Bistable electromagnetic energy harvesting enhanced with a resonant circuit

Ning Yu, Chuanyu Wu, Gaohong Yu and **Bo Yan***

Faculty of Mechanical Engineering and Automation, Zhejiang Sci-Tech University, Hangzhou, China

Abstract. This paper investigates the nonlinear dynamic behaviours of a novel bistable electromagnetic energy harvester with resonant circuit. The bistable characteristic is achieved by coupled magnets. An additional adjustable capacitance is introduced to consist of a resonant circuit to enhance the energy harvesting efficiency compared with the pure resistive energy harvesting circuit. The analytical solutions of the steady-state response displacement and the output voltage are derived via the harmonic balance method. The effects of excitation frequency, excitation amplitude value, potential well and the resonant frequency of the circuit on the energy harvesting characteristics of the bistable energy harvester are discussed. The experiments have been to test and verify the theoretical and simulation results. It demonstrates that the proposed harvester has complex chaotic motion and better performance of output voltage than the traditional one after tuning the resonant frequency of the circuit.

Introduction

Recently, energy harvesting is attractive for their good application potential in the field of powering the microelectronic components in the ambient environment of broad frequency range[1]. Electromagnetic vibration energy harvesting technology has the advantages of high efficiency, low cost and strong durability. However, conventional electromagnetic energy harvesters are designed as linear resonant oscillators. The limited frequency range results linear energy harvester in a narrow effective working range[2]. In this case, nonlinearity has been proposed to fill this short coming.

Possessing the ability of tuning dynamic stiffness characteristic, nonlinear energy harvesting has attracted widely attentions. For the bistable energy harvesters (BEH) under random base excitations, the dynamic response mechanism and enhanced energy harvesting were numerically and experimentally verified by Litak. The tristable energy harvesters (TEH) can be optimally designed so that it increases the frequency bandwidth and achieves a high energy harvesting efficiency at coherence resonance under a low-level excitation.

The previous scholars mainly concentrated on a pure external load resistance to harvest the ambient vibration. Yan et al. [3] analysed the TEH with a series resistor-inductor (RL) resonant. The result shows the TEH with the RL circuit can greatly enhance energy harvesting efficiency. And it's another method to improve the energy harvesting efficiency of nonlinear energy harvesters. Zhou et al. [4] made a further analysis for a TEH with a RL resonant circuit. It found the effect of the excitation amplitude and the electromechanical coupling coefficient on the energy harvesting performance.

Results and discussion

This paper proposes the theoretical model and experimental investigation of a broadband vibration electromagnetic energy harvester with twin-well potential. The effects of various initial conditions and the resonant frequency of the circuit on the energy harvesting characteristics of the bistable energy harvester are discussed. The performance of the output voltage of the energy harvester with resonant circuit is compared to the one with pure resistance. It can be seen from the figure 1 that the maximum output voltage of the harvester with resonant circuit is bigger than the conventional one. It demonstrates that the proposed harvester has a larger bandwidth for harvesting the high energy interwell oscillation.

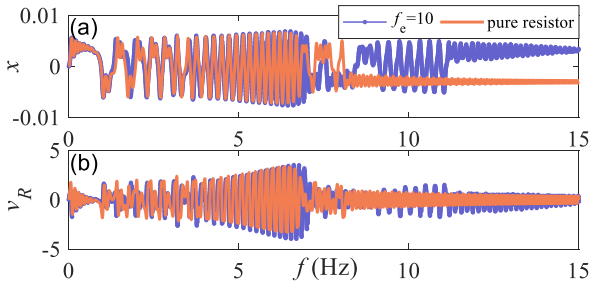

Figure 1: Comparison of (a) displacement and (b) output voltage of the BEH with the resonant circuit and the pure resistor.

References

[1]Yang Z, Zhou S, Zu J W, et al. (2018) High-Performance Piezoelectric Energy Harvesters and Their Applications. *Joule*. 2(4): 642-697.

[2]Liu W, Liu C, Ren B, et al. (2016) Bandwidth Increasing Mechanism by Introducing a Curve Fixture to the Cantilever Generator. *Appl Phys Lett.* 109(4): 043905.

[3]Yan B, Zhou S, Litak G. (2018) Nonlinear Analysis of the Tristable Energy Harvester with a Resonant Circuit for Performance Enhancement. *Int J Bifurcat Chaos*. 28(07): 1850092.

[4]Huang D, Zhou S, Litak G. (2019) Analytical Analysis of the Vibrational Tristable Energy Harvester with a Rl Resonant Circuit. *Nonlinear Dynam*. 97(1): 663-677.