Infinitum

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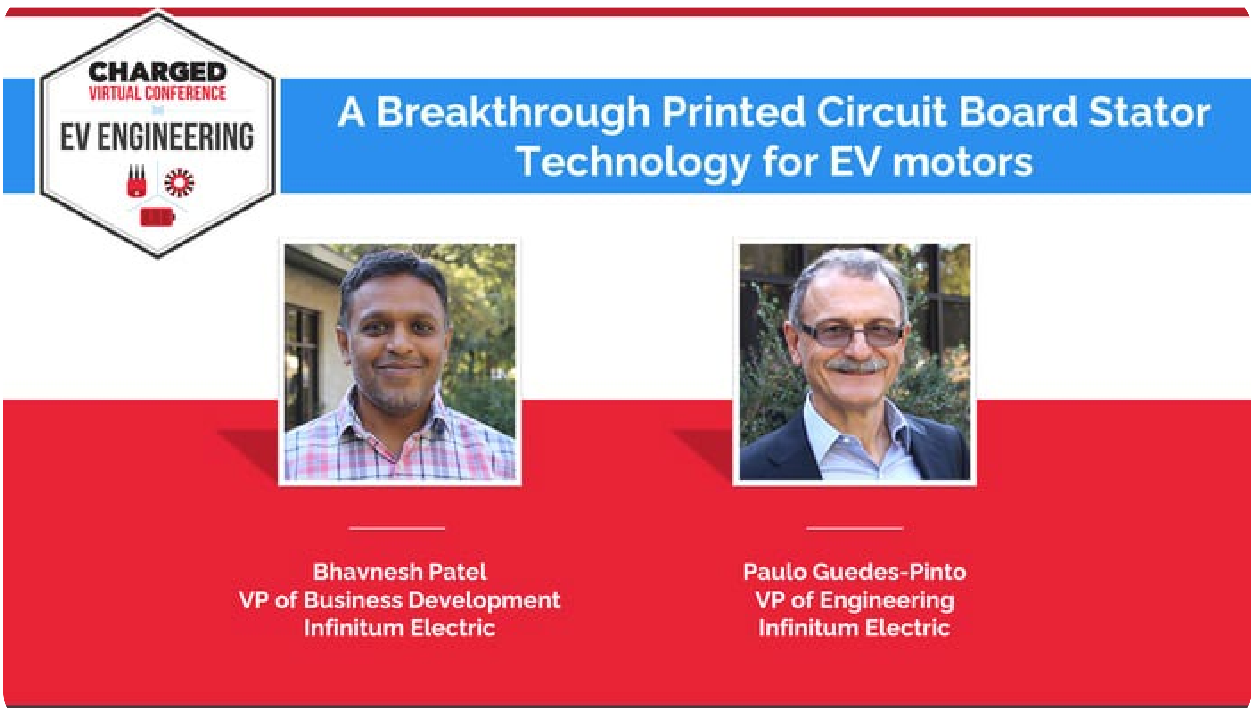
Q&A From Our Webinar:
A New Innovative Printed Circuit Board Stator Technology for EV Motors



In Fall 2021, Infinitum was a participating sponsor of the ChargedEV Virtual Conference alongside a number of our industry partners. As the pace of innovation in the electric vehicle (EV) space quickens, it's imperative that we make time for knowledge sharing.

Charged EV Presentation WIP v8

As part of the event, we hosted a session focused on our new, innovative printed circuit board stator technology for EV motors. If you missed it, the full session and presentation materials are available on our website. To see our motor up close, check out our YouTube channel.

We received a number of questions during our presentation and wanted to take some more time to address them. If you have any additional questions, please don't hesitate to reach out to our team.

Tell me more about temperature:

What is the ideal temperature for the motor's operation?

Our EV motors are designed for a wide range of ambient conditions from -40 °C up to 100 °C. Most of our motors use a standard FR-4 PCB substrate material with a glass transition temperature of 180 °C and are typically designed with a maximum temperature rise within that limitation. If necessary, the FR-4 substrate could be swapped out to meet more extreme temperature and environmental requirements.

Can the motor benefit from oil-submersion cooling?

We have tested a motor with oil spray cooling, and we managed to increase power density by a factor of 3. Check out our recent blog for more information about our testing rig and findings.

Are the rotors cooled? Or just the stator?

Rotors do not require cooling, as there's no heat generated in the rotor. Since the stator is the only source of electrical losses, direct coolant application offers a significant advantage. During Infinitum's axial-flux motor test, oil was sprayed directly over the surface of the stator which maximized heat transfer away from the current-carrying copper.

Is temperature sensing incorporated into the stator?

Yes, temperature sensing is incorporated into the stator in two different ways. A Resistance Temperature Detector (RTD) is mounted onto the stator surface, and Infinitum's control algorithm estimates the temperature of the stator by periodically injecting DC current and calculating stator resistance.

Are you using inner layers and external layers in the FR-4 substrate? Is there any compensation between the two due to heat dissipation differences?

Inner layers tend to run hotter than external layers by about 5 to 10 °C, so there's a small temperature gradient between the two.

Tell me more about power:

What's the maximum power for the motor?

We are currently designing motors for traction applications rated up to 100 kW, continuous power. Power is scalable depending on the application. For example, this technology was scaled up to 3 MW for a wind turbine application.

Air core motors typically have a low power factor. How do you compensate for that?

That's a common misconception. The power factor is high (around 90%) because the stator inductance is very low. Resistance dominates the motor impedance.

Tell me more about components and materials:

What is the PCB stator made of?

Typically, the stator is made of FR-4 glass-epoxy laminate. We opt for different materials under extreme temperature and/or environmental conditions.

How many layers do you use in the PCB?

It varies based on the application and how many stators are included in the system. We've designed stators with as few as 6 layers all the way up to 24. We have a design tool that helps us figure out exactly how many layers we need based on system requirements.

What type of semiconductors do you use to drive the motor?

Our inverter uses SiC MOSFETs. They are more efficient than silicon-based IGBTs and can operate at much higher switching frequencies, which provides better control over the voltage applied to the motor. SiC MOSFETS can also withstand much higher temperatures.

Do you use flex or rigid based boards?

Our PCB stators are rigid.

Tell me more about system operations...

What's the operational range of the motor?

Infinitum can design motors that operate from very low speeds up to 20,000 rpm and higher. Likewise, for power, we can design for a couple of watts up to several hundred kilowatts.

Could you explain how bearing currents are eliminated?

The shaft-induced voltage in the motor is well under 1 V. At this voltage level, bearing currents are non-existent or negligible. For any final mitigation, Infinitum fine tunes the PWM control algorithm and employs common mode chokes where needed.

What's the situation with leakage flux with no iron in the stator?

Magnetic flux flows between two rotors with the stator positioned in the middle. There is very little leakage flux.

Tell me more about how this motor might fit into my application...

Does this technology also work for radial-flux machines?

No. That would require curved multilayer rigid PCBs. That is not possible with current PCB manufacturing processes.

Is possible to use PCB motors for in-wheel automotive applications?

For many in-wheel applications, an axial-flux motor is going to be more challenging to configure, but depending on the specifications of the system, it can be done using a stacked module approach to achieve high torque. As you increase the torque, the diameter of an axial-flux motor increases. For in-wheel applications, you're generally looking for a motor that isn't geared; therefore, it'll operate at a lower speed and the diameter will be wider.

Do you require reduced magnet mass per kW?

Magnet mass depends on power, speed, rotor diameter, and efficiency. It has to be determined on a case-by-case basis depending on the application.

Is it possible to use this motor to build a generator?

Yes. You'd need a power converter to tie the generator to the grid. Infinitum motors operate at a higher frequency than the typical 50 to 60 Hz, so the generator output would go to a rectifier and then through an inverter to be able to tie into the grid. Infinitum is currently working on a design for a 16 kW, 20 kVa generator.

Tell me more about how this motor stacks up…

What is the current power density in PCB motors versus a conventional motor?

Our motors are typically at least 50% lighter than conventional iron core motors with the same rating, so the kW/kg ratio is two times higher. Our traction motor designs have a power density ranging from 8 to 12 kW/kg.

Is the efficiency of the axial-flux switched reluctance motor higher than these motors?

The efficiency is comparable, but they're fundamentally different forms. Infinitum motors are surface-mount, synchronous permanent magnet machines, so the topology is completely different from a switched reluctance motor. On a switched reluctance motor, there's no excitation on the rotor; Infinitum motors have permanent magnets on the rotor. Because Infinitum's motors use an air core construction, there is no torque ripple and no magnetic noise, which tend to be issues with switched reluctance motors.

Today, the EV industry is trending towards 800 V powertrain voltage and more and more SiC-based inverters. Is your motor suitable to such voltage and high operating frequency?

Yes. Our 150 kW design is based on an 800 V DC bus voltage, and we already use SiC MOSFETs in our inverters. Infinitum expects to have prototypes ready for testing in 2022. We're in mass manufacturing for industrial applications, but we're still at earlier stages for traction applications.