



Shipboard Distribution Systems: Present and Future

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Naval Electric Power System Design

The primary aim of the electric power system design will be for survivability and continuity of the electrical power supply. To insure continuity of service, consideration shall be given to the number, size and location of generators, switchboards, and to the type of electrical distribution systems to be installed and the suitability for segregating or isolating damaged sections of the system.

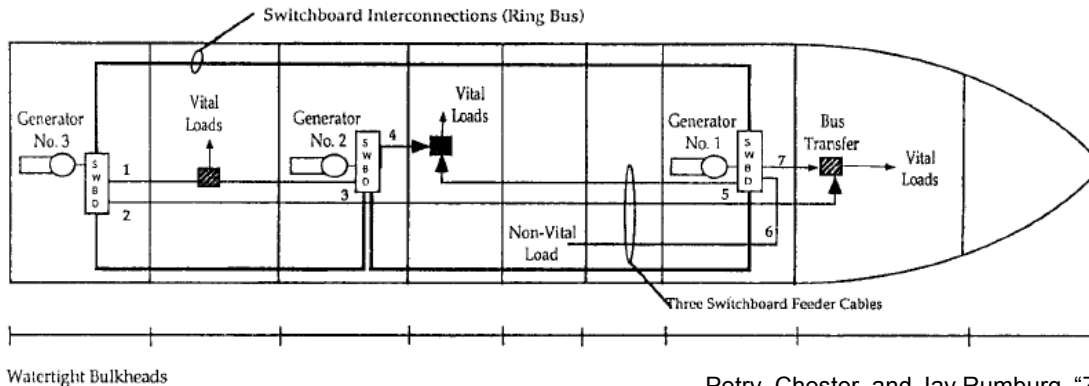
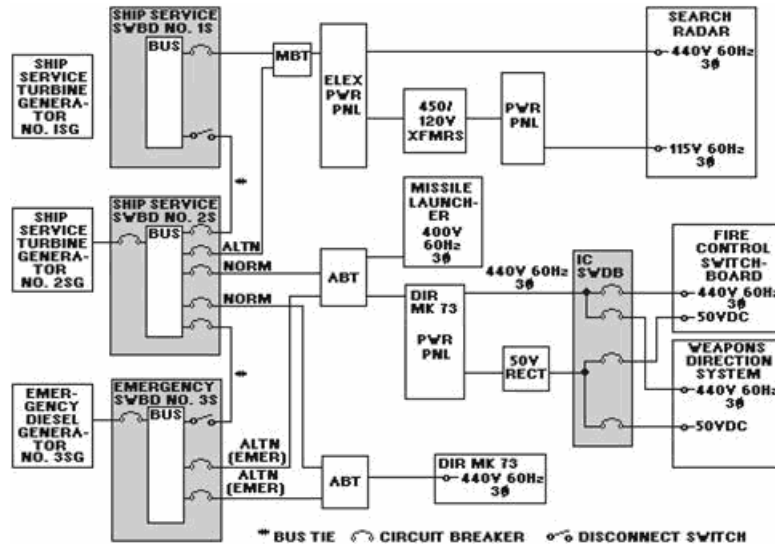
- NAVSEA DESIGN PRACTICES and CRITERIA
MANUAL, ELECTRICAL SYSTEMS for SURFACE
SHIPS, CHAPTER 300
NAVSEA T9300-AF-PRO-020



Shipboard Electrical Distribution Systems

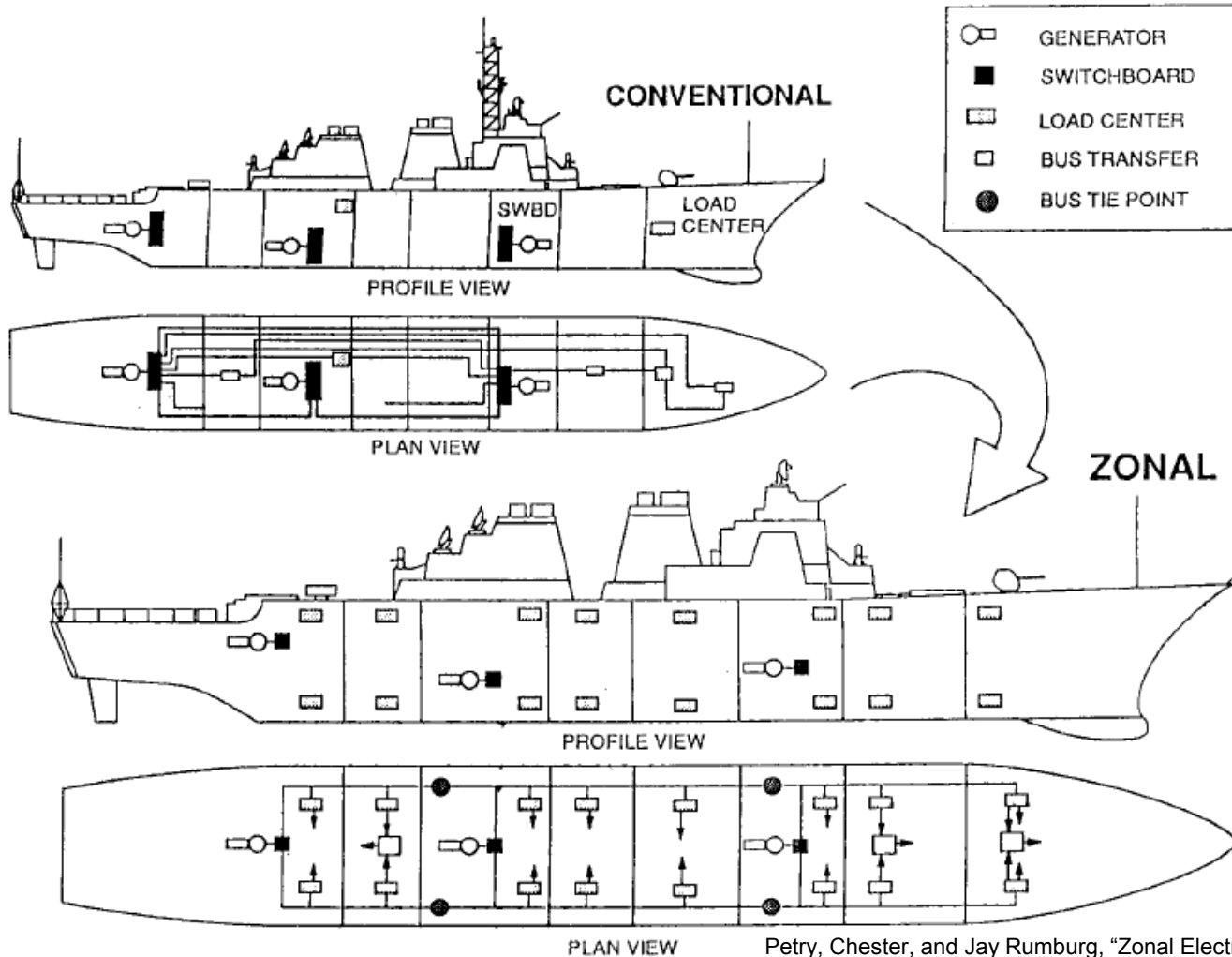
- Radial Ship Service Distribution Systems
- Low Voltage Zonal AC Distribution Systems (non-IPS)
- Medium Voltage Zonal AC Distribution Systems
- Commercial Integrated Electric Drive
- DDG 1000 IPS (Integrated Power System)
- NGIPS MVAC (Medium Voltage AC)
- NGIPS MFAC (Medium Frequency AC)
- NGIPS MVDC (Medium Voltage DC)

Radial Ship Service Distribution



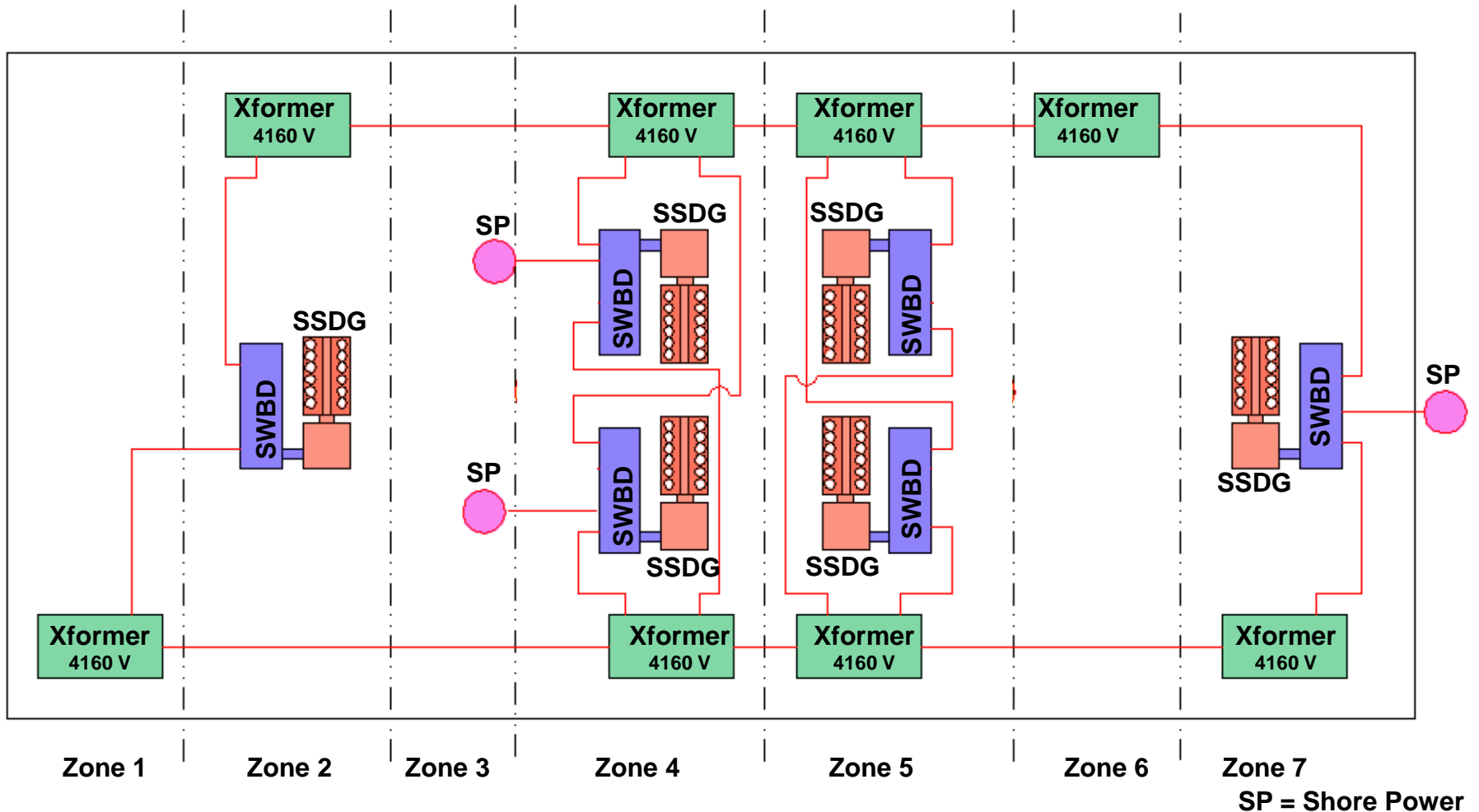
Petry, Chester, and Jay Rumburg, "Zonal Electrical Distribution Systems: An Affordable Architecture for the Future", ASNE NEJ, May 1993.

Low Voltage Zonal AC Distribution

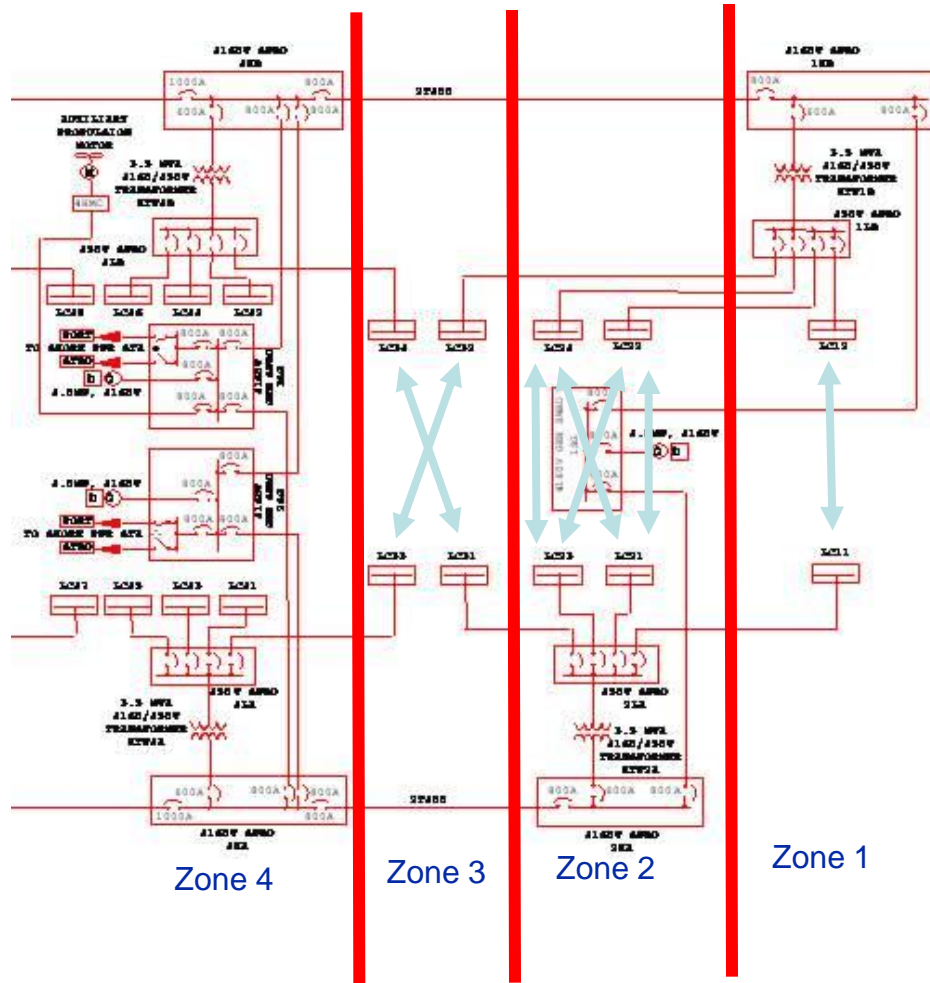


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Medium Voltage Zonal Distribution

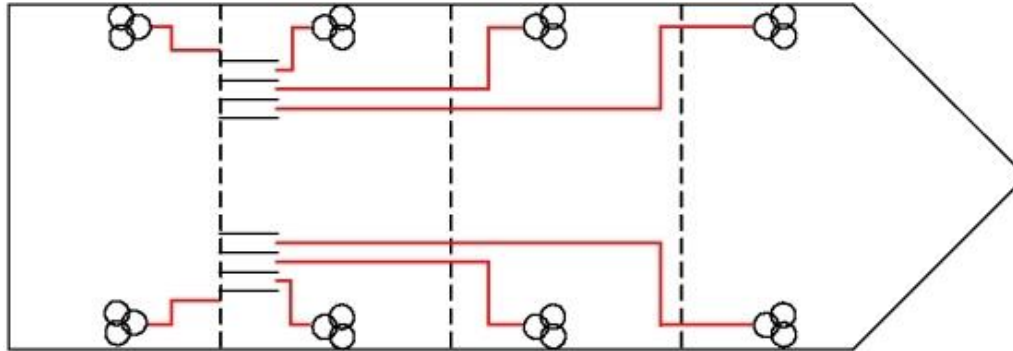


Medium Voltage Zonal Distribution: Interface with in-zone Low Voltage Distribution

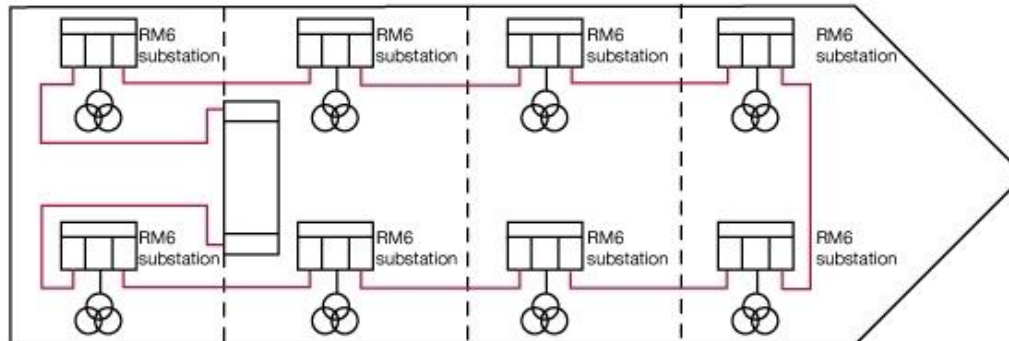


Cruise Ship Radial vs Zonal System

Radial configuration



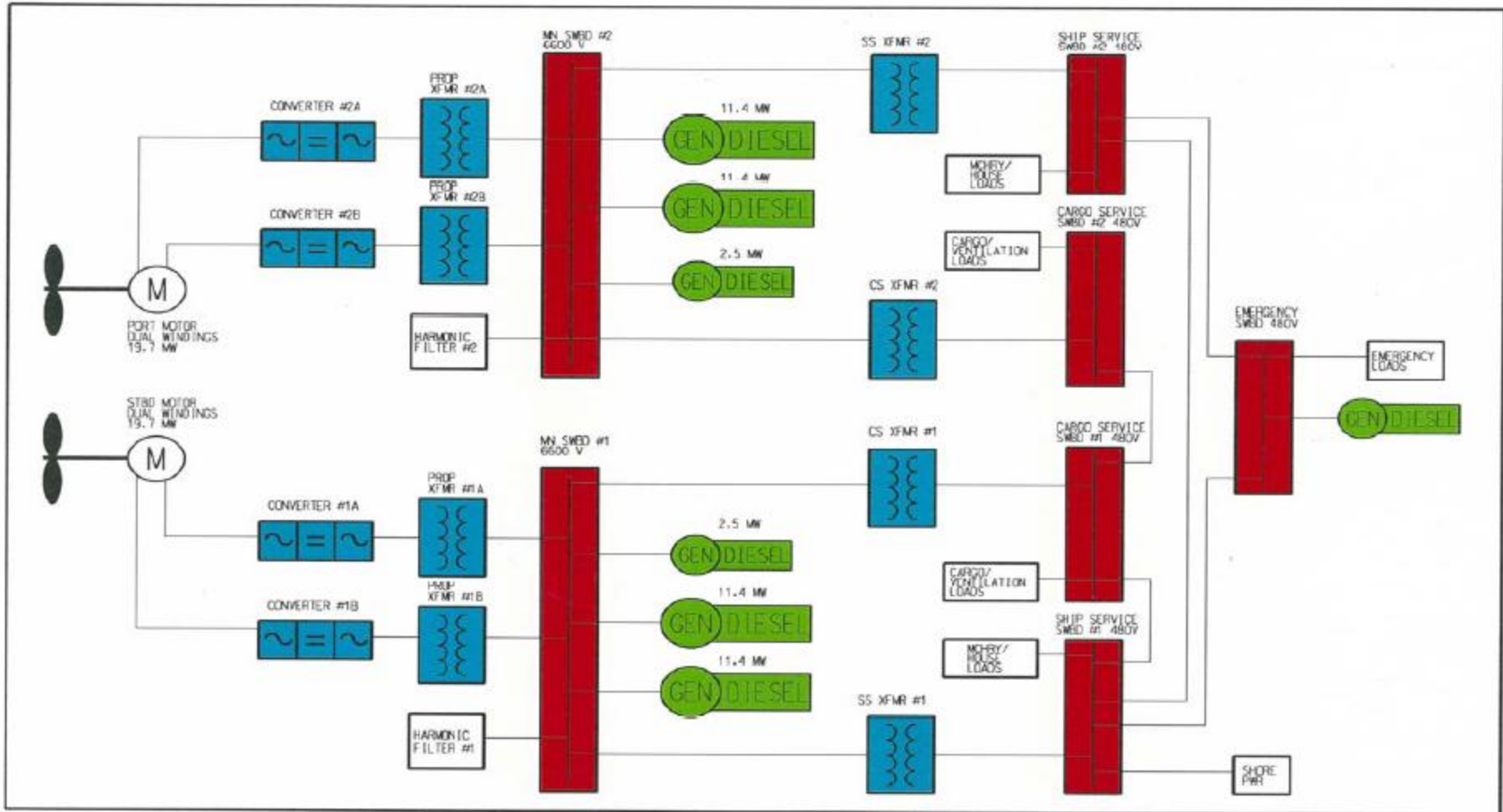
MV Loop (Zonal) configuration



Example of a cruise liner architecture

http://www.schneider-electric.com/sites/corporate/en/solutions/business_segments/marine/marine-solutions/the-ring-main-units-solution.page

Commercial Integrated Electric Drive



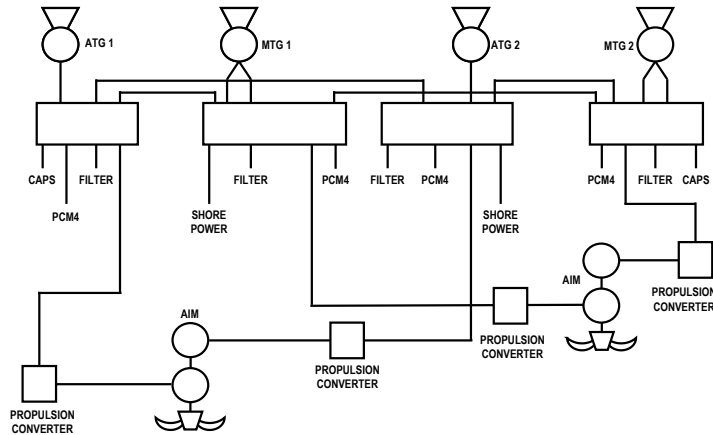
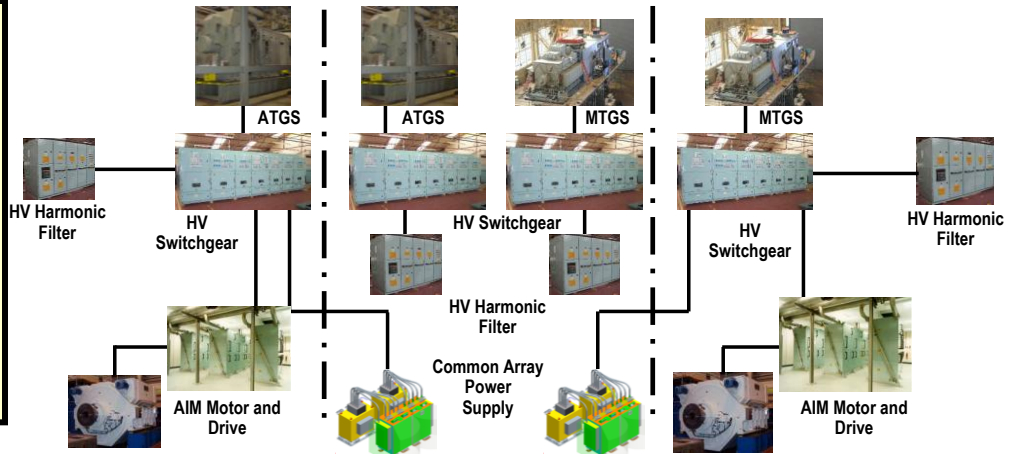
TOTE DISTRIBUTION DIAGRAM (TRAILER SHIP)

Dave McMullen, General Dynamics NASSCO, presentation to ASNE – SNAME Electric Ship Design Symposium 2009

DDG 1000 IPS – Medium Voltage

HVPS (Converteam)

- Power Generation 78 MW Installed
 - (2) Main Turbine Generators
 - (2) Auxiliary Turbine Generators
- Propulsion System
 - (2) 34 MW Tandem Advanced Induction Motors and Drives
- Distribution System
 - (4) Modified COTS switchboards and protection systems



HVPS Benefits

- Survivability – Separation and redundancy
- Reliability – Graceful degradation of systems
- Power Flexibility – installed power available for propulsion and ship service
- Cost – mature and ruggedized COTS based Technologies

DDG 1000 IPS – Low Voltage

IFTP System (DRS Technologies)

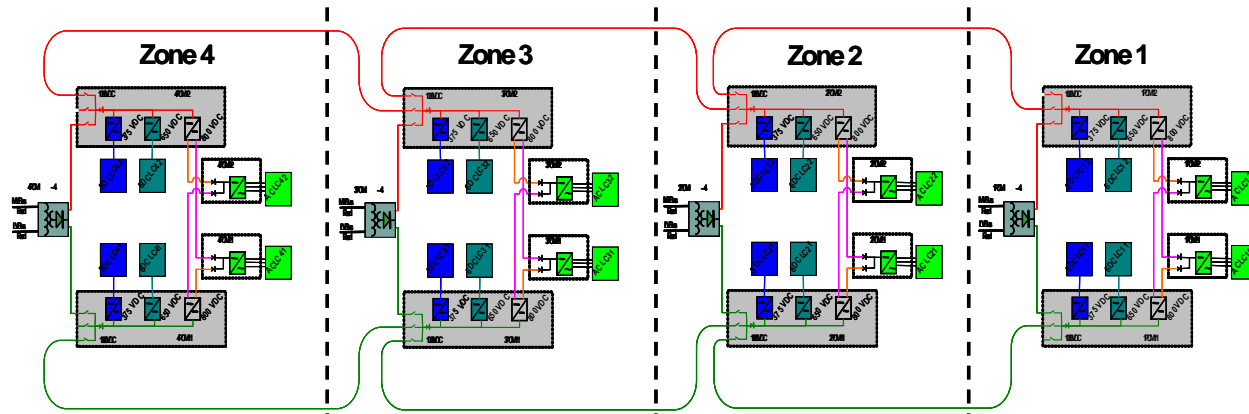
- 4 Zone 1000 VDC Distribution System
- Power Conversion
 - (4) 3 MW PCM-4's
 - (8) PCM-1's
 - (8) PCM-2's
- (16) Load Centers

SSDS System (Various Suppliers)

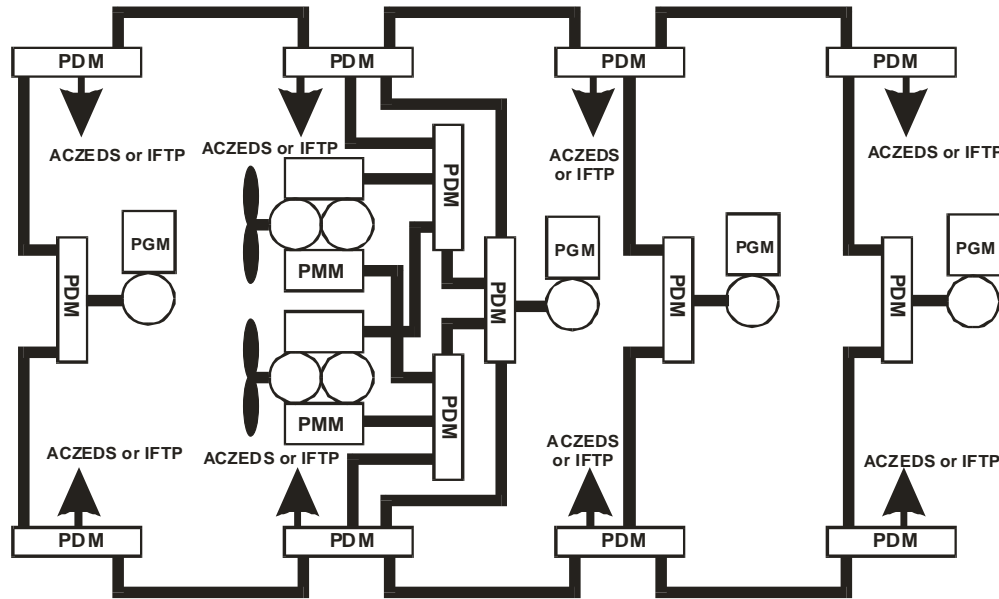
- PCU/UPS for Power Conditioning and Energy Storage
- (2) 500 kW EDGs
- Distribution Transformers
- Automatic Bus Transfer Switches
- Power & Lighting Panels

LVPS Benefits

- Survivability – Zonal Fight-through, EDG and over 2MW UPS
- Multiple power types and quality as required by loads
 - 900 VDC, 650 VDC, 375 VDC, 450 VAC, 208 VAC, 120 VAC
 - Specialized power for individual loads
 - Provides isolation from generation bus harmonics / minor transients
 - Port/Starboard seamless transfer via Auctioneering diodes
 - Power management system to ensure power continuity, quality and availability
- Modularity – ability to expand as load grows



NGIPS Medium Voltage AC



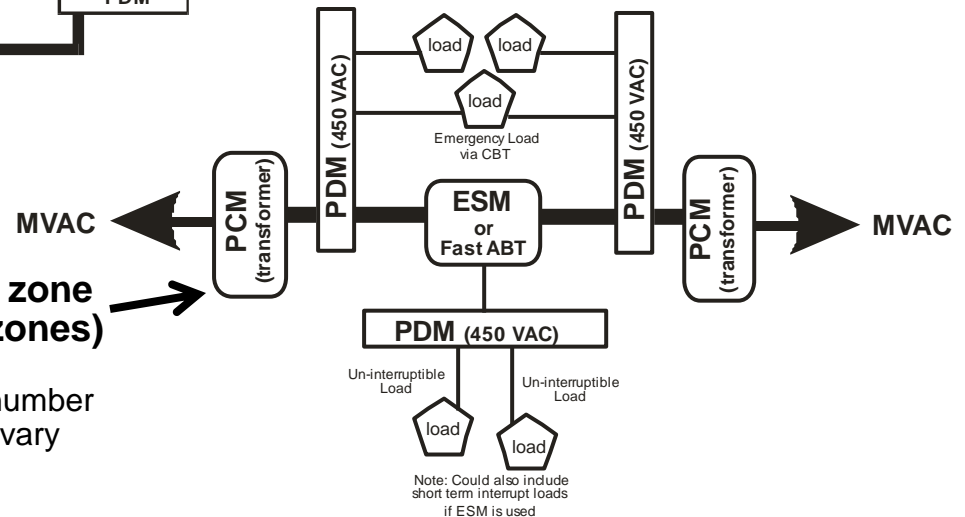
Notional Power Generation Bus

May be in an adjacent zone (shared with multiple zones)

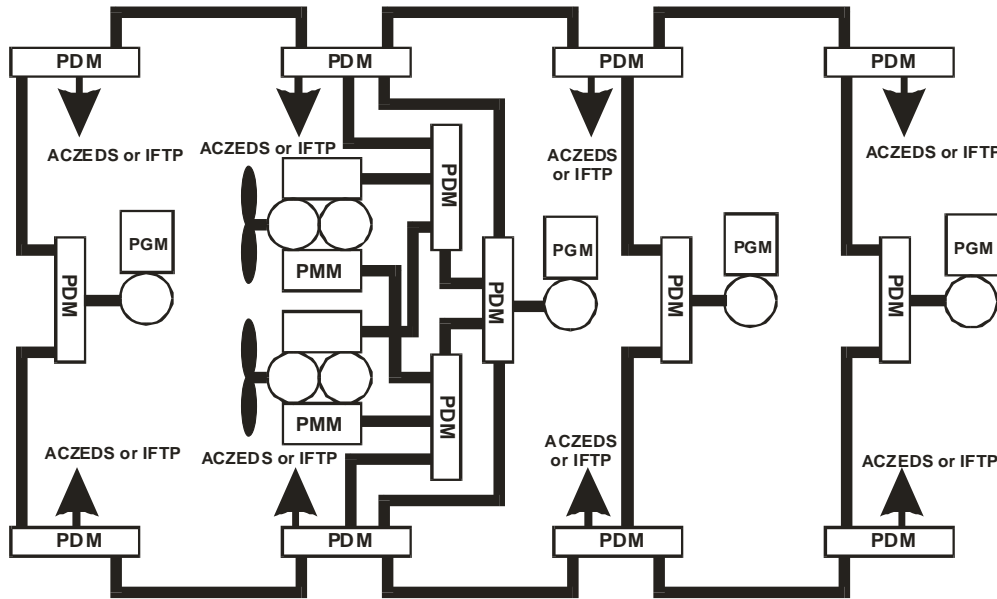
NOTE: Power Generation Bus configurations (including number of zones and number and location of PGMs / PMMs) will vary based on ship requirements

PGM: Power Generation Module
 PDM: Power Distribution Module
 ESM: Energy Storage Module
 PCM: Power Conversion Module
 PMM: Propulsion Motor Module

Notional Zonal Electrical Distribution



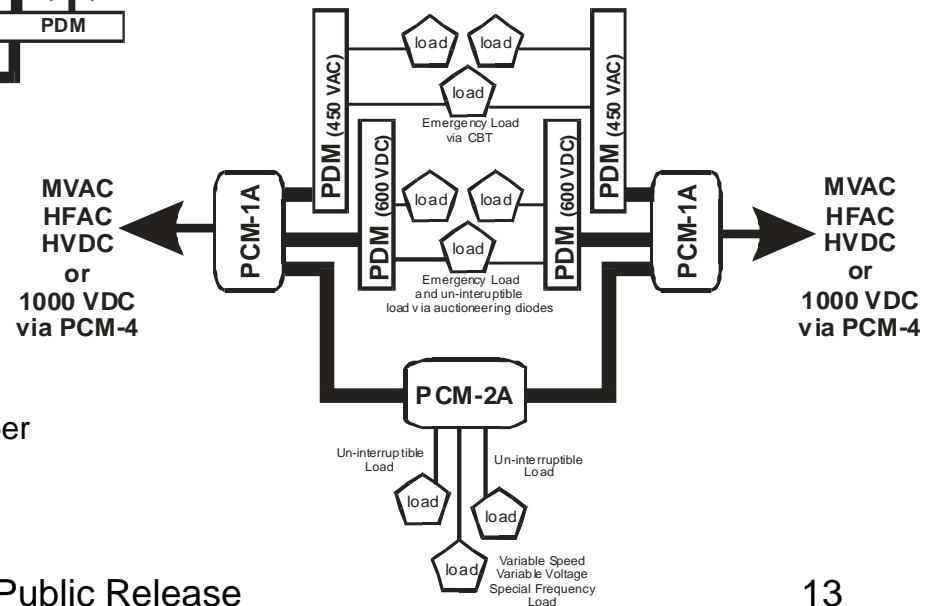
NGIPS Medium Frequency AC



Notional Power Generation Bus

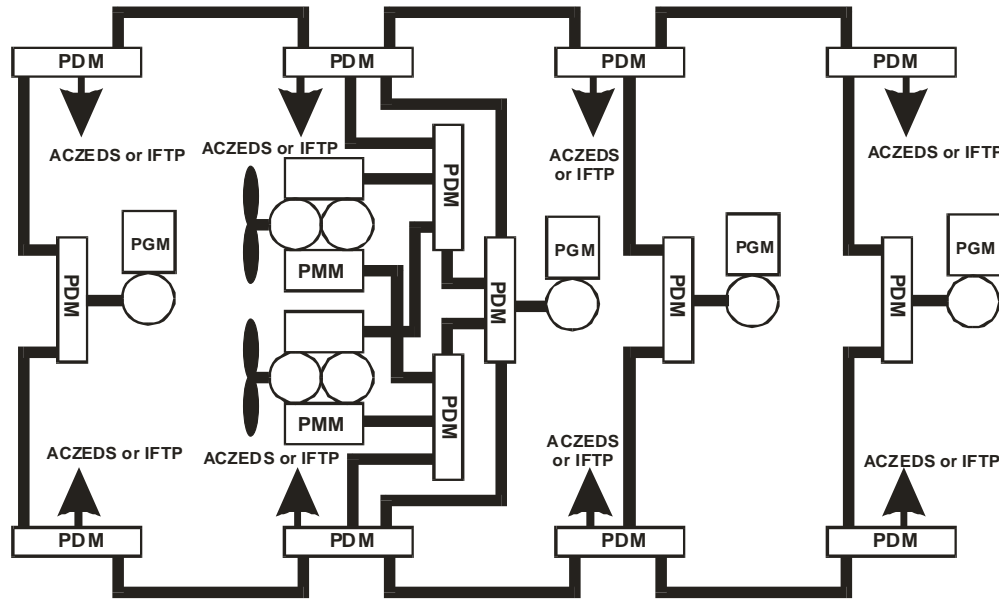
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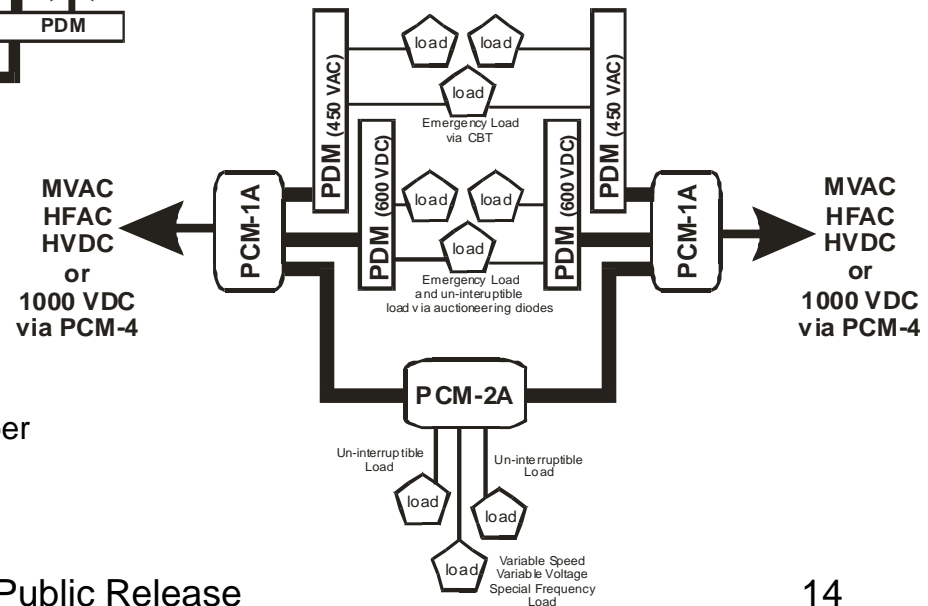
NGIPS Medium Voltage DC



Notional Power Generation Bus

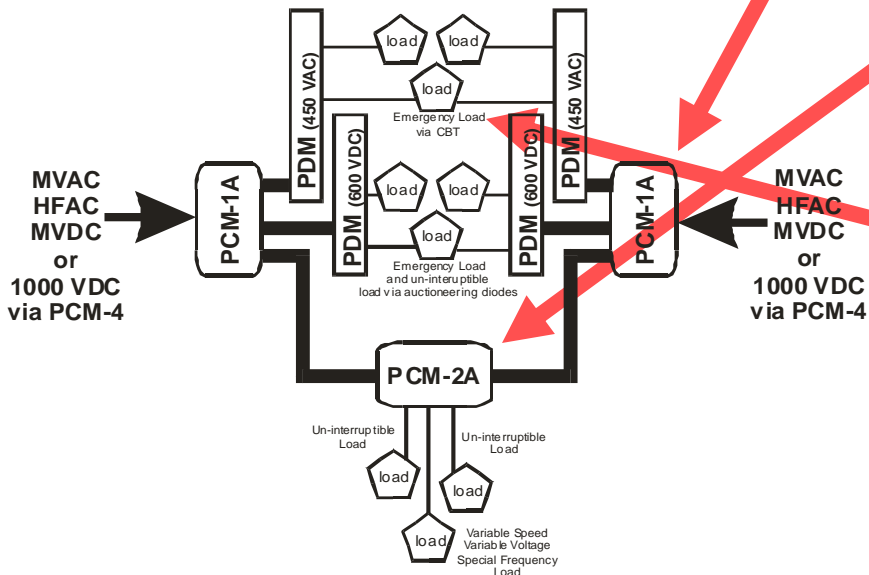
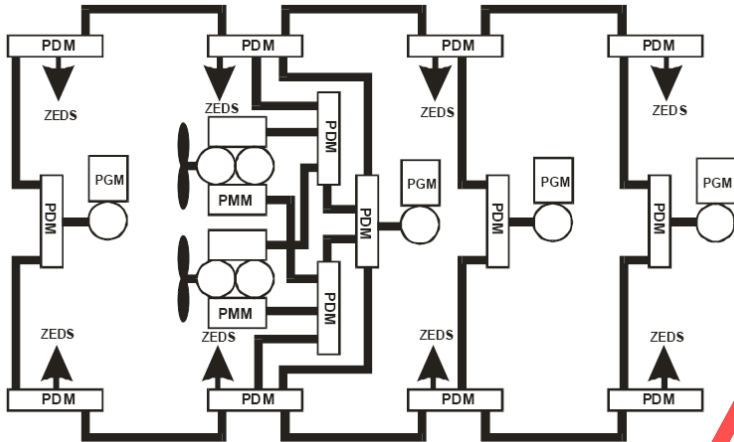
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Notional In-Zone Architecture



PCM-1A

- Protect the longitudinal bus from in-zone faults
- Convert the power from the longitudinal bus to a voltage and frequency that PCM-2A can use
- Provide loads with the type of power they need with the requisite survivability and quality of service

PCM-2A

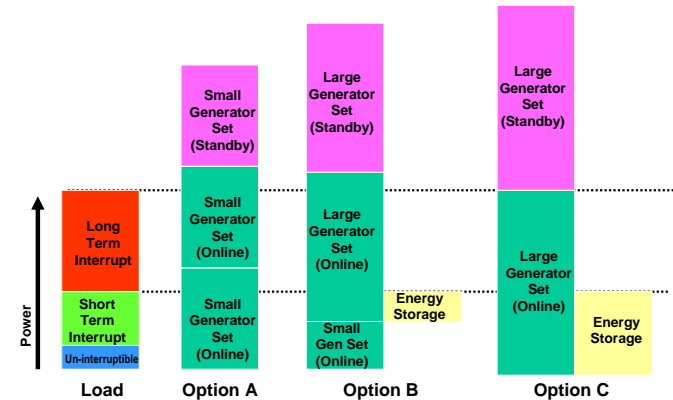
- Provide loads with the type of power they need with the requisite survivability and quality of service
- IPNC (MIL-PRF-32272) can serve as a model

Controllable Bus Transfer (CBT)

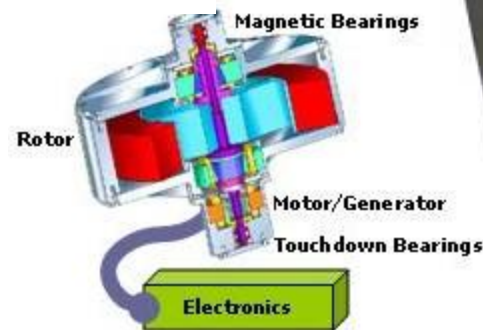
- Provide two paths of power to loads that require compartment level survivability

Energy Storage

- Many Potential Uses for Energy Storage
 - Reduce rolling-reserve requirements by providing short-term hold-up of loads while a generator is being brought online.
 - Could be important for pulse power loads
 - Holding up a bus while long-term interrupt loads are shed in an orderly manner.
 - Providing startup power to generator sets in a “dark ship” start.
 - Provide pulse power to loads.
 - Level loading to delay bringing on an additional generator.



General Atomics
Series CMF
Energy Storage Capacitor
E: > 100 kJ
Density = 1.8 J/cc
Millisecond discharge



SAFT DAUPHIN Module
E: > 9 kWh
U average: 3.5V
Mass: 120 kg
Volume: 60 liters
Li-Ion



Electrical Distribution System Take - Aways

- Move towards Zonal Systems
 - Reduced cable requirements (cost and weight)
 - Improved producibility
- Move towards Medium Voltage generation and transmission
 - Higher Power Levels
 - Integrated Electric Drive
- Increased use of Power Electronics in Naval Systems
 - Power Density
 - Power Quality and Quality of Service
 - Limit fault currents
- Increased use of Energy Storage in Naval Systems
 - Quality of Service
 - Energy Conservation
 - Reduced Rolling Reserve requirement