifecycle Model


- Builds on and brings together threads from various sources (industry / academic partners)
- Establishes consistent approach to HMI development (process industries)

API 1165 Recommended Practice for Pipeline SCADA Displays

ASM Consortium Guidelines Rev 3-2008 Effective Operator Display Design

ANSI/HFES 100-2007 Human Factors Engineering of Computer Workstations

ANSI/HFES 200-2008 Human Factors Engineering of Software User Interfaces

ISO 9241 Ergonomic requirements for office work with display terminals

ISO 11064 Ergonomic design of control centers

EEMUA 201 Process plant control desks utilizing human-computer interfaces: a guide to design and human-computer interfaces

NUREG-0700 Rev. 2-2002 Human-System Interface Design Review Guidelines
ISA Standard 101 – Lifecycle Approach

Considerations of sensory and cognitive limits of operators, situational awareness, ergonomics

Focus is on HMI lifecycle

Custom Approach

• HMI Philosophy
• Style Guide

Consistent Documentation

• HMI Philosophy
• Style Guide
• Toolkits

Continuous Work Processes

• Change Management (MOC)
• Audit
• Validation
Tiers of HPHMI

Philosophy

Navigation

Style Guide

Tier 1 - Overview

Tier 2 – Unit Process

Tier 3 – Unit Detail

Tier 4 – Diagnostic
4. EXAMPLES OF HPHMI IMPLEMENTATION
Example – Tier 1 – Plant Overview

Is the plant doing OK?
Example – Tier 1 – Plant Overview

Is the plant doing OK?
Example – Tier 2 – Unit Process

Process Air Unit Process

Header Distribution

MOV Control/Balance

Is flow balanced?
Example – Tier 2 – Unit Process

Process Air
Unit Process

Header Distribution

MOV Control/ Balance

Is flow balanced?
Example – Tier 2 – Unit Process

BNR Unit Process

Nitrogen Removal Process

Multiple Analytical Values to review/check

Is BNR within range?
HPHMI Approach

Challenges:
• “Loss of view”
• “Too much data”

Opportunities:
• PRO Object Development
• See “at-a-glance”
### PRO in Practice

<table>
<thead>
<tr>
<th>Parameter</th>
<th>iFix HMI Range</th>
<th>“Good” Process Range</th>
<th>Lower</th>
<th>Upper</th>
<th>Lower</th>
<th>Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NITRATE (Pass 1-1/Pass 4-2)</strong></td>
<td>0-20 ppm</td>
<td>0.5 ppm</td>
<td>3 ppm</td>
<td>-0.75</td>
<td>4.25</td>
<td></td>
</tr>
<tr>
<td><strong>NITRATE (Pass 4-5)</strong></td>
<td>0-20 ppm</td>
<td>2 ppm</td>
<td>6 ppm</td>
<td>0</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td><strong>DO (all locations)</strong></td>
<td>0-5 ppm</td>
<td>1 ppm</td>
<td>2.5 ppm</td>
<td>0.25</td>
<td>3.25</td>
<td></td>
</tr>
<tr>
<td><strong>ORP (anoxic)</strong></td>
<td>-2000 to +2000mV</td>
<td>-80 mV</td>
<td>+20 mV</td>
<td>-100</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td><strong>Ammonia (Pass 4)</strong></td>
<td>0 – 50 ppm</td>
<td>2 ppm</td>
<td>5 ppm</td>
<td>0.5</td>
<td>6.5</td>
<td></td>
</tr>
</tbody>
</table>

**Low alarm condition**

Outside normal process range, yellow indicates alarm condition.

**Normal Process Range**

Use red for nitrate/ammonia as higher priority alarm than DO.
Example – Tier 2 – Unit Process

Entire Secondary Profile Displays

- DO, Nitrate, Nox
- RAS, etc.

Is BNR within range?
Example – Tier 3

Equipment monitoring

Blower Information:

• Scroll through many screens
• No summary, at-a-glance
• Alarming issues
• Too much information
• Too little information

Is the 1,000 HP Aeration Blower running OK?
Example – Tier 3

Develop Tier I Screen

Multivariable

At-a-glance, normalize parameters in PRO:

- Capacity
- Temperatures
- Vibrations
- Deviation from SP

From 6 screens with 80+ numbers to….1 screen

Is the 1,000 HP Aeration Blower running OK?
5. ALARM MANAGEMENT – AN INTEGRAL ASPECT OF HPHMI
HMI Design for Alarms

HMI design directly impacts emphasis of abnormal condition. Which HMI is better?

Option 1

Alarm defined by number, color, shape, sound.

Option 2
Definition of an alarm

“An audible and/or visual means of indicating to the operator an equipment malfunction, process deviation, or abnormal condition requiring a response.”

HMI Alarm Problems

Typical SCADA Issues:

- Nuisance alarming
- Alarm Floods
- Alarm Chatter
- Stale Alarms
- Suppressed Alarms
- Event “Alarms”

Poor alarm management can contribute to loss of situational awareness
ISA 18.2 Alarm Management Framework

Alarm Philosophy
- Priority
- Distribution
Rationalize
- “Bad Actor” Resolution
- Measure and Benchmark
Audit

Not just during startup and commissioning of a SCADA system….but continuously update.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Title</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Philosophy</td>
<td>Define processes for alarm management and ASRS’</td>
</tr>
<tr>
<td>B</td>
<td>Identification</td>
<td>Determine potential alarms</td>
</tr>
<tr>
<td>C</td>
<td>Rationalization</td>
<td>Rationalization, classification, prioritization, and documentation</td>
</tr>
<tr>
<td>D</td>
<td>Detailed Design</td>
<td>Basic alarm design, HMI design, and advanced alarming design</td>
</tr>
<tr>
<td>E</td>
<td>Implementation</td>
<td>Install alarms, initial testing, and initial training</td>
</tr>
<tr>
<td>F</td>
<td>Operation</td>
<td>Operator responds to alarms, refresher training</td>
</tr>
<tr>
<td>G</td>
<td>Maintenance</td>
<td>Maintenance repair and replacement and periodic testing</td>
</tr>
<tr>
<td>H</td>
<td>Monitoring and Assessment</td>
<td>Monitoring alarm data and report performance</td>
</tr>
<tr>
<td>I</td>
<td>Management of Change</td>
<td>Process to authorize additions, modifications, and deletions of alarms</td>
</tr>
<tr>
<td>J</td>
<td>Audit</td>
<td>Periodic audit of alarm management process</td>
</tr>
</tbody>
</table>
HMI alarm priorities

ISA 18.2-2009 suggests 3 (or 4) priorities. Distribution shown below:

1. Critical alarms should comprise ~5% of total alarms.

Source: ANSI/ISA 18.2
HMI Alarm Metrics and Benchmarking

Alarms “acceptable” ~1/10 min (150/day)

Alarms “maximum manageable” ~2/10 min (300/day)

Alarm **Floods**: No more than 10 alarms / 10 min

Priority **Distribution**: ~5% or less, Highest Priority

**Stale and Chattering Alarms**: Zero

<table>
<thead>
<tr>
<th>Metric</th>
<th>Target value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Announced alarms per operating position</td>
<td>Target value: very likely to be acceptable</td>
</tr>
<tr>
<td>Announced alarms per day per operating position</td>
<td>~150 alarms per day</td>
</tr>
<tr>
<td>Announced alarms per hour per operating position</td>
<td>~6 (average)</td>
</tr>
<tr>
<td>Announced alarms per 10 minutes per operating</td>
<td>~1 (average)</td>
</tr>
<tr>
<td>distribution</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Metric</th>
<th>Target value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage of hours containing more than 30 alarms</td>
<td>~&lt;1%</td>
</tr>
<tr>
<td>Percentage of 10-minute periods containing more</td>
<td>~&lt;1%</td>
</tr>
<tr>
<td>than 10 alarms</td>
<td></td>
</tr>
<tr>
<td>Maximum number of alarms in a 10-minute period</td>
<td>~&lt;1%</td>
</tr>
<tr>
<td>Percentage of time the alarm system is in a</td>
<td>~&lt;1%</td>
</tr>
<tr>
<td>flood condition</td>
<td></td>
</tr>
<tr>
<td>Percentage contribution of the top 10 most</td>
<td>~&lt;1 to 5% maximum, with action plans to address</td>
</tr>
<tr>
<td>frequent alarms to the overall alarm load</td>
<td>deficiencies</td>
</tr>
<tr>
<td>Quantity of clustering and fleeting alarms</td>
<td>Zero, action plans to correct any that occur</td>
</tr>
<tr>
<td>Stale alarms</td>
<td>Less than 5 present on any day, with action plans to address</td>
</tr>
<tr>
<td>Announced priority distribution</td>
<td>5 priorities: ~80% low, ~15% medium, ~5% high or</td>
</tr>
<tr>
<td></td>
<td>~90% high or ~15% medium, ~5% high, ~1% “highest”</td>
</tr>
<tr>
<td></td>
<td>Other special purpose priorities excluded from the calculations</td>
</tr>
<tr>
<td>Unauthorized alarm suppression</td>
<td>Zero alarms suppressed outside of controlled or approved methodologies</td>
</tr>
<tr>
<td>Unauthorized alarm attribute changes</td>
<td>Zero-alarm attribute changes outside of approved methodologies or management of change</td>
</tr>
</tbody>
</table>

Source: ANSI/ISA 18.2
Conclusions: Benefits of HPHMI

Before
- Engineer and software features drives design
- Ineffective overview of processes
- Emphasis on numerical displays
- Little use of embedded trending
- Poor use of color
- Too many alarms to handle

After
- Design driven by operator mental model
- Effective “at-a-glance” process overviews
- Emphasis on analog displays and patterns
- Effective use of roadmap trending
- Appropriate use of color
- Alarms properly rationalized

Increasing situational awareness & effectiveness of HMI
Revisit Learning Objectives

• Recognize key components of a plant or facility Human Machine Interface (HMI)

• Define situational awareness as it relates to SCADA systems and identify common HMI pitfalls working against it

• Describe how High Performance HMI (HPHMI) concepts serve to enhance situational awareness

• Identify how methodologies such as ANSI/ISA 18.2 alarm management approach support HPHMI and are critical to SCADA system success

• Outline how to benchmark and measure the performance of HPHMIs and related alarm management systems
References

• ANSI/ISA-101.01-2015, Human Machine Interfaces for Process Automation Systems
• ANSI/ISA-18.2-2009 Management of Alarm Systems for the Process Industry
• The High Performance HMI Handbook by Bill Hollifield, Dana Oliver, Ian Nimmo, Eddie Habibi, PAS 2008
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