National Aeronautics and Space Administration

NASA

TECHNOLOGY SOLUTION

Power Generation and Storage

Double-Fed Induction Linear Alternator

Ironless Stirling alternator operates efficiently at extremely high temperatures

Innovators at NASA's Glenn Research Center have developed a lightweight, double-fed induction linear alternator capable of highly efficient extreme-environment performance. While traditional linear alternators cannot withstand temperatures of 250°C, this innovation has the ability to operate at 950°C with increased performance and efficiency. The innovation replaces the traditional permanent magnet with a copper electromagnetic Halbach circular array (essentially a 3D printed copper coil). Its simple design also eliminates iron, slip rings, and - because it is fabricated as a single piece - adhesives. As a result, it is easy to maintain, does not require iron flux containment and experiences minimal electromagnetic interference. When used with the double action extremely light thermo-acoustic (DELTA) converter, the engine/alternator system is one-tenth the weight of a traditional system. This economical alternator enables unprecedented performance for high-temperature environments such as aircraft power systems, micro combined heat and power (CHP), and downhole drilling.

BENEFITS

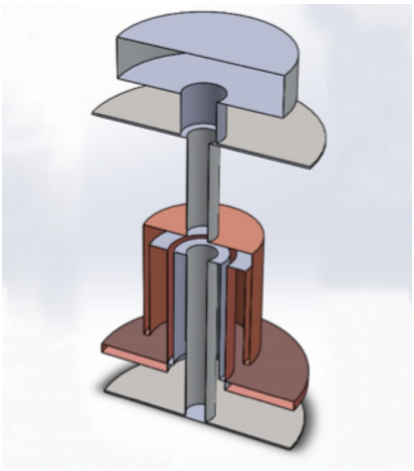
- Compact: eliminates the need for permanent magnets, reducing size and weight
- Reliable: reduces electromagnetic interference emissions and eliminates the need for maintenance due to its simple design
- Efficient: achieves 25% greater efficiency than conventional liner alternators
- High-temperature capable: operates at temperatures up to 950°Ca 280% increase over the state-of-the-art
- Affordable: uses simple 3D printing technologies, enabling low-cost manufacturing

THE TECHNOLOGY

This technology was developed to address the limitations of traditional, single-fed linear alternators, which require permanent magnets, adhesive bonding organics, and heavy iron laminations for flux control. They experience eddy-current losses and require electromagnetic interference protection. Furthermore, they have a limited operational temperature range (only up to 250°C), which typically declines to below 200°C as the adhesive bonding organics outgas and degrade over time. Consequently, they are limited to approximately 93% efficiency at ambient temperatures.

Glenn's novel linear alternator addresses all of the limitations of its predecessors and engenders a number of desirable new qualities - notably the ability to reduce eddy-current losses by 25% and operate at 99% efficiency at temperatures up to 950°C. It features a concentric, additively manufactured monolithic copper plunger and stator. The stator is a stationary single copper Halbach array, whereas the plunger is a moving electromagnetic copper Halbach array. A direct current is delivered through the conductive piston flexure support, which also provides reactive power for resonance. It creates a fixed magnetic field similar to that of a permanent magnet, but the magnetic field is channeled inward by the Halbach mover, doubling its strength. By utilizing standard double-fed induction control methods, the reactive power can be transferred and adjusted between both coils. This maximizes system efficiency and minimizes weight. This innovative technology will enable a new class of vastly superior linear alternators with the ability to operate at extreme temperatures with increased performance and efficiency. This is an early-stage technology requiring additional development. Glenn welcomes co-development opportunities.

This innovative alternator is ideal for use in high-temperature environments such as CHP systems



The system includes an additively manufactured monolithic copper mover and stator

APPLICATIONS

The technology has several potential applications:

- Power (CHP, solar, stirling or free-piston engines, cryocoolers, auxiliary power units)
- Unmanned vehicles
- Oil and gas
- Commercial space
- Turbines

PUBLICATIONS

Patent No: 10,581,355

See also LEW-TOPS-106 "Double-Acting Extremely Light Thermo-Acoustic (DELTA) Convertor"

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