Session 2b
Staines I
Selected GA Power Conversion Projects

- Electromagnetic Aircraft Launch System (EMALS)
- Rail gun
- Electric ship integrated power system
EMALS Concept

- IGBT-based inverters
- 150 MW over 2-3 seconds
EMALS Inverter Issues

- **Power density**
- **Switch power and voltage capability**
- **Pulsed operation/thermal management**
  - Present devices designed for continuous operation
  - Internal connections and thermal designs should permit full utilization of the material in the device under pulsed operation
- **Cost**
  - Advantages of lower weight and volume of an advanced switch needs to be accompanied by a reduced cost per kW
# Future EMALS Switch Characteristics

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>Where We Are</th>
<th>Where We Want to Be</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage</td>
<td>3300 V</td>
<td>5000 - 6000 V</td>
</tr>
<tr>
<td>Current</td>
<td>1500 A</td>
<td>2000 - 3000 A</td>
</tr>
<tr>
<td>Repetitive Peak Current</td>
<td>2400 A</td>
<td>4800 A</td>
</tr>
<tr>
<td>Forward Voltage Drop</td>
<td>2.5 V</td>
<td>2.0 V</td>
</tr>
<tr>
<td>Turn On Time</td>
<td>0.2 μs</td>
<td>0.02 μs</td>
</tr>
<tr>
<td>Turn Off Time</td>
<td>0.8 μs</td>
<td>0.08 μs</td>
</tr>
<tr>
<td>Switching Frequency</td>
<td>15-20 kHz</td>
<td>20 kHz</td>
</tr>
<tr>
<td>Thermal Resistance (junc-case)</td>
<td>0.0085 K/W</td>
<td>0.0042 K/W</td>
</tr>
<tr>
<td>Thermal Resistance (case-sink)</td>
<td>0.004 K/W</td>
<td>0.002 K/W</td>
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</tbody>
</table>
Integrated Power System (IPS) Electric Propulsion and Ship Service Power

- The first surface combatant using IPS is DDG 1000 with two propulsion motors rated at 37 MW and ship service loads > 12 MW

- This is a major first step for IPS, but what are the next steps to meet the future IPS needs?

- Spiral insertion of new mission systems such as pulse energy weapons will increase the electric load demands even further
Flexible Power Generation, Distribution and Management

Power Generation - Rectified Alternators - 80 Plus MW

Propulsion Power
- AC Motors - 70 Plus MW
- DC Motors - 70 Plus MW
- IFTP Ship Service Power
  - AC & DC Loads 10 - 15 MW

Electric Weapon Power
- High Powered Weapons Systems
  - Inertial Energy Storage 100's MJ
  - Capacitive Energy Storage 100's MJ
  - Direct Connection 10's MW

Rectifiers
- DC Link

Bi-Directional Power Flow
- Rectifiers

- • High speed rectified alternators
- • Quiet DC propulsion motors
- • High power radar systems
- • Pulsed electromagnetic weapons

IFTP
- Ship Service Power
- AC & DC Loads
- PCM-1
- PCM-2
- DC Link
- Rail Gun EMALS
- Rail Gun
- Laser/Others

AC & DC Loads

Direct Connection

10's MW

100's MJ

100's MJ

10 - 15 MW

10's MW
Rail Gun Mission

Hypersonic projectile Launch (MACH 7.5)

Ballistic Trajectory

Minimizes Susceptibility to GPS Jamming & Simplifies Deconfliction

Above Sensible Atmosphere

85 nm

GPS-aided GNC

Direct Fire
Horizon in 6 seconds

In-Direct Fire
200+ nm in 6 minutes

Fixed Targets at Long Range
(MACH 5+ Impact)

Low Cost Precision Strike

Area Targets
Volume Fires

Relocatable Targets
Low Latency

Long Range
Time Critical
Persistent
All Weather (24/7)
Rail Gun Power Requirements

- Current source to charge 200 MJ caps to 11 kV
- Max 10 shots per minute → 35 MJ/s average
- Prime power from two 35 MW MT-30 turbines
- Require high power density (> 2 MW/m³) to fit in available shipboard volume
Charging of msec-Pulse EM Weapon Systems

- Repetitive operation requires MW-class charger
- Largest part of rail gun system is cap bank
- 2 J/cc available for charging times < 20 sec
- Fast charging minimizes capacitor volume, even for single-shot operation
- Energy density of established capacitor films is saturated - look for reductions in rest of system
- Charging supply is next largest sub-system
- High power density MW-class chargers fundamental to practical pulsed EM weapons