New tech promises to boost electric vehicle efficiency, range

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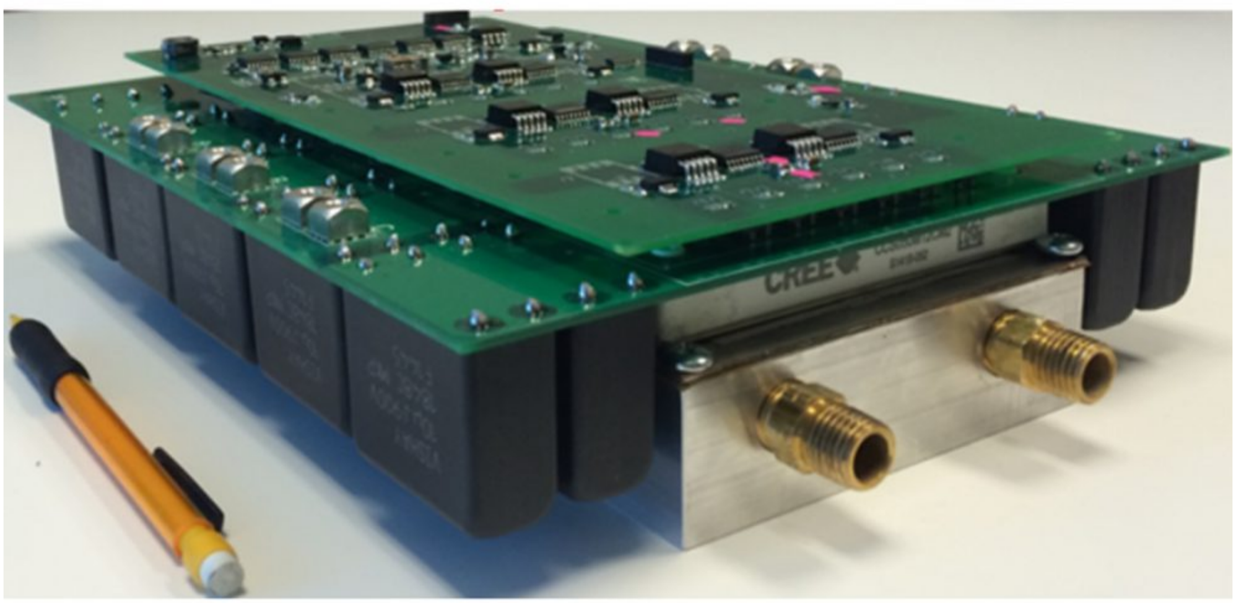

The new inverter, made using silicon carbide components. Credit: Iqbal Husain.

Researchers at North Carolina State University have developed a new type of inverter device with greater efficiency in a smaller, lighter package – which should improve the fuel-efficiency and range of hybrid and electric vehicles.

Electric and hybrid vehicles rely on inverters to ensure that enough electricity is conveyed from the battery to the motor during vehicle operation. Conventional inverters rely on components made of the semiconductor material silicon.

Now researchers at the Future Renewable Electric Energy Distribution and Management (FREEDM) Systems Center at NC State have developed an inverter using off-the-shelf components made of the wide-bandgap semiconductor material silicon carbide (SiC) – with promising results.

"Our silicon carbide prototype inverter can transfer 99 percent of energy to the motor, which is about two percent higher than the best silicon-based inverters under normal conditions," says Iqbal Husain, ABB Distinguished Professor of Electrical and Computer Engineering at NC State and director of the FREEDM Center.

"Equally important, the silicon carbide inverters can be smaller and lighter than their silicon counterparts, further improving the range of electric vehicles," says Husain, who co-authored two papers related to the work. "And new advances we've made in inverter components should allow us to make the inverters even smaller still."

Range is an important issue because so-called "range anxiety" is a major factor limiting public acceptance of electric vehicles. People are afraid they won't be able to travel very far or that they'll get stuck on the side of the road.

The new SiC-based inverter is able to convey 12.1 kilowatts of power per liter (kW/L) – close to the U.S. Department of Energy's goal of developing inverters that can achieve 13.4 kW/L by 2020. By way of comparison, a 2010 electric vehicle could achieve only 4.1 kW/L.

"Conventional, silicon-based inverters have likely improved since 2010, but they're still nowhere near 12.1 kW/L," Husain says.

The power density of new SiC materials allows engineers to make the inverters – and their components, such as capacitors and inductors – smaller and lighter.

"But, frankly, we are pretty sure that we can improve further on the energy density that we've shown with this prototype," Husain says.

That's because the new inverter prototype was made using off-the-shelf SiC components – and FREEDM researchers have recently made new, ultra-high density SiC power components that they expect will allow them to get closer to DOE's 13.4 kW/L target once it's incorporated into next generation inverters.

What's more, the design of the new power component is more effective at dissipating heat than previous versions. This could allow the creation of air-cooled inverters, eliminating the need for bulky (and heavy) liquid cooling systems.

"We predict that we'll be able to make an air-cooled inverter up to 35 kW using the new module, for use in motorcycles, hybrid vehicles and scooters," Husain says. "And it will boost energy density even when used with liquid cooling systems in more powerful vehicles."

The current SiC inverter prototype was designed to go up to 55 kW – the sort of power you'd see in a hybrid vehicle. The researchers are now in the process of scaling it up to 100 kW – akin to what you'd see in a fully electric vehicle – using off-the-shelf components. And they're also in the process of developing inverters that make use of the new, ultra-high density SiC power component that they developed on-site.

A paper on the new inverter, "Design Methodology for a Planarized

High Power Density EV/HEV Traction Drive using SiC Power Modules," will be presented at the IEEE Energy Conversion Congress and Exposition (ECCE), being held Sept. 18-22 in Milwaukee. Lead author of the paper is Dhrubo Rahman, a Ph.D. student at NC State.

A paper on the new, ultra-high density SiC power component, "Development of an Ultra-high Density Power Chip on Bus Module," will also be presented at ECCE. Lead author of the paper is Yang Xu.

More information: "Design Methodology for a Planarized High Power Density EV/HEV Traction Drive using SiC Power Modules"
Authors: Dhrubo Rahman, Adam J. Morgan, Yang Xu, Rui Gao, Wensong Yu, Douglas C. Hopkins and Iqbal Husain, North Carolina State University
Presented: Sept. 18-22, 2016 IEEE Energy Conversion Congress and Exposition, Milwaukee

Abstract: This paper provides a methodology for overall system level design of a high-power density inverter to be used for EV/HEV traction drive applications. The system design is guided to accommodate off-the-shelf SiC power modules in a planar architecture that ensures proper electrical, thermal, and mechanical performances. Bi-directional interleaved DC-DC boost structure and a three-phase voltage source inverter (VSI) have been utilized with the primary focus on the size, weight and loss reduction of passive components. A stacked layer approach has been used for a unique PCB-based busbar, ultra-low profile gate driver, and controller board. This holistic design approach results in a highly compact traction drive inverter with power density of 12.1 kW/L that has lower volume and weight compared to the commercially available state-of-the-art power converter systems.

"Development of an Ultra-high Density Power Chip on Bus (PCoB) Module"

Authors: Yang Xu, Iqbal Husain, Harvey West, Wensong Yu and Douglas Hopkins, North Carolina State University
Presented: Sept. 18-22, 2016 IEEE Energy Conversion Congress and Exposition, Milwaukee

Abstract: A traditional power module uses metal clad ceramic (e.g. DBC or DBA) bonded to a baseplate that creates a highly thermally resistive path, and wire bond interconnect that introduces substantial inductance and limits thermal management to single-sided cooling. This paper introduces a Power Chip on Bus (PCoB) power module approach that reduces parasitic inductance through an integrated power interconnect structure. The PCoB maximizes thermal performance by direct attaching power chips to the busbar, integrating the heatsink and busbar as one, and uses a dielectric fluid, such as air, for electrical isolation. This new power module topology features all planar interconnects and double-sided air cooling. Performance evaluations are carried out through comprehensive electrical and multi-physics simulation and thermal testing for a 1200V, 100A rated single-switch PCoB design. Fabrication and assembly processes are included. For the developed double-sided air-cooled module, 0.5°C/w thermal resistance and 8nH power loop parasitic inductance are achieved.

Provided by North Carolina State University