Aviation Energy Futures

Power Electronics and Electric Machines for Advanced Aircraft

Power electronics and electric machines are critical components of efficient, high-performance aircraft. Improvements to these components create enormous energy efficiencies, enable cost savings, and ensure fail-safe operations.

National Renewable Energy Laboratory (NREL) researchers are developing innovative power electronics, electric motors, integrated electric traction drives, and thermal management systems to build highly efficient, lightweight, ultrareliable powertrains for aircraft.

What You Need To Know

- **Power Electronics Control Aircraft Energy Flow**—Power electronics, electric machines, and electric-drive systems help aircraft control and convert electricity into usable forms for flight operations. It is possible to yield a 3%–5% efficiency increase in conventional jet-engine-based airplanes through drivetrain hybridization.
- **Performance and Reliability Are Key**—The electric components used in aviation must be ultralight, ultraefficient, and extremely reliable—and fully compliant with federal safety regulations. NREL's integrated state-of-health monitoring gives components an edge while estimating the remaining life of the propulsion system.

Case Study: Accelerating an All-Electric Aircraft Powertrain

Under the Advanced Research Projects Agency—Energy (ARPA-E) Aviation-class Synergistically Cooled Electric-motors with iNtegrated Drives (ASCEND) project, NREL researchers partnered with General Electric to develop a 2-MW electric aircraft powertrain that can enable flight for a narrow-body commercial aircraft with all-electric propulsion. NREL helped develop:

- A transformational permanent-magnet motor with an embedded cooling system.
- A modular inverter, fully integrated into the motor, that reduces the footprint of high-temperature, high-efficiency silicon carbide inverter modules.
- An ultracompact thermal management system to cool the entire powertrain.

- **Thermal Management Is Critical**—Aircraft components are sensitive to high temperatures, which can prematurely degrade them. Thermal management systems are critical to keep their component temperatures within operational limits, maintain and improve reliability, and increase components' power density.
- **Cost-Saving Opportunities Abound**—Aviation is a $4 trillion market, and any efficiency gain using state-of-the-art power electronics aids in significant cost savings. These efficiency gains are part and parcel of NREL's research.

NREL Offers End-to-End Power Electronics Research and Development

NREL's world-class power electronics research and characterization facilities form an end-to-end pipeline. The result is first-in-the-world designs that are lighter, smaller, and more efficient—and thoroughly tested and validated in NREL's facilities to ensure their lifelong reliability.

The laboratory designs, fabricates, and evaluates novel power electronics completely in-house.

1. **Design**—NREL researchers custom-design new components and systems to meet the needs of aerospace partners.
2. **Fabrication**—NREL builds power electronics from scratch in machining facilities so they can be quickly and seamlessly validated.
3. **Evaluation**—Researchers evaluate new components and systems in world-class characterization facilities to ensure their performance and lifelong reliability.

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Unlock the Benefits of NREL's Power Electronics Research

NREL's key strengths lie in multiphysics simulation and modeling, allowing us to design industry-leading power electronics, thermal management systems, and controls.

- Core power electronics design, including wide- and ultrawide-bandgap switching devices and modules, lightweight and high-power-density DC-DC converters, intelligent gate drivers with wireless communication, onboard state-of-health monitoring systems, high-performance thermal management systems, inverters, battery chargers, and battery management systems.
- Power module design and packaging using intelligent, patent-pending components that ensure world-class switching performance, state-of-health monitoring, and reliability.
- Ultralight materials and ultrareliable converters for motors and components that leverage sophisticated thermal management systems to produce outstanding power density.
- Multiphysics modeling to simulate how power electronics function under stress—from extreme temperature fluctuations of –40°C to 200°C to humidity, vibration, and pressure.
- Thermomechanical reliability testing so power electronics and electric motors can withstand punishing conditions while functioning at peak performance.
- Compliance testing for reliable, light, power-dense components that align with Federal Aviation Administration regulations.
- Electromagnetic interference analysis and mitigation to ensure devices function at peak performance.
- Complex, combined environmental testing to identify and mitigate weaknesses in power electronics package designs, improving aircraft life span, durability, and performance.
- Custom-built machining facilities to fabricate power electronics prototypes in-house.

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