Energy Harvesting to Power Sensing Hardware Onboard a Wind Turbine Blade

Mentors: Kevin Farinholt and Gyuhae Park

Introduction

The changing world climate has sparked renewed interest in domestic energy production. Wind energy is of particular interest in our country as it provides a clean, renewable source that is abundant in the wind corridor of the Midwestern states. Current turbine designs are based on criteria developed by European manufacturers; however, these criteria often fail to address the more severe loading conditions that exist in North America. As rotor diameters increase, blades begin to intersect more complex loading conditions, resulting in structural loads that are unaccounted for by blade designers. In spite of this, manufacturers are pushing toward longer (>50m) blades to increase per turbine production by capturing more of the inbound wind energy. Fig. 1 illustrates the size of a 1.5MW GE wind turbine (note the vehicle parked at the base of the tower). The shift toward larger blades requires more complex structural designs (example shown in Fig. 2) to minimize weight while maintaining structural integrity. Composite materials have become the standard component used in fabricating today's wind turbine blades. One issue with the use of composites is that material level flaws such as voids in epoxy, delamination and surface wrinkles can be introduced in the manufacturing process. These flaws have the potential to grow under sufficient loading, in some cases reaching extents that would endanger the structural integrity of the blade and potentially that of the entire turbine as well.

Fig. 2: 1.5MW GE wind turbines at the Colorado Green & Twin Buttes Wind power project.

To address this issue, sensors can be integrated within the composite to monitor structural health at critical locations within the blade. One limitation with this method is that the sensor network must not provide a conductive path to the hub, as this can increase the turbine's vulnerability to lightning strikes. Thus, the most practical method for deploying these sensors is through a network of wireless sensor nodes. These nodes would be used to monitor discrete locations of the blade, and transmit data to a central receiver in the turbine's nacelle. This data would then be analyzed and conclusions drawn about the overall health of the system.

For such a system to be properly implemented, each sensor node must have a long-term power management strategy. These components would need to operate beyond the lifespan of conventional batteries, and they may be installed in locations of the blade that could not be accessible to maintenance personnel. Therefore, it would be beneficial for the power system to harvest energy from the blades or environment to provide a long-term energy

Fig. 1: X-section of the experimental CX-100 blade.

source. Such systems would be designed to scavenge mechanical, thermal, or solar energy to replenish an energy storage device located onboard the sensor node.

Project Outline

The objective of this project will be to investigate different sources of energy that could be harvested from an operating wind turbine to power sensor nodes that are embedded along the turbine blades. Mechanical, thermal and solar energy sources will be considered in this study, and students will be introduced to various electromechanical, thermoelectric and photovoltaic transducers that can be used to convert ambient energy into an electrical form. As part of this study, student will perform analytical and experimental work in the lab to estimate the energy that can be harvested given the vibration and thermal signatures of a 9m CX-100 experimental turbine blade. Solar films will be investigated to determine efficiencies at different incident angles with the sun, as well as those in a rotating frame of reference.

Students will use the data provided for the CX-100 blade to predict how much energy is expected for different transducers. As students become accustomed to modeling the transducer responses, the focus will shift to the laboratory where they will conduct a series of experiments to quantify the amount of energy that could be expected under simulated operating conditions. An electromagnetic shaker will be used to replicate the vibration data, while students will use an actual blade section in their thermoelectric and solar film studies. Once the students have characterized each transducer, they will investigate the use of multiple energy harvesters to accumulate energy within a single power source such as a super-capacitor or rechargeable battery.

Project Schedule

This project will be conducted over a nine week period. The expected work is outlined in the following timeline:

Week 1: Safety training and project introduction
Week 2: Analytical study of piezoelectric, thermoelectric, and photovoltaic materials
Week 3: Continue analytical study, analyze vibration data from CX-100 blade
Week 4: Begin laboratory experiments – focus on piezoelectric/ thermoelectric materials
Week 5: Continue experiments – focus on photovoltaic materials
Week 6: Continue experiments – compare results with analytical studies
Week 7: Couple power output from each of the energy harvesters
Week 8: Perform charging tests
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., 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.

3.Bierschenk, J. 2008, "Optimized Thermoelectrics for Energy Harvesting," *IEEE International Symposium on Applications of Ferroelectrics,* vol. 1.

4. Dondi, D., Brunelli, D., Benini, L., Pavan, P., Bertacchini, A., Larcher, L., 2007, "Photovoltaic Cell Modeling for Solar Energy Powered Sensor Networks", *2nd International Workshop on Advances in Sensors and Interface, IWASI*, June 26-27, 2007