Optimization of a Thermoelectric Conversion System

J. R. Chase[1]

[1]Alphabet Energy, Hayward, CA, USA

Abstract

Thermoelectric materials have no theoretical limit to conversion efficiency of heat into electrical power. In order to compete with other forms of power generation and small-scale energy conversion, thermoelectric converters need to maximize their practical usability when integrated with real-world sources of waste heat, and in real-life service environments. This trade-off reduces itself to performance characteristics that can be conveyed in terms of power output per unit cost, and reliability in terms of months to years.

This paper describes a simulation-supported design, development, optimization, and testing technique of a thermoelectric device that can operate at a hot-side temperature of up to 350C continuously, and a cold side temperature from 50C-150C; and that does so for hundreds of hours within laboratory-scale, in-situ testing.

The approach begins by using the COMSOL Multiphysics® software and SolidWorks® in concert toward the high-level design of a mechanical package that delivers idealized, single-point power output behavior. The fabrication process is then studied using thermomechanical stress FEA in order to confidently choose design variables such as bonding materials, mechanical component geometries, and practical limits to size and structure; where the aim is to minimize residual thermal stress and strain.

The COMSOL® software is also employed to design and model the test station itself, using transient and steady-state thermal/mechanical/electrical studies. Finally, the thermoelectric device is built and tested through hundreds of package iterations and in-situ temperature profiles in order to validate simulations with respect to thermal resistance, power curve characteristics (I-V-P), and thereby overall efficiency and power density in both transient and steady-state operation.