Using ISA-101 & High Performance HMIs for More Effective Operations

(Slide Deck for Distribution)

Speaker: Graham Nasby
Voting member of ISA-101 Committee

WEAO Intelligent Wastewater Systems Seminar
Sept 14, 2017 – Canada Centre for Inland Waters – Burlington, Ontario
About the Speaker

Graham Nasby, P.Eng., PMP, CAP

- Water SCADA & Security Specialist
- City of Guelph Water Services

- 10 years in the consulting sector, followed by 2 years at the city

- WEAO and OWWA Member, Member of OWWA Automation Committee
- Co-chair of ISA112 SCADA Systems standards committee
- Voting member of ISA101 HMI Design standards committee
- Voting member of ISA18 Alarm Management standards committee
- Named Canadian Expert on IEC/SCC-TC65 with Standards Council of Canada

- Has published over 30 papers and articles on automation topics
- Received University of Guelph “Mid Career Achievement Award” in 2014
- Named ISA’s technical division leader of the year award in 2013.

- Contact: graham.nasby@guelph.ca
First a Few Acknowledgements

- Thanks to my fellow members of the ISA-101 committee for contributing several of the graphics in this presentation.

- Also special thanks to Bill Hollifield, author of the High Performance HMI Handbook, for kindly letting me use a few of his examples.

- Note: This PowerPoint slide deck is an abbreviated version of the slides that were presented on Sept 14, 2017. The original presentation contained some propriety images which were on loan under a “present only” arrangement with the original authors. Thank you for your understanding.

Using ISA-101 & High Performance HMIs – summary slides
WEAO Intelligent Wastewater Systems Seminar – Sept 14, 2017

Outline

- Why Do We Care About the HMI?
- Operator Effectiveness for Normal Operations and Abnormal Situation Management
- The History of HMIs in Industry
- Examples Common Problems with HMI Screens
- Justifying the development of High Performance HMIs
- High Performance Graphic Principles and Elements
- High Performance HMI Display Hierarchy & Navigation
- How to apply ISA-101 and High Performance HMIs
- Summary and Questions
Operator Effectiveness:

Operations Effectiveness:
• Effective controls, systems, tools, and training to enable operators to effectively detect and successfully handle BOTH normal operations AND abnormal situations.
• The Three Components
  • Effective Alarm Management
  • Control System Performance
  • High Performance HMI
• Effective Operations Requires all three aspects
• Effective Abnormal Situation Management also requires all three
• The Alarm System is an essential but small part of the overall HMI!
• Operator vigilance involves the ENTIRE HMI – not just the alarm system!

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HMIs Past and Present

- Remember the “old days”?
- Provided the “Big Picture”
- Limited Capability
- Many Process Trends
- Status “at-a-glance”
- (but took years to learn)
Poor Graphics Encourage Poor Operating Practices
Common, Ineffective HMI Depictions

- Common, but ineffective process depictions!
- Numbers sprinkled on a screen
- Inconsistent, improper use of color

- No trends, no condition information
- Are these processes running well?
But the graphics got better over time...

- “Improved” Graphic Capability doesn’t seem to make it any better
- At a glance, what can you tell from this screen?

- What is running?
- Is the process running well?
- Is anything abnormal?

- What if you are colour blind?
One of my favourites...

- So glad this is not from our industry!
How do we make better HMIs?

We need to look at what other industries are doing!

Look at industries where the cost of human error is so high that they have spent the time and energy to develop more effective HMIs

- Oil Refining Industry
- Offshore Platforms
- Power Plants
- Chemical Industry
- Railways
- Aviation
- Mining
- Pulp and Paper

- In 2003 a group of end-users from the process industries got together and started working on the ISA-101 HMI Design Standard.... they published it in 2015! ..... It took them 12 years ....
2015 Texas City Oil Refinery Disaster from www.csb.gov

- Just a P&ID - no overview, trends, condition information, or material balance
- Inconsistent colors and alarms. 15 killed, 180 injured, $1.5 billion damage

Cited: Poor HMI was significant contributing factor to the fatal accident

Operators could not tell from the HMI that they were continuing to feed fuel into the fire!
Situation Awareness in Aviation

- Speed
- Altitude
- Position
- Course
- Nearby Airports
- Time Enroute
- Time to next Waypoint
- Time to Destination
- Fuel Remaining
- Proximity to Ground
- Proximity to Rising Terrain
- Positions of nearby aircraft
- Engine diagnostics
- Real-time weather & lightning
- Data on Available Services at Airports
- Comm & Nav Frequencies
- Instrument Approaches
- Glide Radius

Example is the Garmin GTN-650 small aircraft display system
If we designed heads up displays like old HMIs

Does the fighter jet pilot stand a chance?
**The High Performance HMI**

Poor HMIs are cited as contributing factors to major accidents!

<table>
<thead>
<tr>
<th>Task</th>
<th>With “Traditional” HMI</th>
<th>With High Performance HMI concepts</th>
<th>Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detecting Abnormal Situations Before Alarms Occur</td>
<td>10% of the time</td>
<td>48% of the time</td>
<td>A 5X increase</td>
</tr>
<tr>
<td>Success Rate in Handling Abnormal Situation</td>
<td>70%</td>
<td>96%</td>
<td>37% over base case</td>
</tr>
<tr>
<td>Time to Complete Abnormal Situation Tasks</td>
<td>18.1 min</td>
<td>10.6 min</td>
<td>41% reduction</td>
</tr>
</tbody>
</table>

Nova estimated $800,000 per year savings on 1 ethylene plant

PAS-EPRI Study: Similar Results on a Coal-fired power plant

Study by Nova Chemicals and ASM® Consortium

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Figures and Graphic courtesy of PAS (www.pas.com)
High Performance HMI Concepts
Proper Use of Color

- Color is an attention-getter
- Using Red or Green to indicate normal “running” or “not running” makes problems hard to see
- Use color for the abnormal, not the normal
- Can you quickly tell where the problems are on these screens?

If you overuse red or green, it no longer stands out.
Remember these books?
How long did it take to find Waldo?
Common Color Blindness or Deficiency

- Very common, different types
- Color change is not detected well in peripheral vision.
- **Color alone should not** used to differentiate an important status!

Credit: http://wearecolorblind.com/wp-content/uploads/general-example-2-types2.jpg
Credit: http://www.personal.psu.edu/afr3/blogs/siowfa12/color_blind_12.jpg
A word about Colour Schemes

What parts of the screens catch your eye?
You can show a lot of grayscale

In this example, colour is only used to show alarms

HAPPY PLANT = no alarms, no colour
### Blood Tests for Spot

<table>
<thead>
<tr>
<th>Test</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCT</td>
<td>31.7%</td>
</tr>
<tr>
<td>HGB</td>
<td>10.2 g/dl</td>
</tr>
<tr>
<td>MCHC</td>
<td>32.2 6/dl</td>
</tr>
<tr>
<td>WBC</td>
<td>9.2 x10⁹ /L</td>
</tr>
<tr>
<td>GRANS</td>
<td>6.5 x10⁹ /L</td>
</tr>
<tr>
<td>L/M</td>
<td>2.7 x10⁹ /L</td>
</tr>
<tr>
<td>PLT</td>
<td>310 x10⁹ /L</td>
</tr>
</tbody>
</table>

Example adapted from High Performance Handbook

Unless you are vet, how can you know?

Nice Teeth, eh?
### Blood Tests for Spot

<table>
<thead>
<tr>
<th>Test</th>
<th>Results</th>
<th>Range</th>
<th>Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCT</td>
<td>31.7%</td>
<td>24.0 – 45.0</td>
<td>Low -</td>
</tr>
<tr>
<td>HGB</td>
<td>10.2 g/dl</td>
<td>8.0 – 15.0</td>
<td>Normal</td>
</tr>
<tr>
<td>MCHC</td>
<td>32.2 6/dl</td>
<td>30.0 - 36.9</td>
<td>Normal</td>
</tr>
<tr>
<td>WBC</td>
<td>9.2 x10⁹ /L</td>
<td>5.0 – 18.9</td>
<td>Low -</td>
</tr>
<tr>
<td>GRANS</td>
<td>6.5 x10⁹ /L</td>
<td>2.5 – 12.5</td>
<td>Low -</td>
</tr>
<tr>
<td>L/M</td>
<td>2.7 x10⁹ /L</td>
<td>1.5 – 7.8</td>
<td>Low -</td>
</tr>
<tr>
<td>PLT</td>
<td>310 x10⁹ /L</td>
<td>175 - 500</td>
<td>Low -</td>
</tr>
</tbody>
</table>

Example adapted from High Performance Handbook
Analog in Industrial Examples

RECYCLE COMPRESSOR K43

<table>
<thead>
<tr>
<th>Cool gpm</th>
<th>Suct psig</th>
<th>Integ psig</th>
<th>Dsch psig</th>
<th>Suct degF</th>
<th>Inter degF</th>
<th>Dsch degF</th>
<th>E. Vib mil</th>
<th>N. Vib mil</th>
<th>W. Vib mil</th>
<th>Motor Amps</th>
<th>Oil psig</th>
<th>Oil degF</th>
</tr>
</thead>
<tbody>
<tr>
<td>42.7</td>
<td>38.7</td>
<td>185</td>
<td>95</td>
<td>170</td>
<td>170</td>
<td>120</td>
<td>8</td>
<td>9</td>
<td>170</td>
<td>80</td>
<td>290</td>
<td>2</td>
</tr>
</tbody>
</table>

- Alarm Indicator
- Alarm Range
- Desirable Operating Range
- Interlock Indicator

Show Values  Show Trends

Buttons for additional functionality

Image from High Performance Handbook

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Alarm Indications on Graphics

Often Seen

<table>
<thead>
<tr>
<th>Priority 3</th>
<th>Priority 2</th>
<th>Priority 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>480.1 psi</td>
<td>480.1 psi</td>
<td>480.1 psi</td>
</tr>
</tbody>
</table>

Better

<table>
<thead>
<tr>
<th>Priority 3</th>
<th>Priority 2</th>
<th>Priority 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>480.1 psi</td>
<td>480.1 psi</td>
<td>480.1 psi</td>
</tr>
<tr>
<td>Diagnostic</td>
<td>Priority 3</td>
<td>Priority 2</td>
</tr>
<tr>
<td>Priority</td>
<td></td>
<td>Priority 1</td>
</tr>
</tbody>
</table>

Betterer

<table>
<thead>
<tr>
<th>Priority 3</th>
<th>Priority 2</th>
<th>Priority 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>480.1 psi</td>
<td>480.1 psi</td>
<td>480.1 psi</td>
</tr>
<tr>
<td>Diagnostic</td>
<td>Priority 3</td>
<td>Priority 2</td>
</tr>
<tr>
<td>Priority</td>
<td></td>
<td>Priority 1</td>
</tr>
</tbody>
</table>

Best!

<table>
<thead>
<tr>
<th>Priority 3</th>
<th>Priority 2</th>
<th>Priority 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>480.1 psi</td>
<td>480.1 psi</td>
<td>480.1 psi</td>
</tr>
<tr>
<td>Diagnostic</td>
<td>Priority 3</td>
<td>Priority 2</td>
</tr>
<tr>
<td>Priority</td>
<td></td>
<td>Priority 1</td>
</tr>
</tbody>
</table>

Suppressed Alarm

480.1 psi

Show alarms in multiple ways: Colour, Shape, Text (“redundant coding”)

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Adapted from High Performance Handbook
### AIT01-HI Chlorine Treatment High Residual Alarm

<table>
<thead>
<tr>
<th>Alarm: HIGH</th>
<th>Setting: 120 deg C</th>
<th>Priority: 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class: OPERATIONAL</td>
<td>Response Time: &lt;15 min</td>
<td></td>
</tr>
<tr>
<td>Alarm Consequences:</td>
<td>Alarm Causes:</td>
<td>Corrective Actions:</td>
</tr>
<tr>
<td>High Hypo Usage</td>
<td>Hypo Pump Problem</td>
<td>Check dosing rate</td>
</tr>
<tr>
<td>High Dechlor Usage</td>
<td>Pump in Manual</td>
<td>Adjust dosing rate. See. <strong>SOP 26</strong></td>
</tr>
<tr>
<td></td>
<td>Problem with Feed Valve</td>
<td>Visit site and inspect pump</td>
</tr>
<tr>
<td></td>
<td>Bad load of Hypo</td>
<td>Go to site and do manual hand sample</td>
</tr>
<tr>
<td></td>
<td>Problem with Analyzer</td>
<td></td>
</tr>
</tbody>
</table>

Alarm Information Record from the SCADA System’s Master Alarm Database — see the ISA18 alarm management standard
The Importance Of Trends

Embedded “always visible” trends on process displays are always better.

Don’t rely on “trending on demand”, “trend pop-ups” or “trend screens” – in practice they don’t work very well.

Best Practice: Embed Trends on HMI
More concepts with Trending

- Would these graphs help start up your plant?

Adapted from image courtesy of PAS (www.pas.com)
Keep it simple

Poor Vessel and Line Depiction!

Better Vessel and Line Depiction

Not a navigation target

Navigation target

Image from High Performance Handbook
Level Depiction

Very Poor Vessel Level Indication

Better Vessel Level Indication

Trend and Analog Level Indication

Crude Feed TK-21

2 Hrs 86.5%
Status Depiction

Red/Green for status vs. Greyscale & redundant coding

Pumps not monitored by SCADA (no status information) are just shown as mid-gray:
Don’t do this
Or this..
Proper Hierarchy for Displays

- **HIERARCHY for Displays:**
- **Level 1 – Plant or Entire System Overview**
  - Entire Operator Span of Control. “Single-Glance”
- **Level 2 – Sub-Process Overview**
  - More details than a Level 1 display, smaller area
- **Level 3 – Equipment or Details Screen**
  - Specific details about part of the process or control
- **Level 4 – Specific Task or Diagnostic Screen**
  - Very detailed screen, only used for diagnostics
Level 1 Overview

Reactor 1

Run Plan:
Actual:
Comp A Comp B Coal CPC CRM LVL

Prod: Thionite Mid-Run
State: ON
Locks: CLEAR

Balance IN OUT
Rate
60.0 72.0
2 HR

Alarm List/Summary
ACC 0 1 2 3 4 UNACK 0 0 1 1

071608 08:55:07 RX2 LOW CRM QUALITY EXC

Hydrog A

Cycle Comp A
Bed A1
Bed A2
VIB: OK
BRG: OK
OIL: OK
Locks: CLEAR

Hydrog B

Cycle Comp B
Bed B1
Bed B2
VIB: OK
BRG: OK
OIL: OK
Locks: CLEAR

Key Performance Indicators

Conversion Efficiency

Emissions Limit Ratio

Feed System

Aux Systems

Main Menu Reactor 1 Reactor 2 Hydrog A Hydrog B
Feed Sys Aux Sys Menus L2 L3 L4

Image from High Performance Handbook

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Level 2: Control of a Process Sub-Part

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Most of what you already have is probably Level 3

We are out of time!

West Compressor Interlock W-1

<table>
<thead>
<tr>
<th>Initiator</th>
<th>Value</th>
<th>Action</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overspeed</td>
<td>OK</td>
<td>Shutoff West Comp AND</td>
<td></td>
</tr>
<tr>
<td>Or Winding Temp High</td>
<td>OK</td>
<td>Close Inlet &amp; Outlet Block Valves AND</td>
<td></td>
</tr>
<tr>
<td>Or Vibration High</td>
<td>OK</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Or 1 Stg High Pres</td>
<td>OK</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Or 2 Stg High Press</td>
<td>OK</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Or Suction Pres Low</td>
<td>OK</td>
<td>Override East Comp Speed to 100%</td>
<td></td>
</tr>
<tr>
<td>Or Oil Pres Low</td>
<td>OK</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

West Comp Discharge Temp °C

West Comp Flow MSCFH

West Comp Speed %

Image from High Performance Handbook
Back to Level 1 –
How many values/indicators are on this screen?

Reactor 1
- Comp A
- Comp B
- Coal
- CPC
- CRM
- LVL
- Balance
- Rate

Reactor 2
- Comp A
- Comp B
- Coal
- CPC
- CRM
- LVL
- Balance
- Rate

Hydrog A
- Cycle
- Bed A1
- Bed A2
- VIB: OK
- BRG: OK
- OIL: OK
- Locks: CLEAR
- Comp A
- Comp B
- Rate

Hydrog B
- Cycle
- Bed B1
- Bed B2
- VIB: OK
- BRG: OK
- OIL: OK
- Locks: CLEAR
- Comp A
- Comp B
- Rate

Key Performance Indicators
- Conversion Efficiency
- Emissions Limit Ratio

Feed System
- Feed A
- Feed B
- Feed C
- SynG

Aux Systems
- Atv 1
- Atv 2
- Pres
- %IP

Image from High Performance Handbook

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How to show a piping system

Show:

• Topology, not Geography
• Important Status Conditions and Alarms
• Significant highway, railway and river crossing
• Residential areas near pipelines
• Important boundaries (i.e. state lines)
• Moving Analog Indicators indicating performance.
• Direction and content indicators
• Key process values
• Important trends
• Other ideas???
Pipeline Overview Screen

You could show it this way....
This is probably a lot easier to use
High Performance HMI Designs

How do we design and manage our HMI in order to use these concepts?

Introducing the ISA-101 HMI Design Standard
ISA-101 – in a nutshell

- Actual ISA-101 standard is only 64 pages

- Overall design guidance provided in the actual standard, details are in ISA-101 Technical Reports (soon to be available from ISA)

- Has a very robust workflow for developing and managing HMI systems, including a strong Change Management Process

- Focus is on creating screens for situational awareness and operator tasks. Users must be trained on use to use HMIs.

- Facility owners must develop a clear HMI philosophy document and HMI style guide for their HMI system, and couple this reusable software toolkits of screen elements. Without these it is impossible to develop an effective HMI.
The ISA-101 standard is important because it is the first international standard to state minimum requirements for HMI displays, including their design, documentation, and management of change.

**Continuous Work Processes**

- **System Standards**
  - Philosophy
  - Style Guide
  - Toolkits

- **Design**
  - Console Design
  - HMI System Design
  - User, Task, Functional Requirements
  - Display Design

- **Implement**
  - Build Displays
  - Build Console
  - Test
  - Train
  - Commission
  - Verification

- **Operate**
  - In Service
  - Maintain
  - Decommission

**Entry**
- New System
- Major Changes
- New Display
- Display Changes

**Continuous Improvement**
How to get started?

Understand and document what you have

Add some Level 1 and Level 2 displays to give your operators visibility of your entire process for situational awareness

Add some task screens to help with start-up, shutdown or maintenance tasks that are difficult for operators to run

Start developing your HMI Philosophy document and Style Guide to define what you want your system

Start using Revision Control to track changes to your SCADA system’s programming. Implement a Management of Change procedure, so changes are controlled and documented.

Do a pilot project of a few new HMI screens to see how they work.

Talk to your operations team.
Any Questions?

* Not a High Performance HMI