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Dynamics of a 2 DoF galloping-based wind power harvester

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Abstract: Galloping oscillations of bluff bodies are considered as a prospective source of energy for small wind power generating devices. We consider an electromechanical system composed of a rectangular cylinder elastically connected with a magnet that can move in a linear electric generator. The cylinder performs galloping in flow, and the resulting motion of the magnet gives rise to electric current in the circuit. Periodic regimes arising in the system are studied depending on parameters.

Keywords: oscillations, stability, galloping, wind power

1. Introduction

The imperative necessity to reduce the carbon emissions, in order to ensure sustainable development of the society requires active study of different ways of green energy generation. One of such ways, which seems quite applicable for small installations, is extraction of energy from flow induced oscillations, such as fluttering, galloping, etc. Some analysis of dynamics and performance of a galloping-based energy harvester is given in [1].

Energy of oscillations can be converted into electric energy by means of different systems: piezo-elements (which are widely studied in the context of aeroelastic systems, e.g., [2]) or linear generators (e.g., [3]). Here we discuss a 2 degrees of freedom galloping-based system coupled with a linear generator.

2. Results and Discussion

We consider an electromechanical system that comprises a magnet M_1, a rectangular prism M_2, and a linear generator G connected to electrical circuit (Fig. 1). The cylinder and the magnet are connected with a spring and can move translationally along a fixed horizontal axis. The system is placed in a steady horizontal airflow. We only take into account the aerodynamic forces acting upon the cylinder and use the quasi-steady approach to describe them.

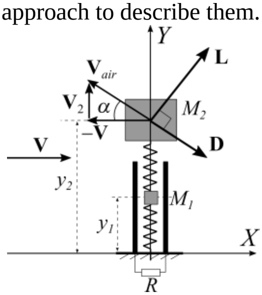

Fig. 1. Scheme of the system

In [4] it was shown that the elastically mounted cylinder (both circular and rectangular) elastically connected with a heavy mass (but without coupling to an electric circuit) performs galloping oscillations under certain conditions. In such situation, the magnet starts moving inside the generator, which induces electric current in the generator coil.

Equations of motion of the system can be represented in the following form:

$$\begin{aligned} & m_1\ddot{y}_1 + k_1 y_1 + h_1\dot{y}_1 + k_2(y_1 - y_2) + h_2(\dot{y}_1 - \dot{y}_2) = F_m \\ & m_2\ddot{y}_2 + k_2(y_2 - y_1) + h_2(\dot{y}_2 - \dot{y}_1) = L\cos\alpha - D\sin\alpha \\ & L_g\dot{I} = -RI + E \end{aligned} \qquad (1)$$

Here L, D are lift and drag forces, $k_{1,2}$ and $h_{1,2}$ are stiffness and damping coefficients of springs, E is the EMF (which is proportional to $\dot{y}_1$), F_m is the force acting upon the magnet from the coil assembly, L_g is the generator inductance, and R is the resistance in the generator circuit.

Evidently, the system has a trivial equilibrium. Analysis of its stability shows that it is unstable if certain conditions on parameters are met. A systematic parametrical analysis of periodic oscillations arising in the system in such case is performed. Characteristics of periodic regimes existing in the system (including the generated power) under different conditions are analysed. Some conclusions about performance of the harvester are drawn.

3. Concluding Remarks

Dynamics of an electromechanical system with two degrees of freedom is considered. Self-sustained oscillations arising in this system due to the galloping effect are studied. The performed simulation shows that this system has a potential for use as a wind power harvester.

References

[1] DAI HL, ABDELKEFI A, JAVED U, WANG L: Modeling and performance of electromagnetic energy harvesting from galloping oscillations. *Smart Materials and Structures* 2015, **24**(4):045012.

[2] WANG KF, WANG BL, GAO YJ, ZHOW JY: Nonlinear analysis of piezoelectric wind energy harvesters with different geometrical shapes. *Archives of Applied Mechanics* 2020, **90**:721-736.

[3] JIN C, KANG HY, KIM MH, BAKTI FP: Performance evaluation of surface riding wave energy converter with linear electric generator. *Ocean Engineering* 2020, **218**:108141.

[4] SELYUTSKIY Y: Potential forces and alternation of stability character in non-conservative systems. *Applied Mathematical Modelling* 2021, **90**:191–199.