Escape from the potential well of bistable vibration energy harvesters using buckling level modifications

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Abstract. During the last decade, nonlinear vibration energy harvesters (NVEH) have attracted research interests for their broadband characteristics. However, they also exhibit low-power orbits in which they may remain stuck, leading to poor harvesting performances. In this paper, we study an orbit jump strategy that allows to jump from one of these low-power intrawell orbits to high-power interwell orbits. This orbit jump strategy is based on the variation of the buckling level of the bistable vibration energy harvester. We start with a brief presentation of the system dynamics, then we analyze the performances gain with the proposed approach.

Introduction

The availability of vibrations in our environment and the development of wireless sensor networks motivates researchers to develop energy harvesting systems to supply low-power electronic systems [1]. NVEH exhibit broader bandwidths compared to their linear counterpart, making them particularly relevant for harvesting energy from broad and time-varying vibration spectrum [2]. However, NVEH exhibit complex dynamics i.e., there exists multiple orbits of different power for a given vibration frequency. Some orbits are of low power, which may lead to poor harvesting performances. Therefore, to improve the performance of NVEH, researchers worked on the development of orbit jump strategies to shift from low-power orbits to higher power orbits [3]. In this study we use a bistable NVEH based on a buckled beam to which we apply an orbit jump strategy based on the modification of the buckling level.

Results and discussion

Figure 1(a) shows a schematic representation of the Duffing-type piezoelectric vibration energy harvester with two stable equilibrium positions (EP) for $x = \pm x_w$ considered from [3]. This NVEH is composed of a mechanical resonator and an electrical extraction circuit. The NVEH is excited with a sinusoidal acceleration of amplitude A and frequency f_d. The harvested power is the one dissipated in the extraction circuit, which is simply a resistor R. This orbit jump consists in dynamically modifying the buckling level by adjusting the EP x_w of the NVEH. We supposed that the system starts on a low-power orbit. The initial value of the EP $x_w(0)$ is x_w, thereafter we modify the EP with a factor k_w^0 at t_0: $x_w(t_0) = k_w^0 x_w(0)$. The new value of the EP is maintained for a certain duration Δt. Then, from the instant $t_0 + \Delta t$ the EP is further modified with a factor k_w^1 such as: $x_w(t_0 + \Delta t) = k_w^1 x_w(0)$. Figure 1(a) shows the evolution of the EP. Therefore, the investigated orbit jump strategy depends on four influence parameters $(t_0, \Delta t, k_w^0, k_w^1)$. We used an evolutionary algorithm in order to find optimum parameters combination. The criterion to maximize is the total harvested energy on a duration of 100 T_d that takes into account the invested energy to modify the buckling level. Figure 1(b) shows an example of a successful application of such an orbit jump strategy for $f_d = 50$ Hz.

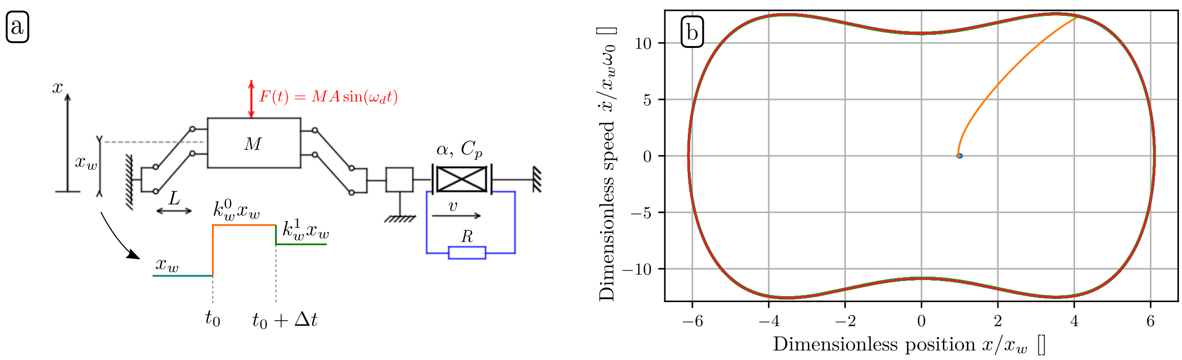

Figure 1: (a) NVEH scheme. (b) Trajectory in the dimensionless phase plane for $f_d = 50$ Hz, $A = 2.5\ \mathrm{m/s^2}$ with $(t_0, \Delta t, k_w^0, k_w^1) = (2 \times 10^{-3}, 7 \times 10^{-3}, 5.30, 3.50)$. The system starts on a low power orbit (blue) and converges to a high power orbit (red).

References

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