NIST/DOE Workshop on Enabling Technologies for Next Generation Electric Machines

Al Hefner (NIST)

http://www.nist.gov/pml/high_megawatt/

Participant Introductions

- **Name**
- **Affiliation**
- **Technology**

NIST High-Megawatt Converters and Machines Workshops

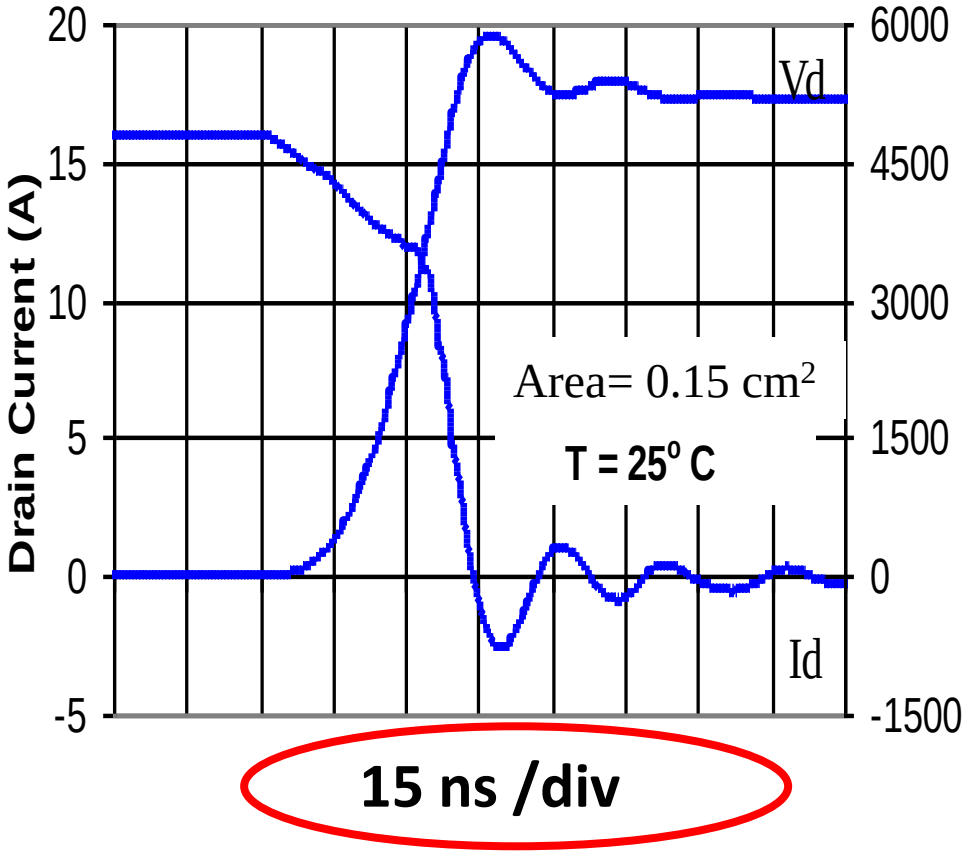
- High-Megawatt Converter Workshop: January 24, 2007
- HMW PCS Industry Roadmap Workshop: April 8, 2008
- NSF Power Converters for Alternate Energy : May 15-16, 2008
- Future Large CO2 Compressors: March 30-31, 2009
- High Penetration of Electronic Generators: Dec. 11, 2009
- Plugin Vehicle Fleets as Grid Storage: June 13, 2011
- Grid Applications of Power Electronics: May 24, 2012
- High-Power Variable-Speed Motor Drives: April, 2014
- High-Power Direct-Drive Motor Systems: September, 2014

DARPA/ONR/NAVSEA HPE Program

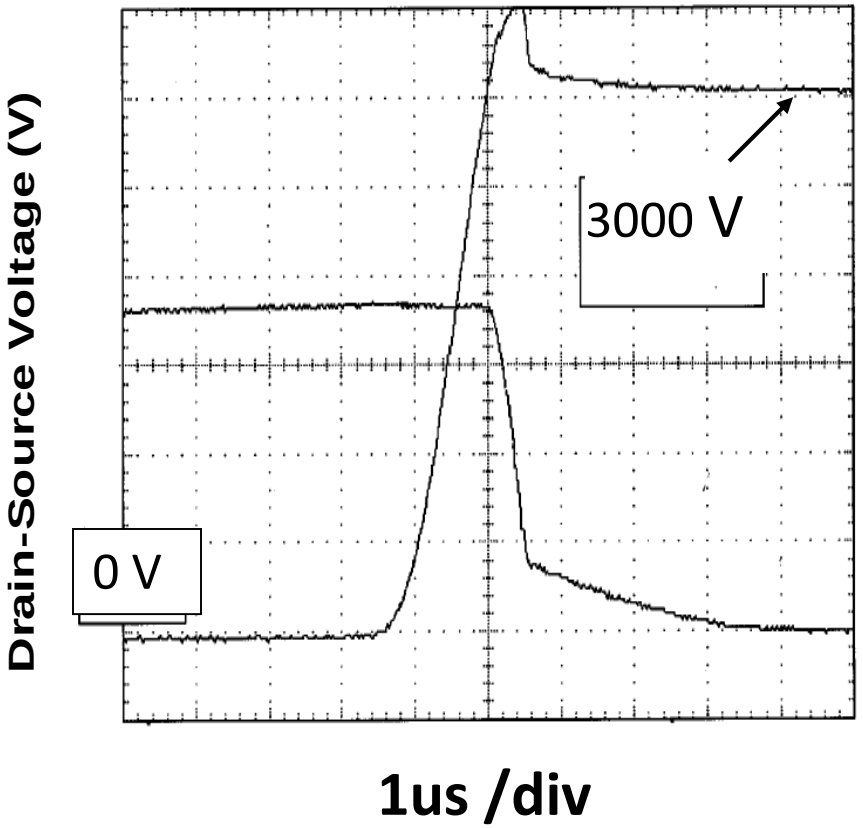
10 kV HV-HF MOSFET/JBS

High Speed at High Voltage

SiC MOSFET: 10 kV, 30 ns



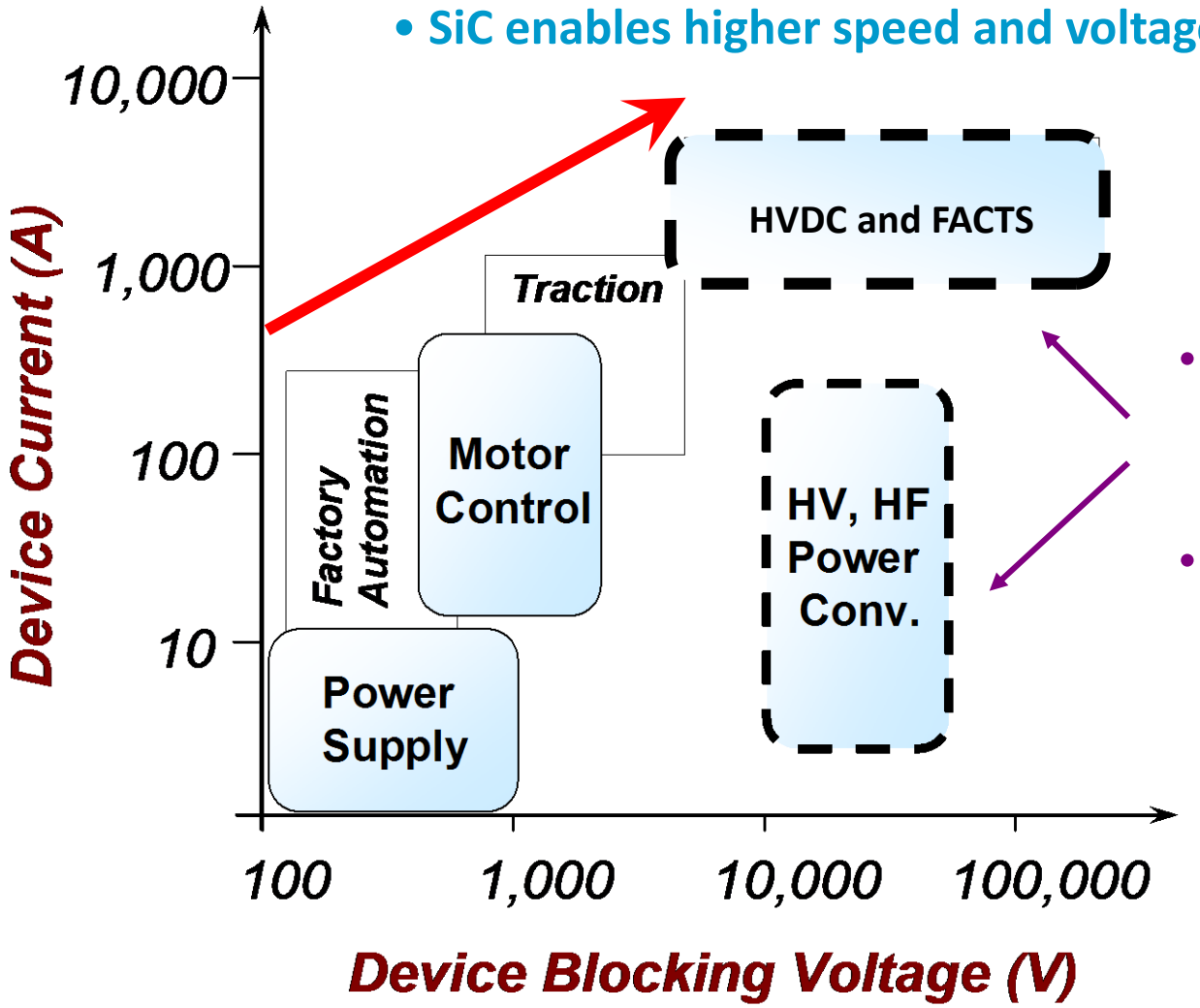
Silicon IGBT: 4.5 kV, >2us



A. Hefner, et.al. "Recent Advances in High-Voltage, High-Frequency Silicon-Carbide Power Devices," *IEEE IAS Annual Meeting,* October 2006, pp. 330-337.

HV-HF Power Semiconductor Applications

- Switching speed decreases with voltage
- SiC enables higher speed and voltage



- Power distribution, transmission and generation
- MV and High-Power Motors

DARPA/EPRI Megawatt Program

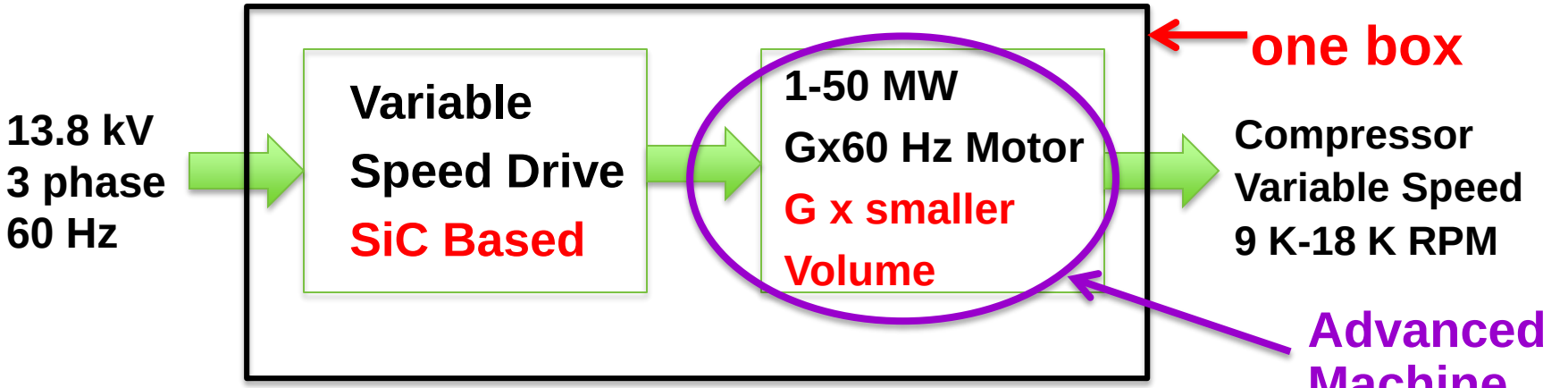
A. Hefner, et.al.; "SiC power diodes provide breakthrough performance for a wide range of applications" IEEE Transactions on Power Electronics, March 2001, Page(s):273 – 280.

US Manufacturing Advantage by combining Several Key Technologies in an Integrated Approach

Traditional

20-40% energy is wasted with throttles and other mechanical devices

New Approach



- Big 60 Hz Transformer replaced by small high frequency Transformer
- Motor size reduced by 5x – cheaper, less magnets
- 20-40% energy per motor system is saved due to Variable Speed Drive – pay-back < 3 years
- Gear Box eliminated
- Smaller Foot-print (up to 5x)

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

http://www.nist.gov/pml/high_megawatt/sept2014_workshop.cfm

Rationale for DOE Investment

- **Goal**: Produce a **step-change impact** that enables **more efficient electricity use**, as well as **increased productivity** and **reduced motor system size and weight** (eliminating a key adoption barrier).

Significant energy savings

- Motors consume 68% of manufacturing electricity (2.8 quads in 2010).[1]
- Industry electricity consumption is expected to increase from 3.3 quads in 2013 to 4.3 quads in 2040.[2]
- Small population of large and very large motors consume most energy.[3]

Motor Size	% of Industry Energy Consumption	% of Industry Motor Population
Large: 100+ HP	59%	2.8%
Very Large: 1000+ HP	16%	0.1%

Opportunity for significant energy "bang" per DOE "buck"!

1 Manufacturing Energy and Carbon Footprint, 2014.
2. "Annual Energy Outlook 2014 with Projections to 2040," U.S. Energy Information Administration (2014).
3. "United States Industrial Electric Motor Systems Market Opportunities Assessment," U.S. Department of Energy Office of Energy Efficiency and Renewable Energy (2002).

http://www.nist.gov/pml/high_megawatt/sept2014_workshop.cfm

Summary

A significant reduction of energy consumed world-wide could be achieved by transitioning large-power motor applications to VSD motors:

- Approximately 14% of the total electricity consumed in the United States flows through large-power electric motors (1-50 MW); e.g., for COG industry
- Many of these motors drive 10,000 to 20,000 RPM mechanical loads through a large gearbox and use mechanical throttles rather than power-electronics based VSDs.

A Previous Workshop (April 2014) defined potential benefits of *advanced machine technologies*, front end power electronics, and their integration. These include:

- High-Electrical-Speed Direct-Drive Motors (high-speed VSD and machine would eliminate need for large gear box and mechanical throttles)
- "Transformer-less" Medium-Voltage Drives (small, high frequency transformer integrated within the VSD would replace large 60 Hz grid-step-down transformer)
- Integrated Motor-Drive System (grid-to-load system delivered as one unit would reduce size, weight, and cost)

Another Previous Workshop (September 2014) defined integrated system approaches using multiple advanced technologies to achieve the advantages.