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

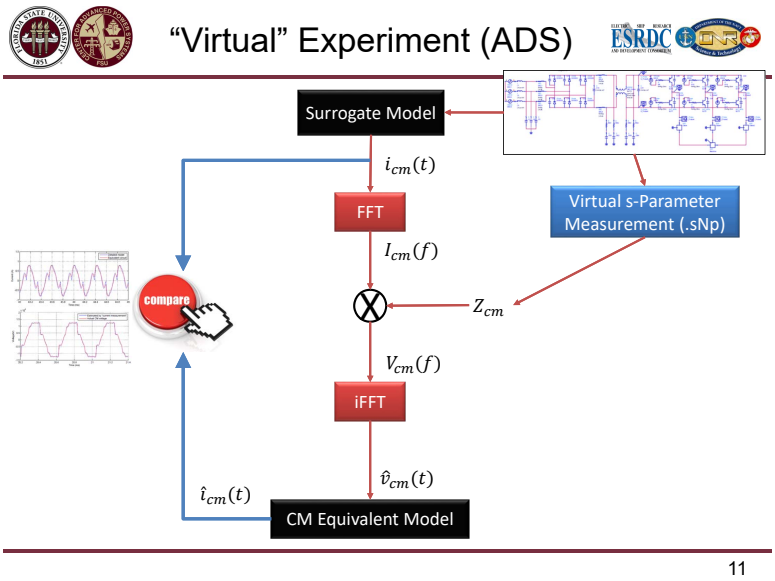
Project Completion: 2017

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].

Technical Point of Contact: Matthew Bosworth(matt@caps.fsu.edu)

References:

[1] Matthew Bosworth and Mischa Steurer. Common-Mode and Grounding Navy Short Course, Philadelphia, PA. Technical report, Electric Ship Research and Development Consortium, 2016.

[2] M. Bosworth, S. Pekarek, and M. Steurer. Common-Mode Equivalent Modeling of a Notional Two-Zone MVDC Ship Power System. In *2017 IEEE Electric Ship Technologies Symposium (ESTS)*, Aug 2017.

[3] M. Bosworth and M. Steurer. Model Population and System-Level Characterization, Tutorial. In *2017 IEEE Electric Ship Technologies Symposium (ESTS)*, Aug 2017.

[4] M. Bosworth, S. Pekarek, and M. Steurer. Grounding and Common-Mode Characterization Interim Report. Technical report, Electric Ship Research and Development Consortium, December 2016.

[5] M. Steurer. S-Parameter Based Framework for Analysis of Common Mode Couplings Between MVDC Power Apparatus. Technical report, Electric Ship Research and Development Consortium, 2017.

[6] M. Bosworth, J. Langston, and M. Steurer. Common-Mode Characterization of MW-Scale DC Variable Voltage Source Converter (Invited). In *2017 IEEE International Midwest Symposium on Circuits and Systems (MWSCAS)*, Aug 2017.

[7] Juergen Hotz. Common-mode characterization of a power electronic building block with silicon carbide mosfet h-bridge. Technical report, University of Applied Sciences Upper Austria, August 2017.

[8] Behshad Mohebali. Characterization of common mode features of a 3-phase full-bridge inverter using frequency domain approaches. Technical report, Florida State University, December 2016.

S-Parameter Based Framework for Analysis of Common Mode Couplings Between MVDC Power Apparatus

PI: Mischa Steurer ONR Grant #: N00014-15-1-2250
Research Faculty, Florida State University – Center for Advanced Power Systems

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

STATUS QUO

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

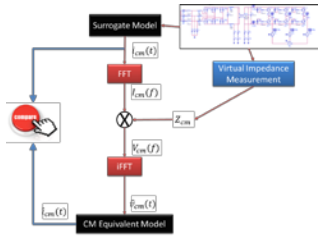
NEW INSIGHTS

Identify new insights

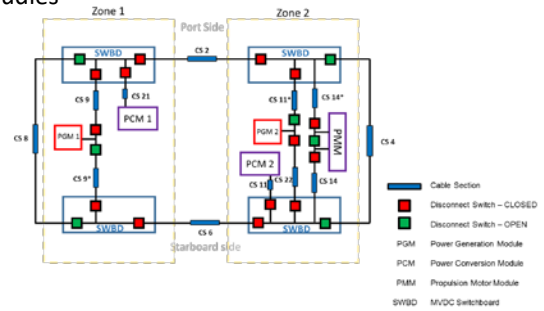
- S-parameters are meaningful to characterize parasitic common-mode coupling effects
- Computational challenges stil exist to incorporate s-parameters into power system circuit simulations

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

QUANTITATIVE IMPACT

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

END-OF-PHASE GOAL

Future Research Opportunities

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