FINITE ELEMENT MODELING AND ANALYSIS OF BISTABLE PIEZOELECTRIC ENERGY HARVESTER

A Thesis

Submitted

By

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Declaration by the Research Scholar

This is to certify that the thesis titled "**Finite Element Modeling and Analysis of Bistable Piezoelectric Energy Harvester**" submitted by me, to the Indian Institute of Technology Mandi for the award of the degree of **Master of Science (by research)**, is a bona fide record of the research work carried out by me in the School of Engineering, Indian Institute of Technology Mandi, under the supervision of Dr. Rajeev Kumar and Dr. Vishal Singh Chauhan. The contents of this thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma.

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Thesis Certificate

This is to certify that the thesis titled "**Finite Element Modeling and Analysis of Bistable Piezoelectric Energy Harvester**" submitted by **Tarun Kumar**, to the Indian Institute of Technology Mandi for the award of the degree of **Master of Science (by research)**, is a bona fide record of the research work done by him under our supervision in the School of Engineering, Indian Institute of Technology Mandi. The contents of this thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma.

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ABSTRACT

Enormous research is going on to reduce the size of portable electronic appliances and the use of self-contained power source is required to make more powerful and lightweight electronic devices without traditional batteries. Moreover for remote applications of the electronic devices it is very challenging as well as uneconomical to replace traditional batteries from the electronic systems. Piezoelectric energy harvester (PEH) may be used to power the small electronic devices but the major limitation of a PEH is generation of sufficient amount of energy essential for the autonomous operation of the portable electronics over the wide range of environmental vibration frequencies.

Energy harvesters based on piezoelectric effect have attracted great research interest as the energy conversion efficiencies of piezoelectric materials are higher than those of electrostatic or electromagnetic materials. But linear PEH scavenge limited amount of power just near the resonance frequencies that rendered the linear PEHs useless in practical environmental vibration conditions.

To overcome such complications, a Bistable Piezoelectric Energy Harvester has been proposed. The harvester has been modeled using Finite Element Method. To harvest the energy over the wide frequency range of environmental vibrations nonlinearity is introduced in the stiffness by mean of two neodymium magnets. Originally triangular cross-section varying width PEH has been considered. Later it has been converted in to varying width PEH with three rectangular sections along length using block pulse functions (BPFs). The use of BPFs enable the use of rectangular patches of PZT-5A. This leads to the reduction in cost as machining PZT other than rectangular patches results in extensive increase in production cost. The varying width piezoelectric cantilever beam is subjected to harmonic base excitation by applying vertical

acceleration of 0.2g (g = 9.81 ms^{-2}). Numerical study indicates that bistable varying width PEH generates at least two times the average power as generated by nonlinear bistable uniform width PEH for same volume of piezoelectric material and for the same linear natural frequency. From the study it has been established that varying width bistable PEH is more efficient than the rectangular bistable PEH and can be implemented in autonomous operation of portable electronic circuits. Further the bistable varying width PEH is optimized using genetic algorithm technique to maximize mean power density. The proposed varying width bistable PEH is used to power to wireless mouse.

Keywords: Piezoelectric energy harvesting, Finite Element Method, Block Pulse Functions, Vibration, Genetic algorithm.

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