



IEEE Recommended Practice for Shipboard Electrical Installations— Systems Engineering

IEEE Industry Applications Society

Developed by the
Petroleum & Chemical Industry Committee

IEEE Std 45.3™-2025
(Revision of IEEE Std 45.3-2015)

STANDARDS

IEEE Recommended Practice for Shipboard Electrical Installations— Systems Engineering

Developed by the

Petroleum & Chemical Industry Committee
of the
IEEE Industry Applications Society

Approved 28 May 2025

IEEE SA Standards Board

Recognized as an American National Standard

Abstract: Recommendations for systems engineering, design, and integration of electrical power systems at the total ship level from concept design through the establishment of the design baseline prior to detailed design are provided in this document. Recommendations for ac power systems, dc power systems, emergency power systems, shore power, quality of service, power quality and harmonics, electric propulsion and maneuvering systems, motors and drives, thrusters, and steering systems onboard ships are established by this document. Present-day technologies, engineering methods, and engineering practices are reflected by these recommendations. This document is intended to be used in conjunction with the IEEE 45™ series of documents.

Keywords: baselines, concept of operations, IEEE 45.3™, radial design, systems engineering, zonal design

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Introduction

This introduction is not part of IEEE Std 45.3-2025, IEEE Recommended Practice for Shipboard Electrical Installations—Systems Engineering.

The IEEE 45™ series comprises eight recommended practices addressing electrical installations on ships and marine platforms. IEEE Std 45.3™ provides the recommended practice for systems engineering of shipboard electrical power systems and is intended for use with the IEEE 45 series of documents. The topics covered in this document should be considered from the beginning of the project and throughout the design and construction processes and thereby should facilitate the integration of electrical power systems at the shipyard level. Adherence to the IEEE 45.3 electrical power systems engineering process provides an effective set of integration requirements and identifies key issues and recommended solutions or options.

The complete set of IEEE 45 series of documents currently consists of:

- IEEE Std 45.1™-2023, IEEE Recommended Practice for Electrical Installations on Shipboard—Design
- IEEE Std 45.2™-2023, IEEE Recommended Practice for Electrical Installations on Shipboard—Controls and Automation
- IEEE Std 45.3™-2025, IEEE Recommended Practice for Shipboard Electrical Installations—Systems Engineering
- IEEE Std 45.4™-2018, IEEE Recommended Practice for Electrical Installations on Shipboard—Marine Sectors and Mission Systems
- IEEE Std 45.5™-2014, IEEE Recommended Practice for Electrical Installations on Shipboard—Safety Considerations
- IEEE Std 45.6™-2016, IEEE Recommended Practice for Electrical Installations on Shipboard—Electrical Testing
- IEEE Std 45.7™-2012, IEEE Recommended Practice for Electrical Installations on Shipboard—AC Switchboards
- IEEE Std 45.8™-2016, IEEE Recommended Practice for Electrical Installations on Shipboard—Cable Systems

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IEEE Recommended Practice for Shipboard Electrical Installations—Systems Engineering

1. Overview

1.1 Introduction

The IEEE 45 series of documents comprises eight standards, IEEE Std 45.1™ through IEEE Std 45.8™. This document, IEEE Std 45.3, provides recommended practices for systems engineering of shipboard and marine platform electrical power system installations.

1.2 Scope

This document provides recommendations for systems engineering, design, and integration of electrical power systems at the total ship or platform level from concept design through the establishment of the design baseline prior to detailed design.

Recommendations for ac power systems, dc power systems, emergency power systems, shore power, quality of service (QoS), power quality and harmonics, electric propulsion and maneuvering systems, motors and drives, thrusters, and steering systems onboard ships are established by this document. These recommendations reflect present-day technologies, engineering methods, and engineering practices. This document is intended to be used in conjunction with the IEEE 45 series of documents.

1.3 Purpose

IEEE Std 45.3 provides a consensus of recommended technical and professional practices for systems engineering and integration of electrical power systems as applied specifically to ships, shipboard systems, marine platforms, and equipment. IEEE Std 45.3 applies primarily to the design of moderately and highly complex vessels and marine platforms, where the complexity of a vessel in this context is a relative measure of the quantity and variety of engineering and integration challenges. In general, designers should selectively apply these recommended practices to address specific systems engineering challenges.

1.4 The IEEE 45 series of documents

The IEEE 45 series of documents and their relationships are shown in [Figure 1](#). IEEE Std 45.3 is a recommended practice addressing the systems engineering of electrical power systems on ships and marine platforms. Electrical power systems integration should be considered from the beginning of the project and throughout the design and construction processes. Adherence to the IEEE 45.3 electrical power systems

integration recommended practice provides an effective set of integration requirements and identifies key issues and recommended solutions or options.

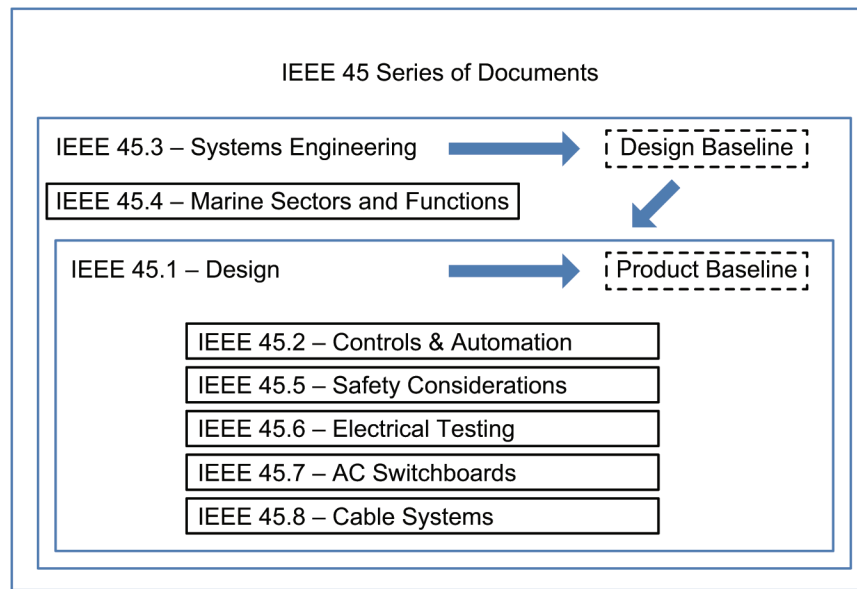


Figure 1—IEEE 45 series of documents

1.5 Relationship between IEEE Std 45.3 and IEEE Std 45.1

During the development of the IEEE 45 series, there was much discussion on the focus of IEEE Std 45.3 and the difference between IEEE Std 45.1 and IEEE Std 45.3.

Figure 2 shows the design process from concept design to product baseline and the relationship between IEEE Std 45.1 and IEEE Std 45.3. This document discusses requirements for all phases of system integration with an emphasis on the phases leading up to the completion of the design baseline.

IEEE Std 45.3 puts heavy emphasis on concept design, preliminary design, and baseline design of electrical power systems to prepare the design baseline for detailed design. IEEE Std 45.1 describes the process of refining and expanding the design baseline of an electrical power system to the extent that the product design baseline is sufficiently complete to be implemented (built and tested).

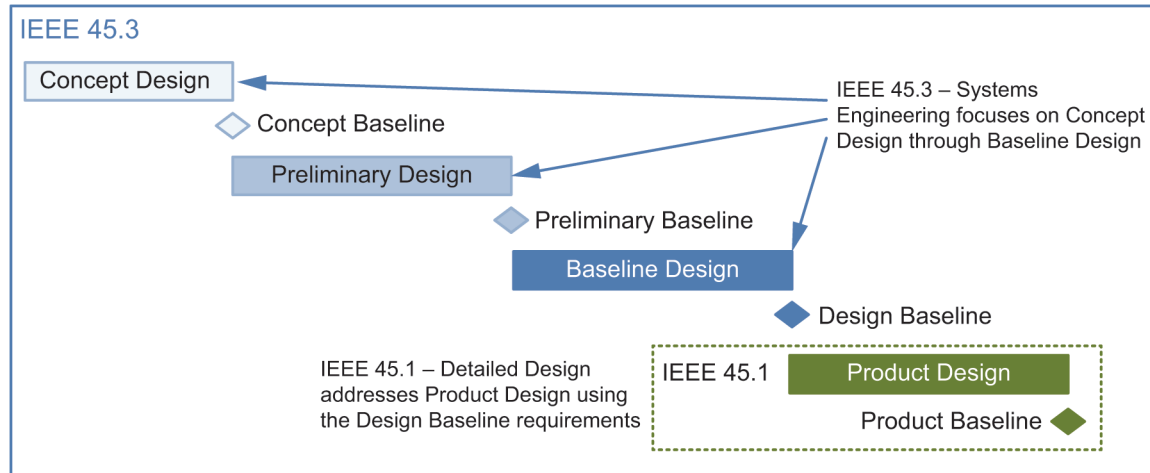


Figure 2—Relationship between IEEE Std 45.3 and IEEE Std 45.1

1.6 Word usage

The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (*shall* equals *is required to*).^{6,7}

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

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

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

2. Normative references

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

ASTM F1166, Standard practice for human engineering design for marine systems, equipment, and facilities.⁸

IACS UR E26, Cyber resilience of ships.

IACS UR E27, Cyber resilience of on-board systems and equipment.

IEC 60092-202, Electrical installations in ships—part 202: system design—protection.⁹

⁶ The use of the word *must* is deprecated and cannot be used when stating mandatory requirements; *must* is used only to describe unavoidable situations.

⁷ The use of *will* is deprecated and cannot be used when stating mandatory requirements; *will* is only used in statements of fact.

⁸ ASTM publications are available from the American Society for Testing and Materials (<https://www.astm.org/>).

⁹ IEC publication are available from the International Electrotechnical Commission (<https://www.iec.ch/>).

IEC 61131 Series, Programmable controllers.

IEC 61499 Series, Function blocks.

IEC 61850 Series, Communication networks and systems for power utility automation.

IEC/IEEE 80005-1™, IEC/IEEE International Standard—Utility Connections in Port—Part 1: High Voltage Shore Connection (HVSC) Systems—General requirements.

IEEE Std 45.1™, IEEE Recommended Practice for Electrical Installations on Shipboard—Design.^{10,11}

IEEE Std 45.2™, IEEE Recommended Practice for Electrical Installations on Shipboard—Controls and Automation.

IEEE Std 45.4™, IEEE Recommended Practice for Electrical Installations on Shipboard—Marine Sectors and Mission Systems.

IEEE Std 45.5™, IEEE Recommended Practice for Electrical Installations on Shipboard—Safety Considerations.

IEEE Std 45.6™, IEEE Recommended Practice for Electrical Installations on Shipboard—Electrical Testing.

IEEE Std 45.7™, IEEE Recommended Practice for Electrical Installations on Shipboard—AC Switchboards.

IEEE Std 45.8™, IEEE Recommended Practice for Electrical Installations on Shipboard—Cable Systems.

IEEE Std 1110™, IEEE Guide for Synchronous Generator Modeling Practices and Parameter Verification with Applications in Power System Stability Analyses.

IEEE Std 1662™, IEEE Recommended Practice for the Design and Application of Power Electronics in Electrical Power Systems.

IEEE Std 1815™, IEEE Standard for Electric Power Systems Communications—Distributed Network Protocol (DNP3).

IEEE Std 1826™, IEEE Standard for Power Electronics Open System Interfaces in Zonal Electrical Distribution Systems Rated Above 100 kW.

ISO 31000, Risk management—guidelines.¹²

ISO/IEC/IEEE 12207™, Standard for Systems and Software Engineering—Software Life Cycle Processes.

MIL-STD-1472, Department of Defense design criteria standard: human engineering.¹³

NAVSEA T9070-A3-DPC-010/310-1, Naval Sea Systems Command, Electric power load analysis (EPLA) for surface ships. (Formerly designated DDS 310-1 rev 1).¹⁴

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¹³ MIL publications are available from the U.S. Department of Defense (<https://www.dsp.dla.mil/>).

¹⁴ Available: <https://apps.dtic.mil/sti/pdfs/ADA568950.pdf>.

3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.¹⁵

baseline: A technical data package defining a configuration item during the design, production, operation, maintenance, and logistic support of its life cycle.

blackout: Aboard ship, a power outage (also *power cut* or *power failure*) of electrical power to an entire ship. A blackout may be characterized as either a dark ship or a dead ship. *Dark ship* is when there is no power generation online, but energy storage is available for control system and startup. *Dead ship* is when there is no generation online and all the energy storage is depleted.

critical equipment: Equipment, should it fail, that may place the vessel, crew, or environment into a hazardous situation. Includes, but is not limited to, emergency equipment required by applicable regulations and classification societies.

critical system: A system, should it fail, that may place the vessel, crew, or environment into a hazardous situation. Includes, but is not limited to, emergency systems required by applicable regulations and classification societies.

dependability: A measure of a system's availability, reliability, and maintenance support. This may also encompass mechanisms designed to increase and maintain the dependability of a system. (IEC 60050-192 [B8])¹⁶

design baseline: The output of the baseline design phase (equivalent to the preliminary baseline of “detailed design” defined below). (*IEEE Standards Dictionary Online*)

detailed design: The process of refining and expanding the preliminary design of a system or component to the extent that the design is sufficiently complete to be implemented. (*IEEE Standards Dictionary Online*)

digital engineering ecosystem: The interconnected infrastructure, environment, and methodology (process, methods, and tools) used to store, access, analyze, and visualize evolving systems' data and models to address the needs of the stakeholders.

digital thread: A data-driven architecture linking information generated across the product's life cycle and serving as the primary source of authoritative data.

electrical power interface: An interface with the primary purpose of transferring electrical power to or from the interface. An electrical power interface is described by voltage, number of phases, frequency, connected power, grounding method, quality of service (QoS) requirement, and power quality standard.

electrical power system concept of operations (EPS-CONOPS): A document describing the expected manner in which the power system is intended to be configured and operated for normal and emergency operating conditions.

electrical power systems integration: The process of ensuring that all electrical components operate or perform as a system. Through each phase of the design process, the iterative application of systems engineering achieves an improvement of performance greater than the sum of the components.

¹⁵ *IEEE Standards Dictionary Online* is available at: <http://dictionary.ieee.org>. An IEEE account is required for access to the dictionary, and one can be created at no charge on the dictionary sign-in page.

¹⁶ The numbers in brackets correspond to those of the bibliography in Annex F.

functional interface: An interface that describes the expected behavior of the component in response to stimulus experienced at the other interfaces. A functional interface is generally specified in the form of a performance specification or dynamic model.

galvanic isolation: (A) A method of electrical isolation where neither the signal nor the common of the output of the isolator is dc coupled to the signal or common of the input of the isolator, except for low-level leakage associated with non-ideal components. (B) A principle of isolating functional sections of electrical power systems to prevent current flows through conductors between the sections. Energy or information can still be exchanged between the sections by other means, e.g., by capacitance, induction, or electromagnetic waves or by optical, acoustic, or mechanical means.

Galvanic isolation is used in situations where two or more electric circuits communicate, but their grounds may be at different potentials. It is an effective method of breaking ground loops by preventing unwanted current from flowing between two units sharing a ground conductor. Galvanic isolation can also be used for safety.

generator start time (t₂): The maximum time to bring the slowest power generation module online.

integrated power system: A ship or platform power system characterized by the transfer of the preponderance of energy by electrical power, including propulsion, under the control of a supervisory controller and where the electrical power system is designed to allow for sharing sources of power among the loads.

master equipment list: A list of shipboard equipment to the level detailed in the ship's weight report.

mechanical interface: An interface that describes the physical interaction of a component with external components or structure. Mechanical interfaces include dimensions, weight, foundation interfaces, and position of physical connections to other systems.

monitoring and control interface: An interface with the primary purpose of communicating information or commands to or from the interface. A monitoring and control interface is usually described in the form of a layered model, such as the OSI Basic Reference Model described in ISO/IEC 7498-1 [B28].

open architecture: The confluence of business and technical practices yielding modular, interoperable systems that adhere to open standards with published interfaces. Open architecture can deliver increased capabilities in a shorter time at reduced cost. Key open architecture principles include the following: modular design and design disclosure, reusable application software, life-cycle affordability, defined interfaces, and process for creating a system design while maximizing re-use of existing modules and software.

product baseline: A technical data package describing the complete design in sufficient detail to enable creating work instructions, ordering material and equipment, and scheduling work.

reconfiguration time (t₁): The maximum time to reconfigure the distribution system without bringing on additional generation capacity.

system life cycle: The period of time that begins when a system is conceived and ends when the system is no longer available for use. (*IEEE Standards Dictionary Online*)

systems engineering: An interdisciplinary collaborative approach to derive, evolve, and verify a life cycle balanced system solution that satisfies customer expectations and meets public acceptability. (*IEEE Standards Dictionary Online*)

technical data package: A technical description of an item adequate for supporting an acquisition strategy, production, engineering, and logistics support. The description defines the required design configuration or performance requirements and procedures required to ensure the adequacy of item performance. It consists of applicable technical data such as models, drawings, associated lists, specifications, standards, patterns, performance requirements, quality assurance provisions, software documentation, and packaging details.

3.2 Acronyms and abbreviations

ABT	automatic bus transfer
CONOPS	concept of operations
DNP3	Distributed Network Protocol
EMI	electromagnetic interference
EPLA	electric power load analysis
EPS-CONOPS	electrical power system concept of operations
FMEA	failure modes and effects analysis
FMECA	failure modes, effects, and criticality analysis
HM&E	hull, mechanical, and electrical
ICD	interface control document
IPS	integrated power system
M&S	modeling and simulation
MEL	master equipment list
MTBSI	mean time between service interruptions
PDSS	propulsion derived ship service
PSID	power system interface device
QoS	quality of service
RM&A	reliability, maintainability, and availability
SOLAS	safety of life at sea
ZEDS	zonal electrical distribution system

4. Systems engineering

4.1 Introduction

Shipboard electrical power systems engineering is the transdisciplinary development and realization of an electrical power system design and concept of operations (EPS-CONOPS); the objective is to cost-effectively design an electrical power system achieving at a minimum the following goals:

- Provide safe and reliable storage and supply of fuel, energy, and power.
- Provide electrical power of the requisite power quality and quality of service to enable ship systems to perform the required functions necessary for the safe operation of the vessel.
- Enable all electrical services necessary for maintaining the vessel in normal operational and habitable condition to be available without recourse to the emergency source of electrical power.

- d) Enable all electrical services required for safety to be available during emergency conditions.
- e) Enable electrical power for essential services to be restored after a malfunction.
- f) Minimize danger to persons on board, the vessel, ship systems/equipment, and the environment from hazards associated with machinery and systems.
- g) Provide a safety system that automatically controls machinery to a fail-safe state in response to a fault that may endanger the safety of persons on board, the vessel, ship systems/equipment, or the environment.
- h) Provide suitable, sufficient, and readily available illumination.
- i) Prevent the occurrence of fire and explosion.
- j) Reduce the risk of fire damage to the ship, the ship's cargo, and the environment.
- k) Reduce the risk of injury to the ship's crew and passengers due to smoke, fires, and flooding.
- l) Provide for the current and future electrical power needs of the customer.

Electrical power systems engineering may include the following elements:

- Engineering baseline development
- Power system architecture development
- Power system element selection and specification
- Electrical power system protection and reconfiguration design
- Interface control
- Cybersecurity
- System analysis, studies, and reports
- Modeling and simulation (M&S)
- Communications architectures and protocol selection
- Quality of service (QoS) implementation
- Grounding system design
- Design for reliability and maintainability
- System testing and acceptance

This document focuses on the engineering phases prior to product design: Concept design, preliminary design, and baseline design. The design baseline is the design artifact that transitions from baseline design to product design.

The term *ship* or *shipboard* used in this document refers to applicable vessels as defined in IEEE Std 45.4.

Prior to product design, the recommended practices of the other IEEE 45 series documents should be considered unless otherwise indicated in this document. In case of conflict between this document and other normative references, the provisions of this document should be followed. In case of conflict between this document and regulations or between this document and invoked class society rules, the regulations and invoked class society rules shall take precedence.

4.2 Engineering phases

4.2.1 General

Engineering involves activities throughout the life cycle of a product. Most often, engineers tend to think of activities necessary to design and develop a product. In reality, the process begins with the identification of the initial concept and proceeds through product design and fabrication. Every system goes through a design process, typically composed of multiple engineering phases. Figure 3 shows the recommended engineering phases and their relationships. Notionally, the engineering phases should be conducted in series.

Each engineering phase should be concluded by establishing a baseline approved by the vessel design team and the owner. This baseline then becomes a configuration item for the project.

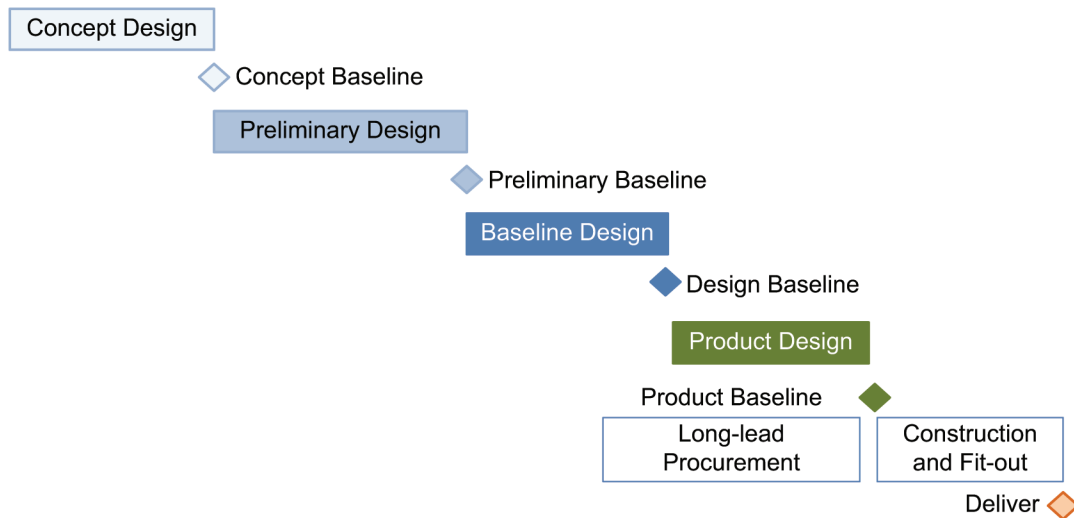


Figure 3—Engineering phases and baselines

4.2.2 Concept design

Concept design is the beginning of the design process. The top-level concepts should be defined during this phase of design. All concepts and requirements should be very general with broad notions of the outcome. The approach should also be generalized. Hardware and software components should be defined in a broad spectrum. The design may have many undefined elements that are intended to be identified later in the process. The concept baseline is the design product from the concept design. The top-level requirements should be established during concept design. Brown [B2] provides guidance on the design of marine engineering systems within the overall ship concept design process.

During the concept design phase, different concepts are investigated, and trade studies are conducted on each concept before a final concept is selected. Models and prototypes may be constructed to conduct these trade studies in conjunction with simulations and analytic analyses. Concept verification should be performed as specified in the IEEE Std 1826.

During concept design, an EPS-CONOPS should be initiated as a statement of the required electrical power system behaviors based on the vessel's expected use. For details, see Clause 11 and Annex C.

4.2.3 Preliminary design

Preliminary design is the second phase in the design process and should build on the concept baseline from the previous design level. The design level finalizes the system requirements, develops the systems architectures, and trades off multiple system and component candidate design solutions. All major equipment is selected and arranged. System analysis is conducted to ensure all requirements are met and to optimize the design. The design and selection of minor equipment may be deferred to later stages if the risk of system rework is minimal. The preliminary baseline is the design product from the preliminary design phase.

4.2.4 Baseline design

Baseline design is the third phase in the design process and should build on the preliminary baseline from the previous design level. At this point in the design, the system and subsystem interconnections should be identified. Most of the design issues should be addressed, and the designers should have specific knowledge of the outcome. The design may still have a few holes and undefined elements, but most of the design should be complete. The design should be analyzed to ensure all requirements are met. Long-lead items should be specified and procurements initiated. The risk of significant system design rework should be minimized. The design baseline is the design product from the baseline design phase.

4.2.5 Product design

Product design is the final phase in the design process and should build on the design baseline from the baseline design phase. All remaining electrical power system components should be specified, design issue questions should be answered, and no undefined elements should be left in the design. Some additional equipment/material may be procured during this phase to support the construction schedule. The product baseline is the design product from the product design phase.

4.2.6 Other activities

4.2.6.1 Construction and fit-out

During construction and fit-out (Figure 3), all remaining equipment and materials are procured, and work packages are developed for the construction trades. Test plans are developed and implemented. Engineering changes are evaluated as needed when discrepancies or construction problems arise. When engineering changes are authorized, they are incorporated into the product baseline and associated vendor specifications and work packages.

4.2.6.2 Long-lead items

To meet production schedules, the procurement of material designated as long-lead items may, as an option, be initiated prior to the establishment of the design baseline. Sufficient engineering should be accomplished to develop specifications for these long-lead items with an acceptable level of risk that the specifications and long-lead item procurement contract require modification due to changes in the design baseline.

4.3 Interface control document (ICD)

4.3.1 General

ICDs are ship-level documents prepared as part of preliminary design and updated as necessary in later stages of design. ICDs should identify functional, electrical power, monitoring and control, and mechanical interfaces for all major equipment or assemblies. ICDs should be configuration controlled. Requirements for interfaces should be consistent with owner requirements, classification or statutory rules, and equipment installation and operation parameters.