ANALYSIS OF VARIOUS ALL-ELECTRIC-SHIP
ELECTRICAL DISTRIBUTION SYSTEM
TOPOLOGIES (PPT)

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MITSG 11-15
Analysis of Various All-Electric-Ship Electrical Distribution System Topologies

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Outline

• Architectural Model
• Notional Ship
• Distribution Systems
• Results and Conclusions
ARCHITECTURAL MODEL
Architectural Model

Metrics:
- weight
- volume
- efficiency (fuel)
- vulnerability
- quality of service
- cost

Fully-integrated simulation of
- electrical,
- hydrodynamic,
- thermal, and
- structural components of the ship operating in a seaway.
Architectural Model

MATLAB, Paramarine

Modules:
- Electrical Distribution System
- Power Train
- Cooling System
- Resistance
- Propulsion Power
- Fuel Usage (Operational Scenario)
- Survivability
Architectural Model

- Ship Object Class
  - Name, Weight, Dimensions (LWH), Location, Orientation, Max Power, Load, (Cost, MTBF)

- PCM, PDM, PGM, PLM, PMM, ESM
  - Effy, SFC as a fn(load)

- BUS Class
  - Loc1, Loc2, Nr of Cables, Conductor Size, (Resistance), Ampacity, MaxV, (MaxPower), Load, Diameter, Weight
Equipment Library

**Engines**
- GE LM2500, LM500
- Rolls Royce MT30, RR4500

**Motors**
- ALSTOM/Converteam
  19MW, 34MW

**Converters**
- AC to DC
  - ABB Rectifier 36MW
  - 12-pulse Rectifier 40MW
  - 12-pulse Rectifier 5MW
- DC to in-Zone
  - Satcon PCM1, PCM2, PCM1A

**Circuit Breakers**
- AC: ABB Emax, ADVAC
- DC: Secheron UR26 and extrapolation

**Energy Storage**
- ABB PCS100
- Battery ESS

**Transformers**
- Federal Pacific GT S1500H

**Motor Drives**
- Sinamics GM150/SM150
- ABB ACS 6309-A18, ACS 800
Equipment Library

Cabling
- General Cable Offshore MVRIG and Polyrad
- 15KV, 2KV and 600V
- single and 3-conductor,
- armored and sheathed, and unarmored
- various ampacities

AC Plants
- Various York, Trane plants from 100-6000 tons

Piping
- Standard CuNi
electrical distribution analysis
fuel usage (operational scenario)
vulnerability

MODULES
Electrical Distribution Analysis

- Max-flow, Min-cost algorithm
- Directed, weighted graph with super-sink
- Loads are filled in priority order
- Network capacity subtracted along the path as each load is satisfied
- Determine load on each component and thus losses.
Operational Scenario

- speed-condition profile,
  - percent time spent at various speeds and battle conditions
- Sample speed profiles

- Actual profiles used include battle condition as well.
Survivability

• Impose damage, then remove damaged equipment/cabling from the directed graph and distribute remaining power on a priority basis.

• Twofold survivability metric in the face of damage:
  – maximum value of all loads that can be serviced, proceeding in priority order
  – highest priority load that cannot be filled while satisfying all higher priority loads

• Survivability scores are averaged over a large number of blasts, and can be calculated or single or multiple blasts.
Loads
Operational Scenario
Electrical Distribution Systems

NOTIONAL SHIP
Notional Ship

- Notional Destroyer, similar to DDG 51
- ESRDC MVDC Baseline topology
- 22 lumped-parameter loads in 4 zones
- plus selected propulsion motors, radar, pulse weapon, and generators.
## Notional loads

<table>
<thead>
<tr>
<th></th>
<th>Cruise</th>
<th>Battle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone 1</td>
<td>1,382</td>
<td>2,790</td>
</tr>
<tr>
<td>Zone 2</td>
<td>1,685</td>
<td>3,241</td>
</tr>
<tr>
<td>Zone 3</td>
<td>2,149</td>
<td>3,890</td>
</tr>
<tr>
<td>Zone 4</td>
<td>839</td>
<td>2,965</td>
</tr>
<tr>
<td>Radar</td>
<td>2,850</td>
<td>3,750</td>
</tr>
<tr>
<td>Pulse Weapon</td>
<td>0</td>
<td>10,000</td>
</tr>
<tr>
<td>Speed (kt)</td>
<td>Load (kW)</td>
<td></td>
</tr>
<tr>
<td>-----------</td>
<td>-----------</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>203</td>
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</tr>
<tr>
<td>10</td>
<td>1,415</td>
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<tr>
<td>15</td>
<td>4,696</td>
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<td>20</td>
<td>10,996</td>
<td></td>
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<tr>
<td>25</td>
<td>24,085</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>60,407</td>
<td></td>
</tr>
</tbody>
</table>
Notional Ship Layout, Generated in Paramarine

Zone 4  Zone 3  Zone 2  Zone 1
## Results

<table>
<thead>
<tr>
<th></th>
<th>Ring Bus</th>
<th>Breaker and a Half</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Weight (lton)</strong></td>
<td>792</td>
<td>693</td>
</tr>
<tr>
<td><strong>Total Volume (ft³)</strong></td>
<td>42,721</td>
<td>38,527</td>
</tr>
<tr>
<td><strong>Annual Fuel (lton)</strong></td>
<td>16,861</td>
<td>16,805</td>
</tr>
<tr>
<td><strong>Total Loss (kW)</strong></td>
<td>3,383</td>
<td>3,382</td>
</tr>
<tr>
<td><strong>Single-Hit Survivability</strong></td>
<td>98.34</td>
<td>97.17</td>
</tr>
<tr>
<td><strong>Double-Hit Survivability</strong></td>
<td>91.25</td>
<td>86.47</td>
</tr>
</tbody>
</table>

Ring bus is lighter and smaller but has reduced survivability.
Conclusions

- Further development of architectural model to include:
  - OOP
  - Modularity
  - Equipment library
- Single/Multi blast survivability
- Efficiency over range of operating conditions
Thank you!