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EDITORIAL

Special Issue on response analysis and optimization of dynamic energy harvesting systems under the presence of uncertainties

This special issue of the ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems: Part B comprises 10 papers related to recent advances and emerging approaches on response analysis and optimization of energy harvesting dynamic systems in presence of uncertainties. A concerted effort was made to achieve broad geographic representation, while the invited papers are characterized by rich thematic and methodological diversity, and present developments on both fundamental research and engineering applications.

More specifically, the contributions can be categorized with respect to the following three distinct themes: (1) Numerical methods for stochastic response analysis, reliability-based design, and performance assessment of energy harvesters; (2) Uncertainty quantification and modelling of energy harvesters; and (3) Inerter-based energy harvesters subject to random excitations.

In the first theme, Grigoriu (Statistics of voltage processes in random environment) developed a method, based on Monte Carlo simulation and by relying on Slepian's model, for calculating excursion statistics of the voltage process above a specified threshold generated by primary-absorber harvesting systems subject to Gaussian stationary excitation processes. These excursion statistics can be viewed as performance metrics, and can be potentially used for optimizing the configuration and parameters of energy harvesting systems in random environments. Further, Petromichelakis et al. (Stochastic response analysis and reliability-based design optimization of nonlinear electromechanical energy harvesters with fractional derivative elements) developed a Wiener path integral based methodology for stochastic analysis and reliability-based design of nonlinear piezoelectric energy harvesters modelled in part using fractional derivatives. The accuracy of the proposed methodology was verified versus Monte Carlo analysis for a wide range of harvesters. Alevras (On the effect of the electrical load on vibration energy harvesting under stochastic resonance) leveraged the concept of stochastic resonance to improve harvested power from harmonic excitations with additive Gaussian noise accounting for the nonlinear effects of the energy harvesting circuitry. A numerical path integral technique was employed to expedite parametric analyses, and recommendations on beneficial circuitry layouts and their parameters were reported. Finally, Arena et al. (Response statistics of U-oscillating water column energy harvesters exposed to extreme storms: application to the case study of Roccella Jonica (Italy)) proposed the use of a trapezoidal storm model to assess the reliability of oscillating water column (OWC) devices, used for energy harvesting from sea waves, against extreme weather conditions. It was shown that peak response statistics of a nonlinear model of the harvester derived by Monte Carlo simulation analysis using the proposed model compare well with data from recorded storm time-histories, thus confirming the suitability of the adopted storm model for safety checks of OWC devices prior to site installation.

Contributing to the second theme, Poblete et al. (Tuning Nonlinear Model Parameters in Piezoelectric Energy Harvesters to Match Experimental Data) proposed and applied a Bayesian updating technique in conjunction with a transitional Markov chain Monte Carlo simulation for estimating the electromechanical properties of piezoelectric energy harvesters based on available experimental data. Moreover, Rajarathinam and Ali (Parametric uncertainty and random excitation in energy harvesting dynamic vibration absorber) explored the feasibility of using a vibration absorber for harvesting energy due to random excitation, and in presence of parametric uncertainties. Optimal electrical and mechanical parameter values were reported related to a two-degree-of-freedom linear system. Finally, Wang et al. (Uncertainty analysis of piezoelectric vibration energy harvesters using a finite element level-based maximum entropy approach) presented a methodology for non-parametric uncertainty quantification of bimorph piezoelectric energy harvesters modelled by standard finite element software.

The effects of uncertainty to mass, stiffness, and electromechanical coupling matrices to the harvested power were quantified, demonstrating the robustness of strongly coupled harvesters.

The third theme includes the contribution of Shen et al. (Power analysis of SDOF structures with tuned inerter dampers subjected to earthquake ground motions), who explored the potential of linear systems equipped with tuned inerter devices to be used for energy harvesting under both white noise ,and colored noise stochastic excitations. To this aim, they performed theoretical and parametric analyses for selecting optimal inerter parameters, and for determining the combined system power output. Further, Asai et al. (Hardware-in-the-loop testing of an electromagnetic transducer with a tuned inerter for vibratory energy harvesting) conducted real-time hybrid testing of an electromagnetic motor with an embedded tuned inerter for energy generation from a randomly excited linear single-degree-of-freedom structure. Experimentally measured power generation performance matched well simulated data derived from a numerical model of the motor controlled via a Kalman filtering approach. It was found that the inclusion of the tuned inerter benefits significantly the energy harvesting. Finally ,Giaralis (An inerter-based dynamic vibration absorber with concurrently enhanced energy harvesting and motion control performances under broadband stochastic excitation via inertance amplification), assessed numerically the potential of an energy harvesting enabled dynamic vibration absorber featuring an inerter element for simultaneously improving vibration suppression and energy generation performances as inertance scales-up through gearing. Favorable results were reported for single- and multi-degree-of-freedom host structures subject to random white noise excitations for various vibration absorber and primary structure properties.

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Agathoklis Giaralis, City, University of London, UK, agathoklis@city.ac.uk
Ioannis A. Kougioumtzoglou, Columbia University, USA, ikougioum@columbia.edu
Pol D. Spanos, Rice University, USA, spanos@rice.edu