# Performance assessment of a Duffing-type vibration energy harvester

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Axis: Valorization of micro-sources of ambient energy. Keywords: Modeling, Nonlinear dynamics

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**Summary:** Harvesting vibration energy presents environmental and societal challenges. **One of the objectives of the Horizon** 2020 Fast-Smart project is the development of vibration energy harvesting systems using lead free piezoelectric ceramics to extract energy from ambient vibration using innovative nonlinear oscillators. Duffing bistable piezoelectric generators address some of these challenges. Their wideband characteristics allow for increased performance when the energy is distributed over a large frequency band. This poster presents the functionalities of a generic numerical tool that has been developed to :

- **1)** Efficiently simulate piezoelectric harvesters (both linear and non-linear);
- 2) Determine and characterize the different orbits according to the driving frequencies;

**3)** Predict the harvested power as a function of the driving frequency.

## 1) Modeling of the bistable generator



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Figure 1: Bistable generator [1].
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The Duffing-type bistable mechanical oscillator coupled to a piezoelectric actuator is modeled by a system of nonlinear differential equations:



Where 
$$A = 2.5 \text{ m.s}^{-2}$$
,  $\omega_0 = 121 \text{ rad.s}^{-1}$  and  $Q = 87$ .



**FECHNOLOGIES** 

monic periodic orbit.

### 2) Behavior analysis: chaos, phase plan, Poincaré section









monic periodic orbit and chaos.





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**Figure 4:** Phase plane,  $f_d = 50$  Hz, first harmonic periodic and sub-harmonics periodic orbits.

## (3) Probability of occurrence and expectation of the harvested power

The expectation of the harvested power is calculated from the probability of ocurrence of all possible orbits and their corresponding harvesting powers for a given driving frequency:  $\mathbb{E}[P_h] = \sum_k r_k P_{h,k}$ 



#### References

[1] T. Huguet. Vers une meilleure exploitation des dispositifs de récupération d'énergie vibratoire bistables Analyse et utilisation de comportements originaux pour améliorer la bande passante. PhD thesis, Université de Lyon, 2018. [2] T. Huguet, M. Lallart, and A. Badel. Orbit jump in bistable energy harvesters through buckling level modification. Mechanical Systems and Signal Processing, 128:202–215, August 2019.

**Figure 5:** Probability of occurrence, orbits' average harvested powers and expectation of the harvested power as a function of the driving frequency.

## **Conclusion and perspectives**

The proposed approach shows that the expectation of the harvested power is almost constant over the frequency range [23 - 50] Hz, which confirm the wideband nature of bistable vibration energy harvesters. Future work will consist in establishing orbit jumping strategies in order to stay on the most energetic orbit which would lead to a drastic enhancement of the bistable vibration energy harvesters' performance.

W. Liu. Conception d'un [3] dispositif de récupération d'énergie vibratoire *large bande*. PhD thesis, Université de Grenoble, 2014.