High Voltage Silicon Carbide
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Next Generation Technologies for Today's Warfighter

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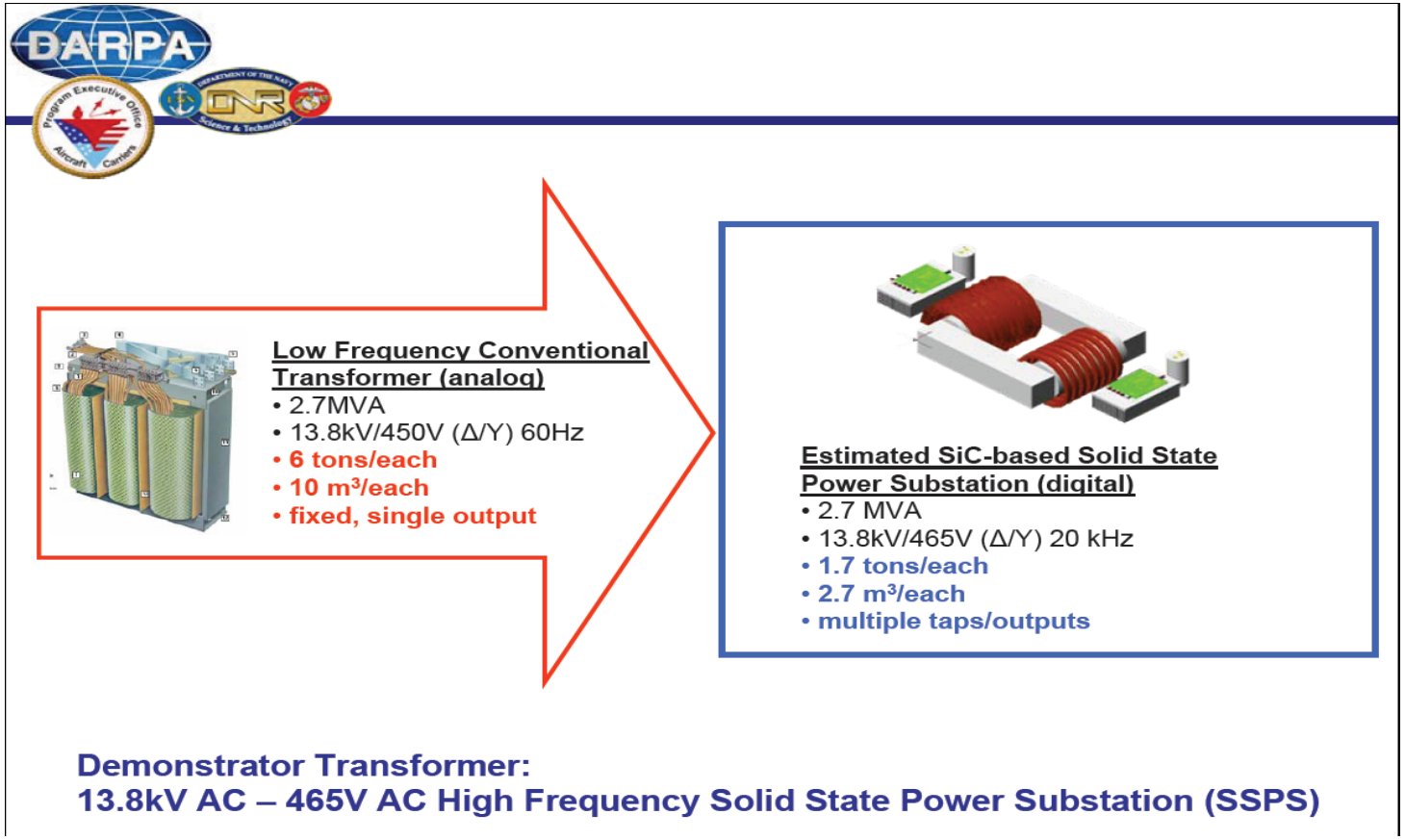
Revolutionary Research . . . Relevant Results

OFFICE OF NAVAL RESEARCH

Solid-State Power Substation (SSPS) - Background

- Part of DARPA 'High Power Electronics (HPE)' program
- Objective – compact, light-weight power converters & transformers for US Navy enabled through high voltage SiC switches



Solid-State Power Substation (SSPS)

- DARPA ‘High Power Electronics (HPE)’ Program

GE Global Research	System Design/ Integration, Component Characterization
CREE, POWEREX	SiC Devices/ Packaging
Los Alamos NATIONAL LABORATORY EST. 1943, IAP	High frequency Transformers
GENERAL DYNAMICS Electric Boat	Ship Integration Requirements
Virginia Tech, UNIVERSITY OF WISCONSIN MADISON	Modeling, Alternative architectures

High frequency transformers size reduction

220 kVA, 60 Hz
dry-type xfmr

330 kVA, 60 Hz
oil-filled xfmr
(1,220 kgs)

Oil-filled design, water-cooled
(45 kgs, IAP Research)

Dry-type design, forced air-cooled
(35 kgs, Los Alamos)

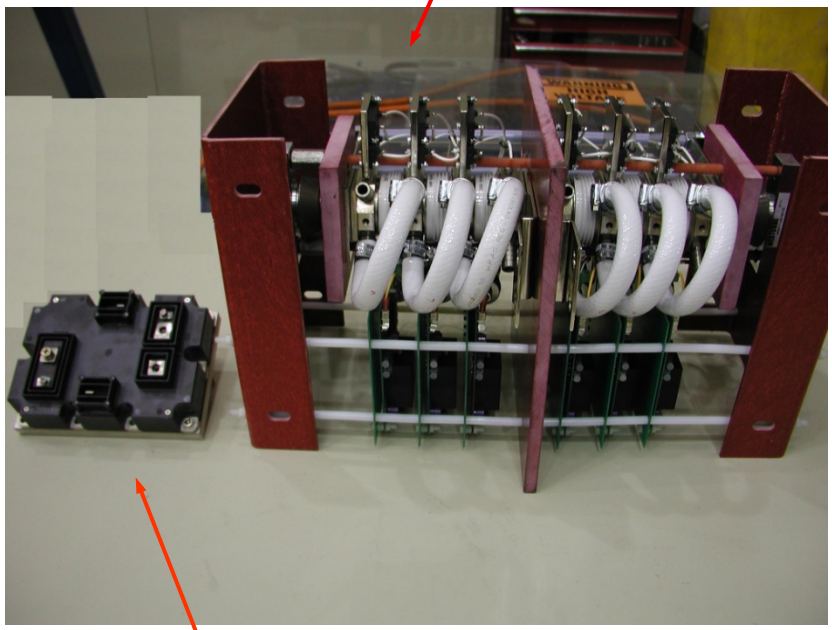
250 kVA, 20 kHz transformers

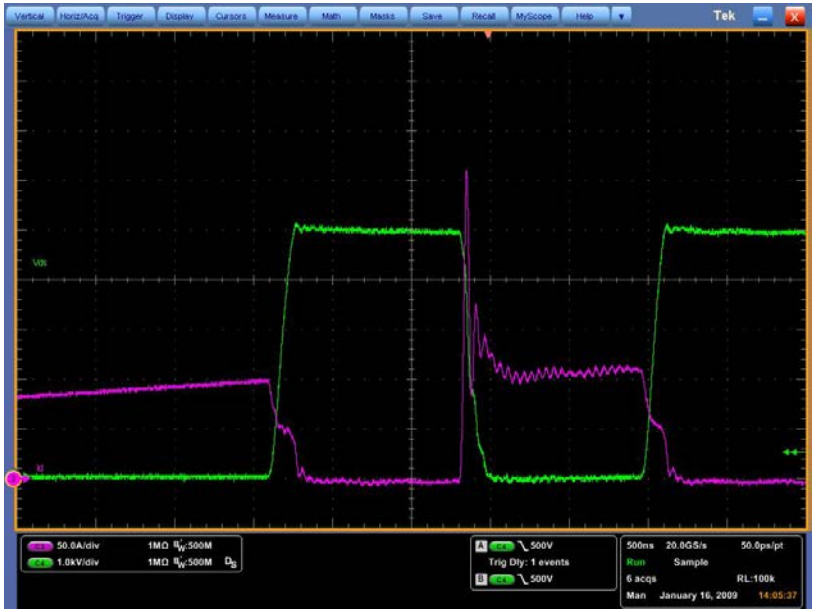
SiC switches - size and performance benefits

Si IGBT assembly, 10kV, 160 amps

(3x 4.5 kV devices in series)

- **Conduction drop > 10 V**
- **Switching time > 3 ms**



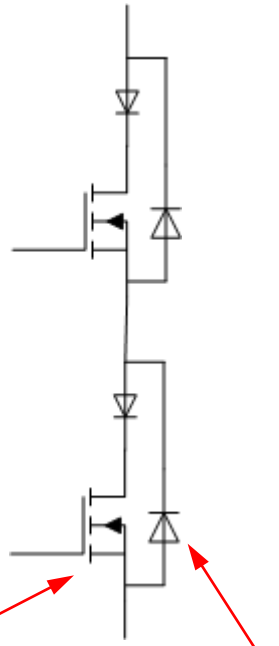


SiC module, 10 kV, 120 amps (Cree, Powerex)

- **Conduction drop < 6 V**
- **Switching time < 100 ns**

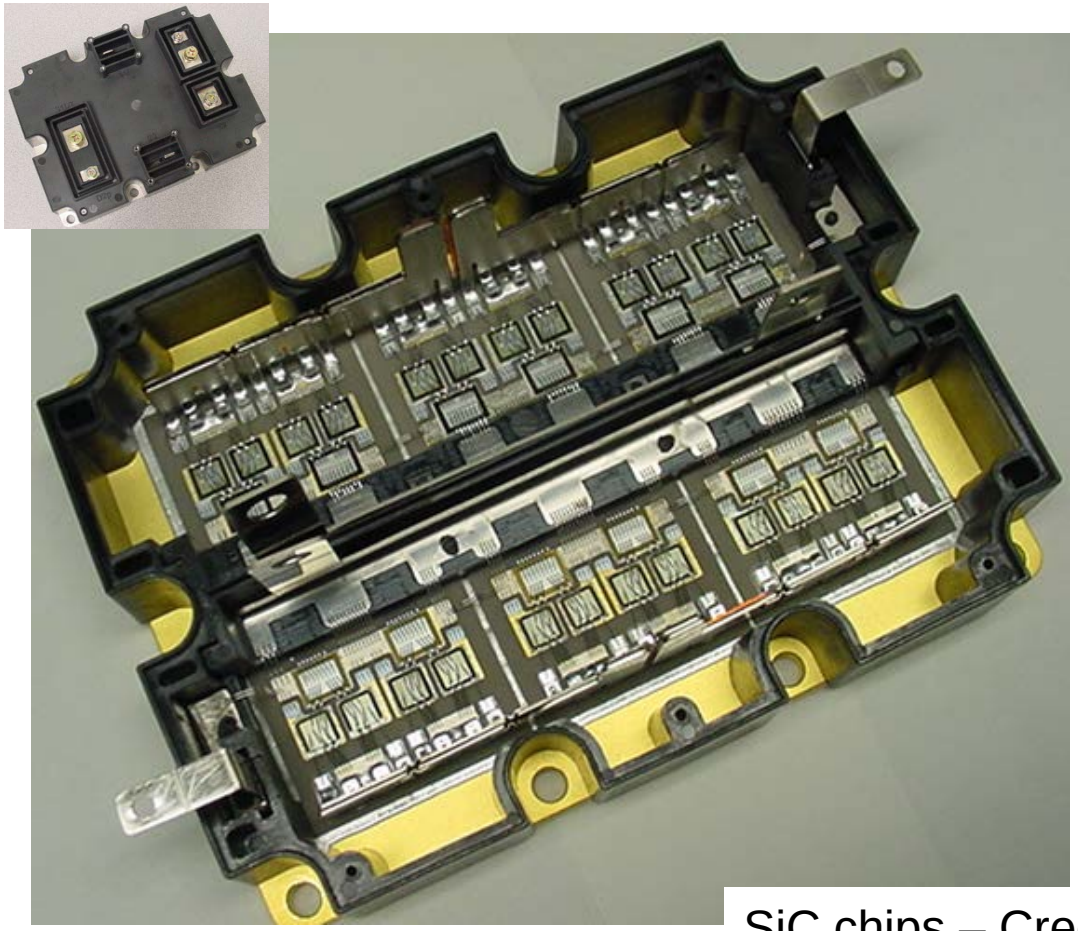
SiC Module: turn-on/ turn-off @ 5kV, 100A

10 kV, 120 A Silicon carbide Half-Bridge Module



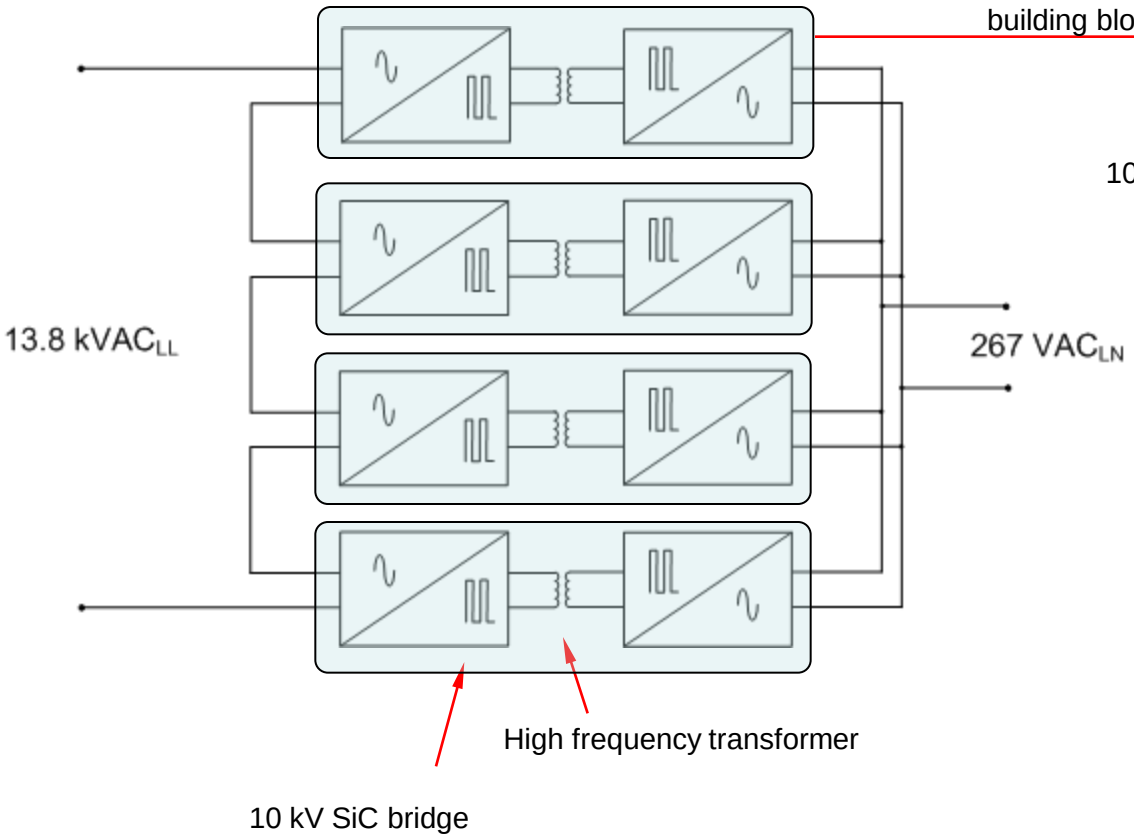
10 kV SiC MOSFET

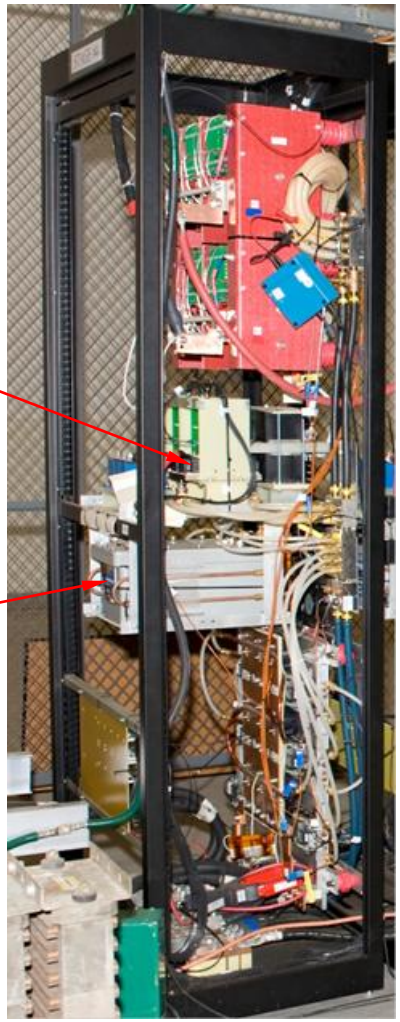
10 kV SiC JBS diode



SiC chips – Cree
Module - Powerex

SSPS - Prototype 250 kVA Building Block



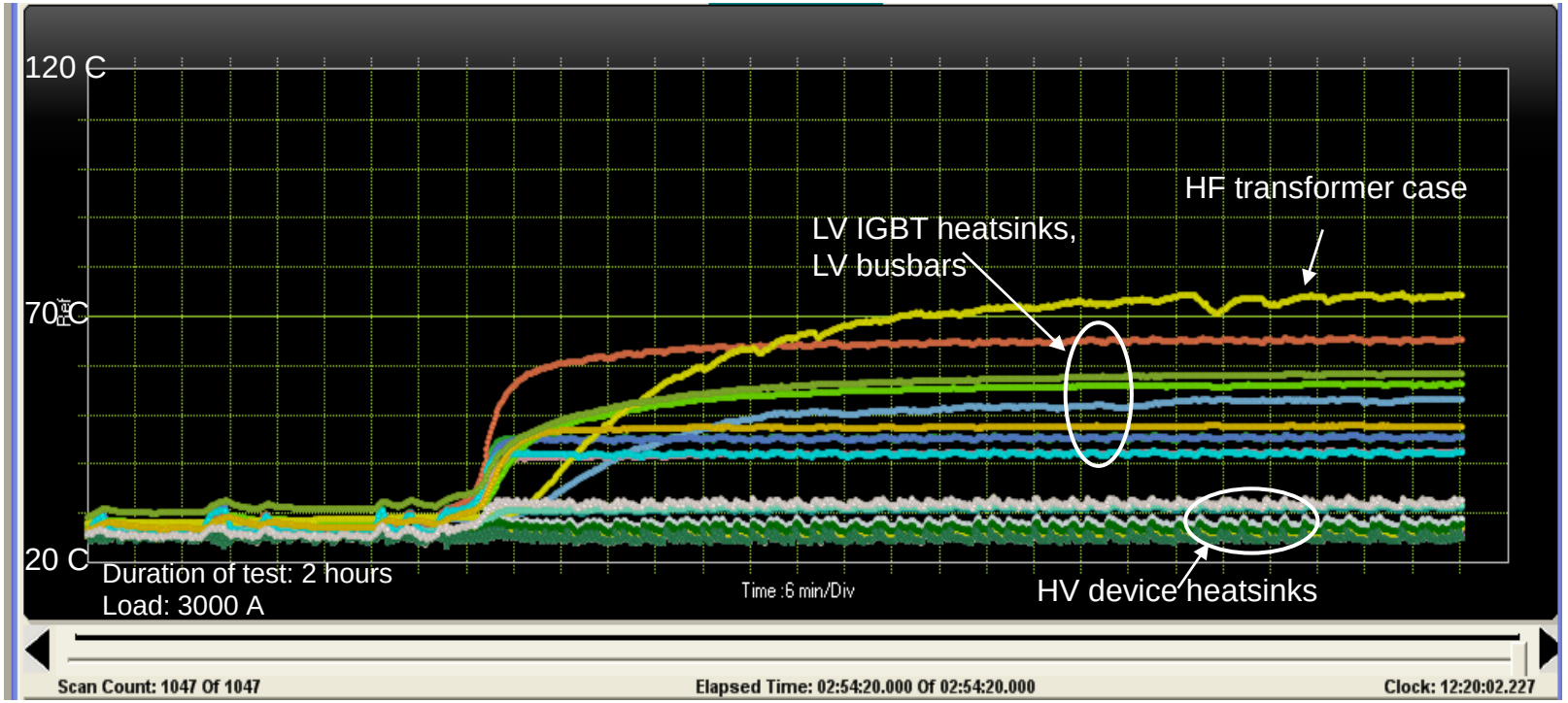


SSPS 1 MVA Prototype Test Results

Single-phase SSPS at Navy test lab

- ✓ Demonstrated at 1 MVA, 13.8 kV/265 V
- ✓ Efficiency at full load > 97%
- ✓ 1/3rd weight of conventional transformer
- ✓ Clean 20 kHz waveforms
- ✓ Balanced sharing of voltages/ currents
- ✓ AC input current/ output voltage THD < 5%

Thermal Measurements



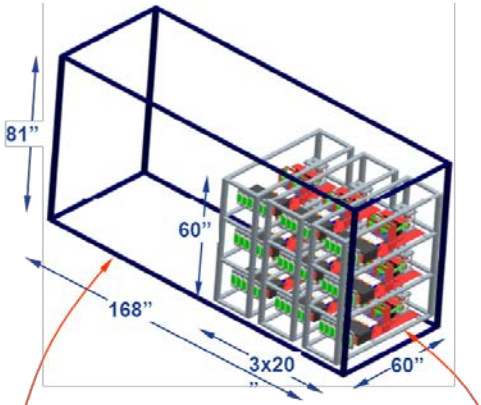
SSPS temperature measurements – 2 hour load test

- Inlet water – 25C
- SiC Modules – low temp rise
- Cooling of HF transformers and busbar/ connections is challenging

HPE program - Ongoing Development

- Option Program
  - 1 MW, 4160Vac – 1000Vdc supply for AMDR radar,
  - TRL6 testing in Q4 2012

- 1/3rd volume, 1/10th weight of existing supply



Prototype under assembly

	Present PCM-4	SiC PCM-4/1A
Weight:	35,000 lbs	3,500 lbs
Volume:	168"W x 60"D x 81"H	60"W x 60"D x 60"H

Testing July 2012 – Real-Time Digital Simulation Power Hardware and Control hardware in the Loop Testing

Potential Industry Applications

Renewables

- Enable power conversion and grid interface at higher voltage to reduce complexity and cost

Rail

- More efficient locomotive drives - reduce switching/diode recovery losses
- Compact transformers/electronics for catenary interface

T&D

- Reduce number of series devices needed to handle high voltage.
- HVDC/ FACTS converters with lower component count/ complexity
- Compact solid-state distribution transformers
  (smaller footprint, added functionality, oil-free)

Challenges for high voltage SiC

- Cost – need market volume and higher yields
- Reliability - need validation from early adopters
- Limited current ratings for present devices/ modules
  - T&D, Drives, Wind applications will require higher ratings
  - Need large-area chips with good yields
- Development of supporting HV components – passives, gate drives, packaging, insulation, ..
- For HV applications, need to be cost-competitive compared with multilevel converters with LV silicon