

IEEE Recommended Practice for Electrical Installations on Shipboard— Controls and Automation

IEEE Industry Applications Society

Sponsored by the
Petroleum & Chemical Industry Committee

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IEEE Recommended Practice for Electrical Installations on Shipboard — Controls and Automation

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IEEE Industry Applications Society

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Abstract: The recommendations for controls, control applications, control apparatus, and automation on shipboards are established by this document. These recommendations reflect the present-day technologies, engineering methods, and engineering practices.

This document is intended to be used in conjunction with IEEE Std 45™.

Keywords: automation, computer based system, control system, IEEE 45.2, interior communication system, monitoring, navigation system, remote control, safety system

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Introduction

This introduction is not part of IEEE Std 45.2-2011, IEEE Recommended Practice for Electrical Installations on Shipboard — Controls and Automation.

The IEEE Std 45 series comprises nine recommended practices addressing electrical installations on ships and marine platforms. IEEE Std 45.2 provides recommended practice for controls and automation and is intended for use with the IEEE Std 45 series of documents. The topics covered in this document should be considered from the beginning of the project and throughout the design and construction processes, and thereby should facilitate the integration of electrical systems at the shipyard level. Adherence to the IEEE 45.2 controls and automation process provides an effective set of integration requirements and identifies key issues and recommended solutions or options.

Previous editions of IEEE Std 45 were developed as single documents addressing all areas. On 9 June 2005 PAR 45 for the Revision of IEEE Std 45-2002 was approved and the revision of IEEE Std 45 as a single document began. It soon became apparent that attempting to cover all issues in a single document would produce a document that was very large and therefore difficult to ballot due to the wide range of issues needed to be addressed. In September 2008 it was decided that the revision of IEEE Std 45 should be developed as a base document with separate documents addressing specific areas.

On 10 December 2008 separate Project Authorization Requests (PARs) were approved for eight separate recommended practices. Subsequently, it was recognized that two areas were very close to balloting and contained important information. Additional PARs were then prepared and approved on 11 September 2009 for Switchboards and 9 December 2009 for Cable Systems bringing the total number of standards in the IEEE Std 45 Series to nine:

- IEEE P45™, Recommended Practice for Electrical Installations on Ships.
- IEEE P45.1™, Recommended Practice for Electrical Installations on Shipboard— Design
- IEEE P45.2™, Recommended Practice for Electrical Installations on Shipboard— Controls and Automation
- IEEE P45.3™, Recommended Practice for Shipboard Electrical Installations—Systems Engineering
- IEEE P45.4™, Recommended Practice for Electrical Installations on Shipboard— Marine Sectors and Mission Systems
- IEEE P45.5™, Recommended Practice for Electrical Installations on Shipboard—Safety Considerations
- IEEE P45.6™, Recommended Practice for Electrical Installations on Shipboard— Electrical Testing
- IEEE P45.7™, Recommended Practice for Electrical Installations on Shipboard—AC Switchboards
- IEEE P45.8™, Recommended Practice for Electrical Installations on Shipboard— Cable Systems

Several other IEEE standards have been prepared or are currently being developed to support the IEEE 45 Series. These include:

- IEEE Std 1580™, IEEE Recommended Practice for Marine Cable for use on Shipboard and Fixed or Floating Platforms
- IEEE P1580.1™, Recommended Practice for Insulated Bus Pipe for Use on Shipboard and Fixed or Floating Platforms
- IEEE Std 1662™-2008^a IEEE Guide for Design and Application of Power Electronics in Electrical Power Systems on Ships
- IEEE Std 1709™-2010 IEEE Recommended Practice for 1 kV to 35 kV Medium-Voltage DC Power Systems on Ships
- IEEE P1826™, Standard for Power Electronics Open System Interfaces in Zonal Electrical Distribution Systems Rated Above 100 kW
- IEEE P60092-510, Electrical Installations in Ships – Part 510: High Voltage Shore Connection Systems (HVSC)

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^a Information on normative references can be found in Clause 2.

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1. Overview

These recommendations establish the minimally acceptable guidelines for the design, selection, and installation of systems and equipment aboard marine vessels applying electrical apparatus for power, propulsion, steering, automation, navigation, lighting, and communications. These recommendations describe present-day acceptable electrical engineering methods and practices. The primary focus of these IEEE Std 45.2 guidelines is on the deliverability of control systems and the equipment, conditions and documentations that should be required. Guidelines for the design and integration of ship electrical systems are discussed elsewhere in this IEEE Std 45™ Series, which comprises nine recommended practices addressing electrical installations on ships and marine platforms.

It is recognized that changes and improvements in shipboard requirements may develop that are not specifically covered herein; such changes, if incorporated in the design, should be equal to the safety and reliability levels established herein and generally in accord with the intent of these standards.

In developing these recommendations, consideration was given to the electrical and engineering requirements promulgated by various regulatory agencies, classification societies, and by the International Maritime Organization’s International Convention for the Safety of Life at Sea (IMO SOLAS), as amended.

This recommended practice was developed by a voluntary consensus body to provide assistance and guidance to regulatory agencies governing electrical engineering requirements.

Corrosion due to improper or inadvertent grounding of control systems is a significant problem in marine platforms. Corrosion is not addressed in this standard; however, it must be considered in the overall design of the platform's control systems.

1.1 Scope

The recommendations for controls, control applications, control apparatus, and automation on shipboards are established by this document. These recommendations reflect the present-day technologies, engineering methods, and engineering practices.

This document is intended to be used in conjunction with the IEEE Std 45.¹

1.2 Purpose

An extension of the baseline technology and methods covered in IEEE Std 45 and IEEE Std 45.2 provides a consensus of recommended practices for control applications and automation in marine electrical engineering as applied specifically to ships, shipboard systems and equipment.

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.

API RP 14F, Design and Installation of Electrical Systems for Fixed and Floating Offshore Petroleum Facilities for Unclassified and Class 1, Division 1 and Division 2 Locations, Fifth Edition.²

ASTM F1166-95a(2006), Standard Practice for Human Engineering Design for Marine Systems, Equipment and Facilities.³

Code of Federal Regulations Title 46 Part 111 (46 CFR 111), Electric Systems – General Requirements.⁴

Code of Federal Regulations Title 46 Part 113.25-25 (46 CFR 113.25-25), Communication and Alarm Systems and Equipment.

Code of Federal Regulations Title 46 Part 113.25-30 (46 CFR 113.25-30), Communication and Alarm Systems and Equipment.

IEC 60068-2-1, Environmental Testing – Part 2-1: Test- Test A: Cold.⁵

¹ Information on normative references can be found in Clause 2.

²API publications are available from the Publications Section, American Petroleum Institute, 1200 L Street NW. Washington, DC 20005, USA (<http://www.api.org/>).

³ASTM publications are available from the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA (<http://www.astm.org/>).

⁴CFR publications are available from the U.S. Government Printing Office, 732 N. Capitol Street, Washington, DC 20401, USA (<http://www.gpo.gov/>).

- IEC 60068-2-2, Environmental Testing – Part 2-2: Test- Test B: Dry heat.
- IEC 60068-2-6, Environmental Testing – Part 2-6: Test Fc: Vibration (sinusoidal).
- IEC 60068-2-30, Environmental Testing – Part 2-30: Test Db: Damp heat, cyclic (12 h + 12 h cycle).
- IEC 60068-2-52, Environmental Testing – Part 2-52: Test Kb: Salt mist, cyclic (sodium, chloride solution).
- IEC 60079, Explosive Atmospheres – Part 0: Equipment- General requirements.
- IEC 60947-1, Low-voltage Switchgear and Controlgear – Part 1: General rules.
- IEC 61000-4-2, Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques - Electrostatic discharge immunity test.
- IEC 61000-4-3, Electromagnetic compatibility (EMC) – Part 4-3 : Testing and measurement techniques - Radiated, radio-frequency, electromagnetic field immunity test.
- IEC 61000-4-4, Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques - Electrical fast transient/burst immunity test.
- IEC 61000-4-5, Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques - Surge immunity test.
- IEC 61000-4-6, Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques - Immunity to conducted disturbances, induced by radio-frequency fields.
- IEC 60437 Ed. 2.0-1997, Radio interference test on high-voltage insulators.
- IEC 62271, High-voltage Switchgear and Controlgear.
- IEEE Std 45™, IEEE Recommended Practice for Electrical Installations on Shipboard.
- IEEE Std 995™-1987, IEEE Recommended Practice for Efficiency Determination of Alternating-Current Adjustable Speed Drives— Part I- Load Commutated Inverter Synchronous Motor Drives.⁶
- IEEE Std 1566™, IEEE Standard for Performance of Adjustable Speed AC Drives Rated 375 kW and Larger.^{7, 8}
- IEEE Std 1676™, IEEE Guide for Control Architecture for High Power Electronics (1 MW and Greater) Used in Electric Power Transmission and Distribution System.
- IEEE Std 1662™-2008, IEEE Guide for Design and Application of Power Electronics in Electrical Power Systems on Ships.
- IEEE Std C37.90™-1989, IEEE Standard for Relays and Relay Systems Associated with Electric Power Apparatus.

⁵IEC publications are available from the Central Office of the International Electrotechnical Commission, 3, rue de Varembe, P.O. Box 131, CH-1211, Geneva 20, Switzerland (<http://www.iec.ch/>). IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (<http://www.ansi.org/>).

⁶ IEEE Std 995-1987 has been withdrawn; however, copies can be obtained from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08854, USA (<http://standards.ieee.org/>).

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⁸ IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08854, USA (<http://standards.ieee.org/>).

IMO Resolution A830 (19) Code on Alarms and Indicators, 1995.⁹

NEMA ICS 1-1993, Industrial Control and System General Requirements.¹⁰

NEMA 250, Enclosures for Electrical Equipment 1,000 V Maximum.

NFPA 70, 2007 Edition, National Electrical Code® (NEC®).^{11, 12}

NFPA 72-2010, National Fire Alarm and Signaling Code.

SOLAS 74, Regulation III-6.4.2.¹³

SOLAS 74, Regulation III/50.

SOLAS 74, Regulation II-1/42.

SOLAS 74, Regulation II-1/43.

UL 363, Knife Switches.¹⁴

UL 489, Molded-Case Circuit Breakers, Molded-Case Switches and Circuit-Breaker Enclosures.

UL 845-2005, Motor Control Centers.

UL 913-2006, Standard for Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II, and III, Division 1, Hazardous (Classified) Locations.

3. Definitions, acronyms, and abbreviations

For the purposes of this document, the following terms and definitions apply. *The IEEE Standards Dictionary: Glossary of Terms & Definitions*¹⁵ should be referenced for terms not defined in this clause.

3.1 Definitions

acceleration-insensitive drift rate: The component of systematic drift rate that has no correlation with acceleration. *See also:* **drift rate; systematic drift rate.**

accommodation spaces: Spaces provided for passengers and crew members that are used for berthing, dining rooms, mess spaces, offices, private baths, toilets and showers, lounges, and similar spaces.

attachment plug: A device that, by insertion in a receptacle, establishes connection between the conductors of an attached cord and the conductors connected permanently to the receptacle.

⁹ IMO publications are available from International Maritime Organization, 4 Albert Embankment, London SE1 7SR UK, (<http://www.imo.org>).

¹⁰ NEMA publications are available from Global Engineering Documents, 15 Inverness Way East, Englewood, Colorado 80112, USA (<http://global.ihs.com/>).

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¹² NFPA publications are available from Publications Sales, National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101, USA (<http://www.nfpa.org/>).

¹³ SOLAS publications are available from International Maritime Organization, 4 Albert Embankment, London SE1 7SR UK, (<http://www.imo.org>).

¹⁴ UL standards are available from Global Engineering Documents, 15 Inverness Way East, Englewood, Colorado 80112, USA (<http://global.ihs.com/>).

¹⁵ *The IEEE Standards Dictionary: Glossary of Terms and Definitions* is available at <http://shop.ieee.org>.

automatic bus transfer (ABT) system: Self-acting equipment for transferring one or more load conductor connections from one power source to another.

auxiliary machinery space: Spaces containing ship-service or mission machinery, but located outside of the main machinery casing.

branch circuit (or final subcircuit): That portion of a wiring system that extends beyond the final overcurrent device protecting the circuit.

capacitance (capacity): That property of a system of conductors and dielectrics that permits the storage of electricity when potential differences exist between the conductors. Its value is expressed as the ratio of a quantity of electricity to a potential difference. A capacitance value is always positive.

capacitor: A device with the primary purpose of introducing capacitance into an electric circuit. Capacitors are usually classified, according to their dielectrics, as air capacitors, mica capacitors, paper capacitors, and so on.

cargo vessel: A vessel that carries bulk, containerized, or ro/ro dry cargo, and no more than 12 passengers. Research vessels, search and rescue vessels, and tugs are also considered to be cargo vessels in these recommendations.

centralized control: The local, remote, or programmed operations of more than one equipment or system from one central control station in a common area or room by a broadly skilled operator or supervisory system.

code cet: *See: coded character set.*

coded character set: A set of characters for which coded representation exist. *Syn: code set.*

computer-assisted system: A system that utilizes separate and standalone computers or processors for arithmetic computational and logic functions. All data manipulation and evaluation (e.g., alarm condition annunciation) functions are performed by the system.

computer-based system: A system that utilizes one or more embedded computers or processors to perform its functions.

continuous duty: A requirement of service that demands operation at a constant load for an indefinite period of time.

control circuit: The circuit that carries the electric signals of a control apparatus or system directing the performance of the controller but that does not carry the main power circuit.

control space: A dedicated area or compartment provided with equipment such as control consoles, gauge boards, control bench boards, switchboards, instrumentation, displays, control switches, communications, and other equipment for the local, remote, or programmed control and monitoring of equipment. The control system equipment may be operated by one or more individuals acting together or independently.

controller: A device or group of devices used to control in a predetermined manner the electric power delivered to the apparatus to which it is connected.

cycle: The complete series of values of a periodic quantity that occurs during a period. (It is one complete set of positive and negative values of an alternating current.)

deterministic: A performance that responds to input signals fast enough to keep a sustained operation moving predictably at its required speed. For purposes of this guide this means that the maximum (1) jitter times, (2) error handling times, (3) task execution times, (4) hardware response times and (5) communication times are known and specified, and further means that a certain control application may be

used without additional consideration of a variability in response time or execution time. Such a system is deterministic for only those certain systems.

direct current (DC): A unidirectional current in which the changes in value (polarity) are either zero or so small that they may be neglected. (As ordinarily used, the term designates a practically nonpulsating current.)

disconnecting means: A device or group of devices used to disconnect the conductors of a circuit from the source of supply.

distribution center (load center): Enclosed apparatus that consists of automatic protective devices connected to bus bars, to subdivide the feeder supply and provide control and protection of subfeeders or branch circuits.

distribution panel: A panel that receives energy from a switchboard or a distribution center and distributes power to energy-consuming devices.

drift rate: The slope at a stated time of the smoothed curve of tube voltage drop with time at constant operating conditions (adapted from ISO/IEC 9945-1:2003).

electronics: That branch of science and technology that relates to devices in which conduction is principally by electrons moving through a vacuum, gas, or semiconductor.

emergency switchboard: A switchgear and control assembly that receives energy from the emergency generating plant and distributes directly or indirectly to all emergency loads.

engineers operating station (EOS): A propulsion control station fitted with instrumentation, control systems and actuators to enable propulsion and auxiliary machinery be controlled and monitored, and the state of propulsion machinery space be monitored, without the need of regular local attendance in the propulsion machinery space.

failsafe: A characteristic in which, upon failure or malfunction of a component, subsystem, or system, the output automatically reverts to a predetermined design state of least critical consequence.

feeder: A cable or set of conductors that originates at a main distribution center (main switchboard) and supplying secondary distribution centers, transformers, or motor control centers. (Bus tie circuits between generator and distribution switchboards, including those between main and emergency switchboards, are not considered as feeders.)

flag state authority: The authority under which a country exercises regulatory control over the commercial vessel which is registered under its flag. This involves the inspection, certification, and issuance of safety and pollution prevention documents.

frequency: The number of periods occurring in unit time of a periodic quantity, in which time is the independent variable.

hertz (Hz): The unit of frequency, one cycle per second.

input reference axis (IRA): The direction of an axis as defined by the case mounting surfaces, external case markings, or both. *Contrast:* **output reference axis.**

line replaceable unit (LRU): The smallest or lowest piece of equipment or subassembly that is replaceable onboard the vessel. Systems and subsystems may contain multiple numbers of them. Typical ones include circuit cards, sealed bearings, and drive motors.

lug: A wire connector device to which the electrical conductor is attached by mechanical pressure or solder.

machinery control room: An enclosed or separated space generally located within the machinery spaces that functions as a central control station.

machinery spaces: Spaces that are primarily used for machinery of any type, or equipment for the control of such machinery, such as boiler, engine, generator, motor, pump, and evaporator rooms.

main machinery space: A space generally confined by the fire-proof boundary of the machinery casing, and normally containing major ships equipment and prime moving equipment, including propulsion services equipment.

manual controller: An electric controller having all of its basic functions performed by devices that are operated by hand.

master switch: A switch that dominates the operation of contactors, relays, or other remotely operated devices.

motor-generator set: A machine that consists of one or more motors mechanically coupled to one or more generators to convert electric power from one frequency to another, or to create an isolated power source.

outlet: A point on the wiring system at which current is taken to supply utilization equipment

output: (A) Data that has been processed. (B) The process of transferring data from an internal storage device to an external storage device.

overcurrent protection (overload protection): The effect of a device, operative on excessive current (but not necessarily on short circuit), to cause and maintain the interruption of current flow to the device governed.

overload relay: An overcurrent relay that functions at a predetermined value of overcurrent to cause the disconnection of the power supply.

NOTE—An overload relay is intended to protect the motor or controller and does not necessarily protect itself.

passenger vessel: A vessel that carries more than 12 persons in addition to the crew.

radar: A device that radiates electromagnetic waves and utilizes the reflection of such waves from distant objects to determine their existence or position.

receptacle: A device installed in a receptacle outlet to accommodate an attachment plug.

receptacle outlet: An outlet where one or more receptacles is installed.

rectifier: A component for converting alternating current (AC) to direct current (DC) by inversion or suppression of alternate half-cycles.

resistor: A device with the primary purpose of introducing resistance into an electric circuit. (A resistor as used in electric circuits for purposes of operation, protection, or control, commonly consists of an aggregation of units. Resistors, as commonly supplied, consist of wire, metal, ribbon, cast metal, or carbon compounds supported by or embedded in an insulating medium. The insulating medium may enclose and support the resistance material as in the case of the porcelain tube type, or the insulation may be provided only at the points of support, as in the case of heavy duty ribbon or cast iron grids mounted in metal frames.)

semiconductor rectifier: A device consisting of a conductor and semiconductor forming a junction. The junction exhibits a difference in resistance to current flow in the two directions through the junction. This results in effective current flow in one direction only. The semiconductor rectifier stack is a single columnar structure of one or more semiconductor rectifier cells.

slip: In an induction machine, the difference between its synchronous speed and its operating speed. It may be expressed in the following ways: **(A)** As a percent of synchronous speed, **(B)** As a decimal fraction of synchronous speed, **(C)** Directly in revolutions per minute.

starter: An electric controller that is used to accelerate a motor from rest to normal speed and to stop the motor. (A device designed for starting a motor in either direction of rotation includes the additional function of reversing and should be designated a controller.)

step-back relay: A relay that operates to limit the current peaks of a motor when the armature or line current increases. It may, in addition, operate to remove such limitations when the cause of the high current has been removed.

switchboard: A metal-enclosed panel or assembly of panels that may contain molded case, insulated case or power circuit breakers, bolted pressure contact or fusible switches, protective devices, and instruments. These devices may be mounted on the face or the back of the assembly. Switchboards are generally accessible from the rear as well as from the front; however, they can be front accessible only.

systematic drift rate: That component of drift rate that is correlated with specific operating conditions.

tank vessel: A vessel that carries liquid or gaseous cargo in bulk.

under-voltage or low-voltage protection: The effect of a device, operative on the reduction or failure of voltage, to cause and maintain the interruption of power in the main circuit.

under-voltage or low-voltage release: The effect of a device, operative on the reduction or failure of voltage, to cause the interruption of power to the main circuit, but not to prevent the reestablishment of the main circuit on return of voltage.

vital services: Services normally considered to be essential for the safety of the ship and its passengers and crew. These usually include propulsion, steering, navigation, firefighting, emergency power, emergency lighting, electronics, and communications functions. The identification of all vital services in a particular vessel is generally specified by the government regulatory agencies.

watertight enclosure: An enclosure constructed so that a stream of water from a hose not less than 25 mm in diameter under a head of 10 m from a distance of 3 m can be played on the enclosure from any direction for a period of 5 min without leakage. The hose nozzle shall have a uniform inside diameter of 25 mm. (NEMA 250 Type 4 or 4X).

3.2 Acronyms and abbreviations

AC	alternating current
CFR	Code of Federal Regulations
DC	direct current
EMC	electromagnetic compatibility
EMF	electromagnetic field

EMI	electromagnetic interference
EOS	engineers operating station
EOT	engine order telegraph
EUT	equipment under test
GMDSS	global maritime distress and safety system
GPS	global positioning system
IEC	International Electro-technical Committee
IEEE	Institute for Electrical and Electronics Engineers
IMO	International Maritime Organization
IRA	input reference axis
LAN	Local Area Network
LED	light-emitting Diode
LRU	line replaceable unit
LVP	low-voltage protection
LVR	low-voltage release
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
PLC	programmable logic control
PBX	public exchange
PIV	peak inverse voltage
PLCS	programmable logic control
RTOS	real-time operating system
RMS	root means square
RO/RO	roll on, roll off
SCR	silicon-controlled rectifier
SOLAS	safety of life at sea
UL	Underwriters Laboratories
UPS	uninterruptible power supply
UV	ultraviolet
VOIP	Voice Over Internet Protocol

4. Control systems

4.1 General

This clause presents a guide for the design and installation of electrical and electronic equipment intended for control of machinery in ships. This clause deals with electrical, electronic, and programmable equipment and systems for control, monitoring, alarm, and protection on board vessels. It includes semiautomatic, fully automatic, and autonomous (unattended) systems, including but not limited to the following:

- Propulsion plants and associated systems including lube oil and fuel systems
- Boilers (oil, gas, or flue gas—main or auxiliary)
- Incinerators
- Steam or combustion turbines
- Liquid and dry cargo handling and storage systems (including liquefied gases)
- Bilge and ballast systems
- Inert gas systems
- Refrigeration systems
- Electric power generating plants and distribution equipment and machinery
- Hotel auxiliary systems
- Damage control alarm and monitoring systems
- Fire detection alarm and monitoring systems
- Navigating bridge control systems

NOTE—Navigating bridge systems are included for those circumstances when machinery control is included in the integrated navigating bridge system. These recommendations address the remote machinery control, alarm, and monitoring aspects only. The navigation system recommendations are in 4.34.¹⁶

4.2 Documentation

Documentation for control and automation systems shall be maintained on board the vessel. This documentation should include electronic versions of plans and technical manuals. The technical manuals shall include failure mode effects analysis, and should include design verification test procedures and Periodic Safety Test Procedures. The plans and specifications should provide machinery arrangement showing location of controls in relation to the controlled units, arrangements, and details of consoles, including all support systems, and plans for all safety-related support systems, including fire detection and protection systems.

Technical manuals for software and firmware should include graphics for human interfaces for operation and installation.

All software and firmware configurations for equipment should have a backup installation copy available on the vessel. This shall be available to re-install the software or firmware resident in the equipment.

¹⁶ Notes in text, tables, and figures of a standard are given for information only and do not contain.

Installation software tools and procedures for reinstallation and testing shall be provided onboard the vessel.

Technical manuals should be provided for the controls and should contain, as a minimum, the following information:

- a) General overall system functional description concept of operations
- b) Operating instructions
- c) Test procedures to evaluate the operation and safety features of the complete system
- d) Trouble identification charts
- e) Maintenance and special repair procedures
- f) Illustrated parts lists and descriptions
- g) Software and firmware Programming and User's manuals
- h) Electrical schematics
- i) Mechanical layout drawings
- j) Special purpose tools and test equipment

The operating instructions for the equipment should include sections providing examples and suggested use of the apparatus to maximize efficiency. The information should include types of conditions that can be encountered and typical responses to those conditions. Normal routine care and testing of the equipment should be discussed. Immediate responses to fault conditions of equipment, including the monitoring or control system itself should be emphasized.

The technical instructions for the equipment should provide complete technical information on the system and the individual equipment items that make up the system. Information should be provided in a manner and in sufficient detail to allow a skilled technician to troubleshoot, identify the fault, and undertake the repair. Detailed testing and calibration procedures for the equipment should be provided and should include recommended test equipment. Any special purpose tools or test equipment that are identified in the technical manuals shall be carried onboard the vessel. The documentation should include information on the various interfaces between the specific items of equipment.

The documentation provided may include the following, as applicable:

- a) Overall description and specification of the system, software, and equipment
- b) Block diagrams for the computer hardware showing interfaces among workstations, local controllers, input/output data acquisition units, communication controllers, communication buses, and so on
- c) Logic flow or ladder diagrams
- d) Description of the alarm system and sequencing matrix, including how alarms are displayed, acknowledged, and assessed (if possible)
- e) Description of system backup units and redundancy features
- f) Description of the communication protocol(s), including estimated data transmission delays
- g) Description of the system security protocol to prevent unauthorized changes to programs
- h) Description of the system with regard to independence of the control/alarm/display systems, safety systems, and emergency shutdown systems
- i) Description of the priority handling of system tasks

- j) Description of uninterruptible power supply, its capacity, and the system's estimated power consumption requirements
- k) Equipment ratings and environmental parameters
- l) Installation methods
- m) System failure modes and effect analysis, or similar analysis
- n) Mimic screens with display variables and manipulated values
- o) Signal table including a list of monitoring points, domains, their alarm settings, normal ranges, types, precision and accuracy, set and reset points, and out of range limits

4.3 Control system design—general

When an automatic machinery control system is provided, the control and monitoring system should be designed and installed to achieve safe and effective operation, to at least the same level as could be obtained by skilled watch-keeping personnel. The system as installed should be capable of meeting all load and operational demands under steady state and maneuvering conditions without the need for manual adjustment or manipulation. Therefore, the system design should accomplish at least the following:

- Unsafe effects of failure of vital automatic systems or remote control systems are minimized by design, and failures are limited to failsafe states (see Table 1).
- Prompt alerting of an appropriate crew member, either directly or by reliable instrumentation and alarms, of machinery failure, flooding, or fire.
- An alternative means to operate the vessel safely and to counteract the effects of the machinery failure, fire, or flooding.
- Indication at an attended control station of the status of operation of the equipment controlled from that location.

Programmable computer-based or computer-assisted systems are to be designed to provide operational capability upon loss of any processing component of the system that may cause hazards to personnel. Unless backup, hardwired safety systems and emergency shutdown systems are fitted, all of a computer-based system's equipment or peripherals should be provided in duplicate and should automatically transfer duty functions to the corresponding standby system/equipment upon failure of an on-line equipment or system. Such action should be alarmed at the remote station. Additionally, particular attention should be paid at least to the following criteria in the design and installation of automatic or centralized control systems:

- a) Maintainability: The capability of keeping the control system in the designed state of operation.
- b) Availability of spare components: The capability of the manufacturer to readily supply components to avoid delaying the operation of the vessel.
- c) Standardization: The types of components used. Items that are readily available should be utilized wherever possible.
- d) Operational capability: The capability of keeping display and control device movements as simple as possible. Direction of control device movements should be parallel to the axis of the display they control.
- e) Reliability: The probability that a system will function within its design limits for a specified period of time.
- f) Accessibility: The ability to maintain components and subsystems without removal of, or interference with, other components and subsystems.

The control systems may be designed to incorporate hierarchical degrees of automation, starting from local manual control to full unattended automatic operation. The control of vital systems should be designed such that loss of automatic features automatically shifts the level of control to the next lower step or the state of least consequence. The design of the system should be such that the transfer to the next lower step does not change the status of the plant or the commanded order from that of the higher level. Additionally, the system should incorporate a feature that allows the operator to set the level of control desired from the main control station. Automatic mode changes shall be alarmed. Typical failsafe states are listed in Table 1.

Table 1—Typical failsafe states

System or component	Typical failsafe states
Cooling water valve	As is or open
Alarm system	Annunciate
Burner valve	Shutdown, limited, or as an alarm
Propulsion speed control	As is
Feedwater valve	As is or open
Controllable pitch propeller	As is
Propulsion safety trip	As is and alarm

4.3.1 Security and Surveillance Systems

For vessels that have limited ship's force, considerations for a ship-wide security and surveillance system is recommended.

4.4 Control system equipment location and console arrangements

Ship motion, anticipated structural vibrations, temperature, and humidity are to be considered when selecting the locations of main and secondary control stations (see 4.19). The routing of water, hydraulic, steam, waste, and other fluid systems piping, electrical power distribution cables, and other systems that could have a negative effect on the operation of the control system if breached or ruptured, should be avoided in the vicinity of the control consoles. If such routing is necessary, care should be taken to protect the consoles from any possible leakage.

Care should be taken to avoid installation of switching equipment in or around the control consoles unless proper shielding from electromagnetic field pulses and power supply spiking is provided.

When an enclosed main control space is located within the machinery spaces, it should have two means of access/egress located as remote from each other as practicable. Windows, if provided, should be shatter-resistant.

The arrangement of control consoles should be such that the operator can safely and efficiently communicate with and control the equipment under all conditions. The indicators, meters, displays, control switches, and levers should be grouped so that trends, abnormal conditions, the indicators of possible

trouble, and devices for corrective action are in a localized area. If light-emitting diodes (LEDs) are used for any display, indicator, or meters and exposure to sun rays is possible, means should be provided to block sun rays and enhance direct sunlight readability.

4.5 Machinery control

4.5.1 General

The control and automation system should support real-time monitoring and control of ship propulsion, electrical, auxiliary, and steering functions.

When provided for essential machinery functions, standby machines should incorporate automatic changeover features. The changeover function should be alarmed. Vital control, safety, and alarm systems should automatically transfer power sources to backup systems upon failure of the operating power source. The system should be designed such that the changeover operation does not further degrade the plant condition by inadvertently compounding the situation.

Electric power for control, monitoring and safety is to be fed from two feeders, one from the main switchboard or other suitable distribution board and the other from the emergency switchboard or an emergency distribution board. The supply status of these feeders is to be displayed and the main power supply failure is to be alarmed. The electric power supply to each of the controls, monitoring and safety systems, is to be individually monitored.

The two feeders are to be connected to a transfer switch in the centralized control station. Power supply controls, monitoring and safety systems may be commonly connected to the transfer switch. The transfer between the power supplies is to be effected automatically upon failure of a supply and by manual means at the centralized control station. Power transfer is to be achieved without a break in power supply.

Where remote control is provided, effective means should be provided to allow propulsion units to be operated under all sailing conditions, including maneuvering.

Control functions from a console may be designed for either remote manual or automatic control. Vital systems that are automatically or remotely controlled should be provided with at least the following:

- An effective primary control system.
- A manual alternate control system. A method should exist that provides for alternative positive control of the vital equipment.
- A safety control system. Methodologies should be incorporated into the control system either in hardware or software that preclude the unsafe operation of the equipment. Unsafe operation is considered to be operation that will cause severe and permanent damage of the equipment, or risk to operating personnel.
- Instrumentation to monitor system parameters necessary for the safe and effective operation of the system. The instrumentation installed should be sufficient to provide a skilled worker with an adequate ability to assess the status, operational performance, and health of the equipment under control. Human factors and ergonomic considerations should be included in the instrumentation design.
- An alarm system. A method should be provided to alert the operator to abnormal and dangerous operating conditions.

Provision should be made for independent manual control in the event of a loss of an element of, or the entire control and automation system. The provision should include methods and means of overriding the

automatic controls and interlocks. The instrumentation and control provided should be capable of supporting the manual operation for indefinite periods of time.

4.5.2 Control hierarchy

For ships with more than one control station, a decreasing authority should be assigned according to the following control station locations:

- a) Local controls at the controlled equipment
- b) Control station(s), in the machinery spaces, closest to the controlled equipment
- c) Remote control station(s) outside of machinery spaces
- d) Navigating bridge (or bridge wing) control station

The control station of higher authority should be designed to include a supervisory means for transferring control from a station of lower authority at all times, and to block any unauthorized request from any station of lower authority. A station of higher authority shall be capable of overriding and operating independently of all stations of lower authority. The overriding action when executed should be alarmed at the remote location affected. Transfer of control from one station to another, except for the specific case of override by a station of higher authority, is to be possible only with acknowledgment by the receiving station. When applicable, if the acknowledgement is not received with a defined period of time, revert back to the original control station.

The control function at a control station of higher authority should not depend on the proper functioning of the control station of the lower authority. Remote control of the propulsion machinery is to be possible only from one location at a time. Transfer of control between stations should be accomplished smoothly and control of the controlled equipment should be maintained during the transfer. This transfer should generate an alarm at both stations. Appropriate indications with discriminatory intelligence should be provided at each station, except locally at the controlled equipment, to identify the station in control and any loss of control.

4.5.3 Control, start, stop, and shutdown conditions

The control system should include a means for emergency stopping the navigation bridge propulsion control system. This feature should be independent of the navigation bridge control system.

For remote starting of the propulsion machinery, the control system should include interlocks or permissives that prevent the remote starting of propulsion machinery under conditions that may be hazardous to the machinery or operating personnel, such as turning gear engaged.

An abnormal (non-routine) automatic or emergency shutdown of machinery should be alarmed at all control stations. Restoration of normal operating conditions should be possible only after a manual reset or permissives have been satisfied.

Loss of control from a remote control station or higher level control for any reason, including loss of power, logic failure, or power conditioning failure, should be alarmed at all stations and the system should be designed to continue to operate the plant in the current state until local control is established.

4.6 System design characteristics

Efforts should be taken to minimize the probability of a failure of any one component or device in the control circuit, causing unsafe operation of the machinery. There should be no single points of failure that will disable the control system. Where multiple auxiliaries such as normal and standby are installed for vital services, any single failure should be limited in effect to only one of the auxiliaries, and such failures should not render any reserve automatic or manual control, or both, inoperative.

All electric and electronic devices and components should be suitable or suitably packaged for use in a marine environment, resistant to corrosion, treated for resistance to fungus growth, not affected by shipboard vibration or shock loading, and capable of providing their intended function at typical environmental temperature and humidity levels. All control equipment should be designed to perform satisfactorily without adverse susceptibility to electromagnetic fields, power switching spikes, or other electromagnetic noise that might typically be encountered in the operating environment, or induced on interconnecting cables (see 4.19).

4.7 Control system power supply

Feeders supplying power to the control console should be provided with overload and short-circuit protection. Where circuits are protected by fuses, control system protection should be subdivided and arranged so that failure of one set of fuses will not cause maloperation or failure of other circuits or systems. Isolation of faults should be readily accomplished.

Power for monitoring, alarms, and vital controls should be supplied from an emergency source upon failure of the main power supply. Power conversion equipment, if required by the design, should be of the solid-state type. Power conversion devices should be redundant, arranged to operate in parallel, with any device capable of supplying the full load of all units powered by the system they serve.

Designs in which the control system is isolated into separate sections controlling major equipment and systems that are operated independently of each other may use separate power conversion devices for each section, with one spare, readily interchangeable with any unit.

Individual protective devices should be provided such that activation does not remove both the main and emergency power sources.

4.8 Continuity of control power

The control system should be designed to include an uninterruptible power supply (UPS) that has sufficient capacity to maintain power to the control system for a period sufficient to bring the emergency power generator on line, or if necessary, to safely shut down the equipment. The quality and operation of the UPS supply should be such that the control equipment experiences no disturbance or interruption in power. Nominal capacity should be for a period of not less than 30 min at full rated load with voltage degradation not more than 10% of rated level.

Control and automation systems, including monitoring, alarms, and vital controls should have redundant power supplies.

4.9 Voice and data communication systems

Communications systems for control stations should include voice as a minimum, and may include data, and emergency backup systems.