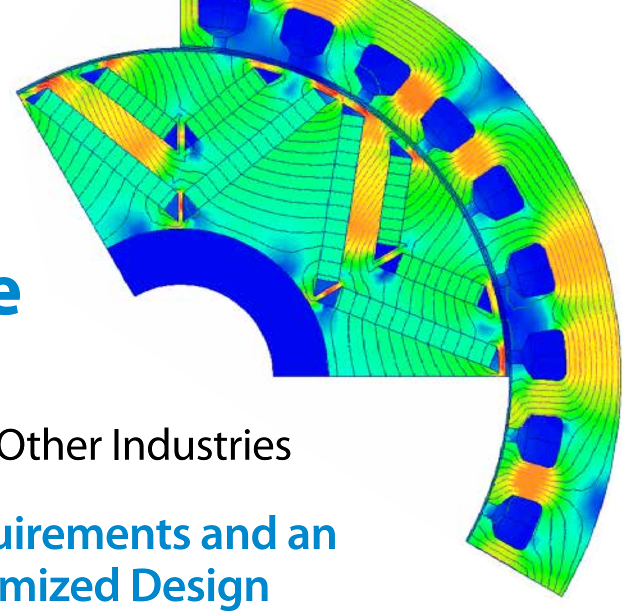
A Novel High-Temperature Generator/Motor Design



With Applications in Geothermal Drilling and Other Industries

The National Renewable Energy Laboratory (NREL) has designed, built, and tested a novel high-temperature generator for efficient power generation in a 250°C environment.

This work was completed under an Advanced Research Projects Agency - Energy (ARPA-E) project partnered with Tetra Corporation and TPL Inc, focused on upgrading power electronics in Tetra's advanced drilling system for harsh, high-temperature geothermal drilling environments. NREL is investigating additional applications for this design, which exceeded initial performance targets, as either a generator or motor capable of efficient performance at high temperature.

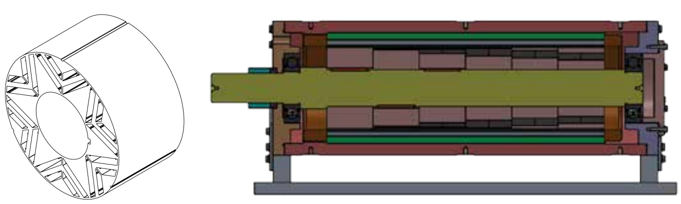


Figure 1: The high-temperature was design. One simulation result is shown above.

Requirements and an Optimized Design

Researchers at NREL designed a generator for high-temperature efficiency and demagnetization resistance that is capable of meeting the requirements in the table below. The device was modeled and optimized in Ansys Motor-CAD and Ansys Maxwell. The same design and components can be used for a motor instead of a generator.

Optimized Downhole Generator Design s Performance

Parameter	Requirement
Outer Diameter	0.238 m
Shaft Diameter	0.080 m
Length	0.5 m
Output Power	30 kW
Speed	1,000 rpm
Optimized Target Efficiency at 250°C	85%
Specific Power	0.22 kW/kg
Self-Starting	yes

Validated Performance in a 250°C Environment

Materials for high-temperature operation were carefully selected, and a prototype device was manufactured outside the laboratory and tested at NREL. The results from the efficiency mapping tests showed that the measured efficiency is slightly lower than the efficiency predicted by finite element analysis (FEA), but within the expected bounds of mechanical losses that are not accounted for in the FEA solutions. Nonetheless, the measured results are still satisfactory.

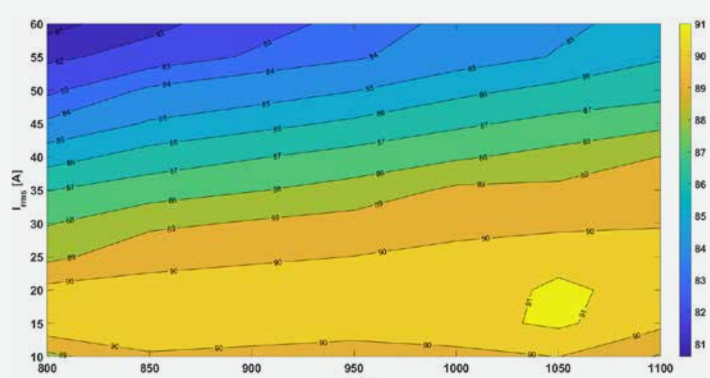


Figure 2: Measured efficiency map of the repetitive, pulsed electric drill (RePED) generator in a 250°C environment.

Potential Improvements and Redesign

This generator was specifically designed for a downhole drilling environment, which required a specific geometry, lower revolutions per minute (rpm), and components that can survive the harsh pressure and corrosive conditions in a geothermal well. There is significant opportunity to tailor the design for non-drilling applications. NREL's performance models that were validated against the prototype are being used to explore modifications for use in the other high-temperature environments listed below.

Demonstrated Performance of Downhole Generator	
Metric	**Measured Result**
Measured Efficiency[1] at 30°C	91.5%
Measured Efficiency[1] at 250°C	84.50%
Internal Temperatures at 250°C Ambient	≥315°C
Output Power	35 kW
Speed	1,000 rpm
Line Current (I_{rms})	51 A

[1] At design point rpm and current

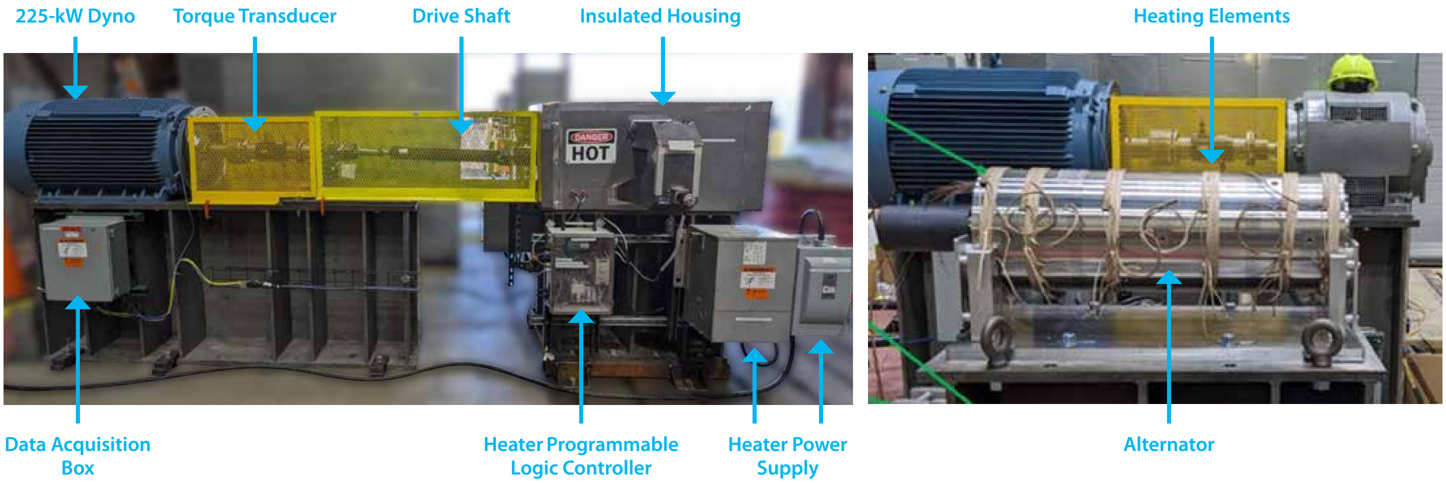


Figure 3: High-temperature generator testing at NREL. The generator under test is wrapped in heating elements, inside the insulated housing.

Applications

Oil and Gas

Application in some oil and gas reservoirs requires high-temperature drilling systems, where the bottom hole temperature exceeds 200°C.

Aviation and Aerospace

Generators and motors with demonstrated performance at high temperature have widespread application in aerospace and electric aviation, where reliability is paramount. Using high-temperature motors could eliminate heavy and costly cooling systems.

Electric Grid

Thermally stable generators may have applications in the electrical grid.

Electric Vehicles

Alternators are used in every type of automobile, including those with internal combustion, hybrid, and electric motors.

Geothermal

Downhole power will enable advanced high-energy and hybrid drilling systems, improving the speed of drilling and deployment of enhanced geothermal systems.

For more information about this research, contact:

Ben McGilton, ben.mcgilton@nrel.gov

NREL

National Renewable Energy Laboratory
15013 Denver West Parkway, Golden, CO 80401
303-275-3000 • www.nrel.gov

NREL prints on paper that contains recycled content.

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy
Operated under Contract No. DE-AC36-08GO28308

NREL/FS-5700-89915 • May 2025