### Introduction

- The studied topology for this project is a Medium Voltage, Medium Frequency, Bi-Directional Dual Active Bridge.

- The topology consists of a 3-level Neutral Point Clamped Full-Bridge Converter on both sides of a High-Frequency Transformer.

- With the emerging field of power electronics, we aim to develop an integrated EMI characterization platform for new generations of power electronic converters using Wide Band Gap (WBG) power semiconductors for medium voltage systems.

- A Common-Mode (CM) equivalent model for the system is derived. A simulation software, PLECS, is then used to compare measured results from a Mixed-Mode (MM) circuit and the derived CM circuit.

- Eventually, we will be able to have compared results from a hardware implementation within our EMI characteristic testbed.

### Characterization of EMI

- WBG devices have transformative impacts on power delivery, management, and increased power density.

- When using WBG converters you will encounter higher switching frequency, high voltage edge rates (dV/dt) and increased dc bus voltage. This results in significant EMI spectral content.

- Traditional IGBT based systems:
  - Operational Frequency: 1-50 kHz
  - Extended Dynamics: up to 500 kHz

- WBG based systems:
  - Operational Frequency: 10 kHz - 1 MHz
  - Extended Dynamics: up to 100 MHz

- WBG devices result in CM voltage sources, thus CM emissions, that are spectrally rich throughout the conducted emissions band (10 kHz - 30 MHz).

- In this “Near RF” range, lumped element analysis starts to become inadequate and changes how we look at EMI characterization, modeling, and mitigation.

- Packaging impedance is important in this “Near RF” range.

### Impacts of EMI

- Spectral content in the “Near RF” range means:
  - Capacitor and low turn inductors exhibit behavior dominated by parasitic effects.
  - Bus planes, cabling, and high turn-count inductors become “electrically small” and exhibit wave-like behavior.

- In the presence of high frequency switching power semiconductors, there is a propagating path for dV/dt induced current across the modules’ direct bonded copper substrates.

- High electrical potentials on isolated heat sinks and high-frequency magnetic cores in the presence of high dV/dt induced displacement currents into the equipment chassis introduce coupling effects that can lead to degradation of equipment.

- Therefore, it is SO important to understand EMI management in WBG devices compared to the outdated Silicon devices.

### Methodology

- To understand the impacts of the displacement currents through equipment chassis we turn to Common-Mode equivalent models.

- With this equivalent model, we can begin to accurately model the voltage stresses induced from switching across various points throughout the system.

- The equivalent model are derived using techniques that facilitate the transformation of MM system components into CM equivalent components which can be systematically assembled.

- In symmetric systems, the Differential-Mode (DM) and CM behaviors are completely decoupled.

- When asymmetry is in the system, the DM behaviors are integral in understanding the CM behavior.

### Basic Procedure:

1. Starting with CM and DM definitions

2. Use KVL/KCL and apply Transformation Matrices

3. Use derived CM equation and systematically assemble CEM

### Summary & Purpose

- To model the high frequency common-mode effects of the system.

- Drives conducted EMI at the terminals of the high-frequency transformer.

- Understand the switch transition rates (dV/dt) and how they drive displacement currents across the power semiconductor module and insulated substrate into the heatsink.

- Understand how that impacts the insulation requirements of the system.

- Understand what the high frequency common-mode effects have on the transformer (coupling from primary to secondary sides).

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**Modeling and Validation of EMI Trends in Medium Voltage Isolated dc-dc Converters**

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