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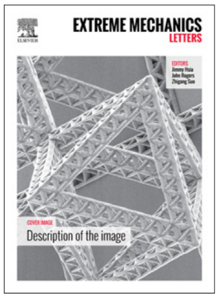

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A multi-modal energy harvesting device for low-frequency vibrations

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Keywords: Energy harvesting, nonlinear finite element, very low frequency, wind turbine

Abstract

This paper presents an innovative design of a low-frequency multi-modal system vibration-based energy harvester (VEH) for powering wireless autonomous monitoring systems of wind turbines of 30 kW. The main objective is to design an energy harvesting device capable to operate in a very low-frequency bandwidth (3 to 10 Hz) increasing as much as possible the operational bandwidth by enhancing the amplitude of the second mode of vibration. The electrical power performance is evaluated for four different energy harvesting designs, which are mainly composed of multi-beams cantilevers with tip masses. For the harvesting system with two multiple-beams trident, a rigid beam is selected to join them. This versatile geometric configuration offers the possibility to modify the vibration characteristics of the harvester in several alternative ways, not only by increasing the tip mass which may be not favorable from a structural viewpoint. The resonant frequencies values, the time voltage signals and the electrical power are obtained through a finite element beam formulation early proposed by the authors, capable to modeling three dimensional systems. The numerical results are validated trough experimental tests. Regarding the output power, the most promising design with two multiple-beams trident with a tip mass delivers 3.96 mW and 13.45 mW in the proposed range of operation (first two resonance frequencies 4.76 and 7.91 Hz, respectively), excited by 1 g of base acceleration. This clearly indicates that the device is a very good candidate for the proposed application of autonomous wireless monitoring.

1. Introduction

Sensing electronic devices is known for their small size and low power consumption. Commonly used sensors are ultrasonic sensors, weather, pressure, humidity and temperature transmitters. Mostly, the electrochemical batteries are the best choice today to power these sensors or electronic devices. Despite the advantages of batteries such as low cost, high energy density and small size, these have disadvantages such as environmental pollution, low durability and inconveniences to recharge, which implies great maintenance [1]. On the other hand, the evolution of alternative energy sources to power electronic devices with low power consumption is growing interest in the science community. In this sense, energy harvesters based on piezoelectric effect represent a very effective mechanism to convert mechanical into electrical energy [2]. Between them, mechanical vibrations as energy source for low-frequency energy harvesting is getting interest in the nowadays research topics [3,4]. In comparison with other mechanical sources, the excitation by low-frequency vibrations is really a challenge since the output power density of the energy harvester is low. In the last years, the researchers have focused on the concept of tuning the harvesters in the fundamental resonance frequency or broaden the bandwidth with the goal to increase the output electrical power employing different harvesting approaches. These energy harvesting devices are based on basically three methods to extract power: a hybrid piezoelectric-electromagnetic