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IEEE Recommended Practice for Electrical Installations on Shipboard

IEEE Industry Applications Society

Sponsored by the
International Marine Industry Committee



Published by
The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

11 October 2002

Print: SH95035
PDF: SS95035

IEEE Recommended Practice for Electrical Installations on Shipboard

Sponsor

International Marine Industry Committee
of the
IEEE Industry Applications Society

Approved 12 September 2002

IEEE-SA Standards Board

Abstract: Recommendations for the design, selection, and installation of equipment on merchant vessels with electrical apparatus for lighting, signaling, communication, power, and propulsion are provided.

Keywords: marine electrical engineering, marine vessels, shipboard systems, ships

The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

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Print: ISBN 0-7381-3381-7 SH95035
PDF: ISBN 0-7381-3382-5 SS95035

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Introduction

(This introduction is not part of IEEE Std 45-2002, IEEE Recommended Practice for Electrical Installations on Shipboard.)

IEEE Std 45-2002, IEEE Recommended Practice for Electrical Installations on Shipboard, constitutes the chief undertaking of the Marine Transportation Committee of the IEEE Industry Applications Society.

As an IEEE recommended practice, this document provides procedures preferred by IEEE. Following the procedures in this recommended practice does not guarantee safety, and users should take all the reasonable, independent steps necessary to minimize risks to safety.

Due to the differences among the requirements of the various classification societies and the insurance companies regarding electrical installations on shipboard, and the lack of any accepted standard engineering regarding electrical installations on shipboard, and the lack of any accepted standard engineering practice for marine installations, the AIEE^a in 1913 appointed the Marine Committee (now called Marine Transportation Committee) to take up the preparation of standard marine rules. The first edition was prepared covering two important divisions; namely, fire protection requirements and marine construction requirements. They were adopted by the American Bureau of Shipping and published as Section 37 of their Rules for the building and classing of vessels. As the first edition of the rules did not cover the entire field of use of electricity on shipboard, the Marine Committee of the Institute was continued. The recommendations were considerably amplified in the editions issued in 1920, 1927, 1930, 1938, 1940, 1945, 1948, 1951, 1955, 1958, 1962, 1967, 1971, 1977, 1983, and 1998.

This edition updates the 1998 edition. The standard has been reorganized to eliminate duplications and make it easier to use. It includes many significant additions, changes, and deletions to reflect North American and International marine electrical engineering technology and the latest system design, installation, and test practices necessary to ensure safe and reliable operation.

^aIn 1963 the American Institute of Electrical Engineers (AIEE) merged with the Institute of Radio Engineers (IRE) to become the Institute of Electrical and Electronics Engineers, Inc. (IEEE).

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IEEE Recommended Practice for Electrical Installations on Shipboard

1. Overview

1.1 Scope

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.

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.

1.2 Purpose

The main purpose of this recommended practice is to provide a consensus of recommended practices in the unique field of marine electrical engineering as applied specifically to ships, shipboard systems, and equipment.

1.3 Vessel classification

1.3.1 Vessel classification this recommended practice is applicable to

These recommendations have been prepared for application for the following vessels:

- a) Tank vessels—All vessels whose principle purpose is the carrying of combustible or flammable liquid cargo in bulk.

- b) Passenger vessels
 - 1) All vessels of 100 gross tons or more whose principle purpose is the carrying of passengers.
 - 2) Small passenger vessels under 100 gross tons carrying more than 6, but less than 150 passengers, or has overnight accommodations for less than 50 passengers.
 - 3) Small passenger vessels carrying more than 150 passengers or with overnight accommodations for more than 49 passengers.
- c) Cargo and miscellaneous vessels—All vessels carrying freight for hire not covered in other groups, all tugboats and tow boats, all seagoing barges not covered in other groups.
- d) Mobile offshore drilling units (MODU)—A vessel, other than a “mobile inland drilling unit,” which is capable of engaging in drilling or workover operations for the explorations and exploitation of subsea mineral resources. These recommendations apply to all types of MODUs without production facilities, including, but not limited to, semi-submersible units, submersible units, self-elevating or jack-up units, and drillships and tenders.
- e) Mobile inland drilling units (MIDU)—A vessel, other than a “mobile offshore drilling unit,” which is capable of engaging in drilling or workover operations for the exploration or exploitation of subsea mineral resources and is designed and intended for use in U.S. waters, rivers, inland lakes, bays, or sounds. These recommendations apply to all types of MIDU without production facilities, including, but not limited to, inland barges and posted inland barges.
- f) Offshore supply vessels.
- g) Nautical school vessels.
- h) Oceanographic research vessels—All vessels engaged in oceanographic research.
- i) Noncombatant vessels—Including all naval auxiliary ships, military supply vessels, and icebreakers.

1.3.2 Vessel classification and facilities this recommended practice is not applicable to

These recommendations have not been prepared for application for the facilities and vessels listed in item a) item b), and item c) because they are outside the scope of this recommended practice and are covered under national and international standards.

- a) Fixed petroleum facilities.
- b) Floating petroleum facilities—A buoyant facility that is securely and substantially moored so that it cannot be moved without a special effort. The term includes, but is not limited to, tension leg platforms, floating production systems, floating production storage and offloading (FPSO), and spar buoy or deep draft caisson vessel. These types of floating facilities are site-specific and not intended for periodic relocation. Other types of floating facilities include permanently moored semi-submersibles and shipshape hulls. All of these types of floating facilities produce hydrocarbons from the well and process them on board and either store them on board and pump the produced hydrocarbon into a pipeline or directly onto another vessel.
- c) Recreational vessels.

1.4 Documentation

Every vessel should be provided with comprehensive sets of as-built electrical installation drawings and instruction books providing complete and detailed information regarding the operation and maintenance of the systems and equipment. Drawings for each system should provide cable routing information, cable identification, cable sizes, loads, protective device settings, circuit data, conductor termination details, and material lists. Calculation of fault currents with associated overcurrent protective device coordination curves should also be provided. Instruction books should include descriptions and illustrations that provide equipment operating instructions, maintenance procedures, test requirements, and spare parts recommendations. A booklet containing the manufacturer’s name, size, type, rating, catalog number, or similar identification for all electrical and electronic equipment on the vessel should also be provided for use by shipboard personnel. An as-built one-line diagram of the ship’s power generation and distribution system should be permanently installed in a location accessible at all times to the engineering personnel.

1.5 Environmental conditions

1.5.1 Normal design and operating conditions

Systems and equipment should be suitable for continuous operation under the following shipboard conditions:

- a) Exposure to moisture-laden and salt-laden atmosphere, weather, sun, high wind velocities, and ice.
- b) Equipment and systems shall be designed for temperature extremes and conditions expected. Typically, the following conditions can be used: ambient temperature values of 40 °C in accommodation areas, and similar spaces; 45 °C in main and auxiliary machinery spaces; 50 °C for rotating machinery and propulsion equipment in main and auxiliary machinery spaces containing significant heat sources such as prime movers and boilers; and 65 °C in the uptakes of machinery spaces containing prime movers and boilers; all at relative humidities up to 95%. The design value for seawater cooling temperature should be 32 °C.
- c) Roll and pitch of a vessel underway, as shown in Table 1.

Table 1—Roll and pitch requirements

	Roll		Pitch	
	Static (°)	Dynamic (°)	Static (°)	Dynamic (°)
Ship service equipment	15	22.5	5	7.5
Emergency equipment ^a	22.5	22.5	10	10
Switchgear	45	45	45	45

^aIn vessels designed for carriage of liquefied gases and of chemicals, the emergency power installation is to remain operable with the vessel flooded to its permissible athwartship inclination up to a maximum of 30°.

- d) Vibration of a vessel underway: Electrical equipment should be constructed to withstand at least the following:
 - 1) Vibration frequency range of 5–50 Hz with a velocity amplitude of 20 mm/s.
 - 2) Peak accelerations due to ship motion in a seaway of $\pm 5.9 \text{ m/sec}^2$ for ships exceeding 90 m in length, and $\pm 9.8 \text{ m/sec}^2$ for smaller ships, with a duration of 5–10 s.

1.5.2 Abnormal design and operating conditions

Special conditions for a specific ship design or operating arrangement may require special consideration. Examples of such conditions include, but are not necessarily limited to

- Exposure to damaging fumes or vapors, excessive or abrasive dust, steam, salt-spray, ice, sunlight, physical damage, and so on
- Exposure to high levels of shock and vibration
- Exposure to high or low temperatures
- Operation in flammable atmospheres (see Clause 33)
- Exposure to unusual loading or unloading conditions affecting list and trim
- Unusual operating cycles, frequency of operation, poor power quality, special insulation requirements, stringent or difficult maintenance requirements, and so on

1.6 Equipment construction, testing, and certification

Electrical apparatus and equipment should be constructed and tested in accordance with the requirements of appropriate national and international equipment standards. Standards specifically addressing marine requirements should be used whenever applicable. Many appropriate standards are referenced in this document. All electrical equipment should be tested and certified, with labeling and follow-up services (i.e., listed) by a recognized independent laboratory acceptable to the authority having jurisdiction.

1.7 Application of various national and international standards

CAUTION

It is recognized that various national and international standards for equipment and installations are not identical. However, it is recognized that mixing of standards is occasionally necessary. Therefore, the application of any of these standards is the choice of the user, authority having jurisdiction, and classification society.

Special precautions must be exercised when mixing equipment designed to different national and international standards. Coordination of different equipment design and testing standards, construction ratings, installation methods, and performance must be carefully analyzed.

1.8 Materials

1.8.1 Corrosion-resistant parts

Where essential to minimize deterioration due to marine atmospheric corrosion, corrosion-resisting materials, or other materials treated in a satisfactory manner to render them adequately resistant to corrosion, should be used. Silver, corrosion-resisting steel, copper, brass, bronze, copper-nickel, certain nickel-copper alloys, and certain aluminum alloys are considered satisfactory corrosion-resisting materials.

The following treatments, when properly performed and of a sufficiently heavy coating, are considered satisfactory corrosion-resistant treatments:

- Electroplating
- Sherardizing
- Galvanizing
- Dipping and painting (phosphate or suitable cleaning, followed by the application of a coating system) meeting the requirements of ASTM B117-97¹).

These provisions apply to the following components:

- Parts. Interior small parts that are normally expected to be removed in service, such as bolts, nuts, pins, screws, cap screws, terminals, brushholder studs, springs, and so on.
- Assemblies, subassemblies, and other units where necessary due to the unit function, or for interior protection, such as shafts within a motor or generator enclosure, and surface of stator and rotor.

¹Information on references can be found in Clause 2.

- Enclosures and their fastenings and fittings. Enclosing cases for control apparatus, outer cases for signal and communication systems (both outside and inside), and similar items, together with all their fastenings and fittings that would be seriously damaged or rendered ineffective by corrosion.

1.8.2 Flame-retardant materials

Flame-retardant materials and structures should be used to the maximum extent practicable throughout the vessel. These materials should have such fire-resisting properties that they will not convey flame nor continue to burn for longer times than specified in the appropriate flame test.

Compliance with the requirements of the preceding paragraph should be determined with the apparatus and according to the methods described in appropriate nationally recognized test laboratory standards for the materials and structures being considered, unless specific applicable tests are invoked in these recommendations.

1.9 Brittle material

Porcelain or other brittle insulating materials should not be used for bus supports, lamp sockets, receptacles, fuse blocks, and so on, where the material is rigidly fastened by machine screws or equivalent.

2. References

This recommended practice shall be used in conjunction with the following publications. Unless the standard is specifically dated, the current approved edition shall apply.

ANSI/NEMA ICS 1-1993, Industrial Control and Systems General Requirements.²

ANSI/NEMA MG 1-1998, Motors and Generators.

API RP 14F-1999, Design and Installation of Electrical Systems for Fixed and Floating Offshore Petroleum Facilities for Unclassified and Class I, Division 1 and Division 2 Locations.³

API RP 14FZ-2001, Design and Installation of Electrical Systems for Fixed and Floating Offshore Petroleum Facilities for Unclassified and Class 1, Zone 0, Zone 1, Zone 2 Locations.

API RP 500-1997, Classifications of Locations for Electrical Installation at Petroleum Facilities Classified as Class I, Division 1 and Division 2.

API RP 505-1997, Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class I, Zone 0, Zone 1, and Zone 2.

API Std 541, Form-Wound Squirrel-Cage Induction Motors - 250 Horsepower & Larger, 3rd Edition, 1995.

ASTM D-178-2001, Standard Specification for Rubber Insulating Matting.⁴

ASTM B117-97, Standard Practice for Operating Salt Spray (FOG) Apparatus.

²ANSI publications are available from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (<http://www.ansi.org/>).

³API publications are available from the Publications Section, American Petroleum Institute, 1200 L Street NW, Washington, DC 20005, USA (<http://www.api.org/>).

⁴ASTM 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/>).

ASTM D229-96, Standard Test Methods for Rigid Sheet and Plate Materials Used for Electrical Insulation.

ASTM F1003-86 (R1992), Standard Specification for Searchlights on Motor Lifeboats.

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

BS 6883-1999, Specification for Elastomer-Insulated Cables for Fixed Wiring in Ships and on Mobile and Fixed Offshore Units.⁵

CSA C22.2 No. 45, Rigid Metal Conduit.⁶

CSA C22.2 No. 38-1995, Thermoplastic Insulated Wires and Cables; (Gen. Instr. 1).

IEEE Std C37.04™-1999, IEEE Standard Rating Structure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis.^{7, 8}

IEEE Std C37.13™-1990 (Reaff 1995), IEEE Standard for Low-Voltage AC Power Circuit Breakers Used in Enclosures.

IEEE Std C37.20™-1987, Switchgear Assemblies - Including Metal Enclosed Bus.⁹

IEEE Std C37.20.1™-1993 (Reaff 1998), IEEE Standard for Metal-Enclosed Low-Voltage Power Circuit Breaker Switchgear.

IEEE Std C37.20.2™-1999, IEEE Standard for Metal-Clad Switchgear.

IEEE Std C37.20.7™-2000, IEEE Guide for Testing Medium-Voltage Metal-Enclosed Switchgear for Internal Arcing Faults.

IEEE Std C57.13™-1993, IEEE Standard Requirements for Instrument Transformers.

IEEE Std 43™-2000, IEEE Recommended Practice for Testing Insulation Resistance of Rotating Machinery.

IEEE Std 48™-1996, IEEE Standard Test Procedures and Requirements for Alternating-Current Cable Terminations 2.5 kV through 765 kV.

IEEE Std 112™-1996, IEEE Standard Test Procedure for Polyphase Induction Motors and Generators.

IEEE Std 115™-1995, IEEE Guide: Test Procedures for Synchronous Machines, Part I—Acceptance and Performance Testing, Part II-Test Procedures and Parameter Determination for Dynamic Analysis.

IEEE Std 432™-1992, IEEE Guide for Insulation Maintenance for Rotating Electric Machinery (5 hp to less than 10 000 hp).

⁵BS standards are available from Global Engineering Documents, 15 Inverness Way East, Englewood, Colorado 80112, USA (<http://global.ihs.com/>).

⁶CSA publications are available from the Canadian Standards Association (Standards Sales), 178 Rexdale Blvd., Etobicoke, Ontario, Canada M9W 1R3 (<http://www.csa.ca/>).

⁷The IEEE standards or products referred to in Clause 2 are trademarks owned by the Institute of Electrical and Electronics Engineers, Incorporated.

⁸IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (<http://standards.ieee.org/>).

⁹IEEE Std C37.20-1987 has been withdrawn; however, copies can be obtained from Global Engineering, 15 Inverness Way East, Englewood, CO 80112-5704, USA, tel. (303) 792-2181 (<http://global.ihs.com/>).

IEEE Std 444™-1973 (Reaff 1992), Standard Practices and Requirements for Thyristor Converters for Motor Drives, Part 1-Converters for DC Motor Armature Supplies.

IEEE Std 515™-1997, IEEE Standard for the Testing, Design, Installation and Maintenance of Electrical Resistance Heat Tracing for Industrial Applications.

IEEE Std 515.1™-1995, IEEE Recommended Practice for the Testing, Design, Installation, and Maintenance of Electrical Resistance Heat Tracing for Commercial Applications.

IEEE Std 576™-2001, IEEE Recommended Practice for Installation, Termination, and Testing of Insulated Power Cable as Used in the Petroleum and Chemical Industry.

IEEE Std 835™-1994, IEEE Standard Power Cable Ampacity Tables.

IEEE Std 841™-2001, IEEE Standard for Petroleum and Chemical Industry—Severe Duty Totally Enclosed Fan-Cooled (TEFC) Squirrel Cage Induction Motors—Up to and Including 370 kW (500 hp).

IEEE Std 844™-2000, IEEE Recommended Practice for Electrical Impedance, Induction, and Skin Effect Heating of Pipelines and Vessels.

IEEE Std 1202™-1991 (Reaff 1996), IEEE Standard for Flame Testing of Cables for Use in Cable Tray in Industrial and Commercial Occupancies.

IEEE Std 1580™-2001, IEEE Recommended Practice for Marine Cable for Use on Shipboard and Fixed or Floating Platforms.

IES RP-12-1998, Recommended Practice for Marine Lighting.¹⁰

IMO Resolution A.686 (20 January 1992), Code on Alarms and Indicators.¹¹

JIS C3410, Cables and Flexible Cords for Electrical Equipment of Ships.¹²

MIL-PRF-85045F, General Specifications for Cables, Fiber Optics (METRIC).¹³

NES-711 Issue 2, January 1981, Determination of the Smoke Index of the Products of Combustion from Small Specimens of Materials, as modified in MIL-C-24643, paragraph 4.7.27.¹⁴

NFPA 13, Installation of Sprinkler Systems.¹⁵

NFPA 70-2002, National Electrical Code® (NEC®).

NFPA 77-2000, Static Electricity.

¹⁰IES publications are available from CSSinfo, 310 Miller Avenue, Ann Arbor, MI 48103, USA.

¹¹IMO publications are available from the International Maritime Organization, 4 Albert Embankment, London SE1 7SR, United Kingdom.

¹²JIS standards are available from Global Engineering Documents, 15 Inverness Way East, Englewood, Colorado 80112, USA (<http://global.ihs.com/>).

¹³MIL publications are available from Customer Service, Defense Printing Service, 700 Robbins Ave., Bldg. 4D, Philadelphia, PA 19111-5094 (<http://store.mil-standards.com>).

¹⁴NES publications are available from Procurement Executive, Ministry of Defense, Ship Department, Section TE112, Block G, Foxhill, Bath, United Kingdom.

¹⁵NFPA publications are published by the National Fire Protection Association, Batterymarch Park, Quincy, MA 02269, USA (<http://www.nfpa.org/>).

NFPA 72-1999, National Fire Alarm Code.

SOLAS Consolidated Edition, 1997, Consolidated text of the International Convention for the Safety of Life at Sea, 1974, and its Protocol of 1978: articles, annexes and certificates. Incorporating all amendments in effect from 1 July 1997.¹⁶

UL 13-1996, Standard for Safety for Power-Limited Circuit Cables.¹⁷

UL 62-1997, Standard for Safety for Flexible Cord and Fixture Wire.

UL 73-1993, Standard for Safety for Motor-Operated Appliances.

UL 153-2002, Standard for Safety for Portable Electric Luminaries.

UL 197-1993, Standard for Safety for Commercial Electric Cooking Appliances.

UL 347-1993, Standard for Safety for High Voltage Industrial Control Equipment.

UL 399-1993, Standard for Safety for Drinking-Water Coolers.

UL 444-1994, Standard for Safety for Communication Cables.

UL 486A-1991, Standard of Safety for Wire Connectors and Soldering Lugs for Use With Copper Conductors.

UL 489-1996, Standard for Safety for Molded-Case Circuit Breakers, Molded-Case, Switches, and Circuit-Breakers Enclosures.

UL 507-1999, Standard for Safety for Electric Fans.

UL 595-1985, Standard for Safety for Marine Type Electric Lighting Fixtures.

UL 845-1995, Standard for Safety for Motor Control Centers.

UL 891-1998, Standard for Safety for Dead-Front Switchboards.

UL 913-1988, Standard for Intrinsically Safe Apparatus and Associated Apparatus for Use in Class II, and III, Division I, Hazardous Locations.

UL 921-1992, Standard of Safety for Commercial Electric Dishwashers.

UL 924-1995, Standard for Safety for Emergency Lighting and Power Equipment.

UL 1008-1996, Standard of Safety for Transfer Switch Equipment.

UL 1042-1994, Standard of Safety for Electric Baseboard Heating Equipment.

UL 1309-1995, Standard for Safety Marine Shipboard Cable.

¹⁶SOLAS publications are available from the International Maritime Organization, 4 Albert Embankment, London SE1 7SR, United Kingdom.

¹⁷UL standards are available from Global Engineering Documents, 15 Inverness Way East, Englewood, Colorado 80112, USA (<http://global.ihs.com/>).

UL 1278-2000, Standard for Safety for Moveable and Wall- or Ceiling-Hung Electric Room Heaters.

UL 1558-1999, Standard for Safety for Metal-Enclosed Low-Voltage Power Circuit Breakers Switchgear.

UL 1570-1995, Standard for Safety for Fluorescent Lighting Fixtures.¹⁸

UL 1571-1995, Standard for Safety for Incandescent Lighting Fixtures.¹⁹

UL 1572-1995, Standard for Safety for High Intensity Discharge Lighting Fixtures.²⁰

UL 1598-2000, Standard for Safety for Luminaires for Main Use or Reflector Kit Applications.

UL 1651-1997, Standard for Safety for Optical Fiber Cable.

UL 2021-1997, Standard for Safety for Fixed and Location-Dedicated Electric Room Heaters.

UL 2250-1996, Standard for Safety for Instrumentation Tray Cable.

3. Definitions

For the purposes of the recommended practice, the following terms and definitions apply. *The Authoritative Dictionary of IEEE Standards Terms*, Seventh Edition [B31], should be referenced for terms not defined in this clause.

3.1 General

3.1.1 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.

3.1.2 alternating current (ac): A periodic current with an average value over a period of time of zero. (Unless distinctly specified otherwise, the term refers to a current that reverses at regularly recurring intervals of time and that has alternately positive and negative values.)

3.1.3 asynchronous machine: A machine in which the speed of operation is not proportional to the frequency of the system to which it is connected.

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

3.1.5 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.

3.1.6 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.

¹⁸UL 1570-1995 has been withdrawn; however, copies can be obtained from Global Engineering, 15 Inverness Way East, Englewood, CO 80112-5704, USA, tel. (303) 792-2181 (<http://global.ihs.com/>).

¹⁹UL 1571-1995 has been withdrawn; however, copies can be obtained from Global Engineering, 15 Inverness Way East, Englewood, CO 80112-5704, USA, tel. (303) 792-2181 (<http://global.ihs.com/>).

²⁰UL 1572-1995 has been withdrawn; however, copies can be obtained from Global Engineering, 15 Inverness Way East, Englewood, CO 80112-5704, USA, tel. (303) 792-2181 (<http://global.ihs.com/>).

3.1.7 cargo vessel: A vessel that carries bulk, containerized, or roll-on/roll-off 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.

3.1.8 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.)

3.1.9 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.)

3.1.10 direct-current (dc) commutating machine: A machine that comprises a magnetic field excited from a dc source or formed of permanent magnets, an armature, and a commutator connected therewith. Specific types of dc commutating machines are dc generators, motors, synchronous converters, boosters, balancers, and dynamotors.

3.1.11 electric coupling: A device for transmitting torque by means of electromagnetic force in which no mechanical torque contact occurs between the driving and driven members. The slip-type electric coupling has poles excited by direct current on one rotating member, and an armature winding, usually of the double squirrel cage type, on the other rotating member.

3.1.12 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.

3.1.13 embedded temperature detector: A resistance thermometer or thermocouple built into a machine for the purpose of measuring the temperature.

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

3.1.15 frequency converter: A converter using semiconductor devices to vary the output waveform and frequency to a motor as a means of controlling motor speed and or torque.

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

3.1.17 induction machine: An asynchronous ac machine that comprises a magnetic circuit interlinked with two electric circuits, or sets of circuits, rotating with respect to each other and in which power is transferred from one circuit to another by electromagnetic induction. Examples of induction machines are induction generators, induction motors, and certain types of frequency converters and phase converters.

3.1.18 lighters: A short-range cargo-transfer vessel or barge used for ferrying cargo or personnel.

3.1.19 loran: A long-range radio navigational aid of the hyperbolic type whose position lines are determined by the measurement of the difference in the time of arrival of synchronized pulses. (These devices are rapidly being replaced by satellite-based global positioning systems.)

3.1.20 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.

3.1.20.1 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.

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

3.1.21 manual bus transfer (MBT) switch: Non-self-acting equipment for transferring one or more load conductor connections from one power source to another.

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

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

3.1.24 reactance: The imaginary component ($\pm j$, or $\pm 90^\circ$ phase angle) of impedance, where resistance is the real component with a zero phase angle. Reactance appears in two forms, one as a capacitive reactance (X_c) for a capacitor (C), and the other as inductive reactance (X_l) for an inductor (L). The former has the negative 90° phase angle, and the latter a positive 90° angle. Their values can be expressed in the following relationships:

$$X_c = \frac{1}{2\pi fC}$$

and

$$X_l = 2\pi fL$$

where f is the excitation frequency.

3.1.25 reactor: A device with the primary purpose of introducing reactance into an electric circuit for purposes such as motor starting, paralleling transformers, and control of current.

3.1.26 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.

3.1.27 single-phase circuit: A circuit energized by a single alternating electromotive force.

NOTE—A single-phase circuit is usually supplied through two conductors. The currents in these two conductors, counted outward from the source, differ in phase by 180° or a half-cycle.

3.1.28 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

3.1.29 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.

3.1.30 synchronous machines: A machine in which the average speed of normal operation is exactly proportional to the frequency of the system to which it is connected.

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

3.1.32 three-phase circuit: A combination of circuits energized by alternating electromotive forces that differ in phase by one-third of a cycle (120°).

NOTE—In practice, the phases may vary several degrees from the specified angle.

3.2 Cable installation

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

3.2.2 multicable penetrator: A device consisting of multiple nonmetallic cable seals assembled in a surrounding metal frame, for insertion in openings in decks, bulkheads, or equipment enclosures and through which cables may be passed to penetrate decks or bulkheads or to enter equipment without impairing their original fire or watertight integrity.

3.3 Generators

3.3.1 brushless exciter: An ac (rotating armature type) exciter whose output is rectified by semiconductor devices to provide excitation to an electric machine. The semiconductor devices are mounted on, and rotate with, the ac exciter armature.

3.3.2 brushless synchronous machine: A synchronous machine that has a brushless exciter with its rotating armature and semiconductor devices on a common shaft with the field of the main machine. This type of machine has no collector, commutator, or brushes.

3.3.3 compound-wound generator: A dc generator that has two separate field windings. One supplies the predominating excitation and is connected in parallel with the armature circuit. The other supplies only partial excitation and is connected in series with the armature circuit. It is proportioned to require an equalizer connection for satisfactory parallel operation.

3.3.4 electric generator: A machine that transforms mechanical power into electric power.

3.3.5 exciter: The source of all or part of the field current for the excitation of an electric machine.

3.3.6 homopolar generator: A dc generator in which the magnetic field flux passes in the same direction from one member to the other over the whole of a single air gap area. Characteristically, the machines are high-current, low-voltage generators.

3.3.7 induction generator: An induction machine driven above synchronous speed by an external source of mechanical power.

3.3.8 inductor-type synchronous generator: A generator in which the field coils are fixed in magnetic position relative to the armature conductors. The electromotive forces are produced by the movement of masses of magnetic material.

3.3.9 permanent magnet generator: An electric generator in which the magnetic flux is provided by one or more pairs of permanent magnets.

3.3.10 pilot exciter: The source of all or part of the field current for the excitation of another exciter.

3.3.11 polyphase synchronous generator: A generator whose field circuits are arranged so that two or more symmetrical alternating electromotive forces with definite phase relationships are produced at the terminals. They are usually two-phase, producing two electromotive forces displaced 90 electrical degrees apart, or three-phase, producing three electromotive forces displaced 120 electrical degrees apart. (They are used for marine services and are generally three phase.)

3.3.12 shunt-wound generator: A dc generator in which the entire field excitation is ordinarily derived from one winding consisting of many turns with a relatively high resistance. This winding is connected in parallel with the armature circuit in a self-excited generator. In a separately excited generator, the winding is connected to the load side of another generator or another dc source.

3.3.13 single-phase synchronous generator: A generator that produces a single alternating electromotive force at its terminals. It delivers electric power that pulsates at double frequency.

3.3.14 stabilized shunt-wound generator: Same as the shunt-wound type, except that a series field winding is added. The series field winding is proportioned such that it does not require equalizers for satisfactory parallel operation. The voltage regulation of this type of generator should be the same as shunt-wound generators.

3.3.15 synchronous generator: A synchronous ac machine that transforms mechanical power into electric power. (A synchronous machine is one in which the average speed of normal operation is exactly proportional to the frequency of the system to which it is connected.)

3.3.16 variable speed constant frequency generator (VSCF): An ac generator designed to have a constant frequency output with a variable speed input. This may be accomplished with an induction generator having an ac/ac converter feedback circuit that excites the wound rotor at a frequency to produce a constant frequency output. This may also be accomplished by a synchronous generator whose variable output frequency is fed into a frequency changer that produces a constant output frequency. Basic frequency changers may be of the cycloconverter or dc link type.

3.4 Motors

3.4.1 adjustable-speed motor: A motor whose speed can be varied gradually over a range of speeds, but when once adjusted remains practically unaffected by the load, such as a dc shunt-wound motor with field resistance control designed for a range of speed adjustments.

3.4.2 adjustable-varying-speed motor: A motor whose speed can be adjusted gradually, but when once adjusted for a given load will vary with change in load, such as a dc compound-wound motor adjusted by field control or a wound-rotor induction motor with speed control.

3.4.3 amortisseur winding: A permanently short-circuited winding used for starting induction motors consisting of conductors embedded in the pole shoes of a synchronous machine and connected together at the ends of the poles, but not necessarily connected between poles.

3.4.4 base speed of an adjustable-speed motor: The lowest speed obtained at rated load and rated voltage at the specified temperature rise.

3.4.5 breakdown torque: The maximum torque a motor will develop, with rated voltage applied at rated frequency, without an abrupt drop in speed.

3.4.6 compound-wound motor: A dc motor that has two separate field windings: one, usually the predominating field, connected in parallel with the armature circuit, and the other connected in series with the armature circuit. Speed and torque characteristics are between those of shunt and series motors.

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

3.4.8 electric motor: A machine that transforms electric power into mechanical power.

3.4.9 induction motor: A polyphase ac motor in which the secondary field current is created solely by induction. The motor operates at less than synchronous speed and less than unity power factor. The operating speed is dependent on the frequency of the power source. It is generally the motor of choice for auxiliary drives.

3.4.10 intermittent duty: A requirement of service that demands operation for alternate periods: load and no load, load and rest, or load, no load, and rest, as specified.

3.4.11 locked-rotor torque: The minimum torque of a motor developed for all angular positions of the rotor, when at rest, and with rated voltage and frequency applied.

3.4.12 motor reduction unit: A motor with an integral mechanical means of obtaining a speed different from the speed of the motor.

NOTE—Motor reduction units are usually designed to obtain a speed lower than that of the motor, but they may also be built to obtain a speed higher than that of the motor.

3.4.13 multispeed motor: A motor that can be operated at any one of two or more definite speeds, each being practically independent of the load. For example, a dc motor with two armature windings, or an induction motor with windings capable of various pole groupings.

3.4.14 pull-out torque: The maximum sustained torque that a synchronous motor will develop at synchronous speed with rated voltage applied at rated frequency and with normal excitation.

3.4.15 series-wound motor: A dc motor in which the field circuit and armature circuit are connected in series. Speed is inversely proportional to the square root of load torque. Motor operates at a much higher speed at light load than at full load.

3.4.16 shunt-wound motor: A dc motor in which the field circuit is connected either in parallel with the armature circuit or to a separate source of excitation voltage.

3.4.17 squirrel-cage induction motor: A motor in which the secondary circuit consists of a squirrel-cage winding suitably disposed in slots in the secondary core.

3.4.18 squirrel-cage winding: A permanently short-circuited winding, usually uninsulated (primarily used in induction machines), having its conductors uniformly distributed around the periphery of the machine and joined by continuous end rings.

3.4.19 stabilized shunt-wound motor: A shunt-wound motor that has a light series winding added to prevent a rise in speed, or to obtain a slight reduction in speed, with increase of load.

3.4.20 synchronous motor: A polyphase ac motor with separately supplied dc field and an auxiliary (amortisseur) winding for starting purposes. The operating speed is fixed by the frequency (f) of the system and the number of poles (p) of the motor. (Synchronous speed (r/min) = $120 f/p$). Thus, the speed of the motor can be varied by varying the frequency of the power source. The synchronous motor generally operates at unity power factor and can be used to improve the system power factor. It is generally the motor of choice for ac propulsion systems.

3.4.21 torque margin: The increase in torque above rated torque to which a motor may be subjected without the motor pulling out of step. This is of particular concern with electric propulsion systems.

3.4.22 universal motor: A series-wound or a compensated series-wound motor designed to operate at approximately the same speed and output on either a direct- or single-phase alternating current of a frequency not greater than 60 Hz and of approximately the same rms voltage.

3.4.23 varying-speed motor: A motor whose speed varies with the load, ordinarily decreasing when the load increases, such as a series-wound or repulsion motor.

3.4.24 wound-rotor induction motor: An induction motor in which the secondary circuit consists of polyphase winding or coils whose terminals are either short-circuited or closed through suitable circuits. (When provided with collector or slip rings, it is also known as a slip-ring induction motor.)

3.5 Converters

3.5.1 adjustable speed drive: A converter using controlled rectifier or transistor devices that has the capability of adjusting the frequency and proportional voltage of the output waveform to provide speed control of motors.

3.5.2 direct-current balancer: A machine that comprises two or more similar dc machines (usually with shunt or compound excitation) directly coupled to each other and connected in series across the outer conductors of a multiple wire system of distribution, for the purpose of maintaining the potentials of the intermediate conductors of the system, which are connected to the junction points between the machines.

3.5.3 dynamotor: A form of converter that combines both motor and generator action, with one magnetic field and with two armatures or with one armature having separate windings.

3.5.4 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.

3.5.5 power inverter: A component for converting dc power into ac power.

3.5.6 rectifier: A component for converting ac to dc by inversion or suppression of alternate half-cycles.

3.5.7 static converter/inverter: A unit that employs solid state devices such as semiconductor rectifiers or controlled rectifiers (thyristors), gated power transistors, electron tubes, or magnetic amplifiers to change ac power to dc power, dc power to ac power, or fixed-frequency ac power to variable-frequency ac power.

3.5.8 synchronous converter: A converter that combines both motor and generator action in one armature winding and is excited by one magnetic field. It is normally used to change ac power to dc power, or to create an isolated ac power source.

3.6 Rotating machine ventilation

3.6.1 enclosed self-ventilated machine: A machine that has openings for the ventilating air circulated by means integral with the machine, the machine being otherwise totally enclosed. These openings are so arranged that inlet and outlet ducts or pipes may be connected.

3.6.2 enclosed separately ventilated machine: A machine that has openings for ventilating air circulated by means external to and not a part of the machine, the machine being otherwise totally enclosed. These openings are so arranged that inlet and outlet duct pipes may be connected to them.

3.6.3 open machine: A machine that has ventilating openings that permit passage of external cooling air over and around the windings.

3.6.4 self-ventilated machine: A machine that has its ventilating air circulated by means integral with the machine.

3.6.5 separately ventilated machine: A machine that has its ventilating air supplied by an independent fan or blower external to the machine.

3.6.6 totally enclosed fan-cooled machine (TEFC): A totally enclosed machine equipped for exterior cooling by means of a fan or fans integral with the machine but external to the enclosing parts.

3.6.7 totally enclosed nonventilated machine (TENV): A machine enclosed to prevent the free exchange of air between the inside and outside of the case, but not sufficiently enclosed to be airtight.

3.6.8 totally enclosed water/air cooled machine (TEWAC): A totally enclosed machine with integral water-to-air heat exchanger and internal fan to provide closed-loop air cooling of the windings.

3.7 Equipment enclosures

NOTE—NEMA enclosure-type designations are indicated in parentheses, [e.g., (NEMA 1)]. See Annex C for additional information.

3.7.1 dripproof enclosure: An enclosure in which the openings are so constructed that drops of liquid or solid particles falling on the enclosure at any angle not greater than 15° from the vertical either cannot enter the enclosure, or if they do enter the enclosure, they will not prevent the successful operation of, or cause damage to, the enclosed equipment (NEMA 2 or 12).

NOTE—See Annex C for further information on IP enclosures.

3.7.2 dustproof enclosure: An enclosure so constructed or protected that any accumulation of dust that may occur within the enclosure will not prevent the successful operation of, or cause damage to, the enclosed equipment (NEMA 5).

3.7.3 dusttight enclosure: An enclosure constructed so that dust cannot enter (NEMA 5 or NEMA 12).

3.7.4 explosionproof enclosure: An enclosure designed and constructed to withstand an explosion of a specified flammable gas or vapor that may occur within it, and to prevent the ignition of flammable gas or vapor in the atmosphere surrounding the enclosure by sparks, flashes, or explosions of the specified gas or vapor that may occur within the enclosure.

NOTE—Explosionproof apparatus should bear a nationally recognized independent testing laboratory approval rating of the proper class and group consonant with the spaces in which flammable volatile liquids, flammable gases, mixtures, or highly flammable substances may be present. See Annex A.

3.7.5 general-purpose enclosure: An enclosure that primarily protects against accidental contact and slight indirect splashing but is neither dripproof nor splashproof (NEMA 1).

3.7.6 guarded enclosure: An enclosure in which all openings giving direct access to live or rotating parts (except smooth rotating surfaces) are limited in size by the structural parts or by screens, baffles, grilles, expanded metal, or other means to prevent accidental contact with hazardous parts. The openings in the enclosure shall be such that they will not permit the passage of a rod larger than 12 mm in diameter, except where the distance of exposed live parts from the guard is more than 102 mm; then, the openings may be of such shape as not to permit the passage of a rod larger than 19 mm in diameter (NEMA 1).

3.7.7 oilproof enclosure: An enclosure constructed so that oil vapors, or free oil not under pressure, that may accumulate within the enclosure will not prevent successful operation of, or cause damage to, the enclosed equipment (NEMA 13).

3.7.8 oiltight enclosure: An enclosure constructed so that oil vapors or free oil not under pressure, which may be present in the surrounding atmosphere, cannot enter the enclosure (NEMA 13).

3.7.9 semi-guarded enclosure: An enclosure in which all of the openings, usually in the top half, are protected as in the case of a “guarded enclosure,” but the others are left open (NEMA 1).

3.7.10 splashproof enclosure: An enclosure in which the openings are so constructed that drops of liquid or solid particles falling on the enclosure or coming toward it in a straight line at any angle not greater than 100° from the vertical cannot enter the enclosure either directly or by striking and running along a surface.

3.7.11 submersible enclosure: An enclosure constructed so that the equipment within it will operate successfully when submerged in water under specified conditions of submergence depth and time (NEMA 6P).

3.7.12 waterproof enclosure: An enclosure constructed so that any moisture or water leakage that may occur into the enclosure will not interfere with its successful operation. In the case of motor or generator enclosures, leakage that may occur around the shaft may be considered permissible provided it is prevented from entering the oil reservoir and provision is made for automatically draining the motor or generator enclosure.

3.7.13 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 4 or 4X).

3.8 Control apparatus and switchgear

3.8.1 across-the-line starter: A device that connects the motor to the supply without the use of a resistance or autotransformer to reduce the voltage. It may consist of a manually operated switch or a master switch, which energizes an electromagnetically operated contactor.

3.8.2 automatic starter: A starter in which the influence directing its performance is automatic.

3.8.3 autotransformer starter: A starter that includes an autotransformer to furnish a reduced voltage for starting a motor. It includes the necessary switching mechanism and is frequently called a compensator or autostarter.

3.8.4 circuit breaker interrupting rating (rated short-circuit current): For an unfused circuit breaker, the designated limit of available (prospective) current at which the circuit breaker is required to perform its short-circuit current duty cycle at rated maximum voltage under the prescribed test conditions. This current is expressed as the rms symmetrical value envelope at a time half-cycle after short-circuit is initiated. (For dc breakers, the rated interrupting current is the maximum value of direct current.)

3.8.5 constant-torque resistor: A resistor for use in the armature or rotor circuit of a motor in which the current remains practically constant throughout the entire speed range.

3.8.6 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.

3.8.7 electric controller: A device (or group of devices) that serves to govern, in some predetermined manner, the electric power delivered to the apparatus to which it is connected.

3.8.8 fan duty resistor: A resistor for use in the armature or rotor circuit of a motor in which the current is approximately proportional to the speed of the motor.

3.8.9 full magnetic controller: An electric controller having all of its basic functions performed by devices that are operated by electromagnets.

3.8.10 indicating circuit: That portion of the control circuit of a control apparatus or system that carries the results of logic functions to visual or audible devices that indicate the state of the apparatus controlled.

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

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

3.8.13 metal-clad switchgear: A switchgear assembly that contains medium voltage, withdrawable, electrically operated power circuit breakers. Barriers and shutters are required when the circuit breakers are withdrawn. Insulated bus is required throughout. This assembly requires the separation of each compartment per circuit using grounded metal barriers. These compartments include the circuit breaker, main bus, cable termination, voltage transformers, and low-voltage wiring areas. Voltage ratings covered by this equipment are from 1.01 to 38.0 kV.

NOTE—For additional information, see IEEE Std C37.20.2-1999 or IEC 60298.

3.8.14 metal-enclosed switchgear: A switchgear assembly completely enclosed on all sides and the top with metal (except for ventilating openings and inspection windows) containing primary power circuit switching or interrupting devices, or both, with buses and connections. The assembly may include control and auxiliary devices. Doors, removable covers, or both are provided for access to the interior of the enclosure.

NOTE—For additional information, see IEEE Std C37.20-1987, IEC 60298, or IEC 60947 as applicable.

3.8.15 metal-enclosed low-voltage power circuit breaker switchgear: A switchgear assembly that contains either stationary or withdrawable low-voltage power circuit breakers in grounded metal compartments. The assembly contains bus and connections and may include auxiliary devices. It is rated for use on low-voltage systems with a maximum rating of 635 V ac (ANSI) or 1000 V ac (IEC).

NOTE—For additional information, see IEEE Std C37.20.1-1993 or IEC 60947.

3.8.16 motor control center (MCC): A group of devices assembled for the purpose of switching and protecting a number of load circuits. The control center may contain transformers, contactors, circuit breakers, protective, and other devices intended primarily for energizing or deenergizing load circuits.

3.8.17 molded-case circuit breaker: A circuit breaker assembled as an integral unit in a supporting and enclosing housing of insulating material; the overcurrent and tripping means being of the thermal type, the magnetic type, the electronic type, or a combination thereof.

3.8.18 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.

3.8.19 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.

3.8.20 rated continuous current: The designed limit in rms amperes or dc amperes that a switch or circuit breaker will carry continuously without exceeding the limit of observable temperature rise.

3.8.21 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.)

3.8.22 semimagnetic controller: An electric controller having only part of its basic functions performed by devices that are operated by electromagnets.

3.8.23 solid-state controller: An electric controller that utilizes a static power converter as the primary switching device.

3.8.24 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.)

3.8.25 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.

3.8.26 temperature-compensated overload relay: A device that functions at any current in excess of a predetermined value essentially independent of the ambient temperature.

3.8.27 undervoltage 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.

3.8.28 undervoltage 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.

3.9 Insulation system

An assembly of insulating materials in a particular type of equipment. The class of the insulation system may be designated by letters, numbers, or other symbols. An insulation system class utilizes material having an appropriate temperature index and operates at such temperatures above stated ambient temperatures as the equipment standard specifies based on experience or accepted test data. The system may alternatively contain materials of any class, provided that experience or a recognized test procedure for the equipment has demonstrated equivalent life expectancy.

3.10 Types of circuits and terms

3.10.1 appliance branch circuit: A circuit that supplies energy to one or more outlets to which appliances are connected. These circuits have no permanently connected lighting fixtures that are not a part of an appliance.

3.10.2 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.

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

3.10.4 communication and electronics circuits: Electrical circuits supplying equipment and systems for voice, sound, or data transmission, such as telephone, engine order telegraph, data communication, interior communication, paging systems, wired music systems, fire and general alarm systems, smoke and fire detection systems, closed circuit television, navigational equipment, and microprocessor-based automated alarm and control systems.

3.10.5 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.

3.10.6 demand factor: The ratio of the operating load demand of a system or part of a system to the total connected load of the system or part of the system under consideration.

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

3.10.8 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.

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

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

3.10.11 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.)

3.10.12 intrinsically safe circuit: A circuit in which any spark or thermal effect is incapable of causing ignition of a mixture of flammable or combustible material in air under prescribed test conditions. Test conditions generally consider opening, shorting, grounding, or field wiring, along with failures in the circuit. (See UL 913-1988 for specific information on test conditions.)

3.10.13 lighting branch circuit: A circuit that supplies energy to lighting outlets. A lighting branch circuit may also supply portable desk or bracket fans, small heating appliances, motors of 190 W and less, and other portable apparatus of not over 600 W each.

3.10.14 lighting outlet: An outlet intended for the direct connection of a lamp holder or a lighting fixture.

3.10.15 motor branch circuit: A branch circuit that supplies energy to one or more motors and associated motor controllers.

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

3.10.17 power (or ship service) switchboard: A switchgear and control assembly that receives energy from the main generating plant and distributes directly or indirectly to all equipment supplied by the generating plant.

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

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

3.10.20 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.

3.11 Automatic or centralized control systems

3.11.1 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.

3.11.2 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.

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

3.11.4 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.

3.11.5 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.

NOTE—Typical failsafe states are listed in Table 2.

Table 2—Typical failsafe states

System or component	Preferred 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

3.11.6 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.

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

4. Power system characteristics

4.1 Standard systems

The following distribution systems are recognized as standard:

- a) Two-wire with single-phase ac or dc
- b) Three-wire with single-phase ac or dc
- c) Three-phase, three-wire ac
- d) Three-phase, four-wire ac

4.2 Standard voltages

The following voltages are recognized as standard, as shown in Table 3.

Table 3—Standard voltages

Standard	AC (V)	DC (V)
Power utilization	115-200-220-230-350- 440-460-575-660-2300- 3150-4000-6000- 10600-13200	115 and 230
Power generation	120-208-230-240-380- 450-480-600-690-2400- 3300-4160-6600- 11000-13800	120 and 240

4.3 Standard frequency

For ac lighting and power systems, 50 Hz and 60 Hz are standard frequencies.

4.4 Selection of voltage and system type

For small vessels having minimal power apparatus (up to 15 kW), 120-V, three-phase or single-phase generators may be used, with 115-V, three-phase or single-phase distribution for power and lighting. Single-phase lighting feeders should be balanced at the switchboard to provide approximately equal load on the three-phase system.

For intermediate-size vessels with power apparatus (up to 100 kW), generators may be 230-V, three-phase or 240-V, three-phase; the power utilization at 220 V or 230 V three-phase, respectively; and lighting distribution at 120-V, three-phase, three-wire or 208/120-V three-phase, four-wire. Power and lighting utilization should be at 200/115 V, three-phase.

For large vessels of a size and type that require a dual-voltage system (two systems isolated by transformers operating at different voltages), first consideration should be given to 450-V, 480-V, 600-V, or 690-V generation with power utilization at 440 V, 460 V, 575 V, or 660 V, respectively, and lighting distribution at 120-V or 230-V three-phase, three-wire or 120/208-V, three-phase, four-wire.

For vessels having a very large electrical system requiring higher voltage power generation, consideration should be given to generating at 13,800 V, 11,000 V, 6600 V, 4160 V, 3300 V, or 2400 V with some power utilization at 13,200 V, 10,600 V, 6000 V, 4000 V, 3150 V, or 2300 V, three-phase, respectively, with lower utilization voltages to be derived from transformers.

For vessels requiring dc power generation, and having little power apparatus, 120-V dc generators are recommended with a 115-V dc lighting and power distribution system. Where an appreciable amount of dc power apparatus is provided, 240/120-V dc, three-wire generators and 230-V dc power distribution system and 230/115-V dc three-conductor lighting feeders may be selected. Branch circuits from lighting panelboards should be 115-V dc two-wire.

4.5 AC power system characteristics

Power distribution systems should maintain the system characteristics described in Table 4 under all operating conditions. Power-consuming equipment should operate satisfactorily under the conditions described in Table 4, and it should be designed to withstand the power interruption, transient, electromagnetic interference (EMI), radio frequency interference (RFI), and insulation resistance test conditions inherent in the system. Power-consuming equipment requiring a nonstandard voltage or frequency for successful operation should have integral power conversion capability. Power-consuming equipment should not have inherent characteristics that degrade the power quality of the supply system described in Table 4.

Table 4—Alternating current (ac) power characteristics

Characteristics	Limits
Frequency	
a) Nominal frequency	50/60 Hz
b) Frequency tolerances	$\pm 3\%$
c) Frequency modulation	$\frac{1}{2}\%$
d) Frequency transient:	
1) Tolerance	$\pm 4\%$
2) Recovery time	2 s
e) The worst-case frequency excursion from nominal frequency resulting from item b), item c), and item d) 1) combined, except under emergency conditions	5 $\frac{1}{2}\%$

Table 4—Alternating current (ac) power characteristics (continued)

Characteristics	Limits
Voltage a) User voltage tolerance: 1) Average of the three line-to-line voltages 2) Any one line-to-line voltage, including item a) 1) and line voltage unbalances item b) b) Line voltage unbalance c) Voltage modulation d) Voltage transient: 1) Voltage transient tolerances 2) Voltage transient recovery time e) Voltage spike (peak value includes fundamental) f) The maximum departure voltage resulting from item a) 1) and item d) combined, except under transient or emergency conditions g) The worst-case voltage excursion from nominal user voltage resulting from item a) 1), item a) 2), and item d) 1) combined, except under emergency conditions	$\pm 5\%$ $\pm 7\%$ 3% 5% $\pm 16\%$ 2 s $\pm 2500\text{ V (380-600 V) system}$ $1000\text{ V (120-240 V) system}$ $\pm 6\%$ $\pm 20\%$
Waveform voltage distortion^a a) Maximum total harmonic distortion b) Maximum single harmonic c) Maximum deviation factor	5% 3% 5%
Emergency conditions a) Frequency excursion b) Duration of frequency excursion c) Voltage excursion d) Duration of voltage excursion: 1) Lower limits (-100%) 2) Upper limit ($+35\%$)	$-100\text{ to }+12\%$ Up to 2 min $-100\text{ to }+35\%$ Up to 2 min 2 min

Table 4—Alternating current (ac) power characteristics *(continued)*

Characteristics	Limits
Definitions:	
a) Frequency	
1) Nominal frequency: The designated frequency in Hertz.	
2) Frequency tolerance: The maximum permitted departure from nominal frequency during normal operation, excluding transient and cyclic frequency variations. It includes variations caused by load changes, environment (temperature, humidity, vibration, inclination), switchboard meter error, and drift. Tolerances are expressed in percentage of nominal frequency.	
3) Frequency modulation: The permitted periodic variation in frequency during normal operation that might be caused by regularly and randomly repeated loading. For purposes of definition, the periodicity of frequency modulation should be considered as not exceeding 10 s.	
$\text{Frequency Modulation (\%)} = \frac{\{f_{\text{maximum}} - f_{\text{minimum}}\}}{\{2 \times f_{\text{nominal}}\}} \times 100$	
4) Frequency transient tolerance: A sudden change in frequency that goes outside the frequency tolerance limits, returns to, and remains inside these limits within a specified recovery time after initiation of the disturbance. Frequency transient tolerance is in addition to frequency tolerance limits.	
5) Frequency transient recovery time: The time period from the start of the disturbance until the frequency recovers and remains within frequency tolerance limits.	
b) Voltage	
1) User voltage tolerance: The maximum permitted departure from nominal user voltage during normal operation, excluding transient and cyclic voltage variations. It includes variations such as those caused by load changes, environment (temperature, humidity, vibration, inclination), switchboard meter error, and drift.	

Table 4—Alternating current (ac) power characteristics *(continued)*

Characteristics	Limits
2) Line voltage unbalance tolerance (three-phase system): The difference between the highest and lowest line-to-line voltages. $\text{Line Voltage Unbalance Tolerance (\%)} = \frac{\{E_{\text{maximum}} - E_{\text{minimum}}\}}{\{E_{\text{nominal}}\}} \times 100$ 3) Voltage modulation (amplitude): The periodic voltage variation (peak to valley) or the user voltage that might be caused by regularly or randomly repeated pulsed loading. The periodicity or voltage modulation is considered to be longer than 1 Hz and less than 10 s. Voltages used in the following equation shall be all-peak or all-rms: $\text{Voltage Modulation (\%)} = \frac{\{E_{\text{maximum}} - E_{\text{minimum}}\}}{\{2 \times E_{\text{nominal}}\}} \times 100$ 4) Voltage transient i) Voltage transient tolerance: A sudden change (excluding spikes) in voltage that goes outside the user voltage tolerance limits and returns to and remains within these limits within a specified recovery time longer than 1 ms after the initiation of the disturbance. The voltage transient tolerance is in addition to the user voltage tolerance limits. ii) Voltage transient recovery time: The time elapsed from initiation of the disturbance until the voltage recovers and remains within the user voltage tolerance limits. 5) Voltage spike: A voltage change of very short duration (less than 1 ms).	
c) Waveform 1) Total Harmonic Distortion (THD) (of a sine wave): The ratio in percentage of the rms value of the residue (after elimination of the fundamental) to the rms value of the fundamental. 2) Single Harmonic (of a sine wave): The ratio in percentage of the rms value of that harmonic to the rms value of the fundamental. 3) Deviation Factor (of a sine wave): The ratio of the maximum difference between corresponding ordinates of the wave and of the equivalent sine wave to the maximum ordinate of the equivalent sine wave when the waves are superimposed in such a way that they make the maximum difference as small as possible. $\text{Derivation factor (\%)} = \frac{\{\text{maximum deviation}\}}{\{\text{maximum ordinate of the equivalent sine wave}\}} \times 100$ d) Emergency conditions 1) A situation or occurrence of a serious nature that may result in electrical power system interruptions or deviations, such as the occurrence of ship service generator failure and the emergency generator coming on line.	

^aFor ships with electric propulsion or other adjustable speed drive loads, higher voltage distortion can be accepted on a dedicated power bus if the equipment connected to the dedicated power bus is designed and tested for the actual conditions.

4.6 Power quality and harmonics

Solid state devices such as motor controllers, computers, copiers, printers, and video display terminals produce harmonic currents. These harmonic currents may cause additional heating in motors, transformers, and cables. The sizing of protective devices should consider the harmonic current component. Harmonic currents in nonsensically current waveforms may also cause EMI and RFI. EMI and RFI may result in interference with sensitive electronics equipment throughout the vessel.

Isolation, both physical and electrical, should be provided between electronic systems and power systems that supply large numbers of solid state devices, or significantly sized solid state motor controllers. Active or passive filters and shielded input isolation transformers should be used to minimize interference. Special care should be given to the application of isolation transformers or filtering as the percentage of power consumed by solid state power devices compared with the system power available increases. Small units connected to large power systems exhibit less interference on the power source than do larger units connected to the same source. Solid state power devices of vastly different sizes should not share a common power circuit. Where kilowatt ratings differ by more than 5 to 1, the circuits should be isolated by a shielded distribution system transformer. Surge suppressors or filters should only be connected to power circuits on the secondary side of the equipment power input isolation transformers.

To reduce the effects of radiated EMI, special considerations on filtering and shielding should be exercised when main power switchboards and propulsion motor drives are installed in the same shipboard compartment as ship service switchboards or control consoles.

IEEE Std 519™-1992 provides additional recommendations.

5. Power system design

5.1 General

For the purposes of this document, distribution will include all electrical devices after the switchboard load terminals and before the electrical load power terminals. A distribution system includes, but is not limited to, all power transformers, automatic bus transfer switches, motor control centers, load centers, distribution panels, controllers, feeders, and branch circuits. The distribution system does not include generators, switchboards, and electrical loads.

Shipboard electrical systems may have distribution systems for power, lighting, interior communications, and control systems. Electrical systems can be fed from the ship service generators, emergency generators, or a combination of both. Power for normal lighting should be distributed from the ship's service switchboard. Power for emergency lighting, interior communications, and electronics systems feeders should be distributed from the emergency switchboard. Alternatively, interior communications and electronics systems providing vital services may be supplied utilizing dual feeders via an ABT system from the ship's service and emergency switchboards. (See Figure 1, Figure 2, Figure 3, and Figure 4.)

Where more than one power source (generator and or shore power) is available and the sources are not intended to operate in parallel, a mechanical or electrical interlock to prevent paralleling should be provided.

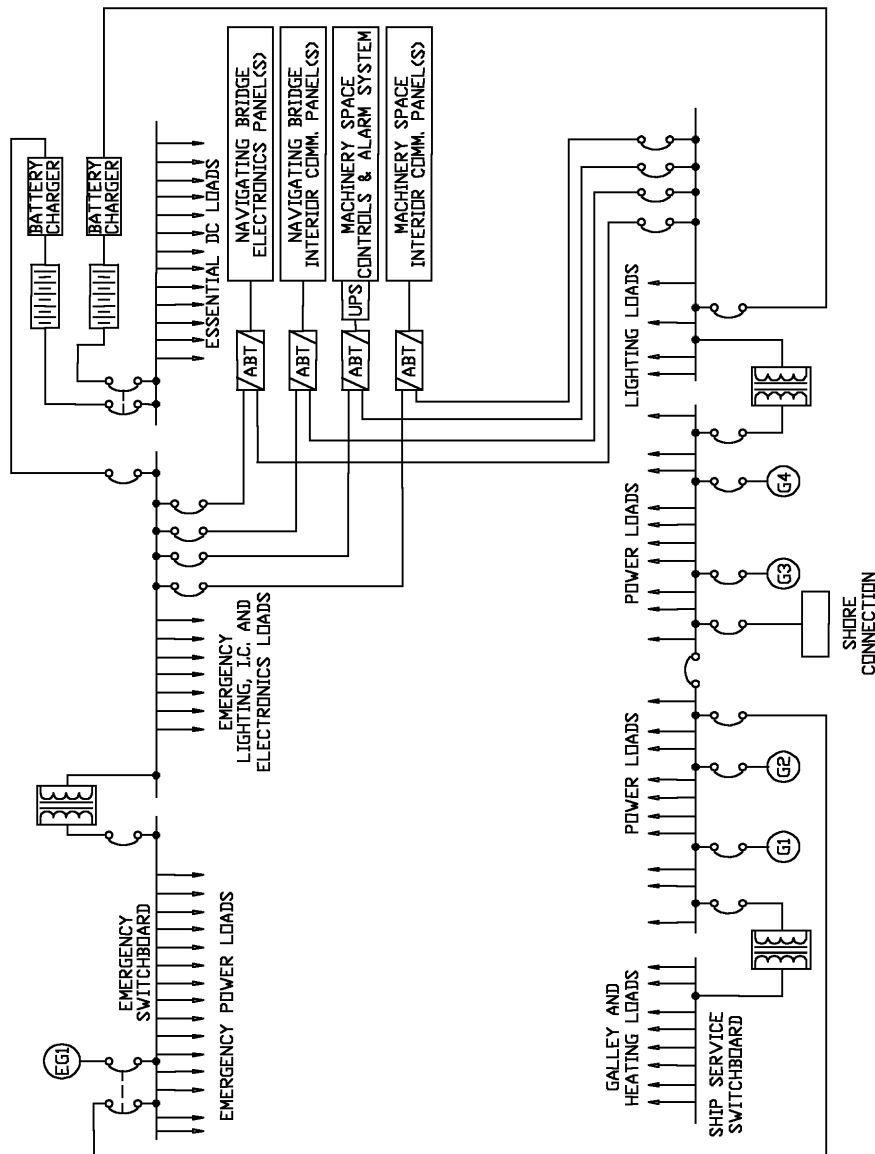


Figure 1—Typical electric plant configuration—cargo vessels

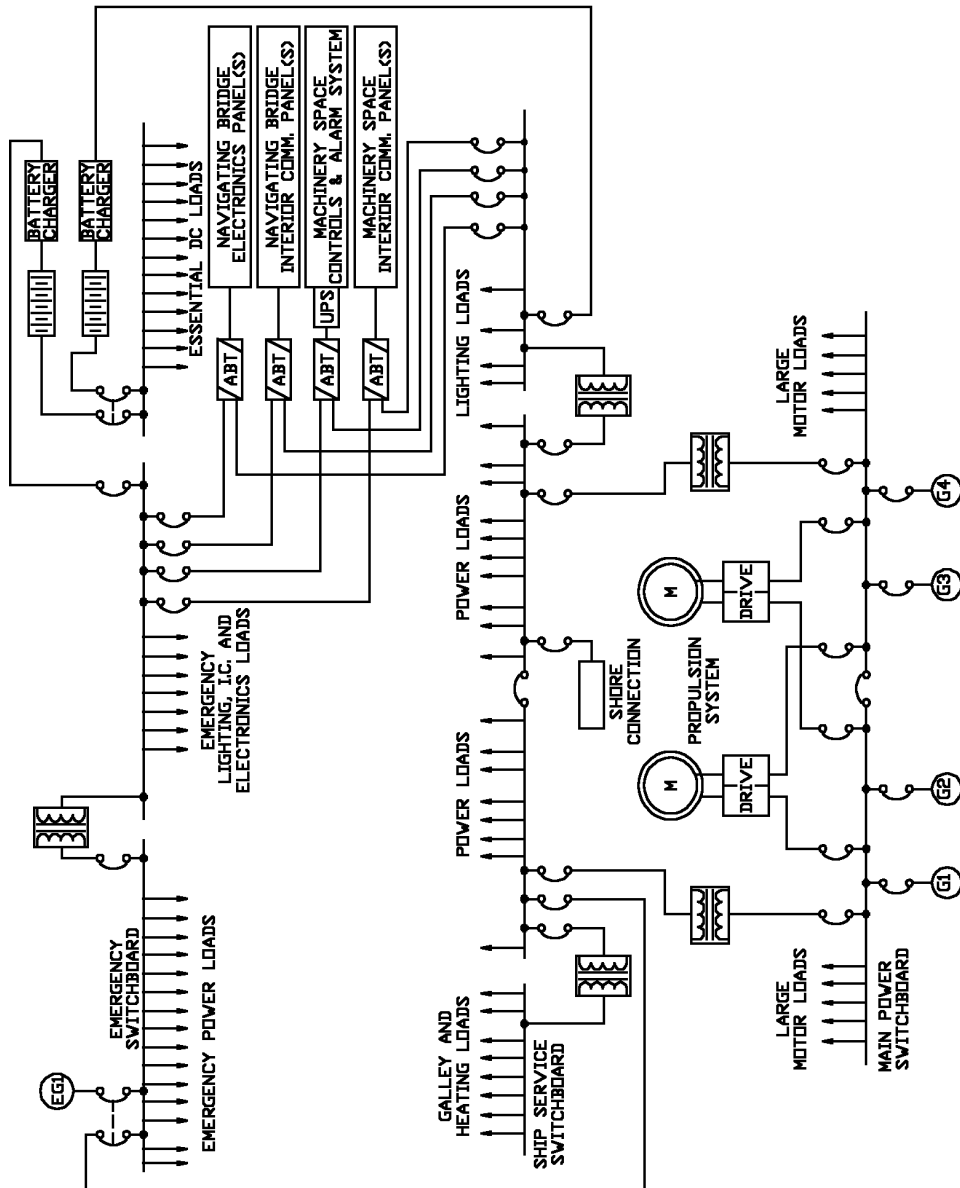


Figure 2—Typical integrated electric plant confirmation—cargo vessels

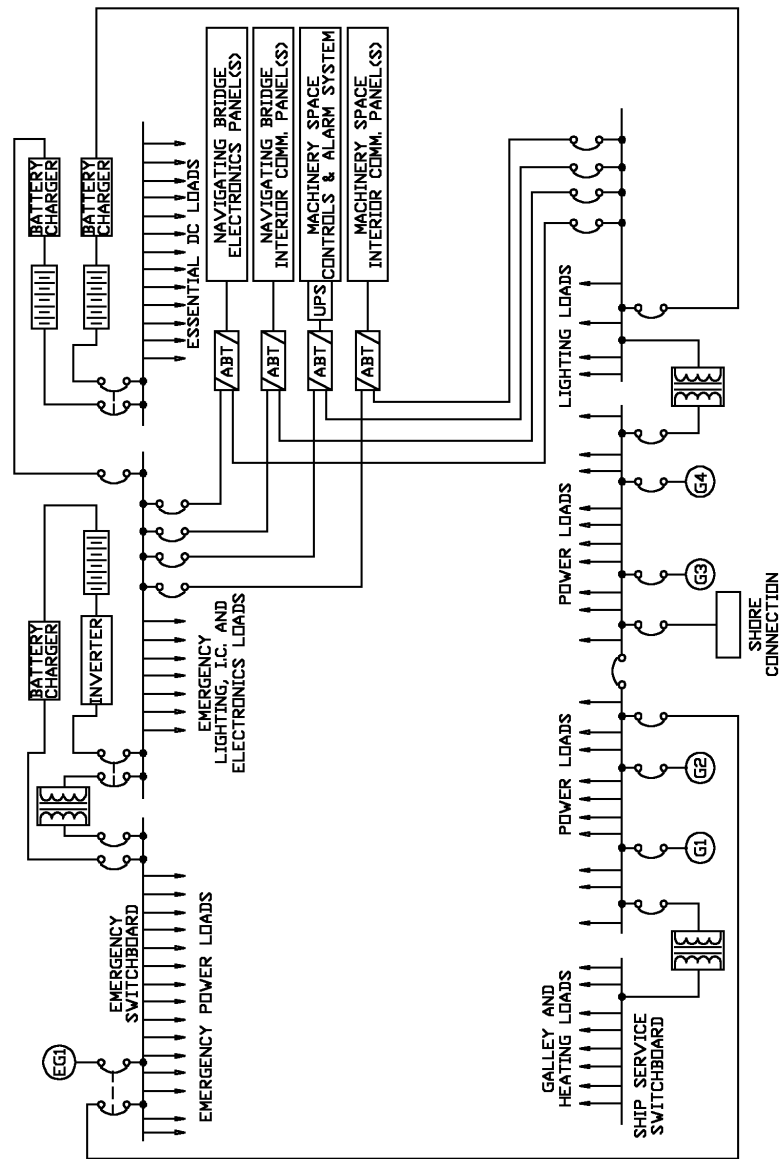


Figure 3—Typical electric plant configuration—passenger vessels

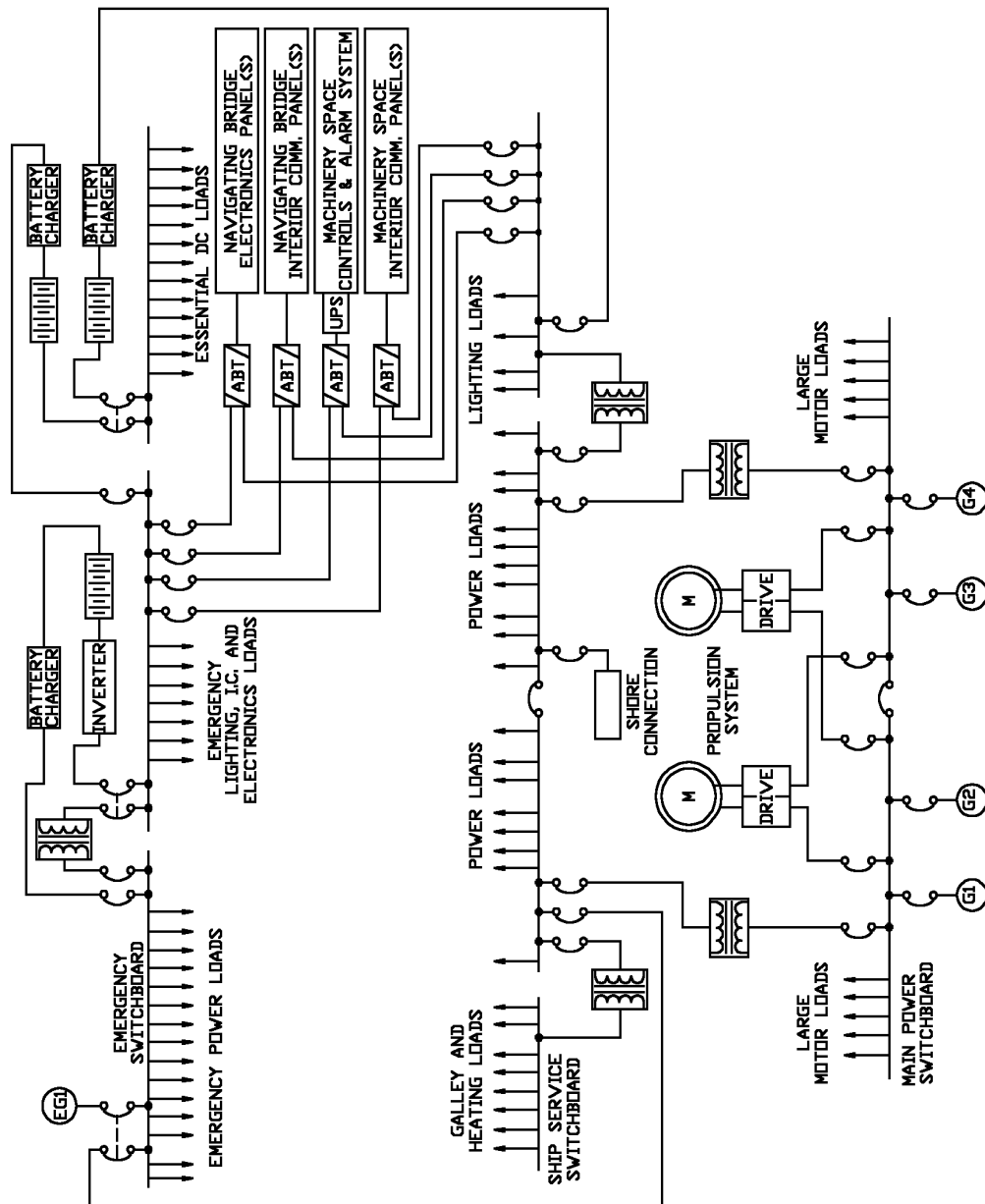


Figure 4—Typical integrated electric plant configuration—passenger vessels

5.2 Circuit elements

All normal current-carrying elements of electrical power supply circuits should be specifically intended for that purpose only. Ship structure should not be used as a normal current-carrying conductor for the electrical power supply distribution systems.

5.3 Shore power

If a shore power connection is provided, a connection box (see 17.7) should be installed in a location convenient for the reception of the cables from the shore. The shore power system should include shore power circuit breaker(s), shore power available indicating light(s), and a phase sequence or phase rotation detection device. Cables from the connection box to the ship service switchboard should be permanently installed. One of the switchboard voltmeters should have the capability to indicate the shore power voltage.

5.4 Demand factors

5.4.1 General

Feeder and branch circuit conductors should be sized for 100% of their connected load, except as given in 5.4.2., 5.4.3, and 5.4. Conductor sizing should be based on published ampacity ratings for the conductors, with applicable derating factors applied for ambient temperature, raceway configuration, and so on. See Clause 24 for additional information. Conductors less than 15 AWG (1.5 mm² for IEC wiring systems; see 1.7) should not be used in any branch circuit.

5.4.2 Lighting, interior communications, and electronics circuits

Conductors for lighting, communications, and electronics circuits should be sized for the total connected load, including not less than 180 VA for each receptacle. The connected load should include 50% of the rating of spare circuits on switchboards or load centers and the average active circuit load for the spare circuits on distribution panels. Loads for circuits supplying electric discharge-type lamps should be computed on the basis of ballast input current. Feeders for circuits including cargo flood lighting receptacles should be calculated on the basis of expected load, but not less than 300 W per receptacle.

5.4.3 Galley circuits

Conductors for galley equipment should be sized on the basis of 100% demand factor for the first 50 kW of connected load and 65% of the connected load in excess of 50 kW.

5.4.4 Individual and multiple motor circuits

Except as recommended in 5.8.1, conductors supplying an individual motor should have a continuous current-carrying capacity equal to 125% of the motor nameplate rating. Conductors supplying more than one motor should have a continuous current-carrying capacity equal to 125% of the largest motor plus the sum of the nameplate ratings of all other motors supplied, including 50% of the rating of spare switches on the distribution unit.

Conductors supplying a group of three or more workshop tool motors should have a continuous current-carrying capacity equal to 125% of the nameplate rating of the largest motor plus 50% of the sum of the nameplate ratings of all other motors of this group.

Conductors supplying two or more motors driving deck cargo winches or cargo elevators should have a continuous current-carrying capacity equal to 125% of the largest motor plus 50% of the sum of the nameplate ratings of all other motors.

Conductors supplying two or more motors driving cargo cranes should have a continuous current-carrying capacity equal to 125% of the largest motor plus 50% of the sum of the nameplate rating of all other motors. Where the conductor supplies two or more motors associated with a single crane, the current-carrying capacity should be equal to 125% of the largest motor plus 45% of the sum of the nameplate rating of the other motors.

Conductors between separate ship service switchboards having connected generators (ship service generator switchboards) should be sized on the basis of 75% of the switchboard having the greatest generating capacity. The drop in voltage from each generator to its switchboard should not exceed 1%, and the drop in voltage between switchboards should not exceed 2%.

Conductors between ships service switchboards and the emergency switchboard should be sized on the basis of the maximum operating load of the emergency switchboard or 115% of the emergency generator capacity, whichever is larger.

Conductors from storage batteries to the point of distribution should be sized for the maximum continuous charge or discharge rate, whichever is greater. Battery conductors for heavy duty applications, such as diesel starting, should be sized for 125% of maximum-rated battery discharge.

5.5 Voltage drop

5.5.1 General

For all distribution circuits, unless stated otherwise, the combined maximum voltage drop from the ship's service switchboard to any point in the system should not exceed 5%.

5.5.2 Feeder and branch circuit continuity

Except as permitted in 5.5.3 and 5.6.1, each feeder and branch circuit supplying a single energy-consuming appliance should be continuous and uniform in size throughout its length. In instances of feeders of large size and exceptional length, junction boxes or splices may be used for ease of installation. When authorized by the appropriate regulatory agency, splices or junction boxes may be permitted to repair damaged cable (see 25.11).

5.5.3 Feeder connections

Where a feeder supplies more than one distribution panel, it may be continuous from the switchboard to the farthest panel or it may be interrupted at any intermediate panel. If the bus bars of any distribution panel carry "through" load, the size of the buses should be suitable for the total current. The size of feeder conductors will ordinarily be uniform for the total length but may be reduced at any intermediate distribution panel, provided that the smallest section of the feeder is protected by the overload device at the distribution switchboard.

5.6 Lighting distribution

5.6.1 Lights controlled from the navigating bridge

A separate feeder should be provided for all lights supplied from the emergency switchboard and located in or controlled from the navigating bridge. On passenger vessels, two feeders may be provided: one from the

temporary emergency (storage battery) bus and one from the final emergency bus. For the feeder supplying navigation lights (from the temporary emergency bus, if provided), the rating of the cable and of the fuse or circuit breaker on the emergency switchboard should be not less than 20 A or not less than 125% of connected load, including allowance for spare circuits, whichever is greater.

One or more distribution panels may be served by the feeders described in this subclause. Through feed, without switch or overcurrent protection, should be provided for the navigation light panel. For all other lights, including any navigation or signal lights not supplied by the navigation light panel, branch circuits, each with a fused-switch or circuit breaker, should be provided.

Floodlights for lifeboat launching should be supplied by branch circuits from the navigating bridge emergency panel, or it may be supplied directly from the emergency system through local lighting contactors controlled from the navigating bridge. Lighting for adjacent launching stations should be supplied by different branch circuits.

One four-conductor, or two-conductor, branch circuit cables should be provided from the navigation light indicator panel for each two-lamp navigation light fixture. Each four-conductor branch circuit cable from the indicator panel should terminate in a waterproof two-circuit, two-gang receptacle located adjacent to the running light. If two-conductor branch circuit cables are provided, each cable should terminate in a single-gang waterproof receptacle. The receptacles should be of the grounding type. Two three-conductor portable cables should be provided for each two-lamp fixture, and each should be fitted with a three-pole plug.

5.6.2 Machinery space lighting

Separate lighting feeders should be installed for each main and auxiliary machinery space. These feeders should not supply fixtures outside the machinery spaces, other than storerooms opening into these spaces. The number and size of the feeders and distribution panels should be determined by the number of fixtures and the extent of the spaces covered. It is recommended that alternate groups of fixtures within these spaces be so arranged that the failure of any one circuit will not leave these spaces in darkness.

5.6.3 Cargo space lighting

Separate feeders should be installed for all cargo lighting. The distribution panels should be located outside of the cargo spaces. Receptacles in cargo spaces should be connected neither to feeders that are used for lighting nor to circuits required for the underway operation of the vessel.

5.6.4 Accommodation space lighting

For vessels provided with structural fire boundary bulkheads forming fire zones, it is recommended that at least two separate feeders be provided exclusively for each vertical zone between two fire boundary bulkheads. These feeders may serve all decks within the zone. One of these may be the emergency lighting feeder. The supply of lights in all passageways and public spaces and in any berthing compartment accommodating more than 25 persons should be divided between two feeders so that if either fails, there will be sufficient light to prevent panic and to permit people to find their way to the open deck. The two feeders serving one compartment should be separated as widely as practicable to minimize the possibility of damage to both from a fire or other casualty.

On passenger vessels, electric service to each passenger stateroom should be supplied by at least two separate branch circuits connected to the general lighting system. The lighting should be so divided that in the event of failure of one branch circuit, there will be sufficient light to permit use of the space.

5.6.5 Two-wire device connections

In grounded systems, the shell of all lampholders should be connected to the grounded conductor, and all single-pole switches should be in the ungrounded conductor. In two-wire ungrounded systems, the color of conductors connected to single-pole switches should be uniform throughout the system.

5.7 Distribution for power equipment

In general, power feeders for cargo elevators, cargo cranes, and cargo winches that should be disconnected when the vessel is underway should not be used to supply ventilation fans, heaters, drainage pump motors, or any apparatus required for the ship's operation.

Separate feeders from switchboards should be run for main and auxiliary machinery space loads, motors for cargo-handling gear, steering gear, navigation and electronics loads, searchlights, and ventilation and air-conditioning loads. Cargo ventilation fans, machinery space ventilation fans, and fans for ventilation of accommodations should not be supplied from the same feeder.

The steering gear motors should be supplied from two different circuits and, where practical, from two different switchboards or switchboard bus sections. These circuits should be widely separated to minimize failure of both feeders due to collision, fire, or other casualty. Both feeders may be connected to the ship service switchboard, or where required by the regulatory agencies, one feeder may be connected to the ship service switchboard and one to the emergency switchboard. Each circuit should have a continuous current-carrying capacity of not less than 125% of the rating of the motor or motors simultaneously operated. The special requirements for electrical power distribution to steering gear systems are described in 32.5.2.

In order to prevent the spread of fire, arrangements should be made to permit stopping all ventilation fans, fuel oil pumps, and lube oil transfer pumps from a central point. For further details, see 11.7.

Separate feeders and distribution panels should be provided for air heaters when they are used extensively. Separate feeders and distribution panels should be provided for galleys equipped with electric ranges, ovens, and other electric apparatus.

5.8 Branch circuits

5.8.1 General

The branch circuit conductors should not be less than No. 15 AWG (1.5 mm² for IEC wiring systems; see 1.7). Cable types and sizes (refer to Clause 24) should be selected for compatibility with all local environmental conditions throughout the length and voltage drop limitations of this subclause. Each branch circuit should be provided with overcurrent protection in accordance with 5.9.5, except as otherwise indicated. The maximum connected load should neither exceed the rated current-carrying capacity of the cable nor 80% of the overcurrent protective device setting or rating.

5.8.2 Heating and cooking equipment

Generally, a separate branch circuit should be provided for each electric heater. An individual heater or a group of heaters may be supplied from a lighting or power distribution panel, depending on the required voltage.

For ranges, bake ovens, and similar galley units in which self-contained or locally mounted protective devices are provided for each individually controlled heating element, only one branch circuit need be provided for each assembled unit.