ISA-101.01-2015 - Human Machine Interfaces for Process Automation Systems

Maurice Wilkins, ISA Fellow, InstMC Fellow, Past-VP - ISA Standards & Practices, Co-chair
ISA101 Committee
Agenda

Introduction

ANSI/ISA-101.01-2015 Human Machine Interfaces for Process Automation Systems Standard Committee

Why the need for the Standard

What is the ISA101 Standard and what does it contain?

ISA101 Walk through

How can we conform
Introduction – Maurice Wilkins

• PhD Chemical Engineer and Executive Advisor to Yokogawa’s Marketing HQ in Tokyo
• 40 years of experience in process control
• Technical Representative on the ISA Executive Board
• Recent past Vice President of the ISA Standards & Practices division
• Co-Chair of the ISA101 HMI standard committee
• Chair of GEL/65 which is the BSI mirror committee to IEC/TC65
• Volunteer Engineering Director and a Fellow of the Institute of Measurement and Control
• Fellow of the IChemE
• Inducted into the Process Automation Hall of Fame in 2011

Thanks to - David Board, ISA England Membership Chair, Co-chair ISA101 WG02
Operator Interfaces Have Changed
Why HMI Graphics matter

- Poor HMI Graphics causes:
  - Confusion
  - Operator Fatigue
  - Low Situation Awareness
- All of the above could:
  - Cause the operator to miss vital information
  - Lead the operator into making a mis-informed decision
  - Make the operator make a mistake
  - Cause a serious accident

Who wants to be responsible for designing an HMI graphic that can lead to this.
• Committee formed in 2006 to establish standards, recommended practices, and/or technical reports for designing, implementing, using, and/or managing HMIs in process automation applications

• Committee makeup
  – As of May 8th, 2019 – members 341
    – 36 Voting Members
    – Producer (Supplier) 24%
    – User 25%
    – Integrator, Eng & Construction 37%
    – General (Academic, Government, Consultant etc.) 14%
  – Worldwide participation in review process
Purpose of the Standard

- Address the design, implementation, and maintenance of human machine interfaces (HMI) for process automation systems, to:
  - Provide guidance to design, build, and maintain HMI which result in more effective and efficient control of the process, in both normal and abnormal situations
  - Improve the user’s abilities to detect, diagnose, and properly respond to abnormal situations
  - Look at the HMI holistically – not just the display

- A Standard is the “What”
- A Technical Report is the “How”
Scope of the Standard

• Addresses HMI’s for automated processes to improve safety, quality, and productivity

• Identifies documentation and design practices that will lead to more effective and maintainable HMI implementations

• Practices defined in ISA101 are intended to be applicable to continuous, batch, and discrete processes

• Devices excluded – the committee agreed to limit the scope to hardware of a minimum size
  – No PDA’s, smart phones, hand held devices or machine interfaces included in this version of the standard (see later)

• **NOTE:** The standard cannot recommend the use of commercial standards or documents such as the ASM Guidelines, texts, etc.
Who Cares About HMI Standards

• Users
  – Responsible for safe and productive operation of equipment and facility
  – Live with the HMI and support it for it’s lifetime

• Integrators, Designers, Engineers
  – Design and build the HMI applications
  – Commission the HMI, and the associated process

• Suppliers
  – Develop the software and hardware needed to build the HMI
  – Develop the interfaces/drivers needed for an HMI to transfer data and information to and from multiple sources
# ISA101 Standard Committee - Leadership

The Co-Chairs of the ISA101 HMI Committee are:

*Dr. Maurice Wilkins (Yokogawa) and Greg Lehmann (AECOM)*

The standard is organized into the following sections:

<table>
<thead>
<tr>
<th>Clause</th>
<th>Title</th>
<th>Leaders</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>General</td>
<td>Maurice Wilkins, <em>Yokogawa</em> &amp; Greg Lehmann, <em>AECOM</em></td>
</tr>
<tr>
<td>1</td>
<td>Scope</td>
<td>Maurice Wilkins, <em>Yokogawa</em> &amp; Greg Lehmann, <em>AECOM</em></td>
</tr>
<tr>
<td>2</td>
<td>Normative References</td>
<td>Nick Sands, <em>Dupont</em> &amp; Dale Reed, <em>Rockwell</em></td>
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<tr>
<td>3</td>
<td>Definition of Terms and Acronyms</td>
<td>Nick Sands, <em>Dupont</em> &amp; Dale Reed, <em>Rockwell</em></td>
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<tr>
<td>4</td>
<td>HMI System Management</td>
<td>Bridget Fitzpatrick, <em>Wood Group</em> &amp; Ian Nimmo, <em>UCDS, Inc</em></td>
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<td>5</td>
<td>Human Factors/Ergonomics</td>
<td>Beth Vail, <em>AECOM</em> &amp; Traci Laabs, <em>Pfizer</em></td>
</tr>
<tr>
<td>8</td>
<td>Performance</td>
<td>Mark Nixon, <em>Emerson Process Management</em></td>
</tr>
<tr>
<td>9</td>
<td>Documentation and Training</td>
<td>Dawn Schweitzer, <em>Eastman Kodak</em></td>
</tr>
</tbody>
</table>
ISA101 Standard Committee - Voting

• Based on established voting rules
  – 20% of committee – to manage the numbers
  – 30% for PR, US, AE and 10% for others
  – 24-month window of participation
  – Weighted toward individual input to standard and participation in calls and meetings
  – Last review was in August 2017

• ISA101 has 36 voting members
  – Not 20% of the committee (341) but, based on the rules…36 qualified
ISA101 Standard

- After many meetings and thousands of comments, on May 27th, 2014 the final draft was sent to the committee for a one-month ballot
  - The ballot was provisionally approved with 31 votes in favor, 2 votes against and one voter not responding
  - 42 committee members submitted 1,162 comments consisting of 829 editorials, 19 major technical and 314 minor technical
  - All had to be addressed
- A short re-ballot was needed to see if anyone wanted to change their vote (per ISA procedures) – the 2 disapprovers came on board
- ISA101 was approved by the ISA S&P board in early 2015
- ISA101 subsequently became an ANSI/ISA standard with ANSI approval in July 2015 (but can be used globally)
- 5-year review due in 2020 and possible submission to IEC
ISA101 Standard – Working Groups

• The focus has now moved to the working groups

• Remember….
  – The standard is the ‘What’ and the TR’s are the ‘How’

• At the 2015 ISA FLM the committee chartered 3 working groups
  – WG1 - HMI Philosophy & Style Guide Development
    – Co-chairs; David Lee and Lothar Lang
  – WG2 – HMI Usability and Performance
    – Co-chairs; David Board and Ruth Schiedermayer
  – WG3 was formed to investigate mobile HMIs
    – Next slide
Earlier in the presentation we said that mobile and machine-based displays were out of scope

BUT...technology has evolved very rapidly so that small displays are not only very clear but also intelligent

- WG3 – HMI for Mobile Devices (formed in 2015)
  - Co-chairs; Mark Nixon and Peder Brandt

At the 2017 SLM it was decided to form WG4 to investigate HMIs for machines

- WG4 was approved by the voting members in August 2017
  - Co-chairs; Arlen Jacobs and David Board
WG2 – HMI Usability and Performance

- Over the past 4 years, WG2 has held dozens of meetings online and face to face, produced 10 drafts and resolved thousands of comments.
- ISA–TR101.02.CD10–2019: HMI Usability and Performance was approved in April 2019 and after a final committee review will be available soon as ISA–TR101.02–2019: HMI Usability and Performance.
- The TR is organized into two parts:
  - The first part is introductory.
  - The main body presents information and examples on how sections of the HMI life cycle activities described in the ISA-101 standard apply to the usability and performance of the HMI.
- The technical report is intended to include examples within the HMI lifecycle, including the continuous work processes of audit, validation, and management of change (MOC).
ISA101 Working Groups

- WG1 – HMI Philosophy and Style Guide
- WG3 – HMI for Mobile Devices
- WG4 – HMI for Machine Displays
- These working groups are still gathering data and now that TR02 has almost been released, the focus will move to the other working groups
What Is ISA101?
HMI Basic Definitions

• Fundamental standard terminology
  – Console
  – Operator Station
  – Monitor
  – Screen
  – Display
  – Pop-up
  – Element

• Necessary to enable common understanding
• The most important **SHALL**
  – The HMI **shall** be developed and managed through a lifecycle model

**CONTINUOUS WORK PROCESSES**

- MOC
- Audit
- Validation

**SYSTEM STANDARDS**
- Philosophy
- Style Guide
- Toolkits

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

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

**IMPLEMENT**
- In Service
- Maintain
- Decommission

**OPERATE**

Continuous Improvement
ISA101 Walk-through – Life Cycle

Life Cycle Entry Points

- There are two entry points for the life cycle:
  - System Standards for a new system or major changes to an existing system which may include migration from a legacy HMI platform.
  - The second entry point is at design for either new display design(s) or display changes.

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**CONTINUOUS WORK PROCESSES**

- MOC
- Audit
- Validation

**SYSTEM STANDARDS**
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- Toolkits

**DESIGN**
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- HMI System Design
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**IMPLEMENT**
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- Build Console
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- Commission
- Verification

**OPERATE**
- In Service
- Maintain
- Decommission

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Continuous Improvement
ISA101 Walk-through – Life Cycle
Continuous Improvement Steps

- There are two continuous improvement steps in the life cycle
  - The first shows a cycle between design and system standards.
  - The second shows a cycle between operate and design.
There are three Continuous Work Processes

- **MOC**
  - Once the HMI is in service, changes to the HMI shall be handled with a Management of Change (MOC) process which includes definition of the portions of the HMI to be covered. This process should include enforcement of and adherence to the system standards (HMI philosophy, HMI style guide, and HMI toolkit components).

- **Audit**
  - Audit is the work process that ensures the HMI is being managed in accordance with the lifecycle and the system standards (HMI philosophy, HMI style guide and HMI toolkit).

- **Validation**
  - More highly regulated industries may require specific validation plans across the lifecycle of the HMI.
ISA101 Walk-through – Life Cycle

Systems Standards

- System standards **shall** be created and used to establish the foundation for the HMI lifecycle.
- Changes to the HMI toolkit shall be accomplished under a management of change process.

**SYSTEM STANDARDS**

| Philosophy     | Style Guide  | Toolkits          |

**Activity**

<table>
<thead>
<tr>
<th>Philosophy development</th>
<th>HMI style guide development</th>
<th>HMI toolkit development</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provide guiding principles and conceptual foundation for HMI design. This includes details on how the HMI is designed and used.</td>
<td>Apply the guiding principles and concepts of the HMI philosophy to provide implementation examples and guidance.</td>
<td>Generate all graphical symbols and other supporting elements as required to implement the HMI style guide.</td>
</tr>
</tbody>
</table>

**Inputs**

| User experience, conceptual user, task, and functional requirements, best practices, standards, guidelines and Human Factors Engineering considerations, work processes, HMI security model. | (This does not include all technical details, though the design needs to be feasible in all target platforms or include preferred work around methods). | HMI style guide, platform experience and expertise, conceptual user, task, functional requirements. |

**Outputs**

| HMI philosophy (independent of platform) | HMI philosophy, platform experience and expertise (to confirm feasibility; develop early proof of concept designs). HMI style guide | HMI toolkit(s) (platform-specific). |
ISA101 Walk-through – Life Cycle
Systems Standards

- **HMI philosophy**
  - The HMI philosophy is a strategic document addressing the guiding principles that govern the design structure of the HMI.
  - The HMI philosophy should provide a foundation of concepts such that new developers and users can grasp the underlying principles and technical rationales, allowing an effective HMI to be created and maintained.

- **HMI style guide**
  - The HMI style guide is a document that contains facility, and/or company specific standards and guidelines for the design and implementation of a configurable HMI.
  - The HMI style guide uses the guiding principles and concepts of the HMI philosophy to establish implementation examples and guidance.
  - As an example, for major dynamic graphic objects, the HMI style guide should contain a description of the object’s behavior, presentation (size, color, etc.) and illustrations of possible states.

- **HMI Toolkit**
  - The HMI toolkit is a collection of design elements for use within the HMI platform.
ISA101 Walk-through – Life Cycle Design

- Appropriate HMI design documentation should be maintained over the lifecycle of the system

<table>
<thead>
<tr>
<th>Activity</th>
<th>Console design</th>
<th>HMI system design</th>
<th>User, task and functional requirements</th>
<th>Display design</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Objectives</strong></td>
<td>To provide hardware and software design for the console. This includes furniture and supporting systems.</td>
<td>Identify design basis for the HMI system.</td>
<td>Identify primary and secondary requirements supported in the HMI.</td>
<td>Identifies conceptual design for displays and the navigation hierarchy. (This may include some prototype displays on complex applications or processes).</td>
</tr>
<tr>
<td><strong>Inputs</strong></td>
<td>User, task, functional requirements. vendor specifications, Human Factors Engineering design standards (see Clause 5).</td>
<td>User, task, functional requirements. control system design standards, network design standards, preliminary network design, security model.</td>
<td>HMI philosophy, HMI style guide, preliminary console design, prior user, task and functional requirements documents.</td>
<td>HMI philosophy, HMI style guide, user, task, functional requirements document(s), user input during review(s).</td>
</tr>
<tr>
<td><strong>Outputs</strong></td>
<td>Console design documents.</td>
<td>HMI system design documents.</td>
<td>User, task and functional requirements document(s).</td>
<td>Display design document(s).</td>
</tr>
</tbody>
</table>
During the implementation stage of the HMI lifecycle, the HMI is built in the target platform software and hardware using the outputs from the previous stages.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Build displays</th>
<th>Build console</th>
<th>Test</th>
<th>Train</th>
<th>Commission</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objectives</td>
<td>Complete construction of displays and supporting items. (User review occurs in the design stage, which include prototypes).</td>
<td>Complete construction of console hardware and software. Test viewing angles, screen elevations, keyboard and input device placement and location of other elements.</td>
<td>Integrated test of HMI and console.</td>
<td>Train users.</td>
<td>Final testing of HMI in production environment.</td>
<td>Verify HMI ready to operate.</td>
</tr>
<tr>
<td>Outputs</td>
<td>Displays, training Materials.</td>
<td>Console</td>
<td>HMI ready to commission, testing documents.</td>
<td>User manuals and online help (as required) Training materials. Updated training materials, training records, trained users.</td>
<td>HMI ready to verify (as required), commissioning documents, approval/acceptance.</td>
<td>Verification documents, HMI ready to operate, approval/acceptance.</td>
</tr>
</tbody>
</table>
Once the HMI has been commissioned and verified, it moves into the operate stage of the HMI lifecycle.

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**Operate**

**Activity** | **In service** | **Maintain** | **Decommission**
--- | --- | --- | ---
**Objectives** | HMI in service. | Ensure HMI is valid and reflects current process conditions. Ensure backups exist for recovery | HMI removed from service

**Inputs** | Commissioning/Verification approval, Approved Management of Change requests to fix errors or to add enhancements or updates to reflect changes in the process. Backups. | (end of life). |

**Outputs** | user manuals and online help, HMI in service. | Management of Change logs, updated HMI, user manuals, training materials and online help. | Management of Change requests. | HMI (or part of HMI) removed from use, archived for approved records period.
General Principles of HMI Design

**Situation Awareness**

- The displays of an HMI’s primary objective is to support the user’s mental model of the plant or process.

- Situation awareness means:
  - being aware of what is happening in the process,
  - understanding the process state now,
  - understanding the likely process state in the future.

- The HMI should support the awareness and understanding of the system and process status.
  - When the process is functioning as expected, the display should exhibit minimal sensory stimuli.
  - As the process deviates from expectations, the HMI should provide visual and/or audible signals with appropriate salience for the situation.
**Situation Awareness**

- What can we do to increase situation awareness

By NOT doing this…
User sensory limits

- Design the HMI to the user’s sensory limits.
- Color impairment, hearing loss.
- Red/Green color impairment – 7 to 10% of males.
- What can we do to conform...

![Diagram showing color vision impairments]
ISA101 Walk-through – HFE and Ergonomics
General Principles of HMI Design

Colour

- Where’s Wally on an HMI Graphic
Color

• The most noticeable colours of a display should be used for the information that is most important.

• In accordance with the facility’s alarm philosophy and ANSI/ISA-18.2-2016, colours used for alarm presentation should be reserved and not used for any other purpose.

• Red, Orange, Yellow (warm colours) use them only for abnormal situations in order to quickly draw the operators attention to them.

• Flashing spinning things – agitator blades spinning – NO!
Colour and Density of displayed information
Background-foreground interactions

- The background should be an unsaturated or neutral colour (e.g., light grey) in order to limit chromatic distortions and ensure the salience of the information displayed.
- Foreground and background colour combinations should provide sufficient contrast.
- The background colour should be selected to provide acceptable and sufficient contrast in expected ambient lighting conditions.
User cognitive limits

- The cognitive processes that transform, reduce, store, recover and use sensory input are important to human performance.

- A user’s performance and the underlying cognitive processes are affected by the workload level, situation awareness, and task complexity, each of which can be optimized by the design of the HMI.
User cognitive limits
User cognitive limits
User cognitive limits
User cognitive limits – What can we do

- Design to the user’s mental model.
- Group relevant data together.
- Provide key data that is relevant to the user’s roles and responsibilities.
- Do not clutter the graphic with data that is only required intermittently.
- Put relevant Data inside of objects then the user can assimilate the information as one chunk of data
- 7 plus or minus 2 chunks of information retained
  - Millar’s Law
Display Hierarchy

Level 1
Overview Display

Level 2
Process Unit Control Display
Level 2
Process Unit Control Display

Level 3
Process Unit Detail Display
Level 3
Process Unit Detail Display

Level 4
Process Unit Support display
Level 4
Process Unit Support display

Provide an overview of the operator’s entire span of responsibility.

Operator’s primary operating display during normal operations for routine changes and monitoring.

Used for non-routine operations. Should provide sufficient information to facilitate process diagnostics.

Interlocks, Diagnostics, Help and Documentation. Usually faceplates or popups.
Level 1 Display

• Used to provide an overview or summary of the key parameters, alarms, calculated process conditions of an operator’s entire span of control on one display.

• On larger systems, they could span multiple screens provided they are all visible at the same time.

• Broadest scope and lowest level of process or system detail.
ISA101 Walk-through – HFE and Ergonomics

General Principles of HMI Design

Level 1 Display

Mixer
1497 RPM

Depositor
34 Psi

Oven
181.3 C
187.9 C
181.1 C
189.6 C
190.2 C

Cooler
127.3 C
90.2 C
76.9 C

Butter 78 %
Salt 73 %
Bicarb 53 %
Raw Materials 61 %
Sugar 68 %
Water 59 %
Cocoa 83 %
Vanilla

Raw Materials
Mixer
Depositor
Oven
Cooling
Flow Wrapper
Case Packer

Units
Flow Wrapper (Minute)
240
300

OEE
Flow Wrapper
81

Case Packer
87

Palletizer
160
50
0

Current Batch
Chocolate Chip
Time to Run 2 Hours 54 Minutes
Batch ID MQ19373
CIP Status Ready

0

1

2

3

4

5

Palletizer Infeed Blocked
Palletizer Infeed Blocked

Palletizer

ISA101 Section 6.3
**Level 2 Display**

- Best described as high level process displays.
- Typically contain more detail than the level 1 displays.
- Should be the operator’s primary operating display during normal operations for routine changes and monitoring.
- Should be task based to allow the operator to perform tasks using a limited number of displays and minimal navigation.
- Provide easy navigation to greater detail provided on the level 3 and 4 displays.
Level 2 Display
**Level 3 Display**

- Best described as system or subsystem detail displays.
- Typically contain more detail than the associated level 2 displays.
- Used for non-routine operations such as line changes, equipment switching, or complex routine tasks.
- Provide sufficient information to facilitate process diagnostics.
- Task based to allow the operator to perform tasks using a limited number of displays and minimal navigation.
- Depending on the specific process, plant, display designs, and overall display hierarchy, this level 3 information may be combined in a level 2, or level 4 presentation.
ISA101 Walk-through – HFE and Ergonomics

General Principles of HMI Design

Level 3 Display
Level 4 Display

- Level 4 displays are characterized as:
  - providing operating procedures for individual pieces of equipment,
  - providing help information for equipment control and diagnostics,
  - containing detailed safety shut downs,
  - containing interlock and permissive information.
- Most likely to be a faceplate
Level 4 Display
Navigation

- An effective and intuitive navigation scheme can directly impact the speed and accuracy of operator intervention.
- The key design basics for navigation are performance, consistency and intuitiveness.
- Make it Simple Don’t confuse.
Navigation

- Example Navigation performance

<table>
<thead>
<tr>
<th>Navigation (Note 1)</th>
<th>Critical displays</th>
<th>1-2 clicks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Non-critical</td>
<td>3 clicks</td>
</tr>
<tr>
<td></td>
<td>displays</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Alarm summary</td>
<td>1 click</td>
</tr>
<tr>
<td></td>
<td>System diagnostics</td>
<td>1-2 clicks</td>
</tr>
</tbody>
</table>
General Principles of HMI Design

**Error avoidance methods**

- Can be as simple as “Are you sure?” prompt
- Electronic Signature
ISA101 – How can we conform?

• Buy the Standard & Technical Reports
  – This ppt is not enough
• ISA Members get free online viewing of the Standard
• Join the committee or one of the working groups
• Think of the end user (operator)
• Stop the clutter
• Design for Situation Awareness
A Clearer Way of Displaying Texas City?
Alarm Standards to reference

- ANSI/ISA-18.2-2016 - Management of Alarm Systems for the Process Industries
  - ISA-TR18.2.2-2016 - Alarm Identification and Rationalization
  - ISA-TR18.2.3-2015 - Basic Alarm Design
  - ISA-TR18.2.4-2012 - Enhanced and Advanced Alarm Methods
  - ISA-TR18.2.5-2012 - Alarm System Monitoring, Assessment, and Auditing
  - ISA-TR18.2.6-2012 - Alarm Systems for Batch and Discrete Processes
  - ISA-TR18.2.7-2017 - Alarm Management When Utilizing Packaged Systems
Thanks!