SiC Enabled High-Frequency Medium Voltage Drive for High-Speed Motors

DE-EE0007252

General Electric (GEGR, GERE, GEA), UTK, Virginia Tech

2016-2019

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Overview

Timeline

- Contract Started Q1 2016
- Projected End Date Q3 2019
- Project ~70% complete

Barriers

- Availability and cost of SiC
- Higher control speed and complexity
- Higher EMI and internal noise

Budget

	2016 Costs $M	2017 Costs $M	2018 TTD $M	Total Planned Funding (2016-Project End Date)
DOE Funded	0.74	2.34	0.44	5.0
Cost Share	0.38	1.19	0.22	2.55
Total Cost	1.12	3.53	0.66	7.55
Cum Cost	1.12 14.8%	4.65 61.5%	5.31 70.2%	

Partners

- GE Renewable Energy
  - Product requirements
  - Support in tradeoff analysis
  - Test equipment
- GE Aviation
  - System integration requirements
  - Test facilities
  - Testing support
- UTK
  - Developing intelligent gate-driver – improves unit reliability by foreseeing failures
- Virginia Tech
  - Developing stacked power module – assesses entitlement for switching series connected devices

Project Objectives

- Develop and demonstrate **<u>two</u>** SiC-based medium voltage converters for:
    1. 3.8MW Type-3 wind turbine: 6000V-3-60Hz / ~0-750V 3ph ~30-90Hz
    2. 1MW 0-21,000rpm PM machine: 0-1600Vac 0-1400Hz
- Achieve: volumetric density <1.4m^3/MW, >97% end-to-end efficiency, eliminate line-frequency transformer
- Achieve >98% efficiency, <5%THD at rated output

Why is this difficult?

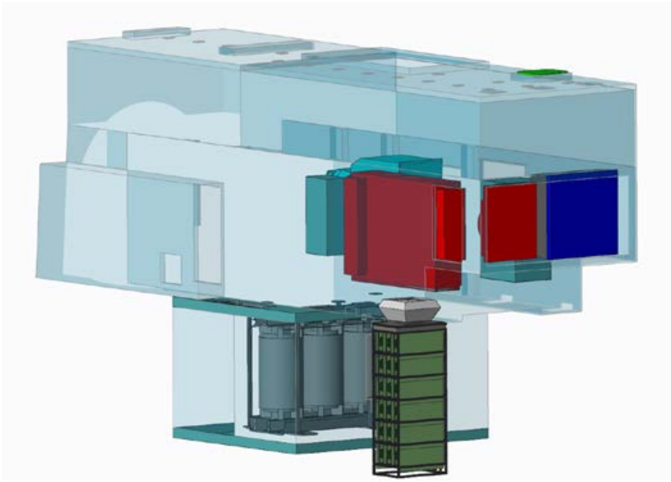
High voltage, low volume, air insulation,… => iterative design
High converter density requires optimized passives
Need faster, more capable controls

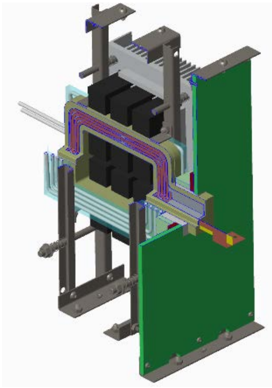
Impact on AMO goals

Wind energy will account for 10% of 2030 US energy production
Enabling hybrid-electric propulsion system for flight readiness by 2022

Technical Innovation – Wind Converter

- Today's converters: liquid cooled, 2-level IGBT bridges operating at ~1.2kHz switching frequency
  Converter LxWxH = 0.9x0.5x2.2, V=0.99m^3
  Transformer LxWxH = 1.9x1.3x2.2, V=5.5m^3
  Weight and volume up-tower
- Replace with an air-cooled, multi-level modular, high-frequency resonant-transformer-insulated converter, occupying <22% of the original volume
- Increase mean-time to forced outage
- Improve converter losses using innovative modulation schemes



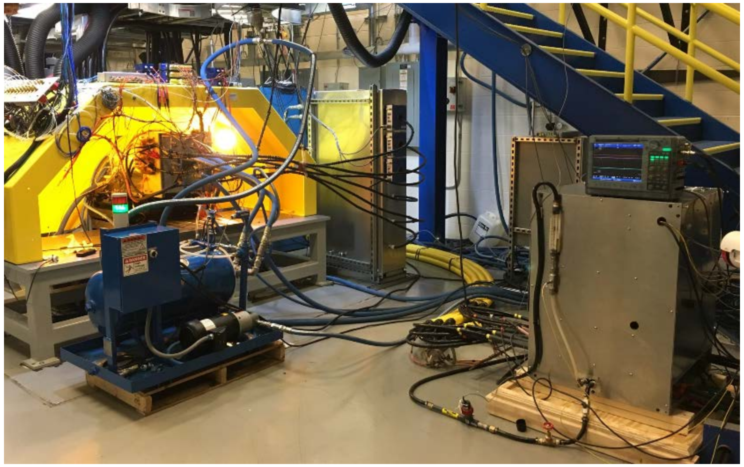


Technical Innovation – HF Converter

- Today's system: two, 2-level IGBT converters, with motor windings connected differentially. Voltage controlled by phase shifting converter voltages
- Replace by a single ANPC converter employing a SiC IGBT hybrid in each phase leg
- Improve waveform quality, improve converter efficiency, and simplify motor connections
- Reduce weight and size by minimizing filter components

Silicon Drive
~5,500 lbs
~95% efficiency

Silicon Carbide Drive
<250 lbs
>98.5% efficiency



Technical Approach

Wind Converter

Standardize design around the smaller building block and use granularity to achieve higher functionality: redundancy, higher voltage quality, improved efficiency

Control cost by automating module manufacturing

Improve system reliability by foreseeing failures. Increase monitoring of devices on the gate drive – UTK developing intelligent gate driver

HF Converter

Minimize switching losses by optimizing bridge design, then use the entire loss budget towards increasing switching frequency to minimize filtering requirements

Optimize modulation to achieve THD target

Scale drive ratings by developing stacked power module – VT working on entitlement of switching series connected devices

Results and Accomplishments

- Met all project milestones for HF converter. Preparing final report (2018 Q2 will be the end of period of performance for HF converter)
- Demonstrated operation of wind PEBBs in 2+2 configuration
- Efficiency >97.5%, +0.2% with the novel switching strategy
  Only one line-bridge modulating while others either ON or OFF, dc-dc converters disabled when their corresponding line-bridge is OFF
- Repeated BIL test with a 3-phase building block
  Failed initial attempt due to imperfect application of sealant in the custom bushing
  Repair and retry in July
- UTK on track
  Gate driver designs complete, characterizing Tj monitoring and dead-time compensation
- VT behind but made progress on foundational capabilities
  Designed and manufactured a scalable converter leg, built analog gate drivers, upgraded power circuit (new lab)

Transition

Wind Converter

Regression testing in Q3 2019 to demonstrate converter readiness for turbine duty

Using final bill-of-materials, develop detailed cost estimates to prove competitiveness

Prove "bankability" by operating a converter on a turbine for up to 6 months. Planned turbine installation in late 2019...

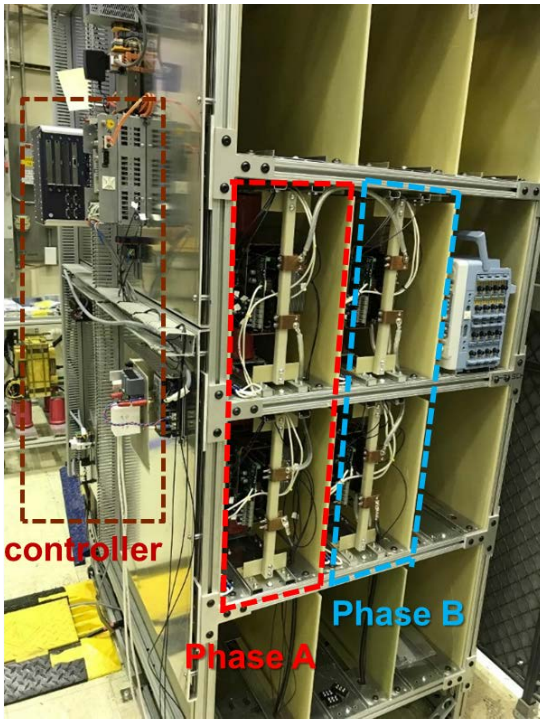
HF Converter

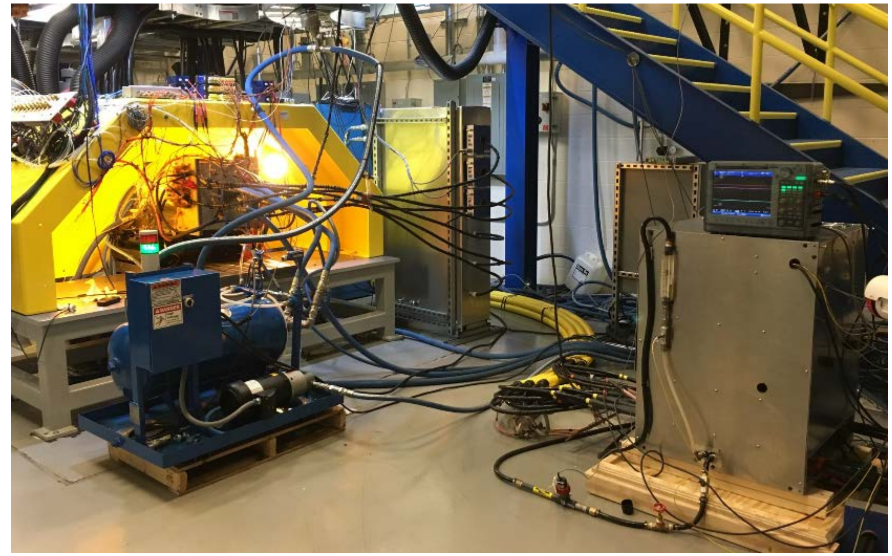
Using lessons learned from this unit to create a Gen2 design on NASA funding

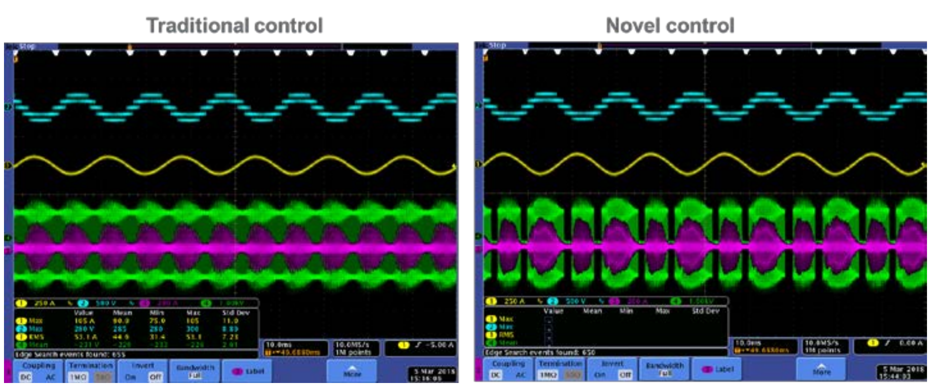
NASA and GE exploring options to integrate the Gen1 unit into NASA's NEAT facility in Ohio

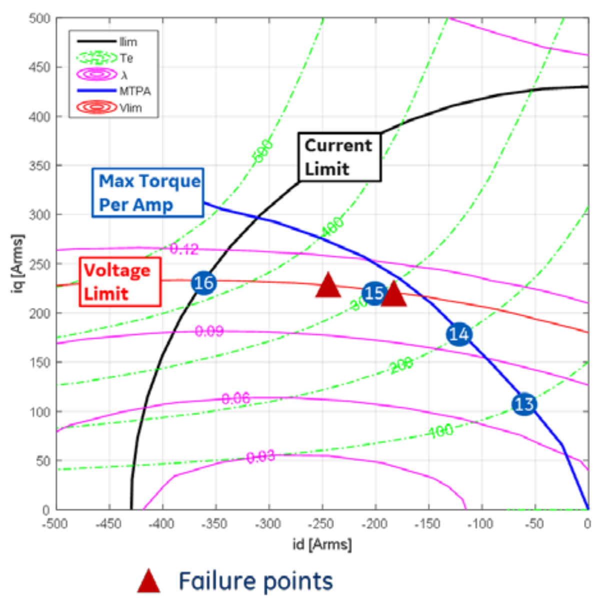
Exploring PM motor design options that take advantage of higher voltage attainable by SiC converter

Questions?









Five test campaigns FW10-26 Overcame major EMI & torsional issues…