Multi-Transducer System for Energy Harvesting

Abstract

Energy is a critical component in any scientific or engineering endeavor. Energy is essential in our ability to observe, measure, analyze and control various systems within the physical world, and advances in modern, low power electronics have fostered an ever increasing need for highly efficient mobile power systems. The standard approach for powering such mobile or remotely-based systems is the use of conventional batteries for energy storage. While this approach is suitable for many applications, there are limitations due to finite lifespan and the need to recharge or replace spent batteries. One alternative to the exclusive use of batteries is energy harvesting, a process which serves to extend the operational lifespan and overall robustness of mobile power systems. In this manner the energy harvester extracts ambient or unwanted energy from a system's surroundings, storing this energy in batteries or capacitors, or using it directly to power necessary hardware.

Project Outline

The objective of this research project will be to investigate the use of multiple transducers in the development of an integrated energy harvesting system. Mechanical and thermal energy sources will be considered in this study, and students will be introduced to various electromechanical and thermoelectric transducers that can be used to convert ambient mechanical and thermal energy sources into an electrical form. As part of the study students will perform analytical and experimental work in the lab to estimate the energy that can be harvested in three separate applications. These applications will correspond to mechanical and thermal data obtained for (1) a bridge under normal traffic conditions, (2) a vehicle engine under idle and normal driving conditions, and (3) a compressor under normal operation. The data for applications (2) and (3) will be provided to the students, however they will have the opportunity to obtain field data for the bridge by placing accelerometers along Omega Bridge in Los Alamos, NM (shown in Figure 1).

Students will use the data from each of these applications to predict how much energy is expected for several different transducers. The principal energy harvesters that will be considered include (1) piezoelectric materials (stack and wafers), (2) a tuned electromagnetic coil, and (3) thermoelectric ceramics. As the students become accustomed to the modeling, they will shift their focus to the laboratory environment where they will conduct a series of experiments designed to simulate the bridge, engine and compressor data sets. An electro-magnetic shaker will be used to replicate the vibrations data, while a heater will be used to replicate the thermal data. Once the students have tuned each individual energy harvester and

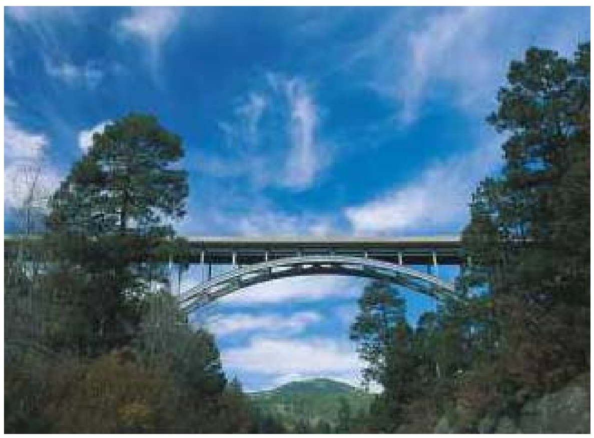

Figure 1: Omega Bridge in Los Alamos, NM.

characterized its response, they will investigate how to utilize multiple energy harvesters (i.e. mechanical and thermal) to accumulate energy within a single power source such as a super-capacitor or rechargeable battery.

The final objective of this project will be to integrate this energy harvesting system with one of the low-power sensor nodes that have been developed here at the Engineering Institute (examples shown in Figure 2). The ultimate goal of this research project will be to harvest enough energy from common real-world systems (e.g. bridges, engines or motors) to power a sensor system that could be used for structural health monitoring or other engineering application.

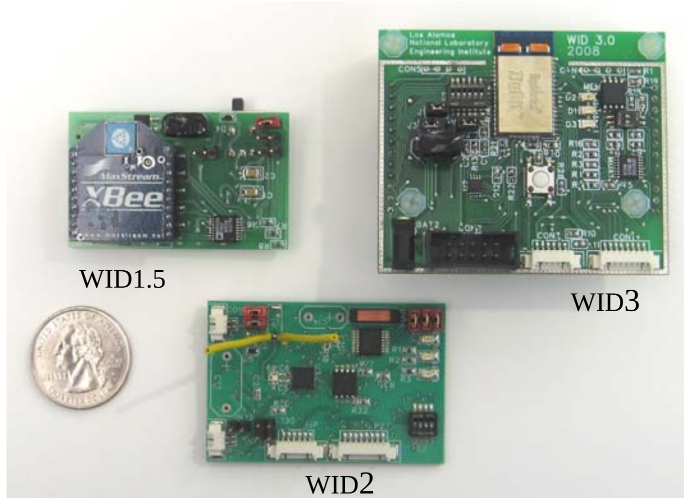

Figure 2: Several versions of the low-power Wireless Impedance Device developed at the Engineering Institute.

Project Schedule

This project will focus on developing a comprehensive understanding of how ionically onductive materials can be used in harvesting electricity from ambient vibrations. This work will be conducted over an eight week period. The expected work is outlined in the following timeline.

Week 1: Safety training and project introduction
Week 2: Analytical study of piezoelectric polymer
Week 3: Measure the vibration and thermal levels on the Omega Bridge
Week 4: Begin laboratory experiments
Week 5: Continue experiments
Week 6: Begin designing electrical components to couple energy harvesters
Week 7: Perform charging tests using capacitors
Week 8: Attempt to power WID2 sensor node using harvested energy.
Week 9: Present project findings

Suggested Reading

1. Park, G., Farrar, C.R., Todd, M.D., Hodgkiss, W., Rosing, T., 2007, "Energy Harvesting for Structural Health Monitoring Sensor Networks," www.lanl.gov/projects/ei/pdf_files/**LA-14314-MS**.pdf
2. Sodano, H., Inman, D., Park, G., 2005, "Comparison of Piezoelectric Energy Harvesting Devices for Recharging Batteries." *JIMSS*, vol. 16, pp. 799-807.
3. Sodano, H., Park, G., Inman D.J., 2004, " A Review of Power Harvesting Using Piezoelectric Materials," Shock and Vibration Digest, vol. 36, no. 3, pp. 197-206.
4. Roundy, S., 2005, "On the Effectiveness of Vibration-based Energy Harvesting," *Journal of Intelligent Material Systems and Structures*, V16, pp. 809-823

Equipment Requirements

Piezoelectric stack and wafer transducers, a series of electromagnetic coils, as well as thermoelectric transducers will be needed for experimental studies. Basic breadboard components will be needed to assemble the energy harvesting circuitry. An electromagnetic shaker will be needed to provide a source disturbance. Accelerometers will be needed to for field and laboratory measurements and a standard analyzer with time and frequency domain capabilities will be needed to capture data.

Software Requirements

Standard mathematical software (MATLAB or Mathematica) will be required for simulations.