

Load Lists

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1. Introduction

Historically, load factor analysis was the principal method for performing an electric power load analysis (EPLA); the creation of the load list and the assignment of load factors was done (and continues to be done in many cases) at the same time as part of the same process. See Glostén (2020), Herbert Engineering Corp (2018) and Elliot Bay Design Group (2017) for examples of a combined EPLA and load list.

Multiple EPLA methods are now recognized; each method requires different load models. For this reason, it makes sense to separate the creation of the load list which contains the data necessary for creating a load model, with the creation of the actual load models. DDS 310-1 for example, recognizes the following load modeling methods:

- 24 Hour Average Load Parametric Equation
- Load Factor Analysis
- Zonal Load Factor Analysis
- Demand Factor Analysis
- Modeling and Simulation Load Analysis
- Stochastic Load Analysis

The load list is the configuration managed list of all the electrical loads on the ship with their characteristics. While load models rely on the data in the load list, the load list data is intended to be independent of the modeling technique. Of course, different types of models require different types of data and the load list must incorporate the required data.

The different models also reflect the different types of analyses that rely upon load modeling. These include:

- Generator capacity sizing
- Power electronic capacity sizing
- Transformer capacity sizing
- Switchboard, load center, power panel capacity sizing
- Cable, bus duct, and bus pipe capacity sizing
- Energy storage capacity sizing
- In-rush current analysis
- Pulsed load analysis
- Quality of service analysis



- Endurance fuel calculations
- Annual energy usage and annual energy cost calculations

Not all the data elements for a given load in the load list are required for all the types of analyses. In many cases, the data elements will be populated based on the order in which the analyses occur. Some analyses do not occur until preliminary design, so the data elements that uniquely map to these analyses may not be populated during earlier concept designs.

2. Proxy loads

The load list should account for all loads onboard the ship. Early in design process, many loads may not be known, or if they are known, their properties may not be known; to address this uncertainty, the load list may contain a number of proxy loads.

A proxy load is used to represent a load or group of loads. Proxy loads may be used in the load list to populate estimates of the load characteristics when the actual data is not known. In some cases, data is incorporated from equipment similar, but not identical, to the equipment that is anticipated will be used. In other cases, properties of loads, or groups of loads, are parametrically estimated or scaled from other ships. Sarrico (2020) provides many parametric relationships. As the level of definition of loads increases, the proxy load estimates are updated.

Multiple small loads that connect to the power system at the same power system interfaces may be lumped together into a single proxy load; electric lighting and electric heaters are often grouped in this way.

Proxy loads have other applications outside of the load list use case; these other applications are not discussed in this document.

The definition of a proxy load should clearly identify what loads the proxy load represents and the assumed properties of each of the constituent loads. As the design evolves, portions of the proxy load may be defined and can be broken out of the proxy load into a separate element in the load list. Knowing how much power (or other attribute) was allocated for that load in the proxy load is important in adjusting the proxy load to eliminate the newly broken out load. For example, initially, all the galley equipment with the same connection to the power system could be lumped together into a galley equipment proxy load. The proxy load would identify all the individual galley equipment functionality it encompasses, and an estimate of the connected load for each of the equipment. The connected load for the proxy load would be the sum of the estimated connected loads of all its constituents. The galley equipment proxy load could contain a function called “microwave oven” and assign a connected load of 1.5 kW based on a market survey of microwave ovens. The proxy load could also include a “Miscellaneous Galley Equipment” component to account for numerous small loads that should be accounted for, but need not be separately identified until detail design. As the design progresses, and equipment is specifically identified, the equipment can be removed from the proxy and separately identified as a load in the load list.



For example, when a specific microwave oven is identified, the microwave oven function is eliminated from the proxy load (and its characteristics such as connected load of 1.5 kW removed from the proxy load connected load) and a new load for “microwave oven” is created with its specific power level (perhaps 1.8 kW) and other characteristics. In some cases, the design process may determine that an assumed functionality in the proxy load is not required; the proxy load can then be adjusted to eliminate the characteristics of this functionality.

Many times, an initial load list is created by adapting the load list (or EPLA) from a parent design and adjusting the loads and characteristics based on differences between the design being conducted and the parent design. Unless one is confident that specific loads on the parent will be used on the current design, one should usually employ proxy loads. The characteristics of the proxy loads should be scaled where needed using physics-based scaling relationships. Note that some systems, particularly mission systems, are not scalable; data from one ship design may be used with minimal adjustment by another design.

If a specific load is only missing a few data elements, it need not be represented by a proxy load. The missing data may either be estimated, or left undefined if not needed for analyses being conducted. The load list entry should identify whether the load characteristic is based on traceable data, estimated, or left undefined. The analyst should ensure that no load characteristics that are needed for a particular analysis is undefined.

3. Developing the load list

The electric load list is used to track all of the loads onboard the ship. As detailed in DPC 310-1, the load list is created based on the following documents:

- Master equipment list
- Mission systems description and one line diagram
- Electrical plant description and one line diagram
- Distributed system descriptions and one-line diagrams
- General/machinery arrangements
- Product model (if it exists)
- Discussions with system designers (if possible)
- EPLAs of similar ships (if available)

While the load list may eventually contain thousands of entries, early on, one should concentrate on the fifty to one hundred largest loads on the ship; these loads will typically comprise between 60% and 80% of the total load. If the equipment fulfilling these loads have not been selected, proxy loads should be used to represent these loads. Similarly, smaller loads (not part of the fifty to one hundred largest loads) may either have their own entry in the load list (if known), or may be aggregated into proxy loads.



Based partially on DPC 310-1, the following data elements should at least be collected (if applicable) for each entry in the load list:

- Nomenclature
- Product breakdown structure identifier
- Location on the ship (zone and/or compartment)
- Point(s) of connection to the power system (power panel, load center, switchboard).
- Identification Plate (nameplate) rating (include units)
- Connected load (kW and kVAR)
- Peak load (kW and kVAR)
- Power type (voltage, number of phases, frequency)
- Load behavior
- Use during different ship operating conditions
- In-rush current demand (if applicable)
- Temperature dependence (if any)
- Tolerance to power interruptions (if applicable)
- Correlation with other loads
- Load shed priority (mission priority)
- References

Often, the above data will not initially be known; analysis must often proceed based on assumptions. These assumptions should be documented and periodically checked for validity. If significant changes are required, analyses should be repeated.

4. Data elements

The composition of a load list is not codified anywhere. The data elements listed below are recommendations based on what is needed to properly model loads for the various types of analysis that may be encountered in the design of shipboard power systems. Depending on the ship, and ship design process, additional data elements may be required.

4.1. Nomenclature

The nomenclature is a descriptive name for the load. If more than one of the same model of equipment is on the ship, the descriptive name for the load should be the same except a unique identifier should be appended. (Diesel Generator Set 1, Diesel Generator Set 2, etc.)

4.2. Product breakdown structure identifier

Used to group loads in an understandable manner to facilitate analysis. SWBS is typically used on naval ships. IEEE std 45.1 provides an alternate taxonomy. Sarrico (2020) lists several additional taxonomies.



4.3. Location on the ship

If known, the compartment the load is located in should be identified. If the compartment is not known, then the zone should be identified if a zonal distribution system is employed. Otherwise, the approximate frame number should be used. The location on the ship should align with the point(s) of connection to the power system; error checking can determine if they are not aligned. Knowing the location of a load can also help uniquely identify the equipment in the overall ship product model and onboard the ship.

4.4. Point(s) of connection to the power system

The load's connection to the power system should be identified; normally the connections would be specific power panels, load centers, or switchboards. Early on, prior to the definition of load centers, associating loads to switchboards is appropriate. Later, as the load centers are identified, the loads should be reassigned to the applicable load center (if not directly connected to a switchboard). Still later, when power panels are defined, loads connected to the power panel should be reassigned to the power panel.

If a load has more than one point of connection, indicate the primary and alternate connection (if applicable.) Normally these loads are powered by a bus-transfer device and the source of the load may be selected manually (MBT), automatically (ABT), or controlled from the control system (CBT).

4.5. Identification Plate (nameplate) rating (include units)

Identifies the rated power (or other load unit such as current) of the equipment as listed on the equipment's identification plate. This rating is not always expressed in terms of electrical power; rated current, and rated mechanical power are common alternatives.

4.6. Connected load (kW and kVAR)

The connected load is the identification plate rating converted to electrical power. For ac loads, both the real (kW) and reactive (kVAR) power should be identified. The conversion process may require estimates for efficiency and power factor; these estimates should be documented in the load list.

4.7. Peak load (kW and kVA)

The peak load is the maximum operating power that the load is anticipated to use; should be no greater than the connected load. Some equipment, such as pumps, will often be selected to that they are not anticipated to ever require the connected load; the peak load will be less than the connected load. For many loads, the peak load and connected load are the same.

4.8. Power type (voltage, number of phases, frequency)

Used to ensure power of the requisite type is provided to the load.



4.9. Load behavior

Provide an indicator of the behavior of the load; how does the peak load differ from the average load. One method is to use a pick list with the following options:

- Constant: When on, load does not deviate substantially from its average value.
- Multi-mode: When on, load has multiple modes, but the load does not change much while in a particular mode.
- Pulsed: When on, load is a pulsed load.
- Cyclic: When on, load is at its peak load for approximately a specified time, then off for approximately another specified time.
- Other: When on, load characteristics are other than one of the above options.
- Unknown: Load characteristics are unknown. More data gathering is required to develop a load model.

For all but the constant load, notes or pointers to another document should provide sufficient information on the load behavior to enable the load to be adequately modeled using the chosen modeling method.

4.10. Use during different ship operating conditions

For each of the operating conditions, an indicator (typically TRUE, FALSE, GROUP or UNKNOWN) if the load is on. If GROUP, then part of a group of loads; see the Correlation with other loads field. If UNKNOWN, additional data gathering is required before the load is modeled.

4.11. Correlation with other loads

Provide information with respect to how this load relates to other loads. For example, if a load is one of five fire pumps, and usually not all five fire pumps are online, but which specific fire pump is online is an operational detail, then this field would include pointers to the other fire pumps and indicate that only a subset should be online at one time.

It may prove beneficial to separately define groups of loads; this field would point to the groups a particular load is a member of. The “rules” for the use of loads within a group would be associated with the group definition.

4.12. In-rush current demand (if applicable)

May be expressed as a current, or optionally, as a multiplier of the connected load converted to a current (In a dc system, the multiplier would be the in-rush current times the nominal rated voltage divided by the connected load). A means should be provided for indicating that an in-rush current is expected, but its magnitude is not known; additional data gathering is required before the load is modeled.



4.13. Temperature dependence

Typically (TRUE, FALSE, or UNKNOWN) if the power used by the load depends on the ambient condition. If UNKNOWN, additional data gathering is required before the load is modeled.

4.14. Tolerance to power interruptions (for QOS analysis)

Recommend using a pick list with an entry chosen for a particular load corresponding to the longest power disruption that can be tolerated from the pick list:

- 0 ms
- 10 ms
- 80 ms
- 0.5 ms
- 2 s
- 2 m
- 5 m
- Unknown

These entries should facilitate choosing technologies to achieve a t1 and t2 that are matched to the loads capability to tolerate power disruptions.

If Unknown, additional data gathering is required before the load is modeled.

Many loads would be expected to tolerate power disruptions of 2 seconds; examples include most motor loads and electrical lighting. A default value of 10 ms is reasonable for most computer-based loads. Loads that can tolerate 5 minutes of interruption usually incorporate thermal inertia; examples include hot water heaters, refrigerators, freezers, electric heaters, and ventilation fans.

4.15. Load shed priority (mission priority)

At a minimum, this field should indicate whether the load is an emergency load or not. Otherwise, this field should depend on the mission priority load shed approach anticipated for the ship. For traditional naval combatants, the loads are categorized as vital, semi-vital, or non-vital. Dynamic mission priority load shedding is tied to operational condition; if dynamic mission priority load shedding is anticipated, categorizing loads into vital, semi-vital, and non-vital for each operational condition may be appropriate.

4.16. References

One or more references should be associated with every data element. These references should be explicitly listed within the load list along with the method of obtaining a copy of the reference. Hypertext links are generally a good way of accessing these references.

5. Managing the load list

Early in concept design, the load list may be managed as part of a ship synthesis software application. As the design matures, management of the load list may shift to a spreadsheet. In preliminary design, it is not uncommon for an engineer (or two) to be assigned full time to keeping the load list aligned with the design (or product model) and improving the data. In preliminary design, a database may be employed. Automatically linking this database to the ship's product model can help ensure alignment of the load list with the design; in many designs however, the linkage is performed manually.

The work associated with obtaining reliable data for the load list should not be underestimated. Vendor datasheets are not always complete. The actual characteristics of a load may not be listed in vendor datasheets, or may depend on equipment options whose characteristics are not separately listed. In some cases, vendors are only willing to provide the required information after an order has been placed. Considerable communication with vendors may be required.

In general, 60% to 80% of the ship's load can usually be accounted for by 50 to 100 of the largest loads. Effort should be expended early on in obtaining good information on these loads; errors associated with smaller loads have a smaller likelihood of requiring rework.

6. References

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

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

IEEE Std 45.3 IEEE Recommended Practice for Shipboard Electrical Installations – Systems Engineering

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