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Military Ground Vehicle Silicon Carbide Needs

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Why High Voltage Power Electronics

- *Fielded Combat Vehicle Electrical Systems are maxed out*
- *New/Modernizing Combat Vehicles have 28VDC requirements >=30kW across all operating profiles*
  - *Stryker SMOD SPS: "capable of supplying 30 kW continuous 28 VDC electrical power, not to be provided by an energy storage device, across the entire operating range of the engine"*
  - *GCV CDD: "capable of generating 45 kilowatts (kW) of quality sustained electric power…"*
- *Alternator technology has reached its max feasibility (25.5-28kW) and new approaches/technologies are required to achieve higher electrical power output*
- *Desires exist to electrify large motor loads: Air-conditioning, propulsion cooling fans, turret drive motors, etc. to gain more horsepower and fuel efficiencies*

New approaches for electrical power systems are required on Military Ground Vehicles

Why High Voltage Power Electronics

- ***Stryker Modernization chose a 600VDC architecture to meet its requirements in 2010. PM-SBCT & GDLS are revisiting that decision this summer due to schedule and integration risks***
- ***All JLTV technology development vendors chose a different high voltage solution to meet their electrical power requirements***
- ***It is likely 600VDC architecture will be chosen for all platforms where the 28VDC requirement exceeds 28kW across all engine operating speeds***

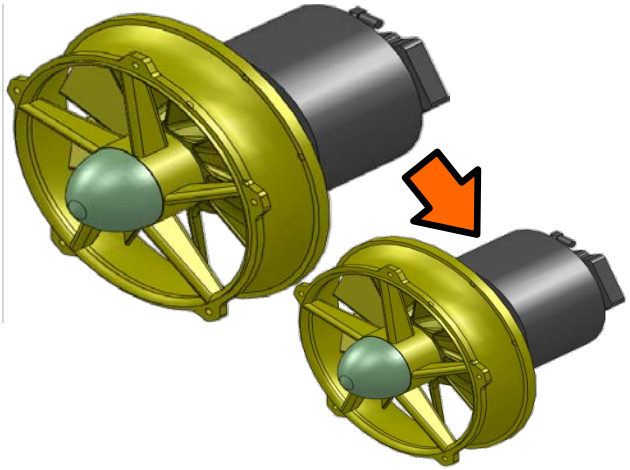
600VDC Technology Hurdles

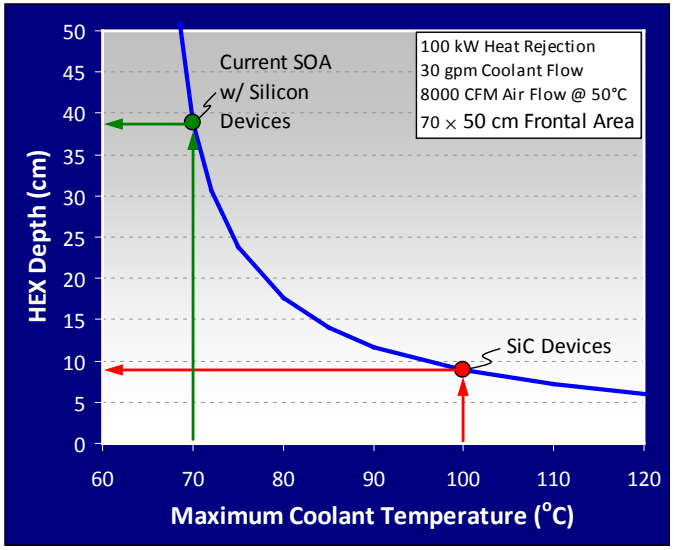
- ***Cannot package HV power system electronics with accompanying air-conditioning and engine upgrades without making some trades***
  - ***SWAP of Si-based electrical system not acceptable***
    - ***Size and weight of the converters***
    - ***Low operating temperature – large cooling system***
    - ***Significant power draw from the engine for the cooling fans***

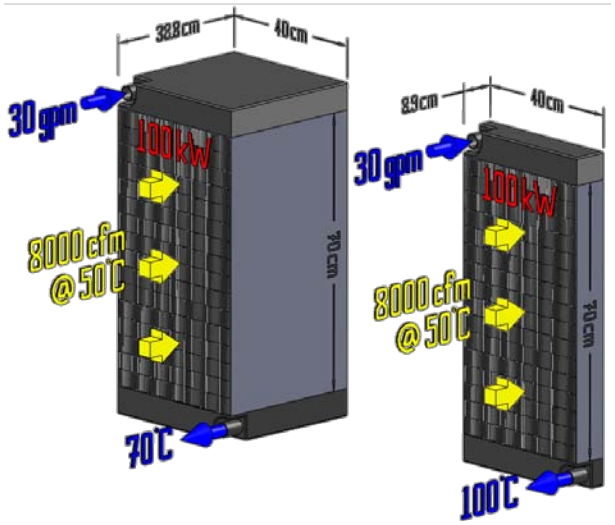
Improved Power Electronics Cooling Attributes

- Si based power electronics require coolant inlet Temperature not to exceed 70 or 80°C resulting in large cooling system size

- SiC can operate at much higher temperatures ≥ 100°C thus reducing the size of The cooling system by half



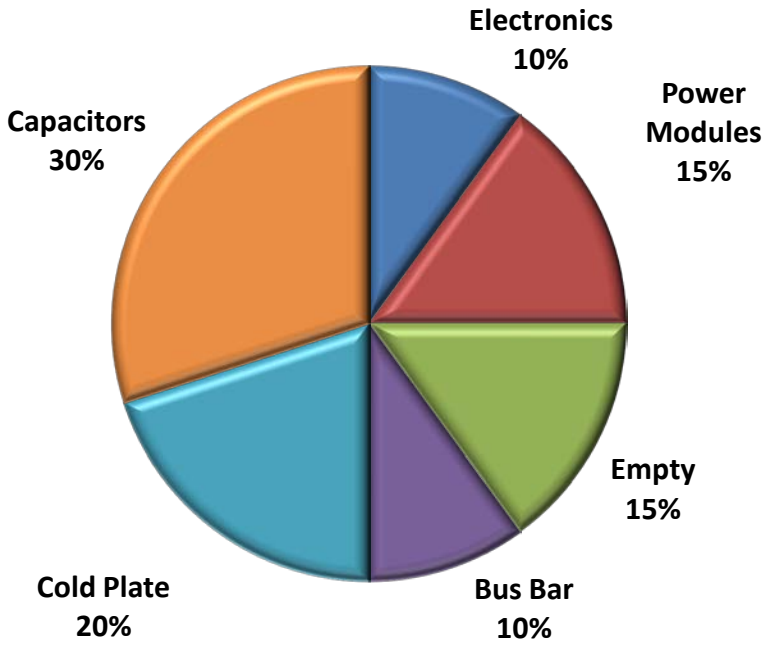


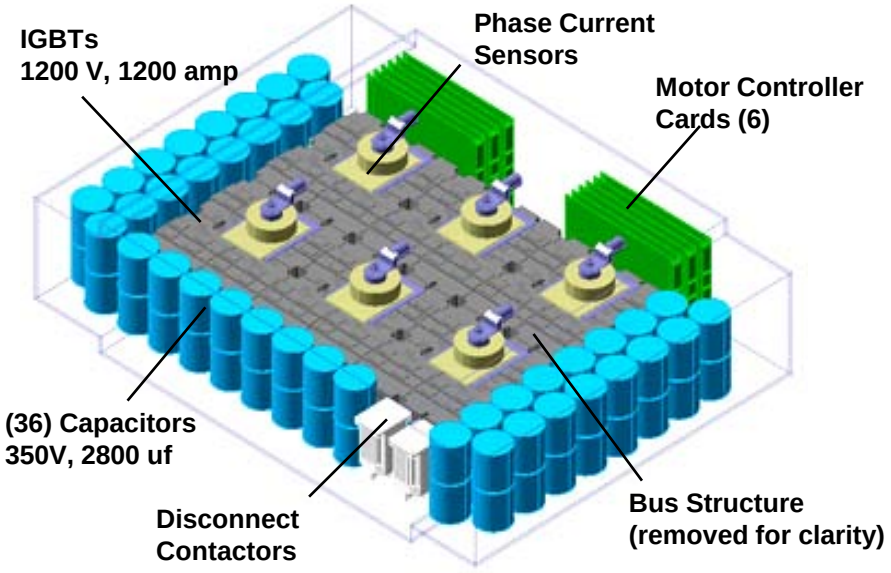


Advanced SiC Components will Reduce the Power Electronics Cooling Burden

Fewer Passive Components

Relative Volume of Power Converter Components





SiC allows for higher frequency switching leading to fewer capacitors and magnetics

MOTIVATION: Increased Performance, Reduced Integration Burden, & Fuel Savings

Why SiC / high power electronic devices?

Reduced SWAP, reduced cooling requirements, increased efficiency at high voltage, and higher operating temperatures. Overall, easier to integrate onto military ground vehicles than silicon based systems.

- **Size / Weight:** Up to 2X smaller and lighter compared to Si circuits.
- **Engine Power:** 70% more efficient than Si Circuits
  - **~5.3 HP gained for every kilowatt recovered of electronic loss**
- **Cooling:** Greater operating temperature (>100°C coolant) and efficiency means cooling system SWAP is significantly reduced
- **Reliability:** Si power electronics (80°C coolant) have no thermal margin. SiC switches (100°C) have up to 60°C margin and can provide some **'Limp Home' functionality**.

FY12 SiC TARDEC Efforts

Continuing efforts:

- Test and evaluation of SiC converters from ARRA efforts
  - 200 kW Traction Motor Drive Inverter
  - 50 kW Motor Drive Inverter for pumps, fans
  - 30 kW Bi-directional DC-DC converter (300Vdc to 28Vdc
  - 180 kW Bi-directional DC-DC converter (300V Battery-to-600V Bus)
  - 30 kW AC Export Power Inverter 300Vdc-to -60Hz @ 10Vac, 220Vac & 208Vac (3-phase)

New Efforts:

- ~160kW SiC Generator Inverter – BAA
- 10kW 600-28VDC SiC DC/DC Converter – TARDEC Omnibus

TARDEC will be competitively looking for industry help to design these components in FY12

Transition Barrier

COST

- **Power electronics for military applications are produced in low quantities, <1000/year in a production run**
- **The SiC module, the high temperature capacitors, and inductors are the major contributors to the high cost of SiC**
- **Complete SiC power electronics cost 5 times more, while offering better SWAP-C performance**
- **Improved manufacturing to increase the yield and larger quantity production are needed to reduce the cost of SiC to the same cost of Si**
  - ***We likely need commercial industry to adopt this technology in order for the production quantities to be sufficient enough to lower the cost for military use***

Questions?