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System reliability analysis of piezoelectric energy harvester under various physical uncertainties

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Abstract

Energy harvesting, which scavenges electric power from ambient, otherwise wasted, energy sources, has been explored to possibly eliminate the battery replacement cost for wireless sensors and self-powered portable electronics. Among ambient energy sources, vibration energy can be converted into electric power through a piezoelectric energy harvester (PEH). Although tremendous advances have been made in design optimization to maximize the output electric power under a given vibration condition, the research in reliability assessment to ensure durability has been stagnant due to the complicated nature of the multiple failure modes of the PEH. Therefore, this study addresses the multiple failure modes of the cantilevered PEH in a three-fold: (i) the interfacial delamination between the substrate and piezoelectric patch, (ii) the fatigue failure of the substrate in the vicinity of the clamping part, and (iii) the dynamic fracture of the piezoelectric patch. In this study, system reliability analysis on the failure modes is performed by using the Generalized Complementary Intersection Method (GCIM) under various physical uncertainties. The GCIM enables to decompose the probabilities of high-order joint failure events into the probabilities of complementary intersection events. The Kirchhoff plate theory-based analytical model is implemented to analyze the electromechanical behaviors of the PEH. Since the durability of the PEH is of great importance to sustainably power wireless sensors, we believe that this study on system reliability analysis will have an immediate and major impact on piezoelectric energy harvesting technology.