



IEEE Recommended Practice for Human Machine Interfaces (HMIs) Used with Electric Utility Automation Systems

IEEE Power and Energy Society

Developed by the
Power System Relaying and Control Committee

IEEE Std C37.1.3™-2025

STANDARDS

IEEE Recommended Practice for Human Machine Interfaces (HMI)s Used with Electric Utility Automation Systems

Developed by the

Power System Relaying and Control Committee
of the
IEEE Power and Energy Society

Approved 27 March 2025

IEEE SA Standards Board

Recognized as an American National Standard

Abstract: The philosophy, design, implementation (including building displays, testing, training, commissioning, and verification), operation (including maintenance and decommissioning) of human machine interfaces (HMIs) used with electric utility automation systems are covered by and provided a basis with this recommended practice.

Keywords: electric utility automation system, HMI, human machine interface, IEEE C37.1.3™, life cycle, lifecycle

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³ Available at: <https://ieeexplore.ieee.org/browse/standards/collection/ieee>.

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Introduction

This introduction is not part of IEEE Std C37.1.3-2025, IEEE Recommended Practice for Human Machine Interfaces (HMIs) used with Electric Utility Automation Systems.

The basis of a human machine interface (HMI) specification used in substation automation systems was originally specified in IEEE Std C37.1™-2007 [B19].⁶ That work was originally sponsored by the Substations Committee. Work was started on an update with a schedule for publication in 2017. In preparation of that material, the working group decided that the scope of IEEE Std C37.1 was too broad to effectively update using one working group. The Substations C0 Subcommittee began work on splitting IEEE Std C37.1 into several standards, specific to topics contained within IEEE Std C37.1. This approach could enable those topics to be addressed more completely to help increase their value to the industry. One topic identified was the HMI used in substation automation systems. With the reorganization of the IEEE Power and Energy Society around 2016, that work was delayed as the work was moved into a new Sponsor—the Power System Relaying and Control Committee (PSRC).

Once relocated to the PSRC, the work was approved by the H Subcommittee with the formation of working group H46. The approved scope expanded the HMI topic from IEEE Std C37.1-2007 [B19] to match the scope of the PSRC. The H46 working group debated the definition of the HMI, looking to other standards for guidance. IEEE Std C37.2™ [B20] had introduced the HMI acronym back in 2008 and work in the ISA (ANSI/ISA-101.01-2015 [B3]) was also referenced.

⁶ The numbers in brackets correspond to those of the bibliography in [Annex A](#).

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IEEE Recommended Practice for Human Machine Interfaces (HMI) Used with Electric Utility Automation Systems

1. Overview

1.1 Scope

This recommended practice applies to, and provides the basis for, the design (including philosophy), implementation (including building displays, testing, and training), operation (including maintenance and decommissioning) of human machine interfaces (HMI) used with electric utility automation systems.

1.2 Purpose

The purpose of this recommended practice is to recommend an industry-specific process for developing HMI used with electric utility automation systems.

1.3 Word usage

The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (*shall equals is required to*).^{7,8}

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (*should equals is recommended that*).

The word *may* is used to indicate a course of action permissible within the limits of the standard (*may equals is permitted to*).

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (*can equals is able to*).

⁷ The use of the word *must* is deprecated and cannot be used when stating mandatory requirements, *must* is used only to describe unavoidable situations.

⁸ The use of *will* is deprecated and cannot be used when stating mandatory requirements; *will* is only used in statements of fact.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

There are no normative references in this recommended practice.

3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.⁹

ergonomics: *See:* **human factors engineering**.

human factors engineering: Refer to ANSI/ISA-101.01-2015.

NOTE—See ANSI/ISA-101.01-2015 [B3].^{10,11}

human machine interface (HMI): A collection of hardware and software that displays data or information for an operator and allows control of or interaction with a physical process or system by an operator.

human machine interface (HMI) philosophy: A strategic document addressing the guiding principles that govern human machine interface (HMI) design. It provides the conceptual foundation for a complete HMI design and includes details on HMI use cases.

human machine interface (HMI) style guide: A document that applies a human machine interface (HMI) philosophy by providing implementation examples and guidance without all of the necessary technical details or any accounting of differences in the target hardware or software platforms.

human machine interface (HMI) toolkit: Applies the human machine interface (HMI) philosophy and HMI style guide into software templates that are used for the building blocks of an HMI using specified HMI application-development software.

pop-up: A smaller screen in a human machine interface (HMI) that appears on top of other larger windows, usually to present the user with information that requires user interaction to close the pop-up, acknowledge the pop-up, or perform some other interaction with an HMI (e.g., control).

primary users: Those people directly responsible for the operation of the physical process or system controlled or monitored from a human machine interface (HMI).

secondary users: Those people who are supporting the operations activities associated with an HMI, whether maintenance, engineering, management, and so forth.

⁹*IEEE Standards Dictionary Online* is available at: <http://dictionary.ieee.org>. An IEEE account is required for access to the dictionary, and one can be created at no charge on the dictionary sign-in page.

¹⁰ The numbers in brackets correspond to those of the bibliography in Annex A.

¹¹ Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

3.2 Acronyms and abbreviations

ADDIE	Analyze, Design, Develop, Implement, and Evaluate
CIP	critical infrastructure protection
CSV	comma-separated value
CT	current transformer
DB9F	D-Subminiature connector with 9 pins and female connector
DNP	Distributed Network Protocol
DNP3	Distributed Network Protocol 3
DMS	distribution management system
EMI	electromagnetic interference
EMS	energy management system
FAT	Factory Acceptance Test
HFE	human factors engineering
HMI	human machine interface
IED	intelligent electronic device
LAN	local area network
PPE	personal protective equipment
RJ45	registered jack-45
rms	root mean square
SAT	Site Acceptance Test
SCADA	supervisory control and data acquisition
SCL	System Configuration Language
SIT	Site Integration Test
SSD	solid-state drive
USB	Universal Serial Bus

4. Lifecycle

4.1 General

An HMI used with electric utility automation systems (i.e., “the HMI”) includes both hardware and software to interact with a physical process or system related to the generation, storage, transmission, distribution, and so forth of electricity. Combined together the hardware and software form an HMI that is the intermediary between a human and a physical process or system related to electric utility systems.¹² The hardware portion of the HMI is briefly discussed in this recommended practice to address the appropriateness of its physical design (e.g., interconnection and placement near, at, or remote to those physical systems) in relationship to and

¹² This type of HMI is therefore different than many other common types of user interfaces that could also be described as an HMI. These other user interfaces are only an interface between a user and the software application, such as a user interface for the development environment of a programming language, a user-interface for document creation, a web-based interface for airplane reservations, and so forth.

impact on the logical design. That logical design has some common elements associated with other standards related to HMI development and other standards related to software development lifecycle models.

With both hardware and software elements, the “HMI life cycle” or “HMI lifecycle” is applicable to a system lifecycle that varies depending on their nature, purpose, and use in that system. ANSI/ISA-101.01-2015 [B3] includes HMI lifecycle stages in Clause 4 and Figure 2; these stages are system standardization, design, implementation, and operation.

There are several other software lifecycle models that could be applied and used for the HMI lifecycle. As software, a software lifecycle model is in ISO/IEC/IEEE 12207-2017 [B32] and contains a common set of stages for a software system that are as follows: concept exploration, development, sustainment, and retirement. This is a comprehensive approach to the software lifecycle. Table 1 maps ISO/IEC/IEEE 12207-2017 [B32] with an assessment of the context for which topics are addressed in this recommended practice. One example could be a decoupling of hardware and software by means of virtualization.

Table 1—Mapping of ISO/IEC/IEEE 12207™-2017 [B32] processes to this recommended practice

ISO/IEC/IEEE 12207-2017 [B32] subclause	ISO/IEC/IEEE 12207-2017 [B32] process	ISO/IEC/IEEE 12207-2017 [B32] definition	Assessment
6.1.1	Acquisition	Obtain a product or service in accordance with the organization’s requirements.	Not addressed.
6.1.2	Supply	Provide the organization with a product or service that meets agreed requirements.	Not addressed.
6.2.1	Lifecycle management	Define, maintain, and assure availability of policies, lifecycle processes, lifecycle models, and procedures for use.	While lifecycle is in scope, the management of that lifecycle is not.
6.2.2	Infrastructure management	Provide the infrastructure and services to projects to support the organization and project objectives throughout the lifecycle.	Not addressed.
6.2.3	Portfolio management	Initiate and sustain necessary, sufficient and suitable projects in order to meet the strategic objectives of the organization.	Not addressed.
6.2.4	Human resource management	Provide the organization with necessary human resources and to maintain their competencies, consistent with business needs.	Not addressed.
6.2.5	Quality management	Assure that products, services, and implementation of the quality management process meet organization and project quality objectives and achieve customer satisfaction.	Not addressed.
6.2.6	Knowledge management	Create the capability and assets that enable the organization to exploit opportunities to reapply existing knowledge, skills, knowledge assets, and system elements.	Not addressed.
6.3.1	Project planning	Produce and coordinate effective and workable plans.	Not addressed.

Table continues

Table 1—Mapping of ISO/IEC/IEEE 12207™-2017 [B32] processes to this recommended practice (continued)

ISO/IEC/IEEE 12207-2017 [B32] subclause	ISO/IEC/IEEE 12207-2017 [B32] process	ISO/IEC/IEEE 12207-2017 [B32] definition	Assessment
6.3.2	Project assessment and control	Assess if the plans are aligned and feasible; determine the status of the project, technical and process performance; and direct execution to help ensure that the performance is according to plans and schedules, within projected budgets, to satisfy technical objectives.	Not addressed.
6.3.3	Decision management	Provide a structure, analytical framework for objectively identifying, characterizing and evaluating a set of alternatives for a decision at any point in the lifecycle and select the most beneficial course of action.	Indirect. This recommended practice helps identify and characterize alternatives.
6.3.4	Risk management	Identify, analyze, treat, and monitor the risks continually.	Indirect. This recommended practice helps identify risks.
6.3.5	Configuration management	Manage and control system elements and configurations over the lifecycle; manage consistency between a product and its associated configuration definition.	Refer to 5.3.
6.3.6	Information management	Generate, obtain, confirm, transform, retain, retrieve, disseminate and dispose of information, to designated stakeholders.	Not addressed.
6.3.7	Measurement	Collect, analyze, and report objective data and information to support effective management and demonstrate the quality of the products, services, and processes.	Not addressed.
6.3.8	Quality assurance	Help ensure the effective application of an organization's quality management process to the project.	Refer to 4.2.
6.4.1	Business or mission analysis	Define the business or mission problem or opportunity, characterize the solution space, and determine potential solution class(es) that could address a problem or take advantage of an opportunity.	Refer to 4.2.
6.4.2	Stakeholder needs and requirements	Define the stakeholder requirements for a system that can provide the capabilities needed by users and other stakeholders in a defined environment.	Refer to 4.2.
6.4.3	System/Software requirements definition	Transform the stakeholder, user-oriented view of desired capabilities into a technical view of a solution that meets the operational needs of the user.	Refer to 4.2.
6.4.4	Architecture definition	Generate system architecture alternatives, to select one or more alternative(s) that frame stakeholder concerns and meet system requirements, and to express this as a set of consistent views.	As applicable to the overall HMI architecture and how software and hardware combine. Refer to 4.2.

Table continues

Table 1—Mapping of ISO/IEC/IEEE 12207™-2017 [B32] processes to this recommended practice (continued)

ISO/IEC/IEEE 12207-2017 [B32] subclause	ISO/IEC/IEEE 12207-2017 [B32] process	ISO/IEC/IEEE 12207-2017 [B32] definition	Assessment
6.4.5	Design definition	Provide sufficient detailed data and information about the system and its elements to enable the implementation consistent with architectural entities as defined in models and views of the system architecture.	Refer to 4.2.
6.4.6	System analysis	Provide a rigorous basis of data and information for technical understanding to aid decision-making across the lifecycle. It is used for a wide range of analytical needs concerning operational concepts, determination of requirement values, resolution of requirements conflicts, assessment of alternative architectures or system elements, and evaluation of engineering strategies (integration, verification, validation, and maintenance).	Integration of the HMI with other systems is outside the scope but is referenced in 4.2.
6.4.7	Implementation	Realize a specified system element; transforms requirements, architecture, and design, including interfaces, into actions that create a system element according to the practices of the selected implementation technology, using appropriate technical specialties or disciplines. Results in a system element that satisfies specified system requirements, architecture, and design.	From the perspective that the HMI is the specified system element, refer to 4.3.
6.4.8	Integration	Synthesize a set of system elements into a realize system (product or service) that satisfies system/software requirements, architecture, and design.	Referenced as needed in 4.2, but not in scope.
6.4.9	Verification	Provide objective evidence that a system or system element fulfills its specified requirements and characteristics.	Refer to 4.3.6.
6.4.10	Transition	Establish a capability for a system to provide services specified by stakeholder requirements in the operational environment. Moves the system in an orderly, planned manner into the operational status, such that the system is functional, operable and compatible with other operational systems. Installs a verified system.	Refer to 4.3.6.
6.4.11	Validation	Provide objective evidence that the system, when in use, fulfills its business or mission objectives and stakeholder requirements, achieving its intended use in its intended operational environment.	Used at many points in the life cycle, one example is 4.3.6

Table continues

Table 1—Mapping of ISO/IEC/IEEE 12207™-2017 [B32] processes to this recommended practice (continued)

ISO/IEC/IEEE 12207-2017 [B32] subclause	ISO/IEC/IEEE 12207-2017 [B32] process	ISO/IEC/IEEE 12207-2017 [B32] definition	Assessment
6.4.12	Operation	Use the system to deliver its services. Establishes requirements for and assigns personnel to operate the system and monitors the services and operator-system performance. In order to sustain services, it identifies and analyses operational anomalies in relation to agreements, stakeholder requirements and organizational constraints.	Refer to 4.4.
6.4.13	Maintenance	Sustain the capability of the system to provide a service. Monitors the system's capability to deliver services, records incidents for analysis, takes corrective, adaptive, perfective, and preventative actions and confirms restored capability.	Refer to 4.5.
6.4.14	Disposal	Ends the existence of a system element or system for a specified intended use, appropriately handle replaced or retired elements, and to properly attend to identified critical disposal needs (e.g., per an agreement, per organizational policy, or for environmental, legal, safety, security aspects).	Refer to 4.6.

As Table 1 shows, this recommended practice does not include many topics from ISO/IEC/IEEE 12207-2017 [B32]. Another IEEE standard related to lifecycles that could be applicable to HMIs is in ISO/IEC/IEEE 24748□1-2018 [B33] that defines the following six example stages for managing a “system-of-interest”: concept, development, production, utilization, support, and retirement. Table 2 shows a mapping of ISO/IEC/IEEE 24748□1-2018 [B33] to the lifecycle stages of this recommended practice.

Table 2—Mapping of ISO/IEC/IEEE 24748-1-2018 [B33] to this recommended practice

ISO/IEC/IEEE 24748-1-2018 [B33] clause	ISO/IEC/IEEE 24748-1-2018 [B33] stage	ISO/IEC/IEEE 24748-1-2018 [B33] definition	Assessment
5.2	Concept	The purpose is to identify each stakeholder's needs, explore concepts, and propose viable solutions.	Tasks in 4.2.3.2 and 4.2.3.3 in the design phase generate the development of the HMI philosophy (refer to 4.2.3.3.2) and HMI style guide (refer to 4.2.3.3.3) that address both the physical design and logical design.
5.3	Development	The purpose is to refine system requirements, create a solution description, build the system (e.g., a prototype), and verify and validate the system.	Tasks in 4.2.3.2 and 4.2.3.3 in the design phase generate the development of the HMI philosophy (refer to 4.2.3.3.2) and HMI style guide (refer to 4.2.3.3.3) that address both the physical design and logical design. Also, in the design phase, 4.2.3.4 addresses creating a prototype as part of the finalization of the HMI toolkit to verify and validate that the HMI toolkit meets all requirements.
5.4	Production	The purpose is to produce the system, inspect, and test.	Building a specific instance of the HMI (e.g., as a product or as a new substation HMI at a greenfield substation) is addressed in 4.3 as implementation, including both the physical and logical design.
5.5	Utilization	The purpose is to operate the system to satisfy each user's needs.	HMI operation is addressed in 4.4.
5.6	Support	The purpose is to provide sustained system capability.	HMI maintenance is addressed in 4.5.
5.7	Retirement	The purpose is to store, archive, or dispose of the system.	HMI decommissioning is addressed in 4.6.

Table 2 shows a better mapping of topics into the stages used by this recommended practice. The HMI lifecycle stages are described sequentially in this recommended practice as follows:

- Design stage (4.2)
- Implementation stage (4.3)
- Operation stage (4.4)
- Maintenance stage (4.5)
- Decommissioning stage (4.6)

This lifecycle sequence includes the design and implementation stages that include a method for project development. There are several models for project development that are commonly applied to software development: waterfall, incremental, spiral, iterative, evolutionary (adaptive), and agile. Refer to ISO/IEC/IEEE 12207-2017 [B32] for a detailed discussion of each project development model and the impacts on the system lifecycle processes that could be applicable to the HMI lifecycle stages presented in this recommended