Advanced Power Systems for Enhanced Capability and Fuel Economy

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Agenda

• Fuel and Capability: Navy Leadership Perspective

• The Situation

• War Fighting Needs Drives Power Systems

• The Problem

• Technology Similarity: Land and Sea

• The Challenge: Irregular Sources and Loads

• The Solution

• Technology Approach

• Conclusions

• Acknowledgments
“simply rely too much on...depleting stocks of fossil fuels...”

g“goal has got to be increased warfighting capability”

“in every case, adoption of new energy tech has led to a strategic advantage for the country”

“remove barriers that will inhibit our ability to get enhanced capability into the hands of our Sailors quickly”

“increase our energy security and operational effectiveness by reducing our reliance on fossil fuels”

“We’re roughly two percent of all the oil that is consumed in the United States. We ought to move ahead, and it isn’t just the military that has to [change], we all have to do it, but the military can serve as an early adopter.”
Energy is a substantial and growing cost element. Consumption reduction is critical to controlling cost and maintaining capability in light of new load requirements.
Looking Forward

New threats and technology development are leading to better and more power hungry solutions in sensors and weapons.

How do you address this on both current and future platforms?

Not like this…

Executing the NGIPS Technology Development Roadmap Paramount
The Next Generation Integrated Power System (NGIPS) Technology Development Roadmap (TDR) defines the path for NGIPS development, providing guidance to Navy and industry developing organizations and forming the basis for coordinated planning and future Navy investments.

- **Medium Voltage, Medium Frequency (MVMF) Systems**
- **Medium Voltage AC (MVAC) Systems**
- **Low Voltage AC (LVAC) Systems**
- **High Speed Generator**
- **Advanced propulsion motors**
- **Common power conversion**
- **Power and energy control**
- **Zonal ship service distribution**
- **Energy Storage**

The roadmap separates Enabling Technologies and includes specific systems such as:

- **Navy Now**:
  - DDG 51 Flt IIA
  - SSN 774

- **Next Navy**:
  - SSBN(X)
  - T-AGOS(X)?
  - DDG 51 Flt III?

- **Navy After Next**:
  - FSC ?
  - DDG(X)?
  - LCS(X)?
Integrated Architectures meet requirements at lower cost
The Problem

National Power & Energy

- Critical to
  - National security
  - Economic growth
  - Public health & safety

- Current/Future demands
  - Greater reliability/resiliency
    - Increased situational awareness
    - Faster response to faults/failures
    - Higher intrinsic reliability
  - More flexibility
    - Shift from centralized to market driven command and control
  - Increased energy security
    - Shift away from dependence on foreign oil

Military Power & Energy

- Critical to
  - Power projection
  - Base security & operations
  - Warfighter health & safety

- Current/Future demands
  - Greater reliability/resiliency
    - Increased situational awareness
    - Faster response to faults/failures
    - Higher intrinsic reliability
  - More flexibility
    - Shift toward IPS and HED
    - Shift toward increased automation for command and control
  - Increased energy security
    - Shift away from dependence on foreign oil
    - Reduce risk to Warfighter

The Military and National power and energy systems face many of the same challenges

Courtesy of Mr. Jim Zgliczynski, General Atomics
Technology Similarity – Land and Sea

At Sea

On Land
Technological Needs Are Similar

Safe, efficient systems are critical to adoption and widespread use

Multiple-rate, high power/energy systems with appropriate thermal Characteristics are necessary for adoption

Commercial
- Storage at Grids Edge
- Transportation

Commercial
- Grid Stabilization

Military
- Ships
- Aircraft
- Vehicles

Military
- Forward Operating Bases
- High Rate Weapons & Sensors
- Generator Ride Through
The US Navy has over 100 years of history designing and operating shipboard microgrids.
The Challenge: Irregular Sources And Loads

Predicatable Load

Erratic Source

Inconvenient Peaking

Smoothed, Baseload Energy Delivery

High rate and Peaky Loads
For both Military and the National power and energy systems, the recognized solution is transformation.
Technology Approach

Advanced Generators With Improved SFC

“Hybrid” Generation and Propulsion Systems

High Efficiency Power Conversion and Electrical Architectures

Optimized Generator Loading

Energy Storage
Energy Storage Is An Enabler For...

Energy Surety
- Online storage devices for backup power
- UPS for protection of sensitive devices
- Closed, signature-free energy source

Fuel Savings
- Single Generator Operations (Shipwide UPS)
- Generator load optimization/scheduling
- Minimization of spinning assets
- Terrestrial distributions (microgrids)

Power Quality
- Advanced GTG Transient ridethrough
- Load changes outside of design space for prime movers

Advanced Loads
- Pulsed applications
- Highly transient loads
- Cyclic load requirements

Current
- Online storage devices for backup power
- UPS for protection of sensitive devices
- Closed, signature-free energy source

Short Term
- Single Generator Operations (Shipwide UPS)
- Generator load optimization/scheduling
- Minimization of spinning assets
- Terrestrial distributions (microgrids)

Medium Term
- Advanced GTG Transient ridethrough
- Load changes outside of design space for prime movers

Power Quality Surety Under Two-Spool GTG Application

Long Term
- Pulsed applications
- Highly transient loads
- Cyclic load requirements

Potential EMRG Load Profiles
Partnering for Transformation…

**GRIDS**
- Flywheels
- Flow Batteries
- Compressed Air

**ADEPT**
- SiC power semiconductors
- GaN
- Advanced Capacitors
- Advanced magnetic materials
- DC Link converter

**Electrofuels**
- Direct Solar fuels

**BEEST**
- Vehicle batteries

**BEETIT**
- Building cooling systems

**IMPACCT**
- Reducing CO₂ Emissions

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**DOD/DOE Collaborative Development**

**Military as Early Adopter**

**Technology Maturation**

**Cost Reduction**

**Commercial Deployment**

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**Energy Security**
- Alternative and renewable energy sources
- Future logistics tools
- Resilient power networks and systems

**Efficient Power & Energy Systems**
- Materials, devices and architectures to increase efficiency, and power density for platforms, and reduce weight for personal power
- Efficient power conversion, switching, distribution, control and thermal management
- Engines, motors, generators and actuators
- Electrochemical, thermal and kinetic energy storage

**High Energy & Pulsed Power**
- Energy storage power system architectures
- Energy pulsed power switching and control
Conclusions

- The cross between ever-growing electrical load and ever-increasing fuel costs presents a complex issue.

- Technologies which can reduce consumption and provide greater power output require specific considerations to implement.

- Smart architectures can support complex loads with enhanced efficiency.

- Shipboard microgrid architectures have been under construction by the Navy for the last 100 years.

- Coordinated approaches can enable commonality and commercial application to reduce cost.
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QUESTIONS?
Growing Sensor and Weapon Load Requirements

Balancing irregular loads with irregular sources (inconsistent and/or lagging transient response) presents a controls and architectural problem for both Shipboard and Terrestrial Microgrids.
US Navy Surface Fleet Energy Storage Vision

- **Advanced Energy Storage Technologies**
  - FY10
  - FY11
  - FY12
  - FY13
  - FY14
  - FY15
  - FY16
  - FY17

- **Ongoing and Approved Programs**
  - ONR SWUPS
  - FRR&DP/PMS320 600kW ESM Demo
  - PMS 320 ESM Trade Study & Spec Development
  - PMS 320 SGO ESM Program of Record
  - PMS 320 Advanced 4MW GTG Program of Record
  - PMS 320 AMDR Interface
  - Electro Magnetic Rail Gun (EMRG) INP
  - ONR/ARPA-E Multifunction Energy Storage Module (Block 3)

- **Increment 1**
  - FRR&DP Derisked ESM Module Deliverable

- **Increment 2**
  - PMS 320 SGO ESM Program of Record

- **Increment 3**
  - PMS 320 Advanced 4MW GTG Program of Record
  - PMS 320 AMDR Interface
  - Electro Magnetic Rail Gun (EMRG) INP
  - ONR/ARPA-E Multifunction Energy Storage Module (Block 3)