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DRIVING ELECTRIC MOTORS USING THERMOELECTRIC GENERATORS AND A POWER ELECTRONIC CONVERTER WITH DIGITAL CONTROL AND ENERGY STORAGE

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Introduction: Thermoelectric Generators (TEGs) are semiconductor devices which are capable of generating a voltage when the two junctions are kept at different temperatures, exploiting the Seebeck effect. Their efficiency is around 5%, but they can be successfully used as a sustainable source of energy in applications where waste heat is rejected from other necessary processes. They are often included in a system together with power electronics and control circuitry because they have features like varying-load interfacing, maximum power point tracking (MPPT), power conditioning and failed module bypassing. Such complex electrical systems have to be designed over a wide range of operation conditions because they are often employed in environments with time-varying temperature differentials and input/output powers. Therefore it is important to understand the behavior of TEGs during thermal and electrical transients to maximise the power production or efficiency of the system.

Our goal is to run an electric motor with the power produced by TEGs, scavenging the thermal energy emitted by a solid fuel combustion appliance. A DC-DC converter with fast digital control and a MPPT algorithm will be used to interface the TEGs to a battery.

A good understanding of the physical behavior of TEGs is fundamental to the proper design of the whole system. We have therefore carried out a **theoretical analysis** of the heat and electrical power flow through the TEG and mechanical components, modelling such a thermo-electrical system as in Fig. 1. The Peltier effect acts only at the junctions of the TEG and the heat propagation inside the TEG is controlled by the 1-D unsteady heat conduction equation with internal heat generation.

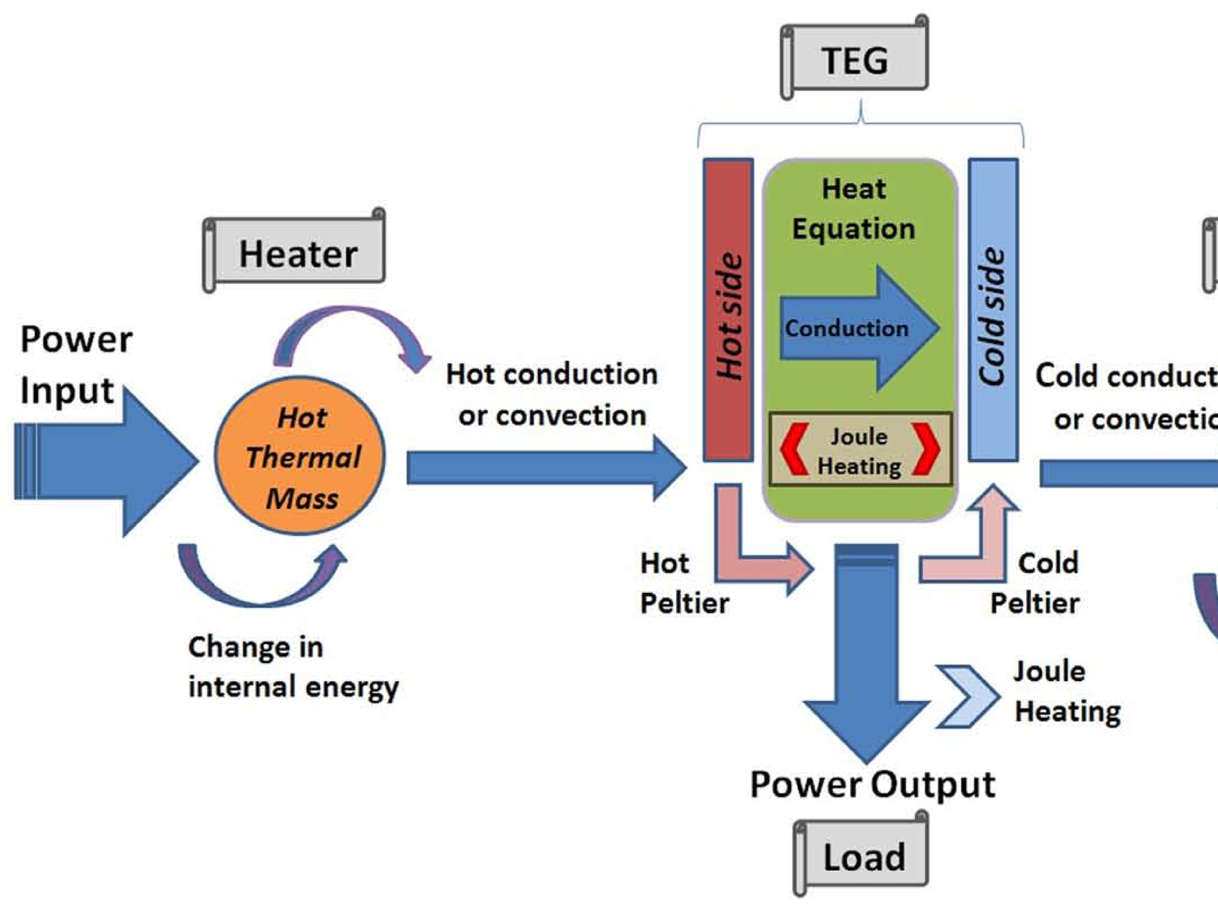
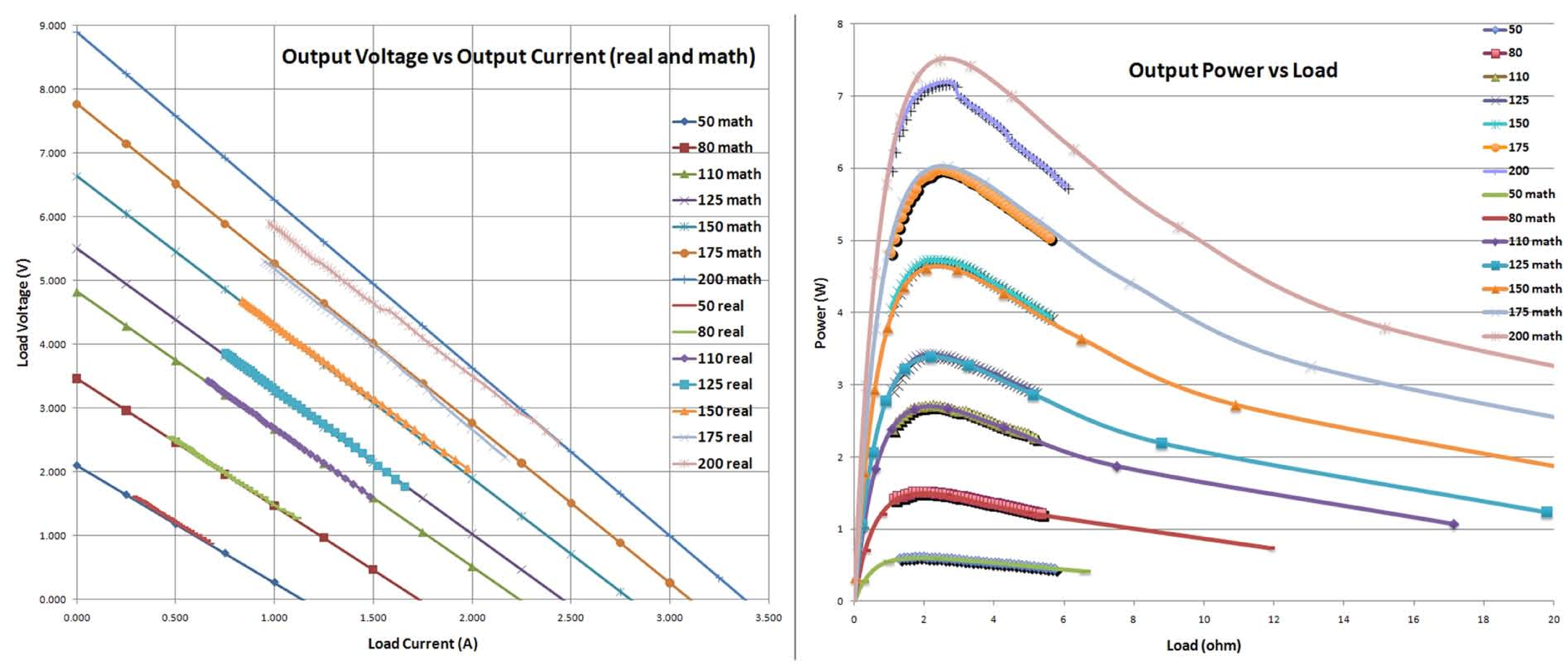


Fig. 1: diagram of the power flow

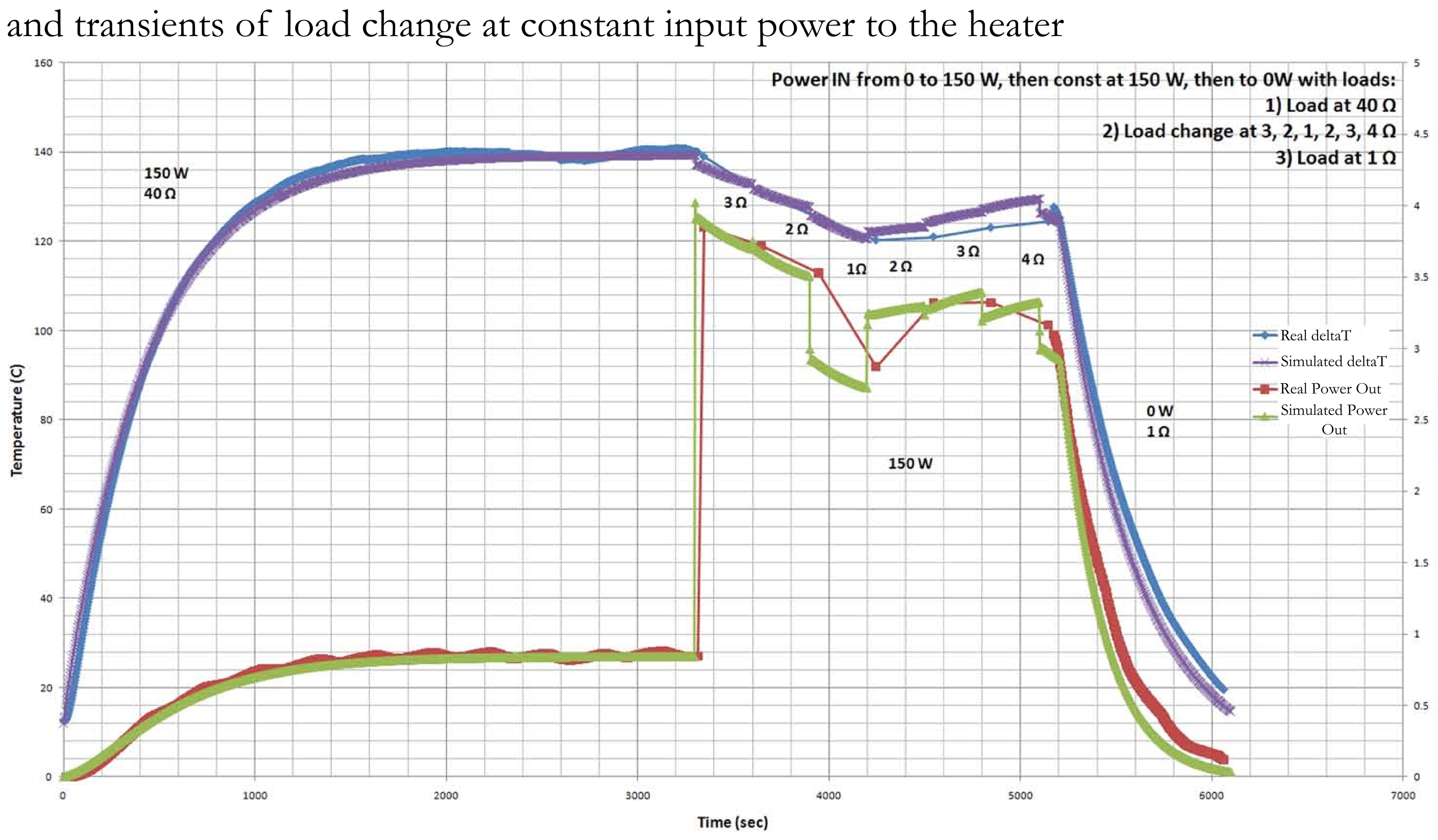
Fig. 2: Electrical characteristic of a TEG module



Using a custom made setup, where aTEG module is sandwiched between a water-cooling block and a high-temperature heater, we carried out the **electrical characterisation** of the TEG, which is a linear function of the temperature; hence it is possible to describe it mathematically, obtaining the plots of Fig. 2.

The model of Fig. 1 has then been created in Matlab and Simulink, including the electrical characterisation of the TEGs being used. Doing a discrete time simulation, we calculate all the temperatures at every fixed-size time step, using the values obtained as initial states in the next iteration. In this way it is possible to simulate the whole system, including hot and cold thermal masses and all the electro-thermal coupled effects.

Fig. 3: Transients of input power to the heater with constant loads, and transients of load change at constant input power to the heater



Using the same experimental setup, we ran several **thermal transient tests** to validate the computer model. Fig. 3 shows one of these, in which the power to the electric heater is initially set to 150 W on open circuit load. After the steady-state has been reached, different loads are set with the same input power of 150 W. Finally, the heater is disconnected from the power supply and the system goes back towards a null temperature gradient. As it can be seen from the graphs, the simulation data match the experimental results quite well.

This model can be used to simulate every similar thermoelectric system. In particular, it will now be used to design the TE generating system for a 500°C stove, including a MPPT algorithm that will be programmed in the microcontroller which digitally controls a DC-DC converter, so that the maximum power can be extracted from the system.

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