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

DE-EE0007252

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

2016-2020

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Overview

Timeline

- Contract Started Q1 2016
- Projected End Date Q1 2020
- Project ~80% 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+ 2019 YTD $M	TTD $M	Total Planned Funding (2016-Project End Date)
DOE Funded	0.74	2.34	1.25	4.33	5.28
Cost Share	0.38	1.19	0.75	2.32	2.83
Total Cost	1.12	3.53	2	6.65 82%	8.11
Cum Cost	1.12 15%	4.65 62%	6.65 82%		

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 – improve unit reliability by foreseeing failures
- Virginia Tech
  - Developing stacked power module – assess series-connected devices as an alternative to HV devices

Project Objectives

- Develop and demonstrate **two** SiC-based medium voltage converters for:
  1. 3.8 MW DFIG Wind turbine: 6 kV, 3ph, 60 Hz / ~0-750V, 3ph, ~30-90Hz

     Achieve volumetric density < 1.4m^3/MW, >97% efficiency, eliminate line-frequency transformer
  2. 1 MW drive for 0-21,000 rpm PM machine: 0-1600 Vac, 0-1400 Hz

     Achieve > 98% efficiency, < 5%THD at rated output

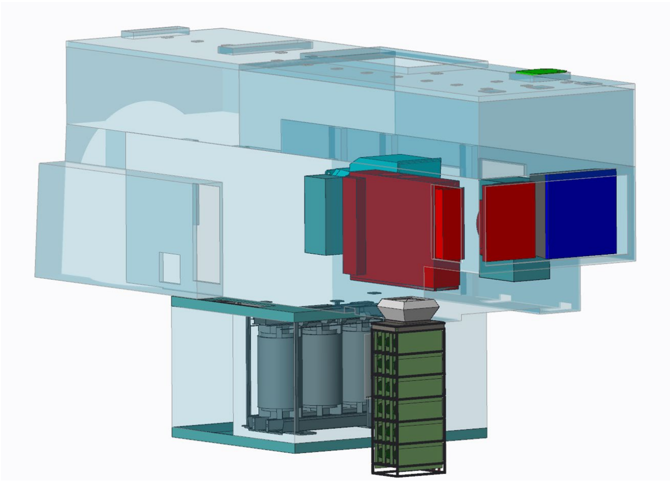
Why is this difficult?

Insulation to withstand high voltage, high frequency
High converter density requires optimized passives
Fast controls with flexibility to handle multiple converter building blocks

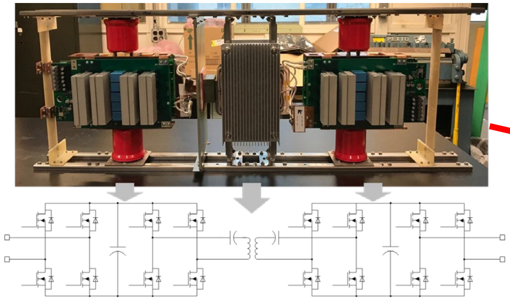
Impact on AMO goals

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

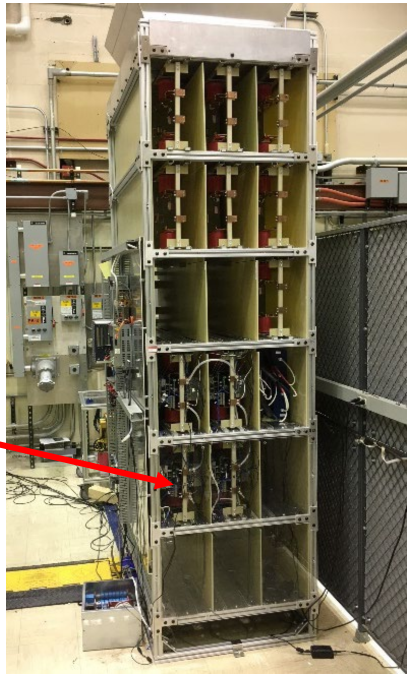
Technical Innovation – Wind Converter



- 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



Building block

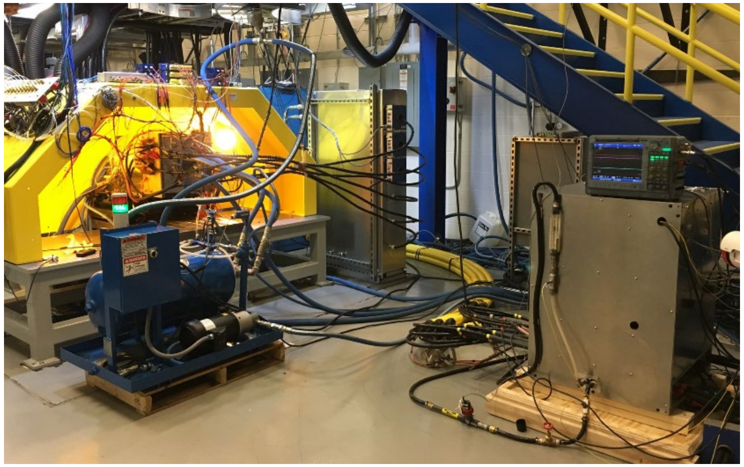


Technical Innovation – HF Converter

- Today's system: 2-level IGBT inverters feeding open-ended motor windings
- Replace by a single 3-level inverter employing SiC MOSFET + Si IGBT hybrid phase legs
- Improve waveform quality, improve converter efficiency, and simplify motor connections
- Reduce weight and size by minimizing filter components

Si IGBT inverter
~5,500 lbs, ~95% eff.

SiC MOSFET inverter
<250 lbs, >98.5% eff.



Dynamometer test stand with PM machine and SiC inverter

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

UTK: Improve system reliability through intelligent gate drive-level monitoring of devices

HF Converter

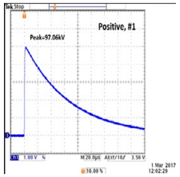
Minimize switching losses by optimizing bridge design, then use the entire loss budget towards increasing switching frequency to minimize filtering requirements

Optimize modulation to achieve THD target

VT: Scale-up of converter voltage ratings through series-connected modules with voltage sharing enforced by advanced gate drives.

Results and Accomplishments

- Met all project milestones for HF converter. Submitted final report for task. Next-gen altitude-ready version of the converter being developed with GE Aviation and NASA
- Demonstrated full power operation of wind PEBBs in 2+2 configuration. Ran 12 series PEBBS @ low voltage to validate controls. Full voltage/ power testing in progress.
- Efficiency >97.5%, novel switching strategies for low losses.
- Successful BIL test for transformer (> 95 kv) and 3-phase building block (> 60 kV)



- UTK tasks completed, preparing final report
  Demonstrated gate drives with Tj monitoring, and analyzed dead-time compensation for PWM controls.
- VT on track
  Designed and manufactured a scalable converter leg, built gate drives with advanced voltage sharing and dv/dt controls

Transition

Wind Converter

Dyno + DFIG, grid-connected testing in Q4 2019 to demonstrate converter readiness for turbine duty

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

HF Converter

Using lessons learned from this unit to create a Gen2 design with NASA/ GE Aviation funding

NASA and GE preparing for altitude-ready Gen2 converter testing at NASA's NEAT facility in Ohio

Thank you!