Architecture Choice

Shipboard Power System Fundamentals

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http://doerry.org/norbert/MarineElectricalPowerSystems/index.htm
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Essential Questions

How does one choose the electrical and propulsion architecture types?	Apply
How does one design the power and propulsion system networks?	Apply
How does one pick between a.c. and d.c. buses for different parts of the architecture?	Apply
How does one choose the voltage level of buses?	Apply

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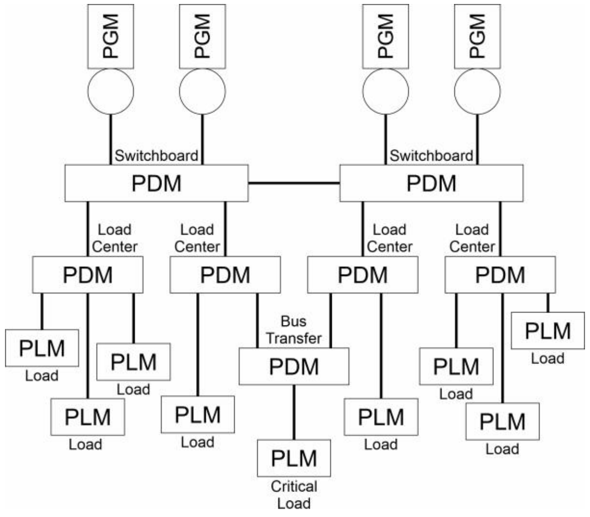
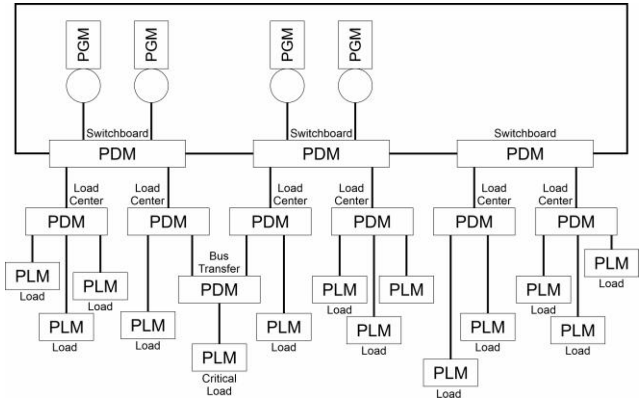
Introduction

- Which Architecture to choose?
  - The architecture that best meets all the customer requirements.
- What is needed?
  - Definition of customer requirements
  - Definition of what is meant by "best"
  - A means for evaluating a proposed architecture
    - Does it meet customer requirements?
    - Is it the best?

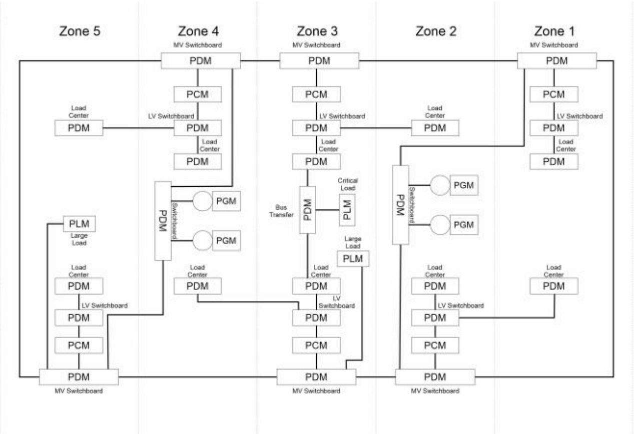
Radial



Ring Bus



Zonal



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Stages of Design

- Concept Design
  - Products
    - Set of requirements.
    - Evaluation of the mission effectiveness of a ship that meets the requirements.
    - Estimated acquisition and life cycle costs.
  - Usually do not need to select an architecture to create products.
    - Eliminate architectures likely not feasible or highly dominated by other architectures.
- Preliminary – Contract Design
  - Product
    - Shipbuilding specification (part of contract between shipbuilder and owner).
  - Usually select the architecture based on trade-studies
    - May leave the choice to shipbuilder in detail design.
- Detail Design
  - Product
    - Design and engineering artifacts required to construct, test, and certify the ship.
  - Shipbuilder Implements the chosen architecture.

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Electrical Power System Architectures

- Commercial Ships
  - Radial Distribution with two or three generator switchboards.
    - Includes emergency switchboard.
    - Generator sets normally located near each other
      - Except emergency generator
  - Passenger ships required by SOLAS to have Safe Return to Port capability should consider ring buses and zonal architectures.
- Naval Ships
  - Smaller ships (including many international naval ships) may employ radial distribution.
  - Others may employ ring buses.
    - Increase survivability by limiting amount of system damage from non-overmatching threats.
  - Larger ships may employ a zonal distribution system.
    - Reduces overall system complexity
    - May be less expensive due to reduced cable lengths for normal and alternate sources of power for mission critical equipment.

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Bus Voltages

- Buses should use a standard nominal system voltage.
  - IEEE Std 45.1
  - MIL-STD-1399 section 300.1 and section 300.2
- Bus voltages depend on the electrical load estimate and load flow analysis.
  - If the load flow results in a maximum current flow exceeding 4000 amps (assuming 0.8 power factor for a.c. systems), a higher voltage should be employed.
    - Circuit breakers with ratings above 4000 amps are unavailable or very expensive.
  - For U.S. naval ships, low voltage solutions employ 450 V a.c. three phase power.
    - Usually, 450 volts a.c. is the best solution if the maximum margined ship service load with service life allowance is less than 5 MW (twice 2.5 MW for split plant operation).
    - Above 10 MW, a medium voltage solution is usually required.
    - Between 5 and 10 MW, a detailed load flow analysis should be conducted to determine the best voltage.

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A.C. vs D.C. buses

- Low voltage solutions
  - A.C. solutions
    - Traditional solution
    - Large industrial base
  - D.C. solutions (Primarily 1 kV)
    - Improved fuel efficiency with diesel engines
    - Easier integration with fuel cells and energy storage systems
    - Better able to integrate large pulsed loads
    - Smaller industrial base (but growing)
- Medium voltage solutions
  - A.C. solutions
    - Traditional solution
    - Large industrial base
  - D.C. solutions
    - Improved fuel efficiency with diesel engines
    - Better able to integrate large pulsed loads
    - Potentially better power quality and quality of service
    - Very limited industrial base

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Propulsion System Architecture

- Major Drivers
  - Sustained speed
    - Typically limited to 50 MW per shaft (< 40 MW preferred).
  - Endurance requirements
    - High efficiency under endurance conditions is desirable.
  - Operating profile
    - High efficiency over operating profile is desirable.
  - Survivability / redundancy requirements
    - May require at least two shafts.
  - Pollution requirements
    - May limit fuels / prime movers employed.
  - Environmental noise requirements
  - Ice Breaking requirements
- Opportunities
  - Arrangement flexibility

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Sustained Speed

- Ships that operate much of their time at or near their sustained speed / service speed with low ship service loads.
  - Mechanical drive propulsion with independent electrical power system often preferred option.
  - Supplying power from Propulsion Derived Ship Service (PDSS) power system may be beneficial.
- Ships that operate much of their time well below their sustained speed / service speed with low ship service loads.
  - Mechanical drive propulsion with independent electrical power system often preferred option
  - Employing a CODAG or CODOG configuration may be beneficial.
- Ships with large ship service loads.
  - Hybrid drives or Integrated power systems (IPS) may be beneficial.

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Endurance Requirements

- For fuel efficiency, diesels are often preferred for operation at speeds relevant for endurance fuel requirements.
  - Diesel Mechanical
  - CODAG or CODOG
  - CODLAG or CODLOG (hybrid architectures)
  - IPS using diesel generator sets
- Gas turbines may be considered to achieve sustained speed requirements above the speeds relevant for endurance fuel requirements.
  - Gas turbines are comparatively smaller and lighter weight for a given power level.
  - Gas turbines usually are less fuel efficient than diesel engines.

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Operating Profile

- Ships with a large ship service load, particularly at low speeds
  - IPS or hybrid architectures often beneficial.
  - Propulsion able to take advantage of the “extra” N+1 generator set.
- Ships with a small service load or operate most of the time near their sustained speed / service speed
  - Mechanical drive often beneficial.
- Ships operating much of their time below sustained speed / service speed
  - CODAG or CODOG
  - CODLAG or CODLOG (hybrid architectures)
  - IPS

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Survivability – Redundancy requirements

- Ships without survivability or redundancy requirements
  - Single shaft if shaft power less than about 40 MW (50 MW max)
- Ships with survivability or redundancy requirements
  - Twin (or more) shafts
  - Possible forward drop down propulsor
  - Use of Azimuthing drives (pods)

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Pollution Requirements

- MARPOL emission limitations
  - Favors IPS architectures
    - Some ferries exclusively use electricity
  - Favors use of alternate fuels

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Environmental Noise Requirements

- Commercial ships
  - Cruise ships operating in environmentally protected areas
  - Maritime research ships
- Naval ships
  - Reduce susceptibility from underwater attack.
- IPS propulsion motors typically quieter than mechanical drive alternatives.

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Ice breaking requirements

- Ice breakers typically employ IPS:
  - Better maneuverability
  - Better torque for breaking ice
  - High efficiency through optimal loading of generator sets.
- Ice breakers increasingly using azimuthing thrusters (pods) as part of an IPS.
  - Better maneuverability

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Opportunities

- Arrangement Flexibility
  - Locate prime movers away from the shaft line
  - Shorten shaft lines
  - Maximize revenue generating spaces (cruise ships – staterooms)
  - Enable more efficient modular construction

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