**Project:** S-parameter Based Analysis of Common-Mode in MVDC Power Apparatus

**Project Completion:** 2017

**Output:** Multiple technical reports and conference papers were written throughout this project. Including two short course presentations at NSWCPD and ESTS 2017.

**Outcome:**

- Developed a common-mode voltage characterization approach using a newly designed LISN (line impedance stabilization network).
- Delivered short courses on grounding and common-mode analysis.
- Developed a Common-Mode Equivalent Notional Two-Zone MVDC Ship Power System model for grounding studies.
- Provided initial characterization of a MW scale power electronic converters common-mode voltages and currents
- Developed and validated through experiments a common mode model of a Silicon Carbide MOSFET H-Bridge used in a MW scale impedance measurement unit developed by Virginia Tech.
- Employed the knowledge gained from this project, including the 2-zone model, in a successful phase-1 STTR project which led to a phase-2 STTR project seeking to develop a Medium Voltage Direct Current (MVDC) Grounding System.

**Project Motivation:** Current ESRDC research in power systems analysis and design aims to understand common-mode coupling and grounding system design. A motivation for concern, at any stage of ship design, is the adoption of a new enabling power system has the risk of increased electromagnetic interference (EMI), when based on power electronic converters. Leakage current (common-mode current) through bearings and the ship hull can lead to unintended operations of components. This current results in a field that can be coupled to other systems, such as sensors and communication equipment, which consequently can result in disturbances of their signals. The focus of this grant is on measurement and characterization of MW-scale equipment to better understand common-mode operational characteristics.
In power electronic dominated combat power and energy systems no universally accepted methodology exist to understand common-mode drivers in systems. To properly model and simulate common-mode behavior in the system context computational burden invariably increases. Characterization of common-mode drivers are not currently well understood for MW-scale equipment. This grant aimed at achieving the following research goals:

- To support early stage design using a common-mode behavioral modeling approach
- To expand common-mode component modeling work into MW-scale equipment
- To build computer simulation models of various converter suitable for grounding studies of entire systems
- To better understanding of SiC-modules’ inherent common-mode sensitivity and their effects on system performance.

In order to achieve the research goals we focused developing methods to validate existing or proposed theoretical analysis of common mode behavior of emerging power electronic converters through experimentation.

**Project Extent:** This project involved multiple researchers from two ESRDC institutions and is documented in a technical reports and papers [1–8].

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References:


Power electronic dominated combat power and energy systems:
• No universally accepted methodology exists to understand common-mode
  drivers in systems
• Computational burden increases to properly model and simulate common-
  mode behavior in the system context
• Characterization of common-mode voltage sources not well understood for
  MW scale equipment
• Need for better understanding of Common-mode effects using SiC-type
  PEBBs

Identify new insights
• S-parameters are meaningful to characterize parasitic common-mode
  coupling effects
• Computational challenges still exist to incorporate s-parameters into power
  system circuit simulations

Characterization of Common-Mode System Level Impacts in MW-scale MVDC Systems

MAIN ACHIEVEMENTS
1. Delivered a short course on grounding and common-mode analysis at NSWCPD
2. Developed a common-mode voltage characterization approach using a “virtual” experiment
3. Successful application of the CPES-IMU at the medium voltage-level (2.8 kV).
4. Developed a Common-Mode Equivalent Notional Two-Zone MVDC Ship Power System model for grounding studies
5. Employed the knowledge from this project, including the 2-zone model, in a phase-1 STTR project which led to a phase-2 STTR project

Current Impact
• Provides insight into system-level common-mode impacts of a zonal MVDC system
• Provides initial characterization of power electronic common-mode voltages and
  currents
• Provide a framework for characterization of system level common-mode impacts
  using modeling and simulation
• Resulted in an industry led STTR Phase 2 efforts on MVDC grounding

Research Goals
• To support early stage design using a common-mode behavioral modeling
  approach
• To expand common-mode component modeling work into the MW scale
  equipment
• To build computer simulation models of various converters suitable for grounding
  studies of entire systems
• To better understanding SiC-modules’ inherent common-mode sensitivity and
  their affects on system performance

Future Research Opportunities
• Development of MV class LISNs needed to characterize common mode behavior of
  MW scale power equipment (DURIP proposal submitted)