



Eaton Workshop on Future of DC Distribution Systems for Stationary and Mobile Applications

Cardinal Engineering LLC

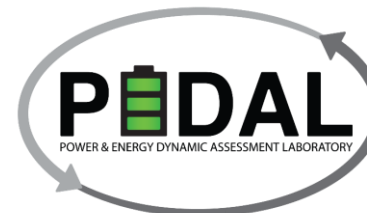
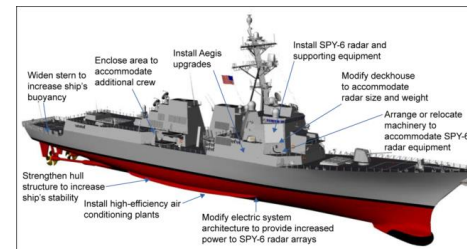
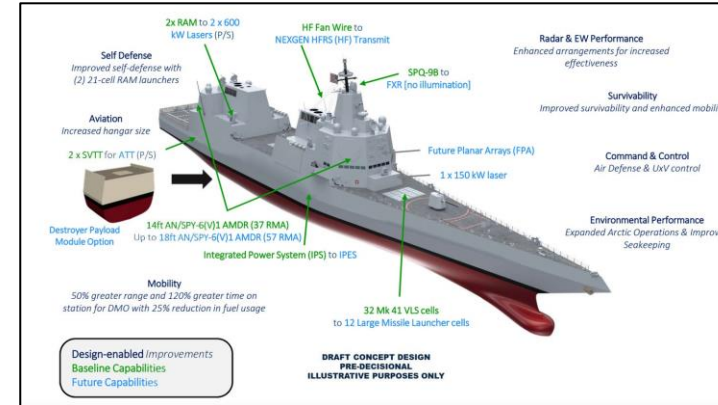
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Power and Energy Systems

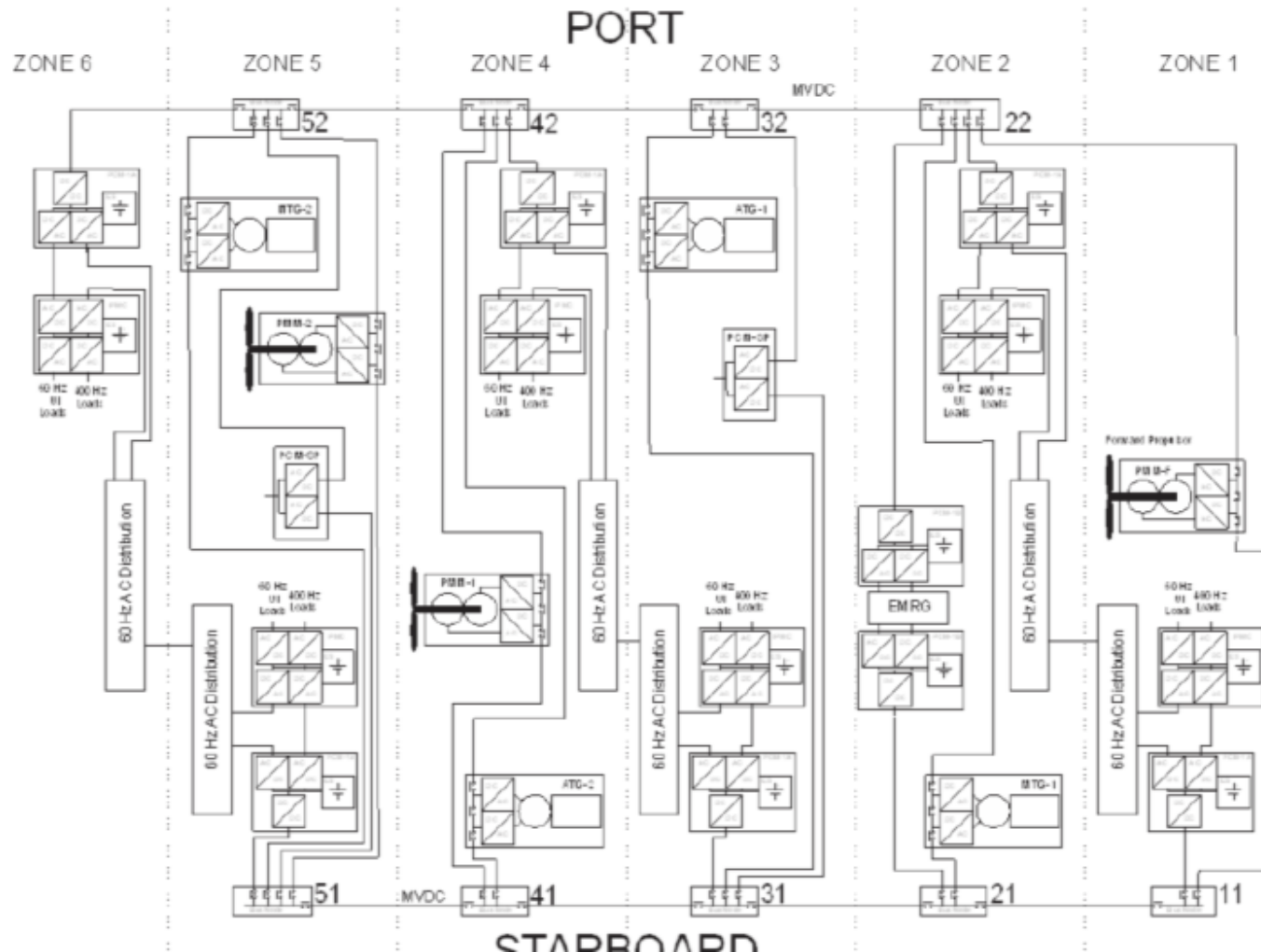


- Shipboard Power System Architectures
 - Interface specification
 - Power conversion, distribution, isolation and circuit protection
 - Generation and Energy Storage systems
 - Power quality assessment and analysis
 - CONOPS development
- Energy storage systems
 - Test procedure and specification development
 - Subject matter expertise for review of technology insertion
 - Laboratory planning, development, and commissioning
- Advanced control systems
 - Design and implementation
- Technology demonstrators
 - Technology road map development
 - Systems Engineering, Program and Project management
 - Realtime, dynamic, hardware in the loop simulation
 - Independent Technical Assessment
 - Design, testing, analysis, and documentation
- Pulsed/High Energy Loads
 - Power System Impact Analysis and test procedure development
 - Railgun Weapon System – Pulsed Power IPT and requirements definition
 - Shipboard interfaces to Directed Energy Weapons / Advanced Sensors



DC Reference Architecture

Navy defines $LVDC \leq 1000VDC < MVDC$



Active SBIR/STTR on MVDC Topics



SBIR/STTR MVDC TOPICS

- N16A T012 MVDC Grounding
 - N21A T005 LVAC Grounding
- N221 T064 MVDC Disconnect Switch
- N211 069 MVDC Partial Discharge and Space Charge
- N162 T109 MVDC Casualty Power System
- N16A T009 MVDC Fault Isolation
- RIF-19-0005808 MVDC SSCB
- N22A T011 Shipboard Creepage and Clearance
- (FY25 submitted) MVDC Protective Relay

Approved for Public Release

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Ship Integration Challenges



- SWaP-C: R&D products only grow in size and weight
 - Power quality – Bring your own energy storage/power conditioning equipment
 - Galvanic isolation (hf XFMR)
 - Reliability and redundancy requirements (N+1)
 - Thermal - have to get the heat out and off the ship
- Controls
 - Needs to work with the ship's controls (not the same on all ships)
 - Power sharing between ship's busses (hard to balance)
 - Fault handling/tolerance, graceful degradation
- Lack of adequate test facilities to prove system level integration
- ESS hazard characterization/certification

DoD Lithium Battery Certification

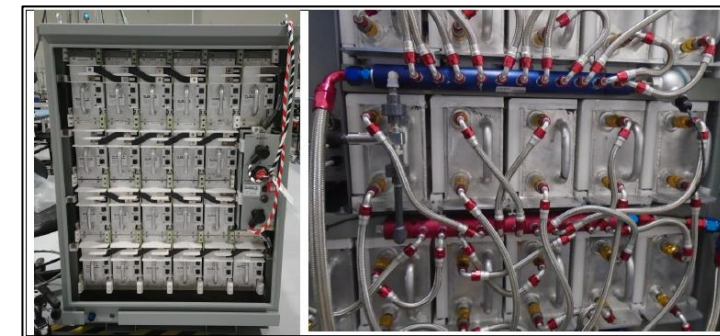


- The Navy's approach, S9310
 - Comprehensive destructive testing
 - Identification of worst-case and maximum-credible events
 - Rigorous configuration control
 - Comprehensive risk assessment
 - Technical Warrant Holder (TWH) review and certification
- Cardinal employee's past performance
 - Lithium battery design with industry
 - Air and liquid cooled designs
 - Integration with power systems
 - Fire suppression systems
 - Oversight of destructive test regimes at Navy and industry facilities
 - Installation, certification, and testing of 1000V, 30kWh lithium battery at Naval Surface Warfare Center Philadelphia Division

Related Past Performance



Battery/Capacitor Hybrid System



1000VDC LFP Battery

Power & Energy Current and Past Performance



- High Energy Battery Characterization Study for the Navy's Operational Energy Office
- The Office of Naval Research's Multifunction Energy Storage Module (MFESM) Future Naval Capability
- Energy Storage Module-Ship (ESM-S) powering the Solid-State Laser (SSL) installed aboard LPD 27
- Naval Surface Warfare Center Philadelphia Division (NSWCPD) Energy Conversion R&D
 - High energy batteries, flywheels, ultracapacitors
 - Supervisory Data Acquisition and Control (SCADA) systems
- Advanced Power Electronics Integration (APEI) program
- Hull, Mechanical and Electrical system subject matter expertise support to PMS320 – The Electric Ships Program Office
- Assessment of DDG 1000 Power System Data Analytics
- Navy Phase I SBIR - Artificial Intelligence/Machine Learning (AI/ML) Hull Mechanical & Electrical Controls
- Land based test site planning, ship power system design, and risk management to PMS460 - The Guided Missile Destroyer DDG(X) Program Office
- Submarine advanced mission system concept of operations feasibility study
- Air and Missile Defense Radar Power Conversion Module (AMDR-PCM) design, integration, and test to PMS 400 - Arleigh Burke Class Destroyer (DDG 51) Program Office
- The Navy's Electromagnetic Railgun Program
 - Naval Surface Warfare Center Dahlgren Division (NSWCDD) hardware delivery & integration support
 - White Sands Missile Range (WSMR) site integration support
 - Joint High Speed Vessel (JHSV) sea trial design
- High Energy Laser Counter-Antiship Cruise Missile Program (HELCAP)
- Remote Essential Power System – USAF SBIR to develop a remote power system to support Forward Operating Bases and Humanitarian Aid/Disaster Relief efforts