**High Resolution Modeling and Real Time Simulation of Shipboard Medium Voltage DC Power System**

Anna Brinck, M.S. Student
Robert Cuzner, Assistant Professor
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**Introduction**

**Future Warships**
The next generation of Navy Warships will have all electric power systems which will supply power to all ship loads ranging from basic ship service to high powered weapons such as lasers and railguns, to ship propulsion via electric motors. The goal of a Medium Voltage DC (MVDC) ship was proposed by Naval Sea Systems Command (NAVSEA) in 2007 and is being developed by the Navy’s own NAVSEA engineers, civilian defense contractors, and a consortium of universities including UW-Milwaukee.

**Why Medium Voltage DC?**

**Disadvantages of Present AC Power Distribution Systems**
- Non-optimized generators because they are limited to speeds that produce 60Hz AC electricity
- Numerous bulky transformers, frequency converters
- Many feeder cables going from generators to loads
- Bulky, electromechanical switchgear

**Advantages of MVDC Power Distribution Systems**
- More precise control of power
- Less weight and cost
- Ability to automate power management, especially during emergency
- Supports high powered pulse weapons
- Possibility of eliminating or reducing circuit-breakers and leaving fault mitigation to power electronic devices
- Modularity for quick and easy maintenance

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**System Level Power Management**

**Survivability**
- Shed appropriate loads in order of mission priority
- Determine health of loads and if it is safe to provide them with power
- Isolate unsafe loads or elements of the power system

**Quality of Service**
- Provide required voltage/current/frequency of electricity to loads
- Ensure balance of power generation and loads
- Provision of power in order of priority of uninterruptible to interruptible loads
- Monitor energy storage (inherent and by design); do not violate capacity

**System Stability**
- Regain desired operating point in response to physical disturbance
- Generator speed maintained to prevent stalling on the low end, and overspeed on the high end
- Bus voltages kept within limits. Must be high enough to provide necessary power but not too high as to exceed capacitor storage limits.

**Fault Response**
- Protective Devices are time coordinated to isolate the fewest possible loads
- The inherent current limiting capability of power electronic devices is utilized and reduces need for (and potentially eliminates) separate circuit breakers and protective devices

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**Power System Layout**

The main image of this poster shows two zones of a four zone DC Ring-Bus Zonal Electrical Distribution System of a Navy Warship. Half of one zone will be simulated in real time using OPAL-RT simulator. Different load configurations will be tested to represent different zones.

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**Power Generation Module**

A ~30MW Diesel Turbine Generator supplies power to the main DC bus and is coupled with an active rectifier or Multi Module Converter (MMC). The main generator and rectifier provide power to the MVDC bus and to the Propulsion Motor Module (PMM,) which consists of two separate motors and drives.

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**Power Conversion Module**

The main intra-zonal power converter is called PCM-1A and contains an input module, internal DC bus, internal power storage, and an output module. PCM-1A feeds intermediate loads from ~500KW to 1MW.

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**Power Distribution Module**

The Power Distribution Module is a switching center containing DC disconnects. When power must be interrupted, power flow is controlled through power electronic equipment while electrical isolation is provided by disconnects in the PDM.

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**Detailed Model**

A high resolution switching model of each power system component and its controls was created in the MATLAB/Simulink environment.

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**Real Time Simulation**

Real time simulation on OPAL-RT simulator is being used to assess effectiveness of power management. Different system configurations and parts of the system are tested by mixing and matching modules.

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**Inverter Module**

Like the PCM-1A, the Inverter Modules contain an input and output module separated by a DC bus. These inverter modules supply uninterruptible loads, 400Hz loads, loads requiring custom power quality, and loads requiring dedicated high power quality.