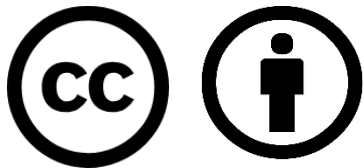


# Power System Survivability

## Ship Electrical Distribution System Design

Revision of October 1, 2026

Dr. Norbert Doerry



<http://doerry.org/norbert/MarineElectricalPowerSystems/index.htm>

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# Essential Questions

What is a design threat and a design threat outcome?

Understand

What are the three elements of survivability?

Understand

What is zonal survivability?

Understand

What is compartment survivability?

Understand

How should zone boundaries be determined?

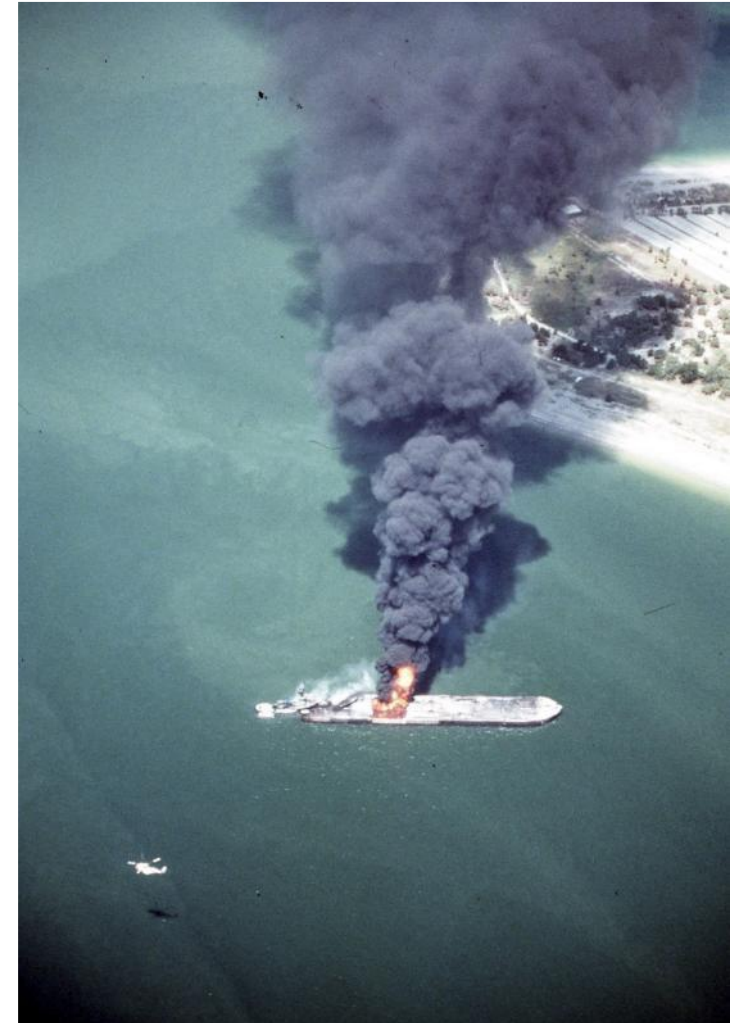
Understand

How is survivability evaluated?

Understand

# Design Threats / Design Threat Outcomes

- Design threats
  - threats that a ship is designed to address.
- Design threat outcomes
  - capabilities that the ship is expected to retain or restore following exposure to a threat.
- Overmatching threats
  - threats that may result in loss of the ship;
  - the ship is not expected to retain capability after exposure to an overmatching threat.



# Elements of survivability

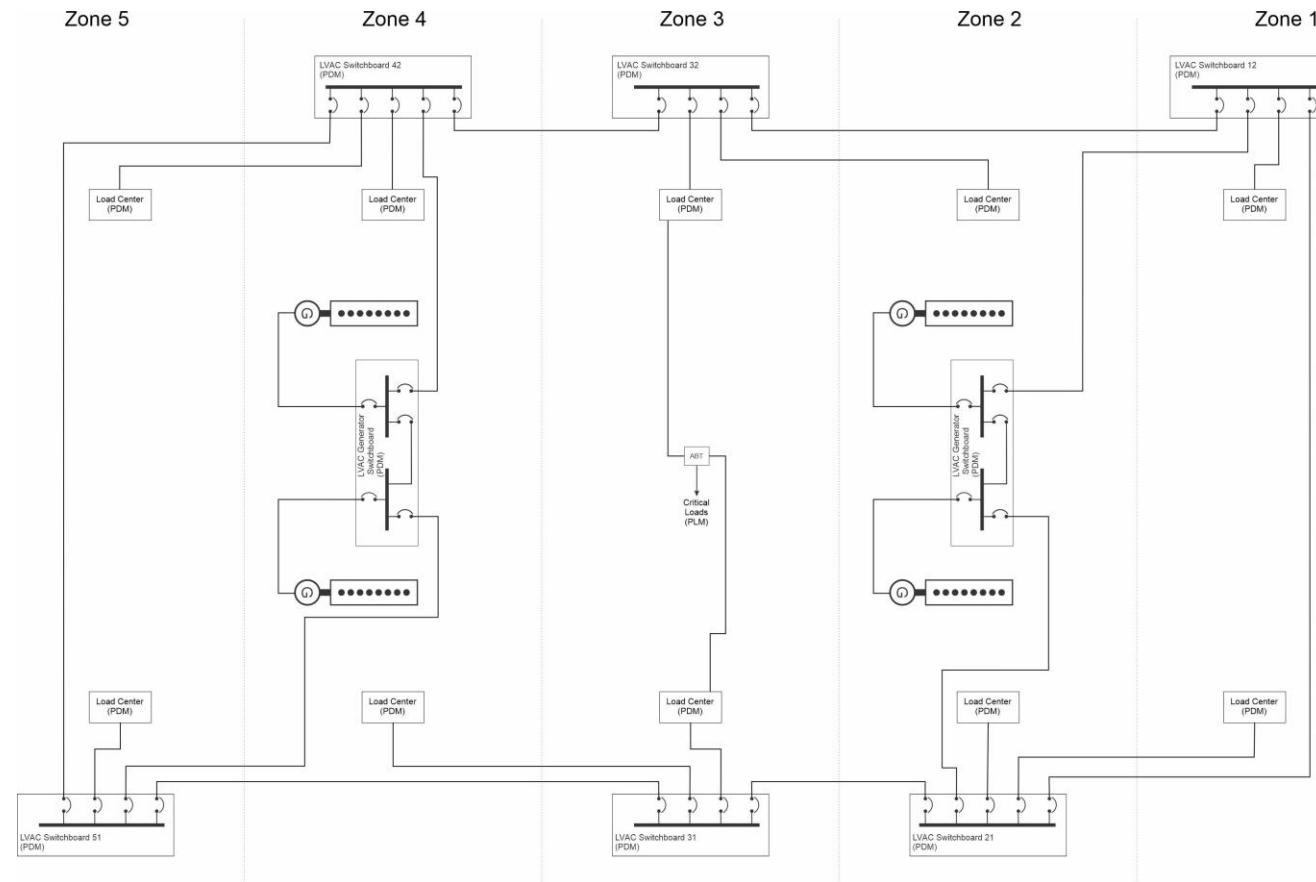
- Susceptibility
  - measures how well the ship avoids the threat such that the ship does not experience damage
- Vulnerability
  - measures how well the ship is able to retain capability when the ship is exposed to the threat and possibly damaged
- Recoverability
  - measures how well the ship is able to restore lost capability following exposure to a threat



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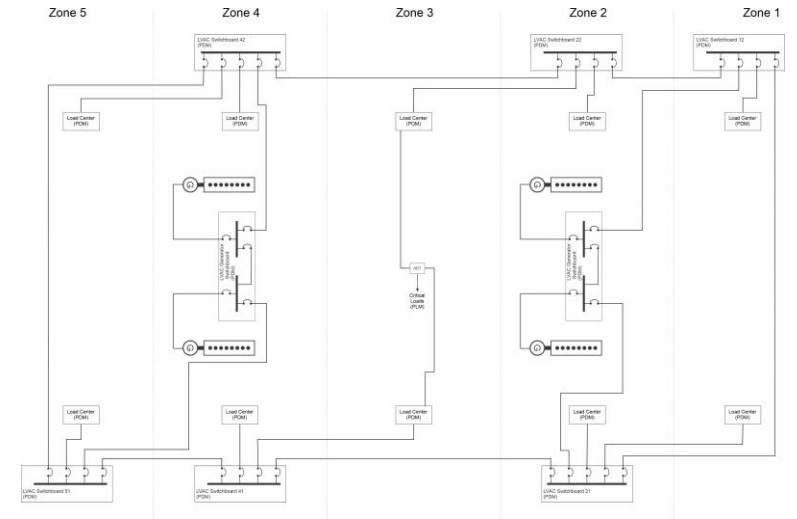
# Zonal survivability

- IEEE Std. 45.1
- For a distributed system,
  - such as the electrical distribution system,
  - zonal survivability is the ability of the distributed system,
  - when experiencing internal faults due to damage or equipment failure confined to adjacent zones,
  - to ensure loads in undamaged zones do not experience a service interruption.
- Because a bounding watertight subdivision transverse bulkhead can be damaged,
  - zonal survivability assumes that two adjacent zones can experience damage due to a single event.
  - The zones should be large enough such that no more than two zones are damaged due to a single event that the ship is expected to survive.”

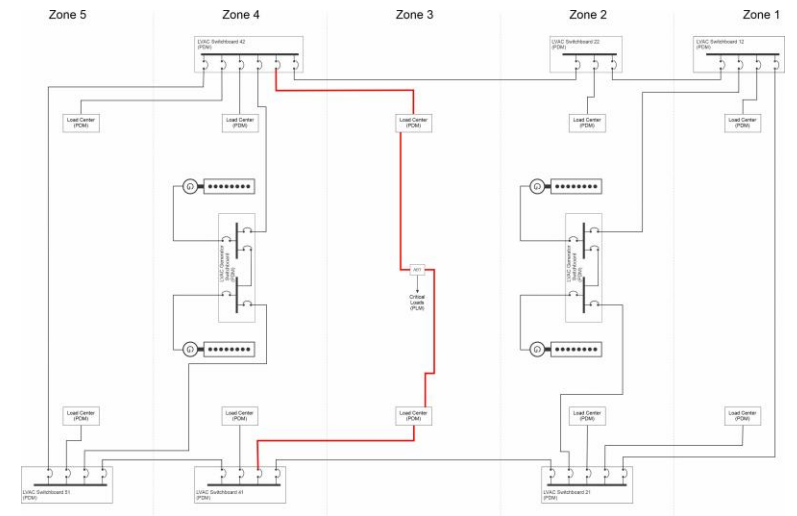


# Compartment Survivability

- IEEE Std. 45.1
- Compartment survivability addresses the ability to recover loads within a damaged zone.
  - In many cases, the damaging event does not damage all of the equipment within a zone.
  - Critical equipment, such as the emergency loads, should have a means of restoring power to them if they are
    - verified to be undamaged and
    - will not cause a hazard if energized.
- Compartment survivability is usually achieved by providing an alternate source for each distributed system that the load requires.
  - For the electrical power system, switching from the normal to an alternate source is accomplished through either a manual bus transfer or an automatic bus transfer.
  - On some naval ships, a casualty power system is provided to enable the rigging of temporary power cables from a load center or switchboard to the critical equipment



**GOOD: Zone 3: Normal and alternate supplies from fore and aft**



**Bad: Zone 3: Normal and alternate supplies both aft  
Loss of zone 4 causes loss of power to all loads in zone 3**

# Casualty Power Systems

- Composed of
  - Portable cables
  - Permanently installed cables
  - Connectors
  - Bulkhead penetrations
- Enables restoring power to emergency loads / loads designated for compartment survivability
- Generally, only found on naval ships

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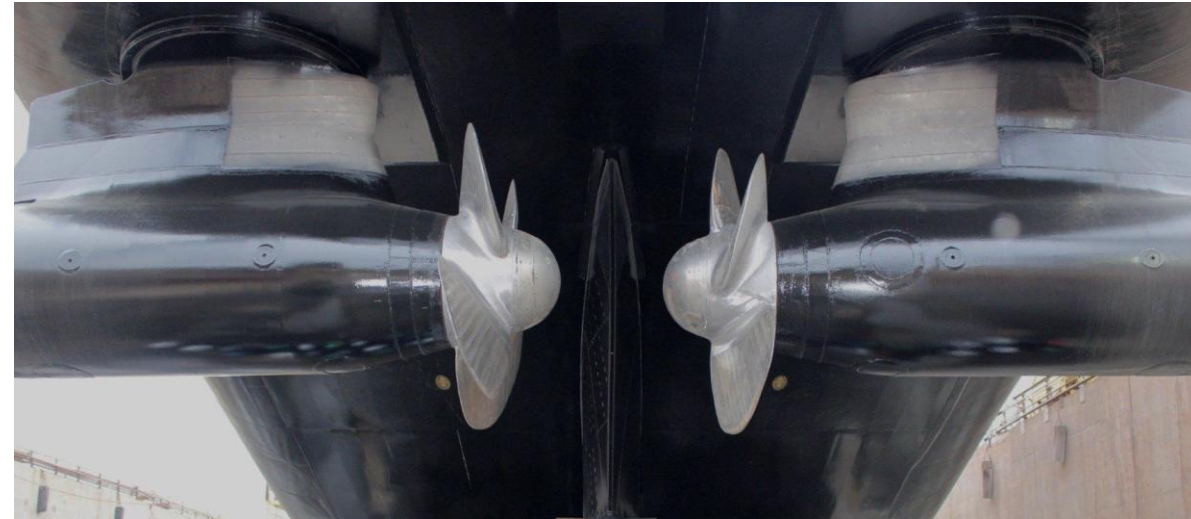
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# Dynamic Positioning

- Dynamic positioning provides an inherent level of survivability for the propulsion system.
- ABS Guide for Dynamic Positioning System
  - “DPS-2 For vessels which are fitted with a dynamic positioning system which is capable of automatically maintaining the position and heading (Station Keeping) of the vessel within a specified operating envelope under specified maximum environmental conditions during and following any single fault, excluding a loss of compartment or compartments.”
  - “DPS-3 For vessels which are fitted with a dynamic positioning system which is capable of automatically maintaining the position and heading (Station Keeping) of the vessel within a specified operating envelope under specified maximum environmental conditions during and following any single fault, including complete loss of a compartment due to fire or flood.”



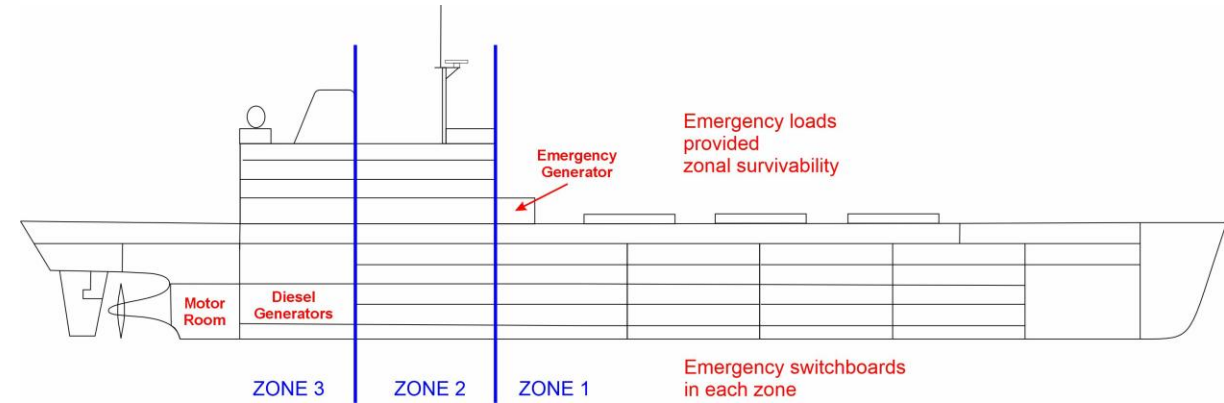
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# Zone boundaries

- Zones should be large enough such that non-overmatching damage to the ship due to an initiating event (such as grounding, collision, fire, or weapon effects) does not extend beyond two adjacent zones. Ships are not designed to survive overmatching damage.
- Zone boundaries should be designed to preclude fire spreading or progressive flooding to extend beyond the initial one or two damaged zones.
  - Zone boundaries should be watertight and should have an A-60 fire rating as defined by SOLAS Chapter II-2.
  - The fire protection system should be designed to detect and extinguish fires as quickly as possible;
    - for non-overmatching threats, fires should be extinguished in no more than 60 minutes.
- For ships required by SOLAS to have the capability for safe return to port,
  - the casualty threshold for fire is no larger than a single zone
  - the flooding requirement of any single watertight compartment is also no larger than a single zone.
  - The boundaries of zones should be selected such that the systems required to remain operational by SOLAS have sufficient redundancy across zones.
- With any two adjacent zones damaged, there should be sufficient capability remaining in the undamaged zones to achieve the survivability objectives of the ship.
- For systems required to be operational following damage and have multiple single points of failure, the single points of failure should ideally be located in the same zone.
- For systems required to be operational following damage and have redundancy, redundant capability should ideally be located in different zones that are not adjacent.
- A ship with a two-compartment damaged stability requirement can satisfy the flooding criteria with zones that span at least a single watertight subdivision. A ship with a three-compartment damaged stability requirement can satisfy the flooding criteria with zones that span at least two watertight subdivisions.

# Evaluating zonal survivability

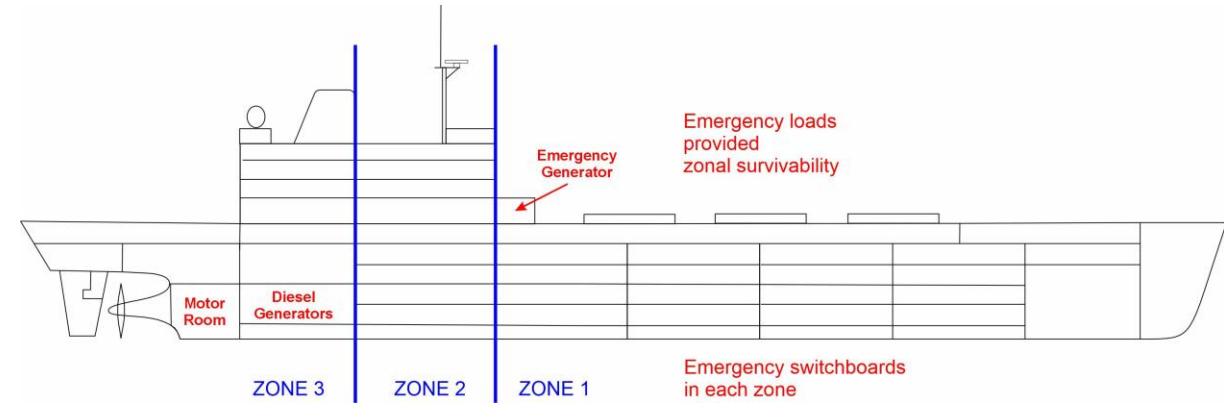
- Examine damaged zone cases
  - All individual zones
  - All pairs of adjacent zones
- With each damaged zone case
  - Ensure sufficient generation and connectivity remains to power loads designated for zonal survivability
  - Ensure sufficient loads remain in undamaged zones to achieve design threat outcome



| Case | Damaged Zones |
|------|---------------|
| 1    | 1             |
| 2    | 2             |
| 3    | 3             |
| 4    | 1 and 2       |
| 5    | 2 and 3       |

# Evaluating compartment survivability

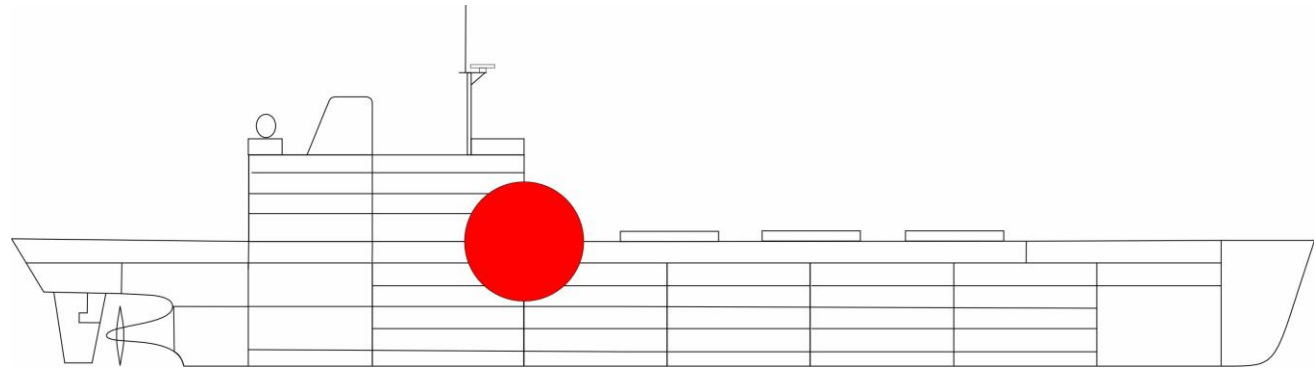
- Extension of Zonal Survivability Analysis
- Examine loads designated for compartment survivability in the damaged zones
  - Ensure sufficient connectivity to undamaged zones
    - Bus Transfer between two feeders
    - Casualty power connection
  - Ensure sufficient generation capacity in undamaged zones



| Case | Damaged Zones |
|------|---------------|
| 1    | 1             |
| 2    | 2             |
| 3    | 3             |
| 4    | 1 and 2       |
| 5    | 2 and 3       |

# Evaluating non-zonal system survivability

- A limited set of locations for damage are assumed.
- Damage to equipment (and structure) from each design threat is assessed.
- Overall impact of the damage on the ability to achieve design threat outcome is estimated.



Non-zonal system survivability assessment much more labor intensive than for zonal survivability. Zonal survivability provides survivability via architecture. Non-zonal systems provide survivability via detail design and analysis.