Wide Bandgap Device Manufacturing

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

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Why Are we Here?

- Low Voltage (600 – 1700 V) SiC Devices are here
- Price of SiC switches will be at ~10 Cents/Amp in 3-4 years
- Many Power Electronics Applications will adopt LV SiC devices over the next 5 years
- 10-15 kV SiC have already been demonstrated in prototype systems (assume Reliable SiC devices and modules will be available at reasonable prices)
- How can we use HV SiC devices in the management of Grid with High Percentage of Renewables while reducing storage requirements?
- Other applications of WBG devices in the Grid.

Grid with High Renewable Content has Low Inertia

- Synchronous Generators have High Inertia due to Kinetic Energy

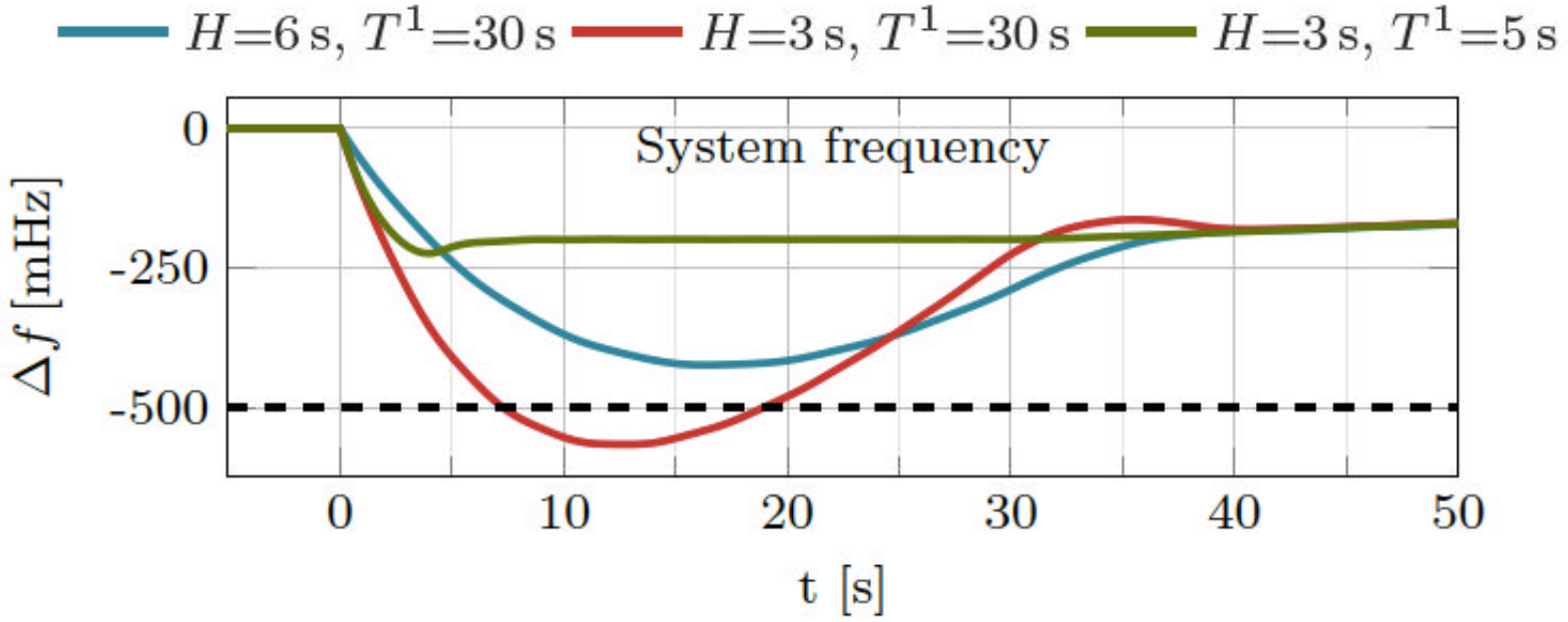
$$\frac{df}{dt} \propto \frac{P_{Gen} - P_{Demand}}{H}$$

H is Inertia

- Increasing Renewables reduces the Inertia in the Grid
- Storage can provide Synthetic Inertia *but*
  - storage is too expensive and
  - has half the life of PV system

Abrupt loss of 3GW Generation in a 250GW Grid

Fast Controls Avoid Large Disturbance in Frequency with Low Inertia



Blue: high inertia (H=6s), ie. No wind & PV power feed in share, nominal frequency control reserve

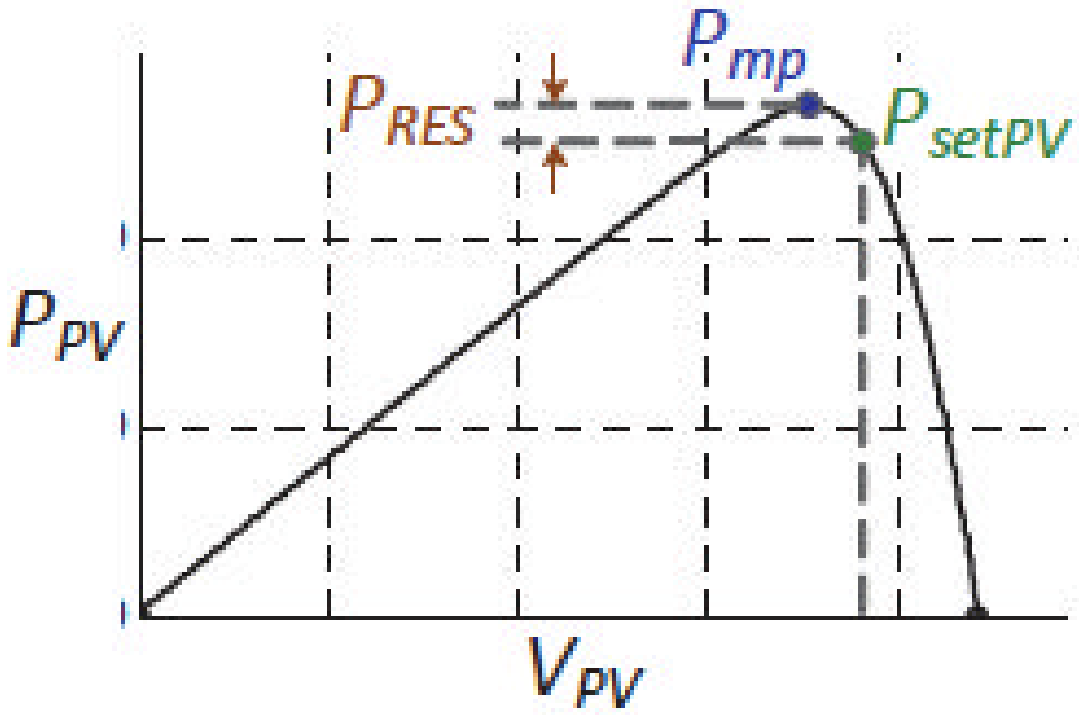
Red: low inertia 9H=3s), ie. 50% wind & PV power feed in share, nominal frequency control reserve

Green: low inertia (H=3s), fast control reserves

Andreas Ulbig, Theodor S. Borsche and Goran Andersson, Power Systems Laboratory, ETH Zurich
"Impact of Low Rotational Inertia on Power System Stability and Operation", 22 Dec 2014

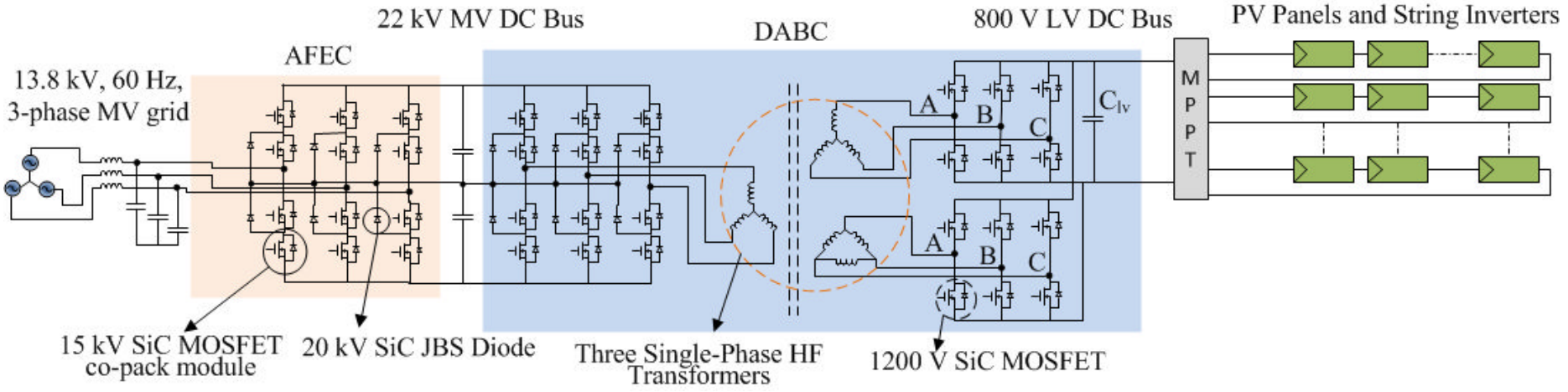
PV Inverters can have Power Reserves

PV inverters operating below the MPPT can have ***spinning*** *reserve real power which can be used to inject additional power as needed.*



Anderson Hoke, Eduard Muljadi, Power Systems Engineering Center, National Renewable Energy Laboratory, Golden, Colorado
Dragan Maksimovic;,Colorado Power Electronics Center, University of Colorado, Boulder, Colorado
"Real time Photovoltaic Plant Maximum Power Point Estimation for Use in Grid Frequency Stabilization"

Enabler for > 50% Renewables on the Grid



- Provide power and voltage support functions in sub-cycle time scales to keep the grid and embedded Microgrids stable.

FREEDM systems center

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Barriers to Acceptance

- ***High Cost*** **of WBG Chips**

  Must reduce the cost of WBG Semiconductors

  10 cents per Amp for 1200 V devices (Merchant Foundry)

- ***Value Proposition*** **of WBG Devices**

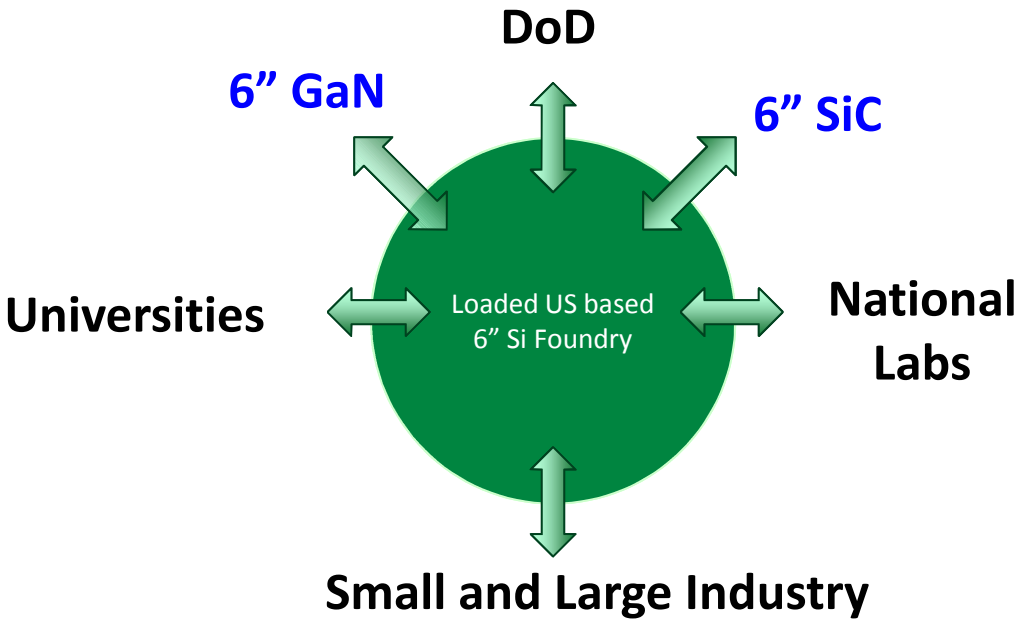
  Power Electronics Demonstration Projects to validate superior performance and reliability

- **PE Community *slow to change* and adopt new technologies**

  Must train Graduate students in benefits and use of WBG devices in Power Electronics (Work Force Development)

- **Reliability, Packaging**

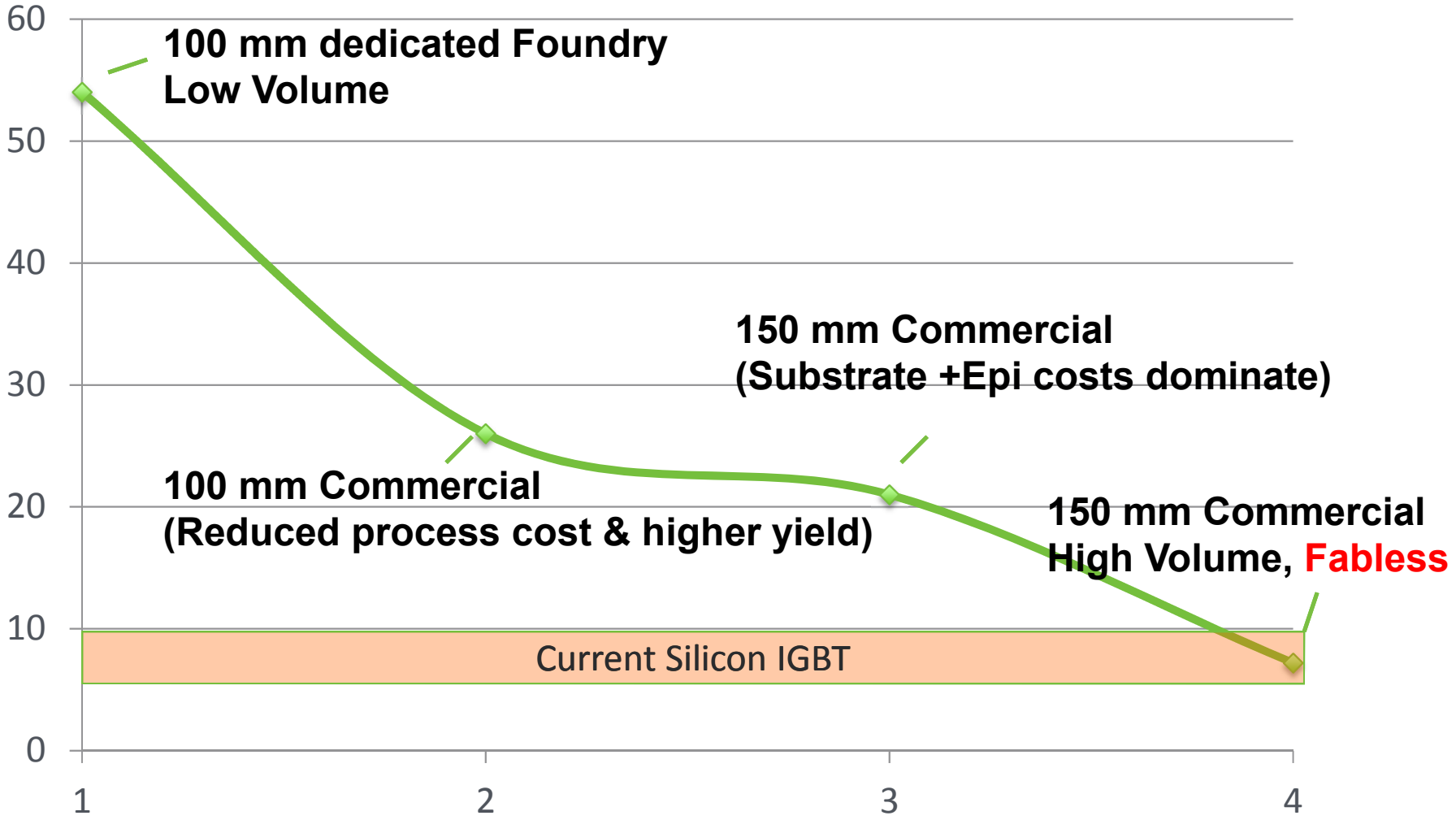
Benefits of Using Commercial Si Foundry



- Typically only 10-20% capacity of commercial foundry utilized
  - 90% of the processes are the same
- Innovation by researchers, small companies and students through design and access to fabless model—similar to MOSIS
- Reduce technology risk…encourage investments by VC firms
  - $10-15 M is required to create a product as opposed to $100 M

SiC and GaN devices can be competitive with Silicon

¢/A for 1200 V, 20 A SiC MOSFET



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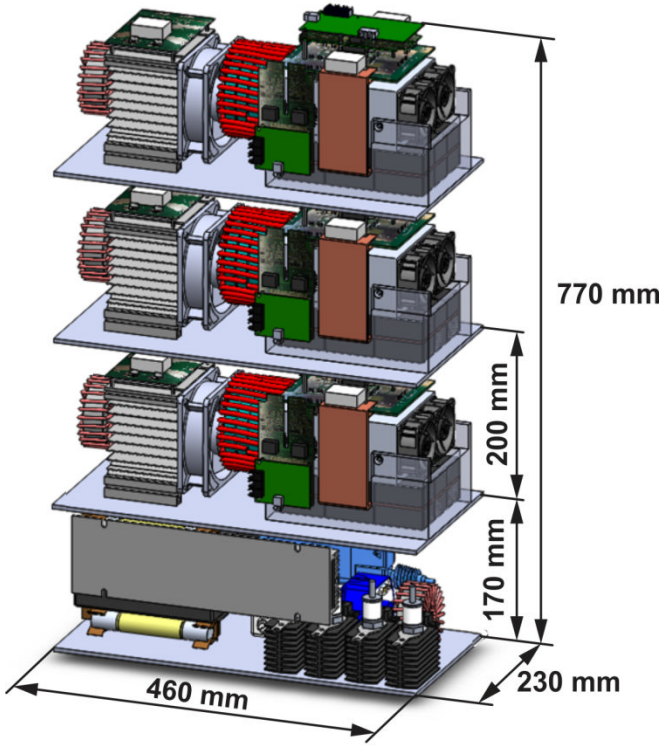
Medium Voltage WBG EV Fast Charger

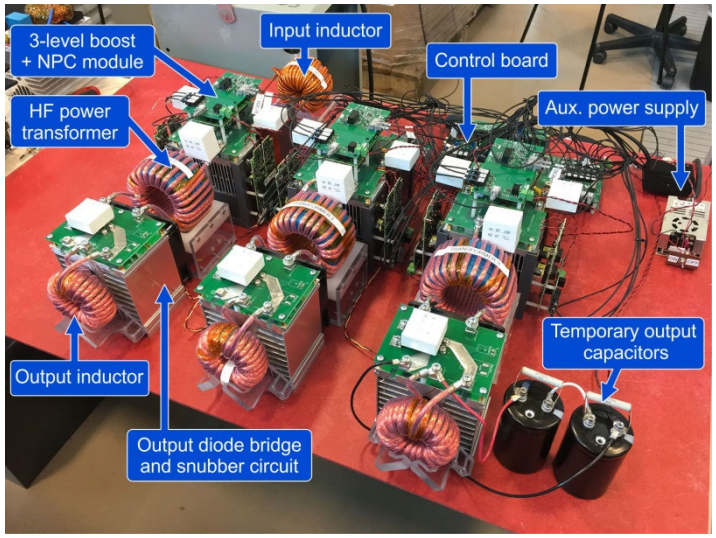
Prof. Srdjan Lukic

- **Objective:** Develop a modular medium voltage WBG EV Fast Charger using SiC semiconductor power devices to exploit the advantages of using WBG Devices



Prototype Rendering & Hardware Implementation

- MV WBG Fast charger
  - 50kW; 2,400Vac to 400Vdc
  - η≥95%,
  - 10 x size reduction; 4x weight reduction



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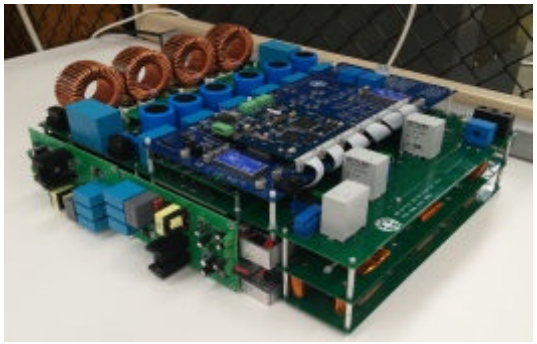
FLORIDA STATE UNIVERSITY

POWERAMERICA

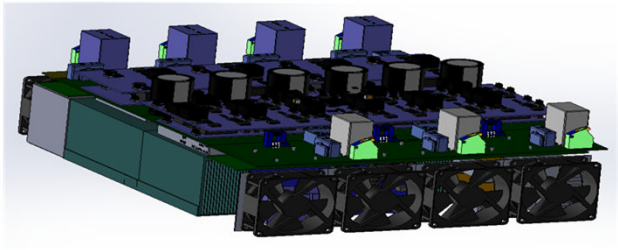
FSU Gen-I 50 kW SiC PV converter

- 99.1%
- 2.5 kW/kg
- 22.7 W/in^3
- Filter-less
- Low CMV



Proposed technology

Proposed **FSU Gen-II 100kW SiC PV converter**



Weight: **25x**
Volume: **35x**

3x

50 kW Si

100 kW Si

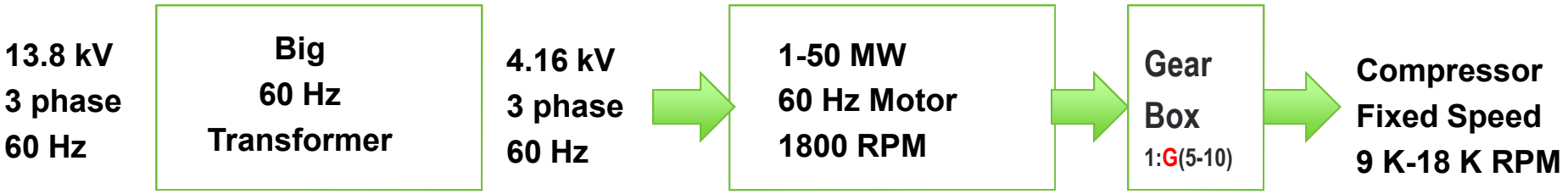
Education/Training:

6 UG&G students in the project

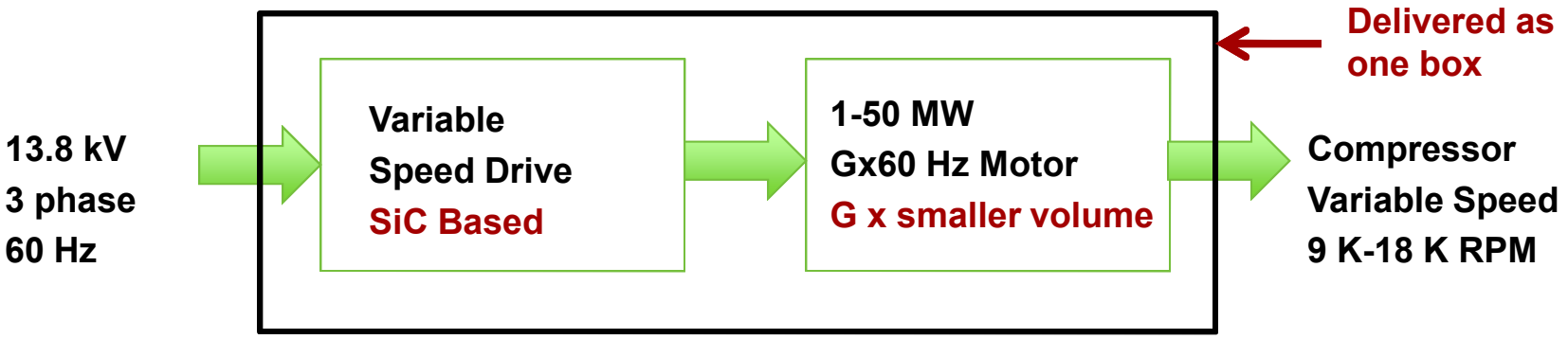
NGEM--Gaining US Manufacturing Advantage ($27M)

Traditional

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

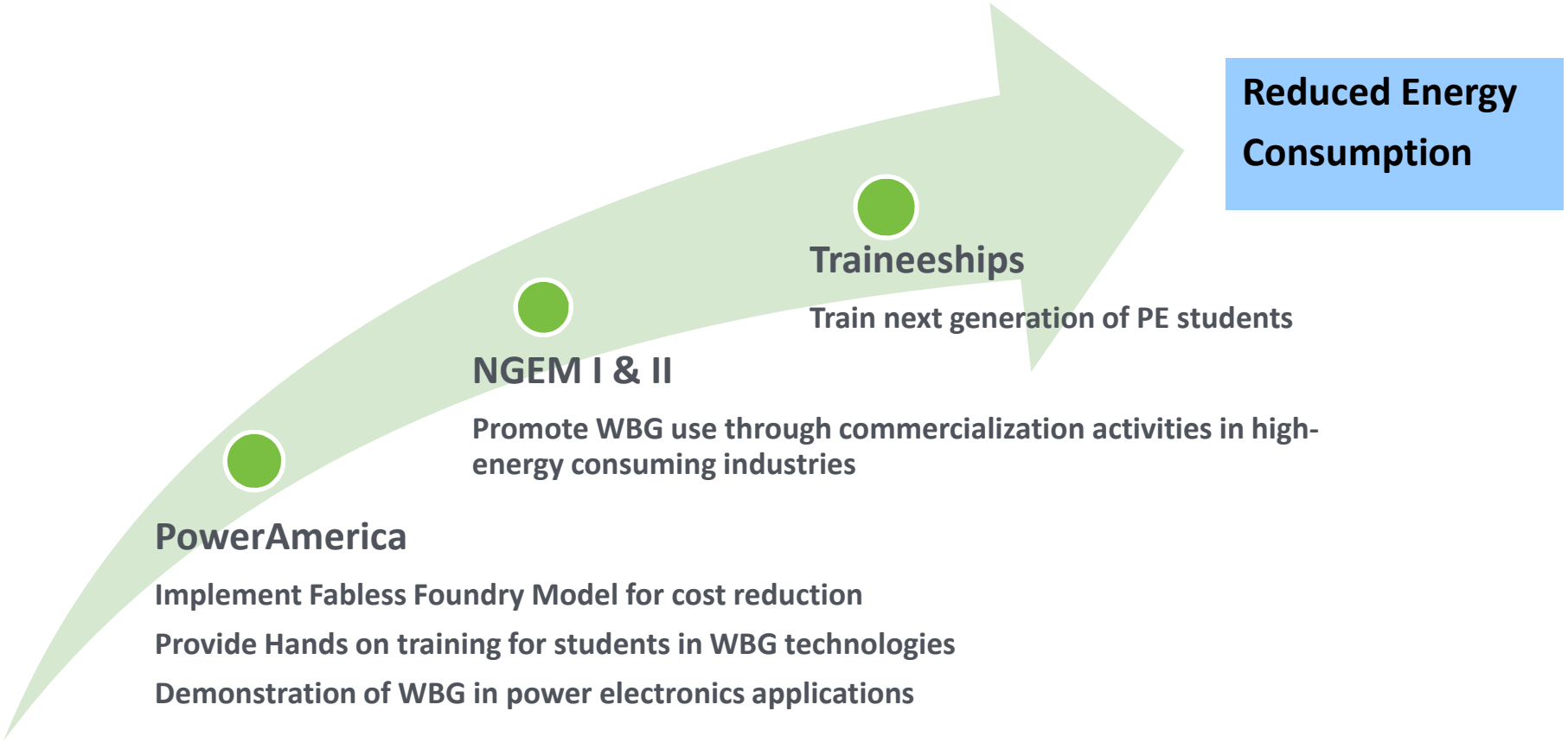


New Approach



- *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)*

Gaining Momentum!



Continuing the Momentum

- NGEMII - Enabling Technologies for Electric Machines
- Continue to promote educational expansion opportunities
  - Increase graduate student training opportunities
  - Fund faculty positions in WBG PE at various universities
- Move into Year 2 projects at PowerAmerica
  - Work on commercialization opportunities from Year 1 successes
- Work on Development of Standards and Regulations for Variable Speed Drives to improve adoption
- >10 kV SiC Power Devices and Systems for Grid Applications