On Vibration-Based Energy Harvesters

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Vibration-based energy harvesting systems have been the focus of many recent investigations. This interest stems from the need to power low-power consumption devices, such as micro electromechanical systems, health monitoring sensors, and wireless grid sensors. These harvesters can replace small batteries that can be used in aircraft systems, such as unmanned aircraft vehicles and micro air vehicles. These harvesters have also been proposed to power devices that rely on batteries, which have a finite-life span and are difficult or expensive to maintain. They can also be used to charge mobile phones. The transduction mechanisms used for transforming vibration to electric energy include: electromagnetic, electrostatic, and piezoelectric mechanisms.

The most common vibration-based energy harvester consists of a cantilever beam, which is generally composed of one or two piezoelectric layers. These layers are bounded by electrodes that harvest energy from the produced voltage. The electrodes are externally connected by an electric circuit that is usually modeled as a simple electrical load resistance. Different beam designs have been considered to maximize the amount of harvested electrical power: bimorph and unimorph piezoelectric cantilever beams that undergo coupled bending-torsion vibrations under transverse and parametric harmonic base excitation.

Recently, a number of studies have addressed harvesting energy from aeroelastic systems. The most common configuration is a rigid airfoil constrained to pitch and plunge supported by linear and nonlinear torsional and flexural springs with a piezoelectric coupling attached to the spring in the plunge degree of freedom. At very low wind speeds, the structural positive damping overcomes the negative damping produced by the airflow and hence the system motions decay with time. As the wind speed exceeds a critical value (called flutter speed), the negative damping increases and overcomes the structural positive damping, resulting in the onset of instability. Above the flutter speed, there are two scenarios, depending on the system parameters. First, the disturbances grow slowly until the nonlinearities put a cap on this growth and the motion becomes an isolated small periodic one (limit cycle). This scenario is called supercritical Hopf bifurcation. In the second scenario, beyond the flutter speed, the system response jumps to a large attractor, which might be periodic, quasi-periodic, or chaotic? This instability is called subcritical Hopf bifurcation, which should be avoided because it may lead to fatigue. For efficient energy harvesting from such an aeroelastic system, one needs to consider its nonlinear aspects and focus on generating energy at low free stream velocities through limit cycle oscillations (LCO), avoiding subcritical Hopf bifurcations.