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BIFURCATION ANALYSIS OF A BISTABLE NONLINEAR ENERGY HARVESTING SYSTEM

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INTRODUCTION

Energy harvesting devices recovers energy from secondary sources as mechanical vibration (piezoelectric), heat (thermoelectric) and light (photoelectric). Some examples among its most promising applications are supporting Internet of Things (IoT) devices, boarded small electro-electronic equipment or even pacemarkers [3][4][5].

FIGURE 1 – Energy harvesting concept.

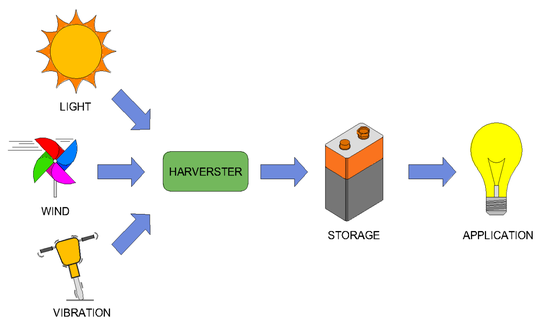
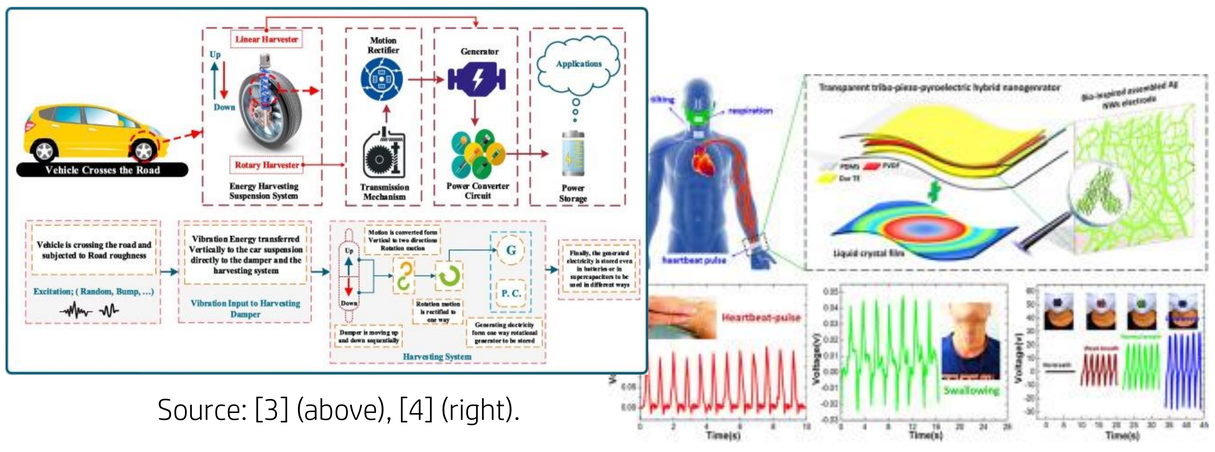


FIGURE 2 – Examples of energy harvesting technologies applications.



Source: [3] (above), [4] (right).

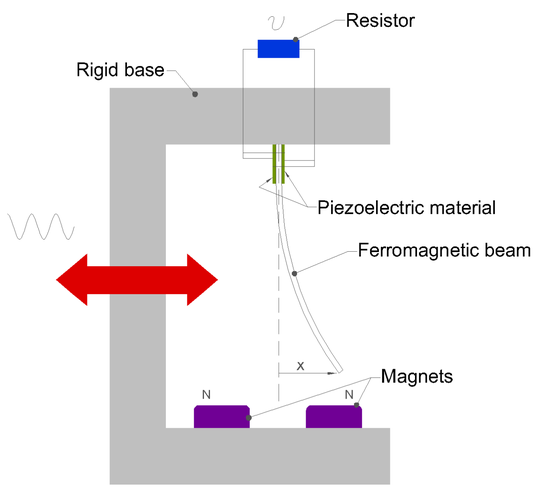
OBJECTIVES

The study aims to Identify:

- ✓ The forcing conditions which provides the best voltage regular responses;
- ✓ The excitation parameters which can be related with the chaos occurrence;
- ✓ The forcing parameters which provides the best voltage signals waveforms;
- ✓ The forcing parameters most able to improve the energy recovering;

MATHEMATICAL MODEL

FIGURE 3 – Energy harvester device [2].



$$\ddot{x} + 2\xi\dot{x} - 0.5x(1 - x^2) - \chi v = f\cos(\Omega t)$$

$$\dot{v} + \lambda v + \kappa\dot{x} = 0$$

$$x(0) = x_0, \dot{x}(0) = \dot{x}_0, v(0) = v_0$$

ξ – Dimensionless damping factor
χ – Dimensionless mechanical coupling factor
κ – Dimensionless electrical coupling factor
λ – Inverse characteristic time constant
f – Dimensionless forcing amplitude
Ω – Dimensionless forcing frequency

CONCLUSIONS

- ✓ Time series analysis provides a detailed system dynamics overview;
- ✓ Forcing parameters sampling ordering affects the voltage results (hysteresis);
- ✓ Low amplitudes combined with low frequencies provides regular dynamics;
- ✓ Chaos occurrence can be related with the harmonic forcing frequency variations;

FUTURE STEPS

- ✓ Investigate the effects of a stochastic component combined with the harmonic external forcing;
- ✓ Investigate the electrical load model influence on the system dynamic response;
- ✓ Investigate the effects of chaos controlling strategies on energy recovering (Leonardo de la Roca - leonardo.roca@uerj.br);
- ✓ Experimental stand analysis;

AMPLITUDE ANALYSIS

FIGURE 4 – In the left, forward (blue scale) and backward (red scale) voltage bifurcation diagrams for $\Omega \in [0.1: 0.1: 0.9]$ and $0.01 \leq f \leq 0.3$; in the right, diagrams sampled for $\Omega = 0.8$.

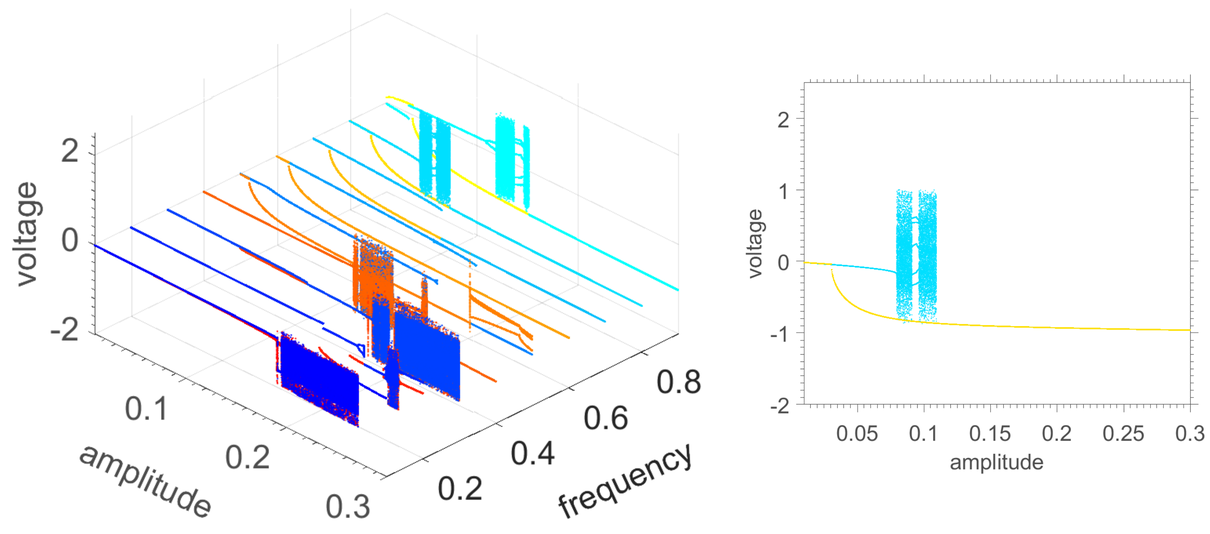
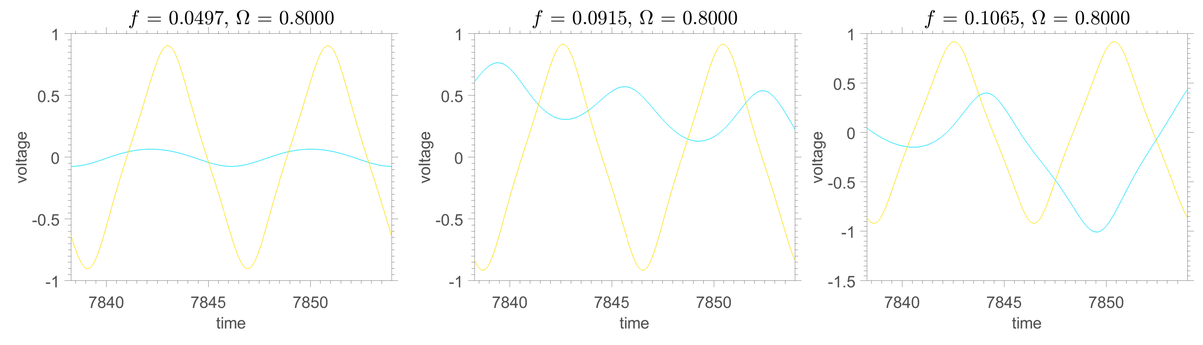


FIGURE 5 – Sampled voltage time series from diagrams for $\Omega = 0.8$ and different amplitudes.



FREQUENCY ANALYSIS

FIGURE 6 – In the left, forward (blue scale) and backward (red scale) voltage bifurcation diagrams for $f \in [0.019: 0.032: 0.275]$ and $0.1 \leq \Omega \leq 1.4$; in the right, diagrams sampled for $f = 0.083$.

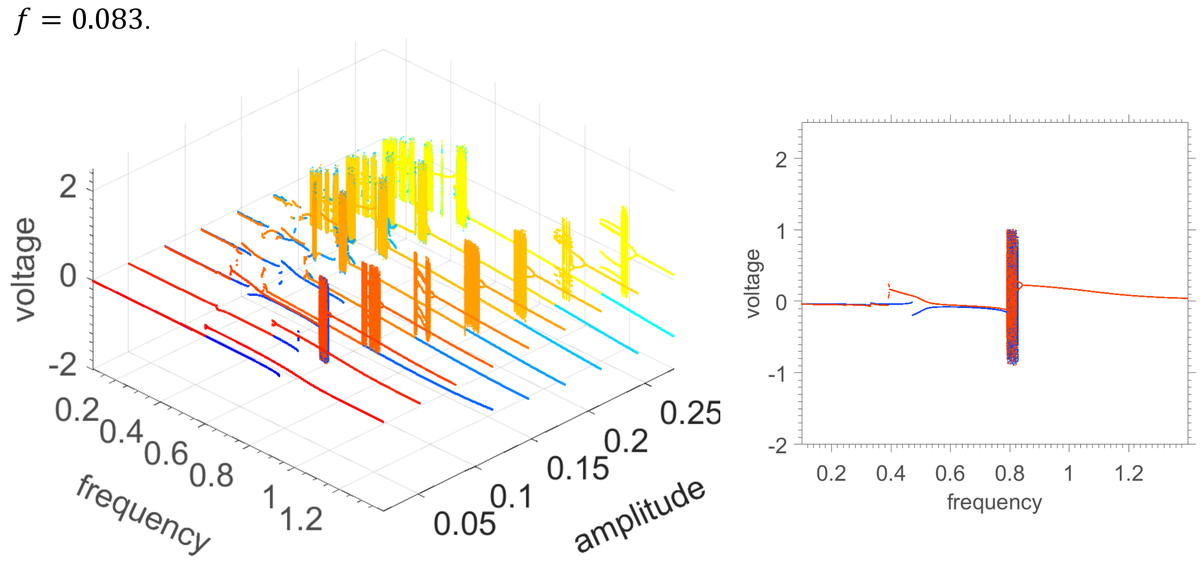
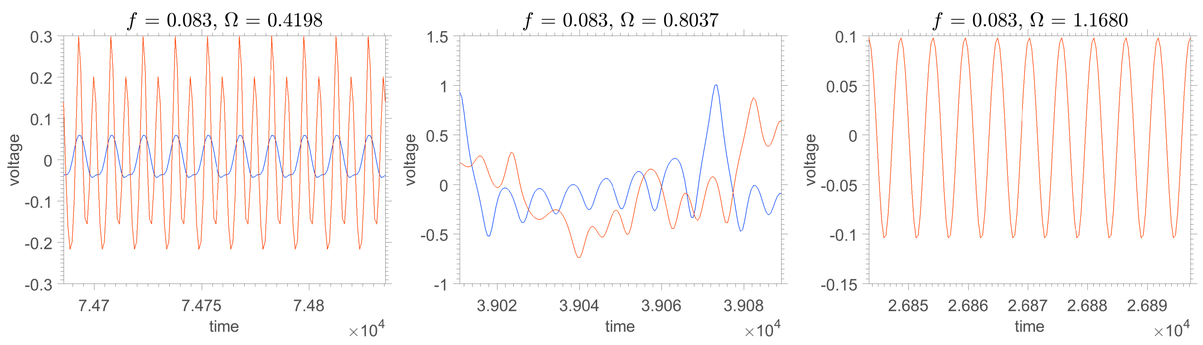


FIGURE 7 – Sampled voltage time series from diagrams for $f = 0.083$ and different frequencies.



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