Energy Harvesting: Computing *without* Batteries?

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Introduction

Wireless sensor networks, where a large number of small sensing and computing devices are deployed in the environment, enables remote sensing and monitoring of climate and environmental conditions within a potential large area which can be in the outdoor environment as well as indoor in buildings. When applied in buildings, a more efficient monitoring of temperature, airflow, lighting, humidity, etc. will not only allow a better indoor climate, but also reduce the amount of energy usages and, hence CO2.

Although the sensing and computing devices are small, they need energy to run! Until recently, energy has been provided by batteries. However, it is possible to harvest energy from the environment, effectively obtaining a free and clean energy source. In this project, we will explore the potential of harvesting energy from temperature differences between an object and its surrounding air. The energy lies in the heat flow between objects and the air, when the air temperature changes. An example of an object could be a road sign, with a large metal mass. When the surrounding air temperature changes due to the weather, objects situated in this air will change temperature correspondingly, but with a small time delay. Due to this time delay there will be moments where a temperature difference between the air and the object arises. This temperature difference can be utilized to harvest electrical energy using a thermoelectric generator (TEG). The TEG creates electrical power when it is placed between a warm and a cold temperature. There will be a heatflow from the warm to the cold side and this heat flow makes electrons move within the TEG, creating an electrical voltage that can be harvested.

Project

In this project a thermal energy harvesting model based on a TEG has been developed in Matlab. It simulates how much energy can be harvested from a certain object in a certain temperature environment. The model can be used to decide whether an object and corresponding temperature environment is suited for thermal energy harvesting and how much energy can be achieved. The model is tested and verified in a free field climate chamber provided by Delta.

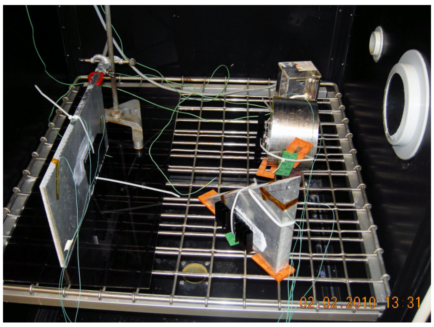

Figure 1 Test setup in free field chamber: 3 objects with TEGs attached. Thin aluminium plate, aluminium triangle and a steel rod.

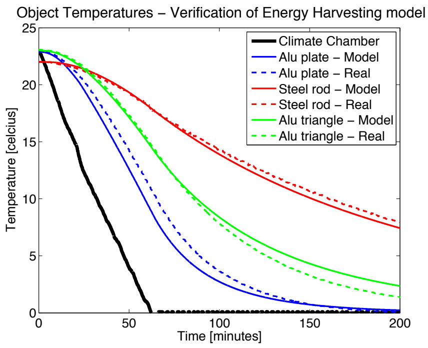

Figure 2 Measured and simulated test object body temperatures. The black line is the surrounding temperature change.

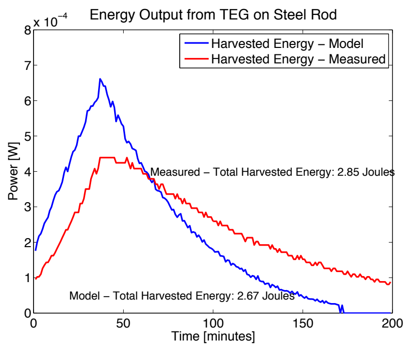

Figure 3 Energy harvested from the steel rod in the free field chamber, measured and simulated.

Due to a surrounding temperature change, the model simulates the object body temperature change (figure 2). This is then used to calculate the temperature difference between air and object. The thermal energy to be harvested is directly proportional to the temperature difference, thus making it possible to simulate how much energy can be achieved from a TEG attached to the object when the surrounding air temperature changes (figure 3).

A wireless sensor node consumes around 0.1W when operating, and it needs max 1s to measure temperature etc. and process and transmit the data wirelessly. This means that a sensor node using 0.1J/operation could be run more than 24 times from the energy harvested in this test. This energy could be spread over a whole day, making it possible to run the sensor once every hour. The amount of energy available depends on the object size and material, and the changing temperature environment. If more energy/operations are needed a larger object could be used to increase the temperature delay, and thus increasing the thermal energy harvesting.

The model predicts that thermal energy harvesting can replace batteries as energy supply for wireless sensor nodes, making it possible to place selfpowered sensor nodes even in positions where other energy harvesting sources as solar or vibrational energy are not present. This opens up many new measurement data not available before.