Chapter 33

Energy Harvesting and Energy Conversion Devices Using Thermoelectric Materials

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ABSTRACT

The authors propose in this chapter an original, self-sustainable, power supply system for wireless monitoring applications that is powered from an energy harvesting device based on thermoelectric generators (TEGs). The energy harvesting system’s purpose is to gather the waste heat from low temperature sources (<90°C), convert it to electrical energy and store it into rechargeable batteries. The energy harvesting system must be able to power a so-called condition monitoring system (CMS) that is used for the monitoring of heat dissipation equipment. The setup used for measurements (including mechanical details) and the experiments are described along with all the essential results of the research. The electronic system design is emphasized and various options are discussed.

INTRODUCTION

Energy harvesting and renewables energies is a major field of interest today for both academic and industrial companies. The chapter deals with a detailed analysis of TEMs (Thermoelectric Materials) and their applications. The internal parameters of a TEM were experimentally determined and based on the results an improved SPICE model was developed. The model is based on the classical governing thermodynamic equations where the parameters dependency of temperature and also the parasitic intrinsic elements were taken into account. A complete SPICE model was proposed and implemented, in which both the thermal and electrical components of a TEM and the complementary components were modelled, along with the simulation of the convective heat transfer phenomena. The modelling

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and simulation parts are not presented in this chapter, but will be referred for a better understanding of the functioning of the system and its performance.

The chapter presents an in detail description of the mechanical subsystem designed and built by the authors. The subsystem purpose is to dissipate with the maximum efficiency the heat from the hot side of a thermoelectric module into the environment where the entire system is supposed to run. For this, a solution based on multiple cooling pipes (microchannel configuration) was chosen, that together with a closed water cooling circuit and a heat exchanger generates a thermo-syphon which requires no electrical energy to dissipate the heat. Another solution, based on heat pipes was also designed and tested for performance, yielding a good solution where a compact design is needed.

The electronics subsystem designed and built by the authors comprises in converters, storage stages for the harvested energy and an energy routing stage that can deliver the energy to different other subsystems (uC, sensors, Wi-Fi communication devices). The design followed an in depth process of simulations, experiments and optimizations in order to deliver the expected results.

**Renewable Energy Review and Trends**

The need for renewable energy sources, other than fossil fuels, has become one of the most critical current issues that led to a significant research into alternative energy sources and energy conversion techniques.

The Renewable Energy Policy Network for the 21st century (REN21, 2011) convenes international multi-stakeholder leaders to enable a rapid global transition to renewable energy and is formed of a numerous steering committees from various countries around the world (US, Japan, Germany, Austria, UK, China, etc). Into their 2012 report, REN21 states that the total renewable power capacity, not including hydropower rose from 315 GW in 2010 to 390 GW in 2011, showing an important growth of 23% (REN21, 2012). This demonstrates the importance paid to this subject by countries all around the world and that efforts are being made to find alternative solutions to natural resources (e.g. petroleum and coal) that are getting depleted.

World primary energy consumption grew by 2.5% in 2011, as presented in Figure 1 by the BP Statistical review of world energy report 2012 (BP, 2012).

The prediction made by the “Science of sustainability” 2006 summary report (Figure 2), that the global energy consumption will reach 12 billion toe (tons of oil equivalent) proved to be correct (as represented in Figure 1) and is expected to increase by 60% until 2030, compared to the value from 1971, as pointed in (Summary Report, 2006) and represented in Figure 2. From this high amount of energy, a large portion is dissipated into ambient air as unused heat which leads to the necessity of techniques capable to recover the wasted heat.

The REN 21 status report states that thermoelectric generators (TEGs), devices that convert heat to electricity, are becoming cost effective and allow wood burning stoves to generate both heat and electricity enabling them to operate fans for improved combustion or provide electricity for other applications. In most applications (energy transportation, factories, thermal engines, electric generators, etc) enormous amounts of heat are wasted. Bitschi (2009) shows that this type of energy is difficult to use due to its low temperature although the amount is very large.
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