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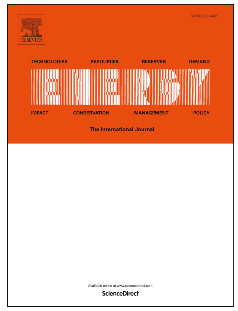

A methodology for low-speed broadband rotational energy harvesting using piezoelectric transduction and frequency up-conversion

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A methodology for low-speed broadband rotational energy harvesting using piezoelectric transduction and frequency up-conversion

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Abstract

Energy harvesting from vibration for low-power electronics has been investigated intensively in recent years, but rotational energy harvesting is less investigated and still has some challenges. In this paper, a methodology for low-speed rotational energy harvesting using piezoelectric transduction and frequency up-conversion is analysed. The system consists of a piezoelectric cantilever beam with a tip magnet and a rotating magnet on a revolving host. The angular kinetic energy of the host is transferred to the vibration energy of the piezoelectric beam via magnetic coupling between the magnets. Frequency up-conversion is achieved by magnetic plucking, converting low frequency rotation into high frequency vibration of the piezoelectric beam. A distributed-parameter theoretical model is presented to analyse the electromechanical behaviour of the rotational energy harvester. Different configurations and design parameters were investigated to improve the output power of the device. Experimental studies were conducted to validate the theoretical estimation. The results illustrate that the proposed method is a feasible solution to collecting low-speed rotational energy from ambient hosts, such as vehicle tires, micro-turbines and wristwatches.

Keywords: rotational energy harvesting, piezoelectric, frequency up-conversion, magnetic plucking, low-speed, broadband

1. Introduction

Over the last decade, power supplies have become a critical bottleneck for the development of wireless sensor networks due to the limited lifetime of batteries and the requirement of regular replacement or recharging [1, 2]. Energy harvesting from ambient wasted energy to generate sustainable electricity for low-power electronic devices is becoming increasingly attractive as an alternative to conventional batteries. By integrating energy harvesting technologies into wireless sensor networks, the networks can operate autonomously with maintenance costs alleviated. In addition, recent advances in ultra-low power electronics [3] also facilitate the idea of self-powered smart sensing using energy harvesting for power supply.

Various types of energy sources, such as heat, light, mechanical motion and fluid flow, are readily available in the places where wireless sensors are installed. Among these sources, vibrational energy has drawn great attention and has been extensively studied for a decade. The progress and research topics on vibration energy harvesting are summarized in several comprehensive review papers, such as vibration energy harvesting from human motion and machine operation in [4, 5], nonlinear mechanisms for broadband energy harvesting in [6, 7] and functional materials for energy conversion in [8]. However, as another type of kinetic energy, rotational energy is less investigated and harnessed for power supply, but has unique dynamics that would be beneficial to some applications, including tire pressure sensing [9, 10], condition monitoring of rotating machines [11, 12] and fluid flow energy harvesting using miniature turbines [13].

The great majority of large scale electrical generation uses a continuously rotating electromagnetic machine for transduction, in which power is extracted from the relative motion between a stationary part, anchored in place, and

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