Electrical Power System Concept of Operations

Norbert Doerry

December 6, 2025

1. Introduction

The electrical power system concept of operations (EPS-CONOPS) documents how the designer intends for the ship's electrical power system to be designed, operated during normal, nominal operations, operated during restorative operations, maintained, repaired, and upgraded. During the design process, the EPS-CONOPS is a working document; the EPS-CONOPS typically starts with only a few items, but rapidly includes additional items as the design evolves and matures; items are added as they become required to support design and analyses activities. The EPS-CONOPS is the foundation, and single source of truth, for providing assumptions for the various calculations, analyses, and simulations performed on the electrical power system. When the ship becomes operational, the EPS-CONOPS enables the crew to gain a full understanding of the ship electrical power system design. IEEE Std 45.3 provides guidance for the content of an EPS-CONOPS.

The EPS-CONOPS complements other system concepts of operation. The Propulsion System Concept of Operations for example, is required in addition to the EPS-CONOPS to perform endurance fuel calculations.

2. EPS-CONOPS uses

The primary uses of the EPS-CONOPS are:

a. Serve as a single source of truth for design assumptions needed to support design and analysis activities (including simulations).
b. Define standard electric plant line-ups.
c. Reflect knowledge gained from electrical power system studies.
d. Provide the basis for establishing load factors and load models in the electric power load analysis (EPLA).
e. Provide operators, designers, and maintainers with insight as to how the designers intended for the electrical power system to operate under different conditions.

Within a digital design environment, the EPS-CONOPS is part of the digital thread; its evolution should be traceable over time. For some data elements, other documents or databases may serve as the single source of truth for the project; in these cases, the EPS-CONOPS should link to the authoritative source of data.

As the EPS-CONOPS evolves, the designer should evaluate the changes in the document and determine if analyses should be repeated to reflect the new information.

3. EPS-CONOPS content

While a standard format for and contents of an EPS-CONOPS do not exist, the following sections of an EPS-CONOPS are recommended:

3.1. Overarching assumptions and requirements

Overarching assumptions and requirements include:

a. Margin and service life allowance policy
b. Ship service life
c. Redundancy requirements
d. Survivability requirements
e. Minimum and maximum loading on generator sets under normal conditions
f. Functions of energy storage
g. Identification of all separately derived systems.[1]
h. QOS Mean Time Between Service Interruption (MTBSI) for each separately derived system.
i. QOS t1 and t2 for each separately derived system.
j. Power quality interface standards for each separately derived system.
k. Grounding system type for each separately derived system.
l. Identification of converters as isolated or non-isolated.

These items should be defined and incorporated into the EPS-CONOPS before they are needed for design and analysis.

3.2. Operating conditions

The operating conditions of the ship are associated with electrical power system line-ups, and with the specific mission system and support system equipment that are online. The operating conditions are typically defined early since they are required to support the EPLA, endurance fuel calculations, and annual fuel calculations. See DPC 310-1, DPC 200-1, DPC 200-2, and IEEE Std. 45.1 for additional guidance.

Typical operating conditions include cruise, mission (or functional), shore, anchor, and emergency. Depending on the ship, multiple mission / functional operating conditions may be defined to fully analyze limiting conditions for the electrical power system.

For each operating condition, the EPS-CONOPS should provide guidance for determining which mission system equipment and support system equipment are online. It is particularly important to identify whether large loads are online or not in

[1] From IEEE Std 3003.1: "**separately derived system**: A wiring system whose power is derived from a generator, transformer, or converter windings and has no direct electrical connection, including a solidly connected grounded circuit conductor, to supply conductors originating in another system."

a particular operating condition; a large load is any load requiring more than 20% of the online power capacity.

See document D_000009 for additional information on operating conditions.

3.3. Operational scenarios

Operational scenarios consisting of a timeline of operating conditions, use of large loads or significant smaller loads, and associated speed-time profiles. Operational scenarios may be employed for example, for analyses such as annual fuel calculations, or for determining the required power and energy capacity of energy storage.

3.4. Mission / payload system information

Load models for each operating condition should be detailed for all large loads (those that are greater than 20% of the online capacity) as well as smaller but significant loads. The load models should detail the power consumption under different operating modes of the equipment, as well as the percentage of time that the equipment is in each operating mode for each operational condition. Initially, this data is typically estimated based on analogy with other similar ships; this estimate should be refined as additional knowledge is gained on how the equipment will be operated in each operational condition. This information is necessary for developing realistic load factors or other load models needed to perform the EPLA.

3.5. Electric load information

Special considerations with respect to specific loads when establishing electrical power system lineup or operation should be described. For example, if one or more loads are anticipated to not meet power interface requirements, the EPS-CONOPS should describe the features of the electrical power system design or operation that are intended to mitigate not meeting the interface requirements.

3.6. Electrical power system machinery lineups

Each operating condition should have a preferred electric plant line-up, generator set scheduling table, and energy storage system mode of operation. The electric plant line-up is typically described by the position (open or closed) of all the bus-tie breakers. The generator set scheduling table indicates that for a given total ship load, which generator sets are online providing power, and how real and reactive power is shared among online generator sets (and energy storage systems providing power). The energy storage system mode of operation describes the ESM function being performed, and whether the energy storage is providing power or not.

The generator set scheduling table is required for many analyses such as endurance fuel calculations, annual fuel calculations, and energy storage system capacity sizing.

Guidance for developing a generator set scheduling table is provided in Doerry and Parsons (2023), Doerry (2022), and document D_00001.

3.7. Nominal operations

The EPS-CONOPS should describe how the electric plant is intended to operate under normal conditions where equipment and software have not suffered failure or damage. Topics include:

a. For each of the operating conditions, what performance attributes should be optimized.
b. The process for transitioning between operating conditions; what is the order of changes to the electric plant lineup.
c. The method employed for power management; what is the process for bringing additional generation capacity online and dropping offline excess generation capacity?
d. The degree of autonomy expected of electrical power system controls for each operating condition.

3.8. Restorative operations

The EPS-CONOPS should describe the intended process for restoring electric plant operation to nominal operations following failure or damage to electrical power system equipment or software. Because of the large number of possible failures, the EPS-CONOPS should describe the overall strategy at a relatively high level. Possible topics include:

a. Load shedding strategy and implementation.
b. Casualty power strategy and implementation. (if a casualty power system is installed)
c. Dark ship start procedures. (no generation online, but energy storage systems functional)
d. Dead ship start procedures. (no generation online; all energy storage systems depleted)
e. Zonal survivability assumptions and procedures.
f. Compartment survivability assumptions and procedures.

3.9. Electrical power system / ship system trade studies

The insights gained from analyses and trade-studies should be documented within the EPS CONOPS, or a link provided to such documentation within the digital thread. The goal for including this information is to ensure any insights gained are reflected in follow on analyses and design activities. Insights of particular interest are those that impact the operation of the electric plant, and those that impact the modeling of large loads or significant smaller loads.

3.10. Maintenance / repair strategy

The EPS-CONOPS should document the maintenance and repair strategy the design is using to minimize service interruptions due to power system equipment failures. The EPS-CONOPS should include a description of how service interruptions may be minimized when any one generator set, energy storage system, power converter, switchboard, or load center is taken out of service for maintenance or repair.

The maintenance and repair strategy should influence power system design including the amount of redundancy provided. To preclude or minimize service interruptions, the system should be designed to minimize the number of single points of failure within the power system; Single-points of failure that do exist should be very reliable. Maintenance activities should be designed to minimize failures, and repair strategies should be designed to minimize down time.

3.11. Modernization strategy

The EPS-CONOPS should document features within the electrical power system design that facilitate modernization of the ship. Possible topics include:

a. How service life allowance should be allocated to the various load centers
b. The number and rating of spare breakers in each switchboard and load center
c. Load equipment for which space, weight, power, and cooling has been allocated, but the equipment is not intended to be installed until a time after ship delivery.
d. Power system equipment for which extra capacity is enabled but not provided at ship delivery. Examples include slots for additional power converter modules in a converter, or the ability to replace a generator set with one of higher rating without having to modify switchboards or other distribution system equipment.
e. List of power system equipment that is expected to be replaced during the ship's service life. Specify whether an equipment removal route, bolted equipment removal plate (BERP) or welded equipment removal plate (WERP) should be considered or installed onboard ship.

4. EPS-CONOPS development

The EPS-CONOPS should be developed incrementally in a configuration managed environment. The contents of the EPS-CONOPS should be developed in the order required to support ongoing analysis. In the earliest stages of design, information needed to support the EPLA and endurance fuel calculations are typically required first. Some data elements may be delayed to preliminary design.

5. References

IEEE Std 45.1 IEEE Recommended Practice for Electrical Installations on Shipboard--Design

IEEE Std 45.3 IEEE Recommended Practice for Electrical Installations on Shipboard--Systems Engineering

DPC 200-1 Calculation of Surface Ship Endurance Fuel Requirements

DPC 200-2 Calculation of Surface Ship Annual Energy Usage, Annual Energy Cost, and Fully Burdened Cost of Energy

DPC 310-1 Electric Power Load Analysis (EPLA) for Surface Ships

Doerry, Norbert, and Mark A. Parsons, "Modeling Shipboard Power Systems for Endurance and Annual Fuel Calculations," SNAME J Ship Prod Des (2023)

Doerry, Norbert, "Optimal Generator Set Loading for Energy Efficiency" ASNE Naval Engineers Journal, June 2022, Vol 134-2, pp. 101-111.

Doerry, Norbert, “Developing a generator set scheduling table,” D_000001

Doerry, Norbert, “Operating Conditions and Profiles,” D_000009