6. Душкін С. Конспект лекцій з дисципліни «Надійність водопровідно-каналізаційних систем» (для студентів 2–3 курсів денної і заочної форм навчання напряму підготовки 6.060101 – Будівництво освітньо-кваліфікаційного рівня бакалавр за спеціальністю «Водопостачання та водовідведення»). Харків : ХНУМГ ім. О. М. Бекет., 2015. 115 с. URL: https://core.ac.uk/download/pdf/33757983.pdf (дата звернення: 01.03.2025).

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THE CREATION OF EFFECTIVE POWER SUPPLIES FOR UNMANNED VEHICLES

Unmanned aerial, ground and marine vehicles are widely used around the world. The movement of these vehicles is provided by engines: internal combustion, electric and their combination. The use of electric engines for unmanned vehicles allows to reduce their cost, eliminate heat signature, reduce sound trace, eliminate exhaust gases, etc. For unmanned aerial vehicles (UAV) like multicopters there is practically no alternative to electric propulsion because of the ease of their control. Ease of operation, high reliability and low cost have become a decisive factor for manufacturers of electrically powered UAVs [1, p. 13]. Today, the bottleneck for all types of unmanned vehicles is their poor power capability [2, p. 677]. This problem is most acute for unmanned aerial vehicles, where the mass of the structure is one of the main indicators [3, p. 67]. This trend directs specialists to search for efficient UAV power supplies. In UAV design, batteries and secondary power supplies (SPUs) are the most massive. However, the power source, as well as the type of propulsion system that provides flight performance, is in direct dependence on the entire power system of the unmanned vehicle. Consequently, adding batteries to the system does not increase flight time or payload. The only way to increase time is to increase the quality of energy conversion, in other words, to increase the specific mass (W/kg) and volumetric specific energy (W/dm^3) of the unmanned vehicle. One of the solutions to this problem can be the use of parametric generators, which will allow to provide efficient energy conversion of the primary power source and create a small-sized and powerful SPUs, which will allow to use a battery of lower power and lower weight, which will increase the range of the UAV.

The first studies of parametric resonance in electric circuits were carried out almost one hundred and fifty years ago in the USSR under the direction of Academicians Maldeshtam and Papaleksi (Mandelstam, L.I. and N.D. Papaleksi. On the parametric excitation of electric oscillations. Zhurnal Tekniche skoy Fiziki. 4(1). 1934. p. 5–29). Even at that time the basics of the theory of parametric oscillations in electrical systems began to be developed and the first samples of such generators were produced. Later, the first publications on the use of parametric voltage regulation in SPUs appeared: US patent 3654546 (1972), French patent 2X34457 (1973), USSR patent 656040 (1979). At present [4, p.18] a parametric converter is understood as a device that converts energy from one form to another by changing parameters, which is actively used in many fields, ranging from electronics and mechanical engineering to aerospace and energy industry.

Thus, based on the above, the following conclusions can be drawn:

– there already exists a whole class of fuel-free electromechanical generating units, the principles of operation of which are not suitable for use for powering unmanned aviation due to the presence of only air as a medium of motion and due to the bulky nature of electromechanical systems;

– parametric resonance in an electric oscillating circuit, where there are no moving mechanical systems and no dependence on the medium of motion, should be considered as promising for power supply of unmanned aviation.

It is known, that in addition to the traditional method of generation and transformation of electrical energy there is a method in which electrical oscillations of significant power are generated in an oscillating circuit without supplying electrical energy to the circuit. This method consists of the following.

One of the most economical ways of excitation of parametric resonance is the switching method. The switching method of excitation of electrical oscillations makes it possible to obtain a jump-like character of change in the inductance or capacitance of the oscillating circuit, a high depth of modulation of the parameters and to provide conditionally constant energy consumption for changing the parameters, which do not depend on the amplitude values of current and voltage in the circuit. Switching consists in the fact that an additional inductive coil or capacitor with a certain nominal value of inductance or capacitance in relation to similar elements of the main circuit is connected in parallel to the oscillating circuit at certain moments of time in a predetermined mode using, for example, thyristors. This makes it possible to change the circuit parameters (inductance, capacitance, oscillation frequency, wave impedance) during each oscillation in accordance with the algorithm of changing the control voltage supplied to the thyristors from a separate pulse generator and thereby achieve parametric resonance without functional connection of current and voltage amplitudes in the circuit with the value of the control voltage. Such switching is able to provide the possibility of oscillation of the circuit in two frequency modes: at the main resonant frequency ω_0 and parametric frequencies $2\omega_0$ or $0{,}5\omega_0$. These frequencies are the resonant frequencies for both modes of the circuit at which the equality of wave, inductive and capacitive resistances is ensured. Thus, the first condition of parametric resonance is provided – multiplicity of the parametric frequency with respect to the basic frequency of the circuit. An additional capacitor or inductive coil is connected at the moment when the maximum current value is reached in the circuit, and it is disconnected at zero current value. The voltage in the circuit at these moments has respectively zero or maximum value. By varying the parameters, part of the oscillation period of the loop operates at the fundamental frequency and part at the parametric frequency. The resulting oscillation is the addition of the above two oscillations. Thus, the essence of the switching method of obtaining parametric resonance is reduced to the fact, that by periodic changes of parameters the contour and the field are constantly removed from the position of energy and force equilibrium with subsequent restoration of this equilibrium, which is accompanied by changes in perturbations and redistribution of associated energies between the contour and the field. The stationary amplitude of parametric oscillations is provided by stabilitrons with shunt resistors connected in parallel to the circuit, which, passing through themselves a part of the charge involved in the process of oscillation and dissipating excessive reactive power, thus limiting the amplitudes of voltage and current within the limits necessary for the performance of the circuit. Functioning of the pulse generator is carried out at the expense of a part of the output power of the device, which is able to ensure full autonomy of the device as a power source.

The proposed energy conversion technology for unmanned vehicles can be extended for more energy-intensive devices, but other conversion methods and other circuitry solutions may need to be applied in another application area.

Bibliography:

1. Xi Hu, Rayan H. Assaad. The use of unmanned ground vehicles (mobile robots) and unmanned aerial vehicles (drones) in the civil

infrastructure asset management sector: Applications, robotic platforms, sensors, and algorithms. Expert Systems with Applications. Volume 232. 1 December 2023. 120897. DOI: https://doi.org/10.1016/j.eswa.2023.120897

2. Abdilla, A. Richards, S. Burrow, Power and endurance modelling of battery-powered rotorcraft. 2015 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS) (IEEE, 2015). Pp. 675–680.

3. Srivatsan Krishnan, Zishen Wan, Kshitij Bhardwaj, Ninad Jadhav, Aleksandra Faust, Vijay Janapa Reddi. Roofline Model for UAVs: A Bottleneck Analysis Tool for Onboard Compute Characterization of Autonomous Unmanned Aerial Vehicles. To Appear in 2022 IEEE International Symposium on Performance Analysis of Systems and Software Preprint Version. April 2022.

4. 参数共振和Floquet理论. URL: https://zhuanlan.zhihu.com/p/670746166 (date of circulation 25.02.2025).

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ДО ПИТАННЯ ОПТИМІЗАЦІЇ ВИТРАТ У МОРСЬКОМУ ТРАНСПОРТІ

Важливим аспектом розвитку морської галузі України під час війни є наукові дослідження, метою яких є мінімізація витрат на морські перевезення та оптимізація маршрутів. Побудова та дослідження математичних моделей спирається на методи математичного аналізу та оптимального управління. Деякі з таких моделей для задач водної інженерії досліджуються в роботі [2].

Розглянемо задачу регулювання швидкістю судна у змінних умовах плавання. Вважаємо спротив води F руху судна пропорційним (у відносних одиницях) квадрату швидкості руху, а потужність силової установки N – кубу швидкості. Нехай S шлях, а v – швидкість. Тоді

$$F = \gamma_1 v^2 = \gamma_1 \left(\frac{dS}{dt} \right)^2; \; N = \gamma_2 v^3 = \gamma_2 \left(\frac{dS}{dt} \right)^3.$$