The High Performance HMI

Proper Graphics for Operator Effectiveness

Mark Carrigan
PAS

Rockwell Automation
Process Solutions User Group (PSUG)
November 14-15, 2011
Chicago, IL - McCormick Place West
Agenda

• PAS Overview
• The History of HMIs in Industry
• High Performance HMI Justification
• Common But Ineffective Process Depictions
• High Performance Graphic Principles and Elements
• High Performance Graphic Hierarchy
• The 7-Step High Performance HMI Development Process
• Summary
• Vice President, Global Business Development at PAS
  – Roles have included Operations Management
  – Managing Director, PAS Middle East

• The History of HMIs in Industry
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• The 7-Step High Performance HMI Development Process
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About PAS

Founded in 1993
- Privately held Texas Corporation
- Process Automation Solutions Provider
- 110 People in 9 Offices worldwide
- Sustainable growth - 300% in 7 years

Business Strategy
- Focused on long term growth
- Significant investment in R&D; >20% of annual revenue
- Ten-year plan on software & technology

Industry Organizations & Strategic Partners
- EPRI, ISA, AICHE, NPRA, EMMUA 191
- Regional engineering firms
PAS Solutions

Realize the Full Potential of Your *People and Automation Systems*

**Operations Effectiveness**

Achieve *Superior Operator Performance and Reduce Vulnerabilities* during abnormal situations and steady state operations.

- Improve Disturbance Rejection
- Minimize Operator Loading
- Optimize Situational Awareness
- Enable Accurate Operator Actions
- Expand Layers of Protection for Safety

**Automation Effectiveness**

*Map the Automation Genome* and expose new possibilities for knowledge retention, collaboration, and decision support.

- Retain Important Plant Knowledge
- Provide a Collaboration Platform
- Enable Change Tracking/Defect Detection
- Provide Disaster Recovery
- Ensure Accurate Documentation
The High Performance HMI:
Proper Graphics for Operator Effectiveness

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The HMI of the Past

- Provided the “Big Picture”
- Limited Capability
- Many Process Trends
- Status “at-a-glance”
The DCS Arrives

- The “Keyhole View”
- Expensive Screens
- Contributed to over-alarming
- Lost “the Big Picture”

Early “Group” Display showing 8 sensors
DCS Graphics Introduced - But No Guidelines!

Poor Graphics Encourage Poor Operating Practices
Common HMI Depictions

Common, but ineffective process depictions!

“Numbers sprinkled on a screen”

Inconsistent, improper use of color

No trends

No condition information
And Even Worse - Vendor Examples...

“Improved” Graphic Capability yields even worse practices.

Only 10% of the screen is used to show poorly-presented numeric data,

90% is a just a “pretty picture”
Other Industries Do It Better

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

GARMIN® 1000 Avionics System
The High Performance HMI

Time after time, poor HMIs are cited as contributing factors to major accidents!

Study by Nova Chemicals and ASM® Consortium

<table>
<thead>
<tr>
<th>Task</th>
<th>With “Traditional” HMI</th>
<th>With High Performance HMI</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>

$800,000 per year savings anticipated on 1 ethylene plant
Texas City BP HMI - a Contributing Factor

- No Overview
- No trends
- No material balance (FLOW IN and FLOW OUT are on different graphics)
- Inconsistent colors and alarms
- No condition indication
- Essentially just a P&ID segment sprinkled with live values.
### Blood Tests for Fluffy -1

<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>

**Answer:** Unless you are a vet, how can you know?
### Blood Tests for Fluffy -2

<table>
<thead>
<tr>
<th>Test</th>
<th>Results</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCT</td>
<td>31.7%</td>
<td>24.0 – 45.0</td>
</tr>
<tr>
<td>HGB</td>
<td>10.2 g/dl</td>
<td>8.0 – 15.0</td>
</tr>
<tr>
<td>MCHC</td>
<td>32.2 6/dl</td>
<td>30.0 - 36.9</td>
</tr>
<tr>
<td>WBC</td>
<td>9.2 x10^9/L</td>
<td>5.0 – 18.9</td>
</tr>
<tr>
<td>GRANS</td>
<td>6.5 x10^9/L</td>
<td>2.5 – 12.5</td>
</tr>
<tr>
<td>L/M</td>
<td>2.7 x10^9/L</td>
<td>1.5 – 7.8</td>
</tr>
<tr>
<td>PLT</td>
<td>310 x10^9/L</td>
<td>175 - 500</td>
</tr>
</tbody>
</table>

After awhile, you might figure it out…
How About Now?

### Blood Tests for Fluffy -3

<table>
<thead>
<tr>
<th>Test</th>
<th>Results</th>
<th>Range</th>
<th>Indicator Low – Normal - High</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCT</td>
<td>31.7%</td>
<td>24.0 – 45.0</td>
<td></td>
</tr>
<tr>
<td>HGB</td>
<td>10.2 g/dl</td>
<td>8.0 – 15.0</td>
<td></td>
</tr>
<tr>
<td>MCHC</td>
<td>32.2 6/dl</td>
<td>30.0 - 36.9</td>
<td></td>
</tr>
<tr>
<td>WBC</td>
<td>9.2 x10^9 /L</td>
<td>5.0 – 18.9</td>
<td></td>
</tr>
<tr>
<td>GRANS</td>
<td>6.5 x10^9 /L</td>
<td>2.5 – 12.5</td>
<td></td>
</tr>
<tr>
<td>L/M</td>
<td>2.7 x10^9 /L</td>
<td>1.5 – 7.8</td>
<td></td>
</tr>
<tr>
<td>PLT</td>
<td>310 x10^9 /L</td>
<td>175 - 500</td>
<td></td>
</tr>
</tbody>
</table>

ABNORMAL VALUES can be seen at a glance.
<table>
<thead>
<tr>
<th>Temperature</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>45.1°</td>
<td>22.5%</td>
</tr>
<tr>
<td>48.2°</td>
<td>96.2% “XYZ”</td>
</tr>
<tr>
<td>50.6°</td>
<td>42.9°</td>
</tr>
<tr>
<td>53.8°</td>
<td>98.2 MPPH 221.2 PSI</td>
</tr>
<tr>
<td>54.9°</td>
<td>45.1°</td>
</tr>
</tbody>
</table>

- DP INH20
  - 12-15: 22.8
  - 1-12: 16.3
  - 1-15: 39.1

- 77.8 MPPH
  - 60.1°: 22.3% “ABC”

**Most graphics in the world basically look like this!**

- Lots of Data
- Not Much Information
- Poor Presentation
- High Mental Workload to Decipher
- Cannot grasp what is going on “at-a-glance”
Analog in Industrial Examples

A Column Temperature Profile

A good profile? Yes, this one is.

Too hot at the top, too cold at the bottom

Deviation or absolute numbers optionally toggled

Optional: Line color indicates abnormality, alarm is not yet activated
P&IDs are not HMIs: A Poor Paradigm

Compressor Status Showing Alarm/Shutdown Limits

- **Recycle Compressor K43**

- **Alarm Indicator** Appears here with Priority Level and Color

- **Alarm Range** depicted and (for some) shutdown value

- Desirable Operating Range shown as dotted lines

- **Alarm Range** depicted and (for some) shutdown or interlock initiator

- Buttons for additional functionality

**Show Values**  **Show Trends**
Analog is Powerful

Analog Indicators with values, direction, and history

Optional Enhancements for Moving Analog Indicators

- Display Measurement variability in the last hour
- Display Current Value: 32.1
- Display Measurement direction – rolling 10 minutes
Analog in Industrial Examples

Material Balance Indicators

Scrubber Material Balance

<table>
<thead>
<tr>
<th>Total Flow IN</th>
<th>Total Flow OUT</th>
<th>Accumulated Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>31.1</td>
<td>27.9</td>
<td></td>
</tr>
</tbody>
</table>

Diff: 3.2
Hours: 22.8
Since: 06/02/07 14:00:00

Reset
Show Trends

Scrubber Material Balance

<table>
<thead>
<tr>
<th>Total Flow IN</th>
<th>Total Flow OUT</th>
<th>Accumulated Difference</th>
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Reset
Show Trends
### Scrubber Material Balance

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</tr>
</tbody>
</table>

- **Diff:** 3.2
- **Hours:** 22.8
- **Since:** 06/02/07 14:00:00

- **Reset**
- **Show Trends**

### Material Balance Indicator Animation
The Importance Of Trends

<table>
<thead>
<tr>
<th>Value Needing Trend</th>
<th>Current Pressure</th>
<th>Alarm Limit</th>
<th>Shutdown Actuation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>235.2 psig</td>
<td>250 psig</td>
<td>300 psig</td>
</tr>
</tbody>
</table>

Very Different Situations that only trends can show!
The Importance Of Trends

- Proper Auto-ranges
- Show boundaries of “What is good”
Always try to clearly depict:

“Where am I?”

“How am I doing vs. what is “good?”
Other Principles

- Don’t get fancy
- Avoid 3-D objects
Proper Level Depiction

- Very Poor Vessel Level Indication
- Poor Vessel Level Indication
- Better Vessel Level Indication
- Crude Feed TK-21
- Trend Vessel Level Indication

2 Hrs
Simple **Output %** numbers can be more effective than tiny scales.
Status Depiction

Pumps with Run Indication Sensor:

Not Running

- Wrong

- Better

Running

- Wrong

- Better

STOPPED
(Shape is Unfilled and darker)

RUNNING
(Shape is Filled and lighter)

Pumps without Run Indication Sensing have a fill matching the background:

Bright saturated color is used to indicate abnormal situations only.
Basic Principles - Hierarchy

HIERARCHY for Displays:

- **Level 1 – Process Area Overview**
  - Entire Operator Span of Control. “Single-Glance”

- **Level 2 – Process Unit Control**
  - Sub-unit controlled by operator

- **Level 3 – Process Unit Detail**
  - Equipment or controller

- **Level 4 – Process Unit Support and Diagnostic Displays**
  - Interlocks, ESDs, diagnostic screens, etc.

- Proper Hierarchy minimizes the number of physical screens and makes for proper navigation

- Graphics designed from P&IDs will **not** accomplish a proper hierarchy!
Level 1 Overview - “At-A-Glance Status”

Reactor 1
- Run Plan: Actual:
  - Prod: Thionite Mid-Run ON CLEAR
  - State: Agit: Locks: CLEAR
  - Balance IN OUT
  - Rate:
    - Comp A: 72.0
    - Comp B: 80.0

Reactor 2
- Run Plan: Actual:
  - Prod: CRM-114 Mid-Run ON CLEAR
  - State: Agit: Locks: CLEAR
  - Balance IN OUT
  - Rate:
    - Comp A: 60.0
    - Comp B: 68.0

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

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

Key Performance Indicators
- Conversion Efficiency
- Emissions Limit Ratio

Feed System
- Feed A
- Feed B
- Feed C
- SynG
- CWT
- CWP
- S10
- S200

Aux Systems
- Atv 1
- Atv 2
- Pres
- %IP
- PWR
- VentiP
- VentT
- MGA

Alarms: ACK UNACK
- P1 P2 P3 P4
- 0 1 2 4
- 0 0 1 1

071608 08:55:07 RX2 LOW CRM –QUALITY EXC

Trend Control
- Reactor 1
- Reactor 2
- Hydrog A
- Hydrog B

Feed Sys
- Aux Sys

Menus
- L2 L3 L4

Main Menu
- Trend Control
- Feed Sys
- Aux Sys

Toggle List / Summary
Level 2 Process Unit Control
7 Steps for Creating High Performance Displays

Step 1: Develop a High Performance HMI Philosophy and Style Guide

Step 2: Assess and benchmark existing graphics against the HMI Philosophy

Step 3: Determine specific performance and goal objectives for the control of the process, for all modes of operation

Step 4: Perform task analysis to determine the control manipulations needed to achieve the performance and goal objectives

Step 5: Design and build high performance graphics, using the design principles in the HMI Philosophy and elements from the Style Guide, to address the identified tasks

Step 6: Install, commission, and provide training on the new HMI

Step 7: Control, maintain, and periodically reassess the HMI performance
Step 1: Philosophy and Style Guide

• Philosophy: the overall principles for creating the HMI
  – Philosophy includes information about the consoles and control room practices.

• Style Guide: The DCS and site-specific collection of graphic elements, indicators, sub-pictures, trend objects, templates, and other specific graphic parts to be used consistently in creating the HMI

• Experience has shown that without a philosophy and style guide, graphics will usually be created inconsistently and improperly.

High Performance HMI Philosophy Example Table of Contents
Note: All sub-sections are not shown.
1.0 Introduction
  1.1 Purpose and Use of a High Performance HMI Philosophy
  1.2 The HMIs Purpose and Functions
  1.3 Functional Description of HMI Elements
    1.3.1 Display Content
    1.3.2 Display Layout
    1.3.3 Display Hierarchy
    1.3.4 Display Navigation
    1.3.5 Alarm Depiction and Alarm Management
2.0 HMI Design Process (considerable detail in this section)
3.0 Purpose and use of an HMI Style Guide and Object Library
  3.1 DCS Specificity
  3.2 Object Library Contents and Usage
4.0 HMI Performance Monitoring
5.0 HMI Management of Change (MOC)
6.0 Control Room
  6.1 Control Room Design Factors
  6.2 Control Room Work Practices
  6.3 Operator Console Design
  6.4 Operator Work Practices

A detailed and comprehensive document!
Step 2: HMI Performance Assessment

Evaluate existing HMIs vs. High Performance Principles and Best Practices

Criteria:
- HMI information during normal conditions.
- HMI information for effectively monitoring abnormal or upset conditions.
- Control room interruptions and distractions by non-essential personnel
- Operator tasks during upset or abnormal conditions.
- HMI compliance to best practices
- Proper Alarm Management

A 100-item questionnaire for use in assessment is included in *The High Performance HMI Handbook*
Step 3: Determine Performance and Goal Objectives for Process Control

This is rarely done!

Performance and goal objectives should be determined for factors such as:

- Process Safety
- Efficiency
- Equipment health
- Production cost
- Catalyst life
- Environmental
- Quality

Different operating modes may have different goals (startup, partial rate, alternative feedstocks, products, etc...)

Performance against goals must be depicted on the HMI
Step 3: Determine Performance and Goal Objectives for Process Control

Example performance and goal objectives:

<table>
<thead>
<tr>
<th>Example: Refining System Modes of Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Rates Product “A”</td>
</tr>
<tr>
<td>Full Rates Product “B”</td>
</tr>
<tr>
<td>End-of-Run Cleanup</td>
</tr>
<tr>
<td>Empty - Standby</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mode: Full Rates Product “A” – Example Performance &amp; Goal Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overhead Purity &gt;99.2%</td>
</tr>
<tr>
<td>Production rate 36,000 lb/hr average on a daily basis</td>
</tr>
<tr>
<td>Energy usage &lt;42 MMBTU/Hr</td>
</tr>
<tr>
<td>Overhead Pressure between 220 psig and 230 psig</td>
</tr>
<tr>
<td>Vent to flare: zero flow</td>
</tr>
<tr>
<td>Recycle compressor vibration and bearing temperatures within limits</td>
</tr>
<tr>
<td>Overall column tray differential pressure &lt; 62 in.H2O</td>
</tr>
<tr>
<td>Sidedraw purity &gt; 88%</td>
</tr>
</tbody>
</table>
Step 4: Task Analysis

- For a task analysis, the operator needs:
  - Information
  - Controls
  - Operations
  - Communications

- Typical tasks include:
  - Controller setpoint and mode manipulation
  - Digital (on-off) point manipulation (pumps, fin-fan banks, compressor loading, valve switching, etc.)
  - Activation and monitoring of advanced control schemes or programmatic controls
  - Observation of lab results
  - Direction of outside operators to perform non-automated tasks
  - Interaction with daily production planning goals & changes
  - Troubleshooting
  - Abnormal Situation response
Step 4: Task Analysis

Example output of Step 4 is used to determine the graphic content for each hierarchy level.

<table>
<thead>
<tr>
<th>Full Rates Product “A” – Necessary Level 2 Display Control Indications &amp; Manipulations</th>
<th>Indicator Type (from Style Guide)</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overhead Analyzer Product Purity</td>
<td>Main Display Trend #1</td>
<td>Desired purity range is 98% - 100%. Default time scale 2 hrs.</td>
</tr>
<tr>
<td>Production rate</td>
<td>Main Display Trend #1</td>
<td>Scale 30,000 to 40,000 lb/hr.</td>
</tr>
<tr>
<td>Calculated hourly energy usage in MMBTU/Hr.</td>
<td>Vertical Scale</td>
<td>Good: 40 to 42. Poor: 42 to 50.</td>
</tr>
<tr>
<td>Overhead Pressure</td>
<td>Vertical Scale</td>
<td>220 psig to 230 psig. Shutdown at 300.</td>
</tr>
<tr>
<td>Vent to flare</td>
<td>Vertical Scale</td>
<td>Zero flow is normal. Scale to 5,000 lb/hr with auto-rescale when exceeded</td>
</tr>
<tr>
<td>Recycle compressor vibration &amp; bearing temperatures</td>
<td>Vertical scale multiple module</td>
<td>See equipment spec 15-A for limits.</td>
</tr>
<tr>
<td>Overall Column tray differential pressure</td>
<td>Main Display Trend #2</td>
<td>30 to 70 in.H2O, alarm above 62. Default time scale 2 hrs.</td>
</tr>
<tr>
<td>Sidedraw purity &gt; 18%</td>
<td>Main Display Trend #2</td>
<td>10% to 25% range, bad below 18%. Time scale 2 hrs.</td>
</tr>
<tr>
<td>Column Pressure Controller PC2011-1</td>
<td>Standard Controller block</td>
<td></td>
</tr>
<tr>
<td>Column Level Controller LC-2011-2</td>
<td>Standard Level depiction</td>
<td></td>
</tr>
<tr>
<td>Reflux pump Start/Stop HS-2011-3</td>
<td>Standard Digital Controller</td>
<td></td>
</tr>
<tr>
<td>Base pump Start/Stop HS-2011-4</td>
<td>Standard Digital Controller</td>
<td></td>
</tr>
</tbody>
</table>
Step 5: Design the Graphics!

Step 5: Design and build high performance graphics, using the design principles in the HMI Philosophy And Elements from the Style Guide, to address the identified tasks.

This sounds easy....
Step 6: Install, Commission, And Provide Training On The New Displays

Implementation and training issues can be complex - thoroughly covered in the HMI Handbook

Some example topics for operator training:

- DCS operating procedures (refresher)
- Aspects of the High Performance HMI Philosophy relevant to operations
- The reasons the HMI was changed and the expected benefits
- Features of the DCS and HMI alarm presentation, annunciation, and management
- Navigation in the High Performance HMI
- Use of trends
- The HMI’s progressive hierarchy
- Graphics for specific situations (such as rate changes, product changes, and shutdowns)
- Changes from the old graphics and proper use of the new graphics
Step 7: Control, Maintain, and Periodically Reassess the HMI Performance

- Operator Surveys
- On-going HMI suggestion system
- Specific HMI performance review after production upsets, incidents, and accidents
Summary

- Poor HMIs have been cited as contributing factors to incidents and accidents
- Poor HMI practices are common
- Proper HMIs are an important success factor
- A *High Performance HMI* is practical and achievable.