John Deere, NREL Develop Inverter for Construction Vehicles

John Deere, NREL Develop Inverter for Construction Vehicles

Hybrid-electric construction vehicles need inverter systems that can operate at high-power and high-temperature conditions. Heavy-duty vehicles from John Deere Electronic Solutions (JDES) could benefit from these types of inverter technologies as some of their heavy-duty vehicle engine coolant system temperatures can reach up to 115°C.

With help from the National Renewable Energy Laboratory (NREL), JDES developed a power-dense inverter that uses wide-bandgap (WBG) semiconductors—a variety of semiconductor that has the potential to support the electrification of heavy-duty vehicles. NREL's expertise in heat transfer and thermal management helped develop a prototype that works well under the high-stress operation of JDES's commercial hybrid loader.

This work supports efforts by the U.S. Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy's Advanced Manufacturing Office to identify solutions to address the increase in electrical energy consumption through the development of more efficient power electronic devices.

New Power Electronics

In the United States, approximately 80% of electrical energy is expected to use power conversion technology in the next decade—a huge increase from the current 30% usage. Even modest improvements to the efficiency of power electronic technologies could result in huge savings. WBG power electronic components are a projected leader as they offer lighter, more compact, increasingly efficient, higher voltage, and potentially robust alternatives to traditional silicon components. WBG technologies like silicon carbide (SiC) have a potential operating temperature that is 2–3X higher than silicon alone. Further research and development are required to exploit the advantages of WBG technologies to their fullest potential.

The technology, however, is still perceived as risky, which is driving costs up and slowing adoption. There is little research being performed on WBG application in heavy-duty vehicles, for example, where hybrid electrical designs could benefit from lighter, more robust components.

The NREL and JDES-designed SiC inverter was tested in JDES's hybrid-electric construction vehicle. *Photo courtesy of John Deere*

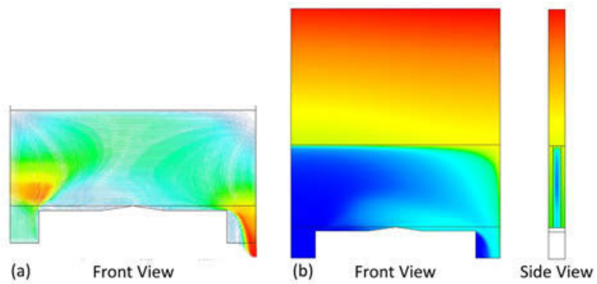
Opportunity

NREL is actively working on research and development to improve the performance of light-duty, electric-drive vehicles with WBG technologies. The performance of heavy-duty vehicles may also improve from WBG technologies, leaving open a research opportunity. If WBG power electronics could be safely and economically produced for heavy-duty vehicles, they could greatly reduce overall operating costs for industries. WBG power electronics could potentially provide:

- **Smaller and lighter components**
- **Safer operations at higher temperatures**
- **Better power conversion efficiency**
- **Inverters and converters that operate at higher voltages and switching frequencies.**

Showing WBG Technology's Potential

JDES and NREL are collaborating through PowerAmerica, a DOE program directed at accelerating WBG technologies. JDES requires a compact inverter capable of withstanding the full range of their vehicle's engine coolant temperatures (≤115°C). NREL helped by modeling the heat transfer within the inverter prototype. The research team developed a computational fluid dynamics model to study the impacts of heating and cooling on the inverter. This research builds on past work completed by NREL and JDES in which a lower temperature (105°C) capable first-generation prototype was built. The team validated the prototype's operation at high temperatures, high pressure, and high-power conversion efficiencies. The results confirmed that the engine radiator fluid could be used to cool the SiC power electronics and led to ongoing efforts between NREL and JDES to improve power density and coolant temperature capability for the second-generation prototype.



Preliminary model showing velocity vectors through fluid region of heat exchanger (a) and temperature profile through module cooling system (b). *Credit: Kevin Bennion, NREL*

Impact

The prior first-generation prototype's success demonstrated the development of the 200-kW 1050 VDC SiC inverter for use in JDES's 644K Hybrid-Electric Wheel Loader, where it was subsequently applied and demonstrated. JDES's new second-generation inverter serves as an example of a technology breakthrough that has the potential to give heavy-duty vehicle operators an edge in the market. The prior demonstration of the first-generation inverter has also placed it among PowerAmerica's portfolio of successful projects that help to de-risk an emerging technology.

Contact

For more information about this work, please contact NREL's Kevin Bennion: Kevin.Bennion@nrel.gov.

NREL

National Renewable Energy Laboratory
15013 Denver West Parkway
Golden, CO 80401
303-275-3000 • www.nrel.gov

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

NREL/FS-5400-73795 • August 2019