Improved SPICE Modeling and Analysis of a Thermoelectric Module

Yacouba Moumouni, Ph.D candidate (yacoubam@unlv.nevada.edu)
R. Jacob Baker, Professor (rjacobbaker@gmail.com)
University of Nevada, Las Vegas, 4505 Maryland PKWY, Box 454026, 702-895-4125

Center for Energy Research (CER)

I. Introduction

Major sources of energy are in limited supply. Renewable resources on the other hand, are those that are replenished rapidly and naturally at human scale. Examples of RE resources include solar, thermoelectric generator, biomass, and geothermal. The thermoelectric module (*TEM*) is considered to be one of the best generators of renewable energy because of their extreme reliability and have no moving parts.

The purpose of this paper is to show both the feasibility of an improved LTspice [1] model for the TEM and, to investigate how laboratory experiments compare to computer simulations using the developed model.

First, the TEM was run as a heat pump or thermoelectric cooler (*TEC*) based on experiments and SPICE simulations.
Second, the TEM was simulated by considering the intrinsic parameters, such as inductance and capacitance. Additionally, only the major physical phenomena (*Seebeck*, *Peltier*, and *Joule effects*) were considered in this analysis. The *Thompson effect* is explicitly neglected in this work due to its smaller contribution in terms of cooling.

The TEG was first run to generate some power and then through the reverse polarity method, it was run as a TEC. A differential temperature of ΔT = 13.43°C was achieved.

II. Background

Parameters were extracted from Datasheet, Device geometries, and Material properties.
The most commonly thermal to electrical analogies were utilized to construct the electrical circuit of the thermal setup.
Experimental results were compiled in the form of a lookup table and then fed into the SPICE simulator using a piecewise linear (*PWL*) model in order to validate the model.

- The TEM is made of semiconducting materials (**Bi_2Te_3**)
- The ceramic substrate is made of alumina (**Al_2O_3**)

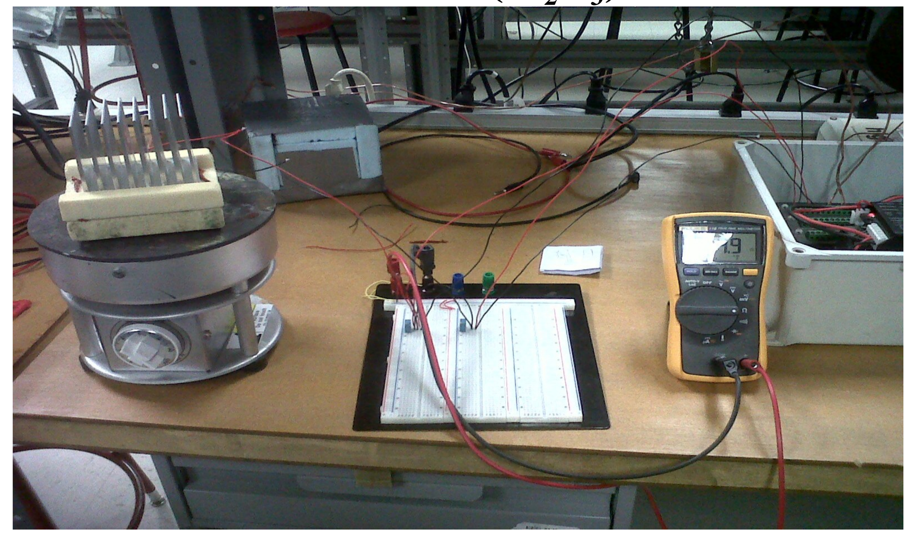

FIGURE 1: Experimental setup of the system

III. Methods

- Analytical Transient Heat Transfer is Cumbersome
- Parameters were extracted from datasheet and device geometries and properties
- Numerical method was proposed
- Thermal to Electrical analogy was utilized
- LTspice software simulator was proposed and used
- A lookup table of real data (T_H and T_L) was created
- Data were fed into the built-in piecewise linear (PWL) command
- The latter scheme improved the simulation speed
- Experimental and simulated results were compared

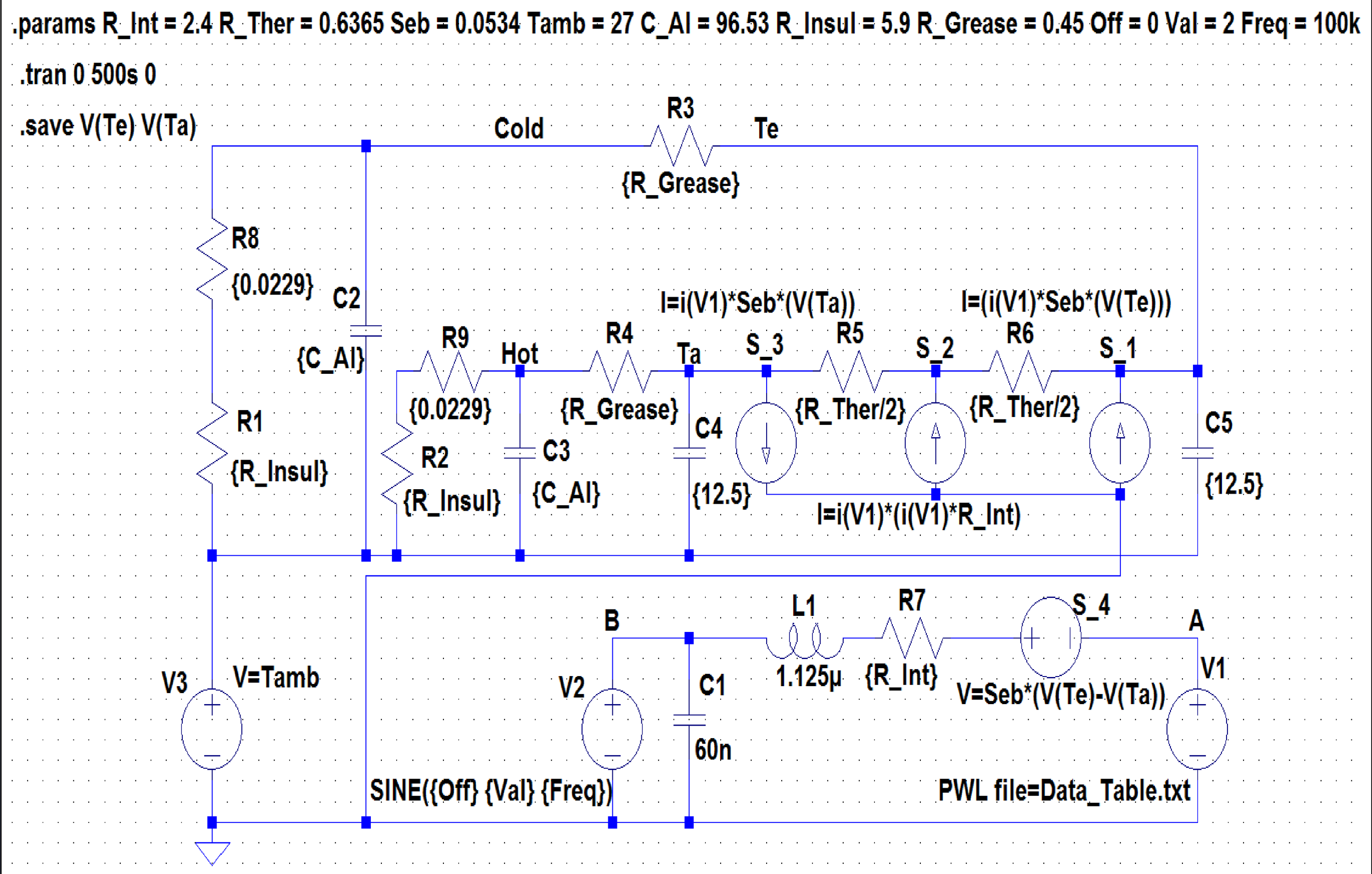

FIGURE 2: LTspice Model of the TEM with internal parasitic (L, C) values

IV. Results

- The TEG parameters were successfully extracted
- A Spice model of the whole Thermal process (TEM, thermal resistances, inductances ,and capacitances) was elaborated through electrical equivalence schemes. The electrical model is shown in Fig. 2.
- A significant temperature difference was developed across the two sides of the TEM as can be seen in Fig. 3 in a short period of time. The maximum differential value attained within that short period of time was 13.43°*C*.
- The TEM device performed perfectly as a heat removal device, i.e. a TEC.
- The overall percent error between the experiment and the simulation was 5.47% on the hot side as compared to 2.52% on the cold side.

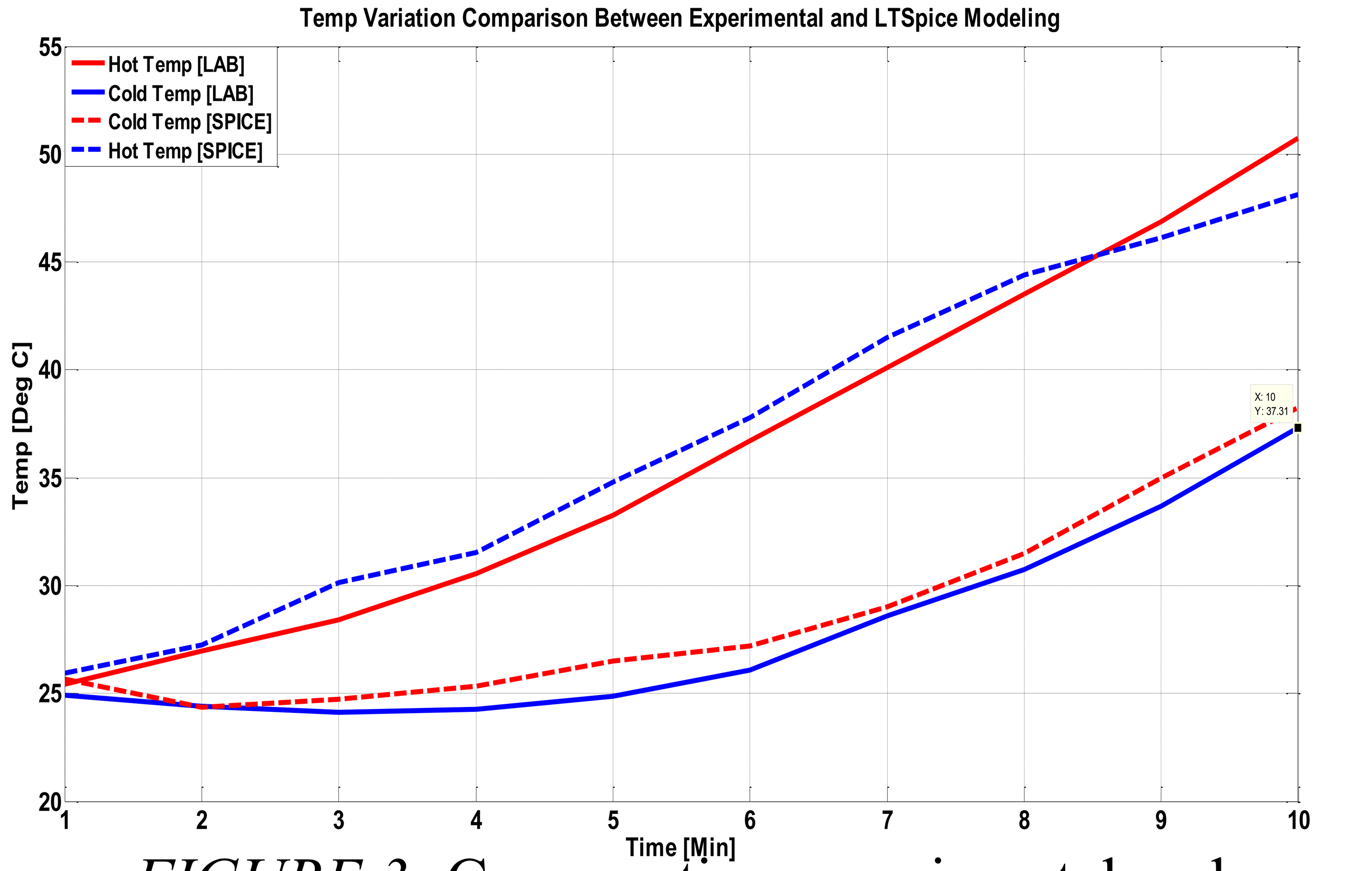

FIGURE 3: Comparative experimental and simulated temperature profiles

V. Conclusions

- An experimental setup was designed and built to characterize and study the performance of a commercial TEM.
- An LTspice TEM modeling scheme was developed through thermal to electrical equivalence strategies
- Despite the test being conducted for a short period of time a significant differential temperature was attained.
- Finally, the experimental and simulated results were presented and compared.
- The minor offset errors are likely coming from the internal parasitic components' effects.
- Overall, both experimental and simulated results were in a good agreement.

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