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A Hybrid Piezoelectric and Electromagnetic Wind Energy Harvester

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Abstract

This research work is aimed to develop a comprehensive coupled dynamic model of a Wind Vortex-Induced Vibrations (W-VIVs) Hybrid Energy Harvester (HEH) to meet the needs of microwatt self-powered wireless sensors for remote areas. It combines two energy harvesters, a Piezoelectric Energy Harvester (PEH) and an Electromagnetic Energy Harvester (EEH). PEH is a substrate with a PZT composite beam fixed at one end and attached to a cylindrical bluff body at the other end. EEH is a magnet attached to a spring in a cylindrical bluff body and moving inside a coil. Because of the PZT deformation by W-VIVs, PEH power is produced. Whereas EEH power is generated due to cutting off the induced magnetic field lines by the permanent magnet. To improve the output power of the energy harvester, HEH is modeled as a two-degrees of freedom equivalent lumped mass system. The physical and design parameters of the system are linked together geometrically and mathematically. The system's coupled equations of motion (EOMs) are derived using the Lagrange method. EOM parameters include the two PEH and EEH sub-systems' physical and electrical properties. EOMs are solved analytically and numerically to find both PEH and EEH powers. Implementing the literature review of physical parameters on the proposed HEH results in a higher HEH output power and bandwidth compared to PEH and EEH standalone. A parametric study of EOM equivalent parameters is conducted to investigate their effects on the maximum power of the HEH. Selected physical parameters are optimized to maximize the output power of HEH using the particle swarm optimization (PSO) algorithm. Two different sets of parameters are implemented into two suggested models of the proposed harvester (one with the coil inside the bluff body and the other with the coil outside the bluff body). It is found that the average RMS power of HEH with coil outside the bluff body is greater than that of the model with the coil inside. In addition, the average RMS power of HEH can reach up to 86.84% greater than that of PEH by proper optimization of the selected model parameters. For the optimization purpose, three types of fitness functions are tested in this
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study: average integrated power, average power, and regular integrated power. They result in close optimized physical parameters. However, the integrated power function has the advantage of increasing the power and the bandwidth. It is found that the maximum HEH power at the second natural frequency of the harvester converges to the value of 60 mW.