AESD - Fuel Cell Integration Study

DESIGN REVIEW

Team Members
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Project Background

• AESD - Advanced Electric Ship Demonstrator
  - Referred to as SEAJET
• Large scale surface ship model
• Operated at Lake Pend Oreille
Project Background

- Current system configuration
  - Transit propulsion power by diesel generator
  - Battery operated during test runs
Transit Mode Power Flow
System Limitations

- Recharge time
- Limited run time
Customer Needs

- High energy density
- Silent operation
- Coordinate with existing distribution system
- Minimal ship modifications
- Proof of concept report
Senior Design Project

Main Objective:
- Complete an advanced Fuel Cell Integration Study on SEAJET
Design Approach

- Establish specifications
- Finalize design options
- Create system model
- Test design options
- Analyze results
## Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output Voltage</td>
<td>714V±5% (tolerance of nominal voltage)</td>
</tr>
<tr>
<td>Voltage Range</td>
<td>Provide the same range as the battery over discharge (580-750V(_{DC}))</td>
</tr>
<tr>
<td>Current</td>
<td>Must be capable of providing at least 75 A/string or TBD if batteries replaced.</td>
</tr>
<tr>
<td>Power/Energy</td>
<td>50kW per string replaced; Allow ship to conduct at least 6 high speed runs consecutively.</td>
</tr>
</tbody>
</table>
## Specifications (cont.)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensions</td>
<td>Fit in to existing space (battery rack)</td>
</tr>
<tr>
<td>Fuel Storage</td>
<td>Meet NAVSEA and Idaho State requirements for fuel storage.</td>
</tr>
<tr>
<td>User Interface</td>
<td>Remote means of control, monitoring, and safety shutdown is necessary due to ship maning.</td>
</tr>
</tbody>
</table>
Interface Options Summary

- Option #1
  - Replace 3 of 12 battery strings with fuel cells
- Option #2
  - Replace all 12 battery strings with fuel cells
- Option #3
  - Replace entire power system with fuel cells
Interface Option #1

• Replace 3 of 12 battery strings with fuel cells
  - Each string will be required to match existing battery strings +/- 5% for voltage and current
  - Requires DC-DC conversions
  - Output power per string must be at least 50kW
Interface Option #2

• Replace all 12 battery strings with fuel cells
  - Allows operation of RIMJET drive independent of batteries
  - Removes need for DC charging system
  - Hotel system distribution battery powered
Option #2 Diagram
Interface Option #3

• Replace entire power system with fuel cells
  - DC-DC conversion
  - Larger fuel cell power system
Option #3 Diagram

- Fuel Cell
- Transit Transformer
- Distribution Transformer
- Switch Gear
- Motor Drives
- Distribution
- RIM Jet
Fuel Cell Characteristics

- Fuel Cells
  - Quiet
  - Need for external fuel
  - High energy density
  - Response times
  - DC output
## Initial Fuel Cell Types Considered

<table>
<thead>
<tr>
<th>Electrolyte</th>
<th>Cell Temp (°F)</th>
<th>Projected Lifetime (HRS)</th>
<th>Cell Contaminant</th>
<th>Single-Cycle Electrical Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proton Exchange Membrane</td>
<td>180</td>
<td>40,000</td>
<td>S,CO</td>
<td>35-40</td>
</tr>
<tr>
<td>Phosphoric Acid</td>
<td>450</td>
<td>40,000</td>
<td>S,CO</td>
<td>35-40</td>
</tr>
<tr>
<td>Molten Carbonate</td>
<td>1200</td>
<td>40,000</td>
<td>S</td>
<td>45-55</td>
</tr>
<tr>
<td>Solid Oxide</td>
<td>1800</td>
<td>40,000</td>
<td>S</td>
<td>45-60</td>
</tr>
</tbody>
</table>
Fuel Cell Selection

- Proton Exchange Membrane (PEM)
### PEM Characteristics

<table>
<thead>
<tr>
<th><strong>Pros</strong></th>
<th><strong>Cons</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast start up time</td>
<td>Easily Poisoned</td>
</tr>
<tr>
<td>Low operating temperature</td>
<td>Expensive</td>
</tr>
<tr>
<td>Waste water</td>
<td>Only hydrogen</td>
</tr>
<tr>
<td></td>
<td>Requires fuel reformer</td>
</tr>
<tr>
<td></td>
<td>Relatively low efficiency</td>
</tr>
</tbody>
</table>
Fuel Cell Selection

• Molten Carbonate
Molten Carbonate Characteristics

Pros
- Not easily poisoned
- Not as expensive
- Various fuels
- No fuel reformer
- Relative high efficiency
- Removes carbon dioxide

Cons
- Slow start up time
- High operating temperature
Modeling and Simulation

- Model current system with MATLAB
- Model fuel cell characteristics
- Model design options for comparison
Analysis

- Construct a lab scale hardware model
- Evaluate fuel cell performance
- Economic cost analysis per option
Results

• Determine cost and benefits for each option
• Recommend best fit design option based on analysis
• Provide final report
Progress To Date

- Established specifications
- Design options
- MATLAB model
- Fuel cell types
Budget

• $8000
• Current Expenditures
  - Travel to Bayview
• Future Expenditures
  - Travel to Bayview
  - Fuel Cell support equipment
    • Electrical Components
Year End Plans

- Continued computer modeling with MATLAB and SIMULINK
- In lab prototype design
- Design analysis
- Cost analysis
- Work analysis
Milestones

• 30 November
  - Snapshot Day Presentation

• January/February
  - Detailed Design Review

• April 25th
  - Senior Design Expo
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