National Aeronautics and Space Administration

TECHNOLOGY SOLUTION

Power Generation and Storage

High-Voltage Power System for Hybrid Electric Aircraft Propulsion

Variable-frequency, doubly-fed electric machines improve efficiency and reduce weight

Innovators at NASA's Glenn Research Center have developed a variable-frequency, alternating current (AC) power system to enable turbo-electric and hybrid electric propulsion. Glenn's technology uses double-fed electric machines and a high-voltage, variable-frequency power system to significantly decrease (by 85%) the weight of an aircraft's power electronics for turbo-electric propulsion, while still providing high specific power and variable thrust. To provide a safe system, the lightweight electric machines operate at high frequency, allowing fast detection and clearance of faults without requiring switchgear that interrupts the current. This design also reduces the protection system's weight, while improving reliability by minimizing fault energy and collateral damage potential. In addition, the system permits either sub-synchronous or super-synchronous operation relative to throttle position, without having to adjust turbine settings. Glenn's innovative system raises the ceiling for hybrid electric aircraft.

BENEFITS

- Cost-effective: Reduces weight significantly in both the power system and the protection system, yielding greater fuel efficiency and very low carbon emissions
- Efficient: Provides 30% variation around engine throttle settings and a maximum of 60% differential variation for twin engine aircraft, so fewer turbine adjustments for variable thrust are needed
- Reliable: Provides increased redundancy due to the multi-mode operation for the doubly fed electric machines and reduction in power electronics and thermal subsystems
- Safer: Uses high-frequency AC and differential protection zones that minimize collateral damage through fast detection and isolation of faults
- High-performance: Offers enhanced turn and bank control through distributed propulsion and use of sub and super-synchronous operation of the doubly fed electric machines

THE TECHNOLOGY

Glenn's novel system supports the NASA Aeronautics Research Mission Directorate (ARMD) strategic plan to leverage advancements in technologies over the next 25 years and beyond, leading to new aircraft configurations with enhanced performance, improved energy efficiency, and reduced CO2 emissions. The electric system is a multi-megawatt micro-grid that converts mechanical energy to electric via generators, and electric energy to mechanical via motor-driven fans. This innovation would use the variation in aircraft throttle settings to produce a high-voltage (20 kilovolts), variable-frequency 9-phase AC distribution system. Using doubly fed electric machines (generator, propulsor, and flywheel) allows for field excitation that can cause variable-frequency or variable speed operation around the commanded throttle setting. The flywheel enables an energy storage system that recovers and reuses energy, while the flywheel slews with the throttle control using the electromagnetic torque produced by the doubly fed electric machine. This design permits both sub-synchronous and super-synchronous operation using limited field excitation power provided through power converters. Finally, the reduced switchgear mass facilitated through the use of a high-frequency AC system, setting-less protection zones, and simplified switches for fault clearance provides enhanced operational capability. This system can be controlled so that fault energy is minimized, preventing collateral damage to aircraft structures even with high voltage distribution. Glenn's innovative system adds performance, efficiency, reliability, and cost savings to cutting-edge hybrid electric technology.

This is an early-stage technology requiring additional development, and Glenn welcomes co-development opportunities.

Glenn's innovative power system reduces weight and improves efficiency in turbo-electric and hybrid-electric aircraft propulsion

Glenn's system clears faults quickly and diffuses excess energy to prevent collateral damage to large throttled engines, such as those aboard ships

APPLICATIONS

The technology has several potential applications:

- Aerospace
- Unmanned vehicles
- Power (e.g., microgrids)
- Marine

PUBLICATIONS

Patent No: 10,450,080; 10,647,439

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NASA's Technology Transfer Program pursues the widest possible applications of agency technology to benefit US citizens. Through partnerships and licensing agreements with industry, the program ensures that NASA's investments in pioneering research find secondary uses that benefit the economy, create jobs, and improve quality of life.

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More Information

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