# Control interaction with mission systems

Norbert Doerry

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## 1. Introduction

Shipboard power systems are designed to be capable of serving all loads needed in any operational condition. However, in order to minimize fuel consumption, a ship may operate with less online capacity and reserve power than needed for any possible contingency. Reserve power is generation capacity in excess of the operating load which may be used for powering additional loads. Consequently, control interactions between large loads that are part of the mission systems and the shipboard power system controls may be designed and implemented to ensure the power system has sufficient capacity when needed. An alternative is to install sufficient energy storage such that there is always sufficient reserve power for large loads.

In the case of pulsed loads, the capability of the power system to support different pulse levels and ramp rates may be dependent on system configuration. A negotiation process between the pulsed load and the power system may enable the pulsed load to operate at the highest level of performance possible within the capability limits of the current ship power system configuration.

## 2. Examples

### 2.1. Large load

A large load is any load requiring more than 20% of the online power capacity supplying that load. In an integrated power system, a propulsion motor, fulfilling the mobility mission requirement, is usually one of the largest loads onboard the ship. It is not unusual for the control system to limit the maximum amount of propulsion power that the operator may employ based on the operating load and online generation capacity. If the operator desires to employ more propulsion power than the limit allows, then the control system typically brings another generator set online before raising the maximum propulsion load limit and allowing propulsion to draw additional power.

Another example is the case of a mechanical drive roll-on-roll-off (RORO) ship where vehicles must operate their internal combustion engines periodically onboard ship. When the vehicles are operating, large ventilation fans are required to remove carbon monoxide and other combustion products from vehicle decks. When the operator commands the ventilation fans to turn on, it is not uncommon for the electrical power control system to inhibit the fans from starting until there is sufficient generation capacity online to power them.

### 2.2. Pulsed Load

The voltage at the interface to a pulsed load is expected to adhere to an interface standard. The pulsed load however, is likely to have desired current and power waveforms that are significantly different from other loads; the power system may not be capable of ensuring the voltage adheres to the interface standard current and power waveforms desired by the pulsed load. If this is the case, then it may be beneficial for the power system controller and the pulsed load to negotiate properties of the power interface to maximize the performance of the pulsed load while still enabling the power system to maintain the voltage waveform at the interface within specification limits. For example, the generator set controls could be commanded to implement optimization based on transient response rather than fuel economy. See Doerry and Amy (2015), Doerry (2017) and Doerry (2020) for more detailed discussion.

### 2.3. Load shedding

A control system interface between the power system control and individual loads can be very beneficial; loads can be commanded to enter a low power mode rather than shutting off power to them completely. In many cases, the loads can resume normal operation faster from the low power mode as compared to a complete cold start when power is restored. In some cases, it may be practical for the load to have multiple power limit levels; the loads may be able to function at reduced capability during one or more levels of load shedding.

## 3. Implementation

The interface between mission system equipment and the power system controls should include definitions for all seven layers of the Open Systems Interconnection (OSI) Model (ISO/IEC 7498-1):

a. Physical layer
b. Data link layer
c. Network layer
d. Transport layer
e. Session layer
f. Presentation layer
g. Application layer

Certain protocols, such as TCP/IP combine OSI Model layers. In general, standard protocols should be selected for the first six layers. Much of the remaining work will involve definitions for the application layer.

 

A simple command-response application layer protocol could look like:

- Load request for use of power from power system
- Power system grants request or commanded to stand by
- Load acknowledges power system response and behaves accordingly
- If load commanded to standby, power system grants request when the power system is ready
- Load acknowledges power system response

The behavior of the load in response to the request being granted or commanded to stand by should be clearly defined.

The behavior of the system if the protocol is not completed within a specific time should also be clearly defined; the request should expire if the protocol is not completed within time.

The protocols should be described in the ship's Interface Control Document (ICD) as detailed in IEEE Std. 45.3.

4. Design issues

The development of interface specification between loads and the power system should consider several things:

- The interface should be testable before the load and power system controls are integrated onboard the ship. Ideally, during factory acceptance testing, the load should demonstrate conformance to the interface requirements; similarly, the power system controls should demonstrate conformance to the interface requirements during its factory acceptance testing.
- System behavior of the integrated system should be demonstrated to be acceptable; in cases where performance is negotiated, the negotiated solution should achieve overall system requirements.
- System behavior when the protocol or negotiations are not completed on time should be demonstrated to not cause hazardous situations. A method to restart and complete the negotiations on time should also be demonstrated.

One should consider the use of hardware-in-the-loop (HIL) simulations, including both control hardware in the loop (CHIL) simulation and power hardware in the loop simulation (PHIL) in development and testing of the power system control to load control interface. For more details on HIL simulation, see IEEE Std 2004.

 

## 5. References

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