Fast Fourier Transform-Based Performance Analysis of a Hybrid Piezoelectric-Electromagnetic Energy Harvester

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Abstract

Energy harvesters that combine multiple conversion mechanisms, such as piezoelectric and electromagnetic, offer an improved solution for powering small, portable devices. These hybrid systems exploit the complementary strengths of each method, where piezoelectric materials excel at generating high voltages in response to mechanical stress. At the same time, EM harvesters are more effective at low frequencies, addressing the limitations of piezoelectric devices. However, despite overcoming these individual shortcomings, hybrid harvesters still face the challenge of generating sufficient power output under low-frequency, random excitations commonly found in real-world environments. This study addresses this limitation by integrating Fast Fourier Transform (FFT) analysis to identify dominant frequencies and optimise system performance. Additionally, signal rectification methods, including the use of a voltage doubler circuit, were explored to enhance the energy conversion efficiency. Experimental results show that under random excitation frequencies ranging from 1Hz to 4Hz, the hybrid harvester consistently generated stable peak voltages, with the voltage doubler achieving a significant improvement, producing 3.8V compared to the 1.5V generated by the full bridge circuit. This work demonstrates that hybrid energy harvesting systems can provide efficient power generation under unpredictable, low-frequency conditions when coupled with optimized signal processing techniques. The findings contribute to the advancement of energy harvesting technologies, offering a sustainable and maintenance-free power source for low-power electronics in dynamic and mobile environments.

Author keywords

Fast Fourier Transform; Hybrid energy harvester; random low-frequency vibration energy

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