Institutionalizing the Electric Warship

CAPT Norbert Doerry
NAVSEA 05DB
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Vision

Organic Surveillance Drone
- High Altitude
- Beam Power to Aircraft
- Minimal Handling - No Refueling

Electromagnetic Gun
- More than 10 MJ on Target
- Megawatt Range

High Powered Sensor
- Combination Sensor and Weapon
- High Powered Microwave
- High Powered Laser

Integrated Power System
- Affordable Power for Weapons and Propulsion
- Power Dense, Fuel Efficient Propulsion
- Reduced Signatures
- Power Conversion Flexibility

All Electric Auxiliaries
- No Hydraulics
- No HP Gas Systems
- Reduced Sailor Workload

High Energy Laser
- Enhanced Self Defense
- Precision Engagement
- No Collateral Damage
- Megawatt Class Laser

NO ENERGETICS ABOARD SHIP!

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Baseline - Programmed Today

LHD 8
Hybrid Electric Drive

CVN 78
High Voltage, High Power Distribution System
Electric Aircraft Launch

DD(X)
Military Integrated Power System

T-AKE
Commercial Integrated Power System

VIRGINIA
Power Electronics

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Institutionalizing Technology

- Early Technology Demonstration
- Incorporation into Production Units
- Standardization of Architecture and Interfaces
- Standardization of Design Process
- Integration into Design Tools
- Full Implementation in Standards and Specifications
- Part of Engineering School Curriculum

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Institutionalizing The Electric Warship

- Early Technology Demonstration
- Incorporation into Production Units
- Historic Focus of Electric Warship Efforts
  - Standardization of Architecture and Interfaces
  - Standardization of Design Process
  - Integration into Design Tools
  - Full Implementation in Standards and Specifications
  - Part of Engineering School Curriculum

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IPS Architectural Components

- Power Generation Module (PGM)
- Power Conversion Module (PCM)
- Power Distribution Module (PDM)
- Propulsion Motor Module (PMM)
- Power Load Module (PLM)
- Energy Storage Module (ESM)
- Power Control Module (PCM)
Zonal Distribution

Based on Zonal Survivability

- Zonal Survivability assumes:
  - Damage will impact only one or possibly two adjacent zones
    - Zones must be large enough to preclude damaging more zones
  - For systems with unsegmented “mains”, damage will not impact at least one longitudinal “main”
    - Requires separation and possibly protection of “mains”

- Zonal Survivability requires:
  - All loads (or Vital loads) in undamaged zones do not experience a “service interruption”

- Additional Design Goals include
  - Minimize “service interruption” to non-vital loads in undamaged zones
  - Minimize “service interruption” to vital loads in damaged zones
So What’s the Problem?

- Zonal Survivability isn’t defined in any authoritative document
- A “service interruption” isn’t defined anywhere either
  - Is it 30 minutes? (Local Control response)
  - Is it 2 minutes? (MIL-STD-1399 hints at this)
  - Is it 2 seconds? (switchgear clearing time)
  - Is it 100 milliseconds? (studies on hold up time)
  - Is it anything greater than 0?
- Don’t have a good way of verifying that the detail design of Cable Routing results in a survivable design.

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Other Electric Warship
Architectural Issues

- Machinery Control System Standards
  - An open software architecture does not exist

- Power Quality Standards Incomplete
  - DC standards aren’t codified
  - “Dirty” bus

- Quality of Service
  - Is the Electric Plant reliable as seen from the loads?

- System Stability
  - Issue largely due to constant power loads
  - No codified system for allocating “stability” for power system elements

- Grounding
  - Historic ungrounded systems on naval ships not aligned with industry practice and less appropriate for growing power systems.
Design Process Issues

- Definition of “Requirements” Terms outdated
  - Sustained Speed
  - Endurance Speed
- Load analysis more critical, but not standardized
  - Power quality (dirty / clean bus)
  - Zonal balancing of loads
  - Margin policy
- Power Distribution Equipment Sizing
  - Load Factors vs Zonal Load Factors vs Demand Factors
  - Inrush currents
- Power Generation Planning
  - Dark Ship Start
  - Preventing cascading failures
  - Transient stability of paralleled large and small PGMs
  - Margin policy
  - Impact of harmonic currents
- System Protection
  - Coordination of breakers
  - Allocation of system protection functions to PGM, PCON, PDM, PMM, PLM, etc.
  - Energy Storage Module requirements derivation

Design Process and associated Design Certification Process not Institutionalized
Design Tools

- Total Ship Integration (Concepts)
  - ASSET
  - LEAPS

- Power System Simulations
  - Currently every program does their own thing
  - Navy (including ONR) has invested in basic technology
    - Virtual Testbed
    - Stability Toolbox
    - Distributed Heterogeneous Simulation
    - Commercial Packages: Saber, ACSL, ...
  - Analytical requirements not established

Electric Warship Design Tools are not Institutionalized
Standards & Specifications

- Naval Vessel Rules
  - Includes provisions for IPS
    - Part 3 Chapter 5 Section 4
  - Doesn’t currently address all issues

- DOD-STD-1399
  - Being updated to address interface issues
  - Update is in progress

  - Under development to be consistent with NVR
  - Update is in progress
Engineering School Curriculum

- Designing IPS ships is part of the concept level design of several Post Graduate programs
  - Treats IPS components at the module level
  - Does not address all aspects of IPS integration

- The development of IPS component technology is an integral part of University research programs

- The design of IPS systems is not addressed in depth.
  - Reflects lack of maturity of IPS design processes
  - Systems Engineering typically taught at a higher conceptual level

- Basics of IPS system design taught as part of the Summer Naval Surface Ship Design Program
  - Summer Professional Development Program taught at the University of Michigan
  - Partnership of University of Michigan, NAVSEA, Virginia Tech, and Naval Postgraduate School
Summary

- Early Technology
  - Demonstration
  - Incorporation into
  - Production Units

- Work has started
  - We are early in the process

- Standardization of
  - Architecture and Interfaces

- Standardization of
  - Design Process

- Integration into
  - Design Tools

- Full Implementation
  - in Standards and Specifications

- Part of Engineering
  - School Curriculum

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Conclusions

- Electric Warship is here
  - Technology Demonstrations complete or underway
  - “Early Adopter” ships complete or in design

- Institutionalizing the Electric Warship has just begun
  - Many issues require resolution
  - NVR and other documents under development should help resolve the issues
  - Need investment in tools and education

- Stay Tuned
  - A lot is happening