ENERGY SAVING. PIEZOGENERATORS

Author: **Andrey NIKIFOROV**, e-mail: andeyworkzilla@gmail.com,
Polina KUSHNIR, e-mail: andeyworkzilla@gmail.com,
Pskov State University
Pskov, Lenin Square, 2, office 23

Abstract. *The object of consideration is a static generator of piezoelectric energy. The purpose of the work is to study the operation modes and designs of piezoelectric converters; selection of a suitable design for the converter; the development of the model of the converter and the determination of its output characteristics. The work is devoted to the development, research and creation of piezoelectric generator of static type. This generator can be a small independent power source of autonomous different devices of radio electronics, as it transforms the free energy of vibrations of the external environment into an electrical signal. In addition, solving problems related to strength characteristics will allow us to use this type of piezo-generators in the future under conditions of a nonlinear stress-strain state.*

Keywords *the piezoelectric generator, piezoelectric effect, the piezoelectric element, vibration, electroacoustic transducer.*

Introduction

The development of technical progress stipulates the improvement of developments in the field of electric generators, for the creation of a new generation of methods and devices intended for obtaining electric energy, without polluting the environment.

Currently, there are many works in the field of nutrition of low-power devices. The development, research and creation of piezoelectric generators is a very urgent and important problem. Interest in this problem is due to the prospect of creating small independent and practically inexhaustible power sources for autonomous various devices of radio electronics. Such sources transform the free energy of vibrations, present almost everywhere, into electrical energy and do not require the presence of external power supplies or the need for periodic replacement of batteries. The analysis of numerous works on obtaining electric energy from vibrations for feeding microelectronic devices shows a significant advantage of the piezoelectric method in comparison with electromagnetic or electrostatic.

The main tasks of this work are: description of a small-sized power generation device based on the piezoelectric effect obtained with a static stressed-deformed state of the piezoelectric element, as well as modeling the transient modes of their operation.

The transformation of mechanical energy into electrical energy

There are not so many methods of converting mechanical energy, often use an electromagnetic generator of electrical energy, such as a turbine. Almost all current power plants use this type of conversion. Nuclear, coal, gas and hydraulic power stations with the help of thermal energy bring the turbine into action, then this energy is converted into electrical energy. Electromagnetic devices can be used in the technology of microelectromechanical systems using micro-turbines, but they require a complex design, as well as fuel.

In addition to electromagnetic energy transformations, there are devices for energy conversion: a magnetohydrodynamic generator (MHD) and a piezoelectric generator (PEG). MHD was invented by M. Faraday. Magnetohydrodynamic generators are not used as a portable power source due to high temperature requirements (2000K) [3], meanwhile, until recently, piezoelectric generators have not been considered for this role, due to the low generation of electricity potential. But, as a rule, piezoceramic (PZT) elements are used for active devices (for example, diaphragms) or signaling devices (sensor, resonator).

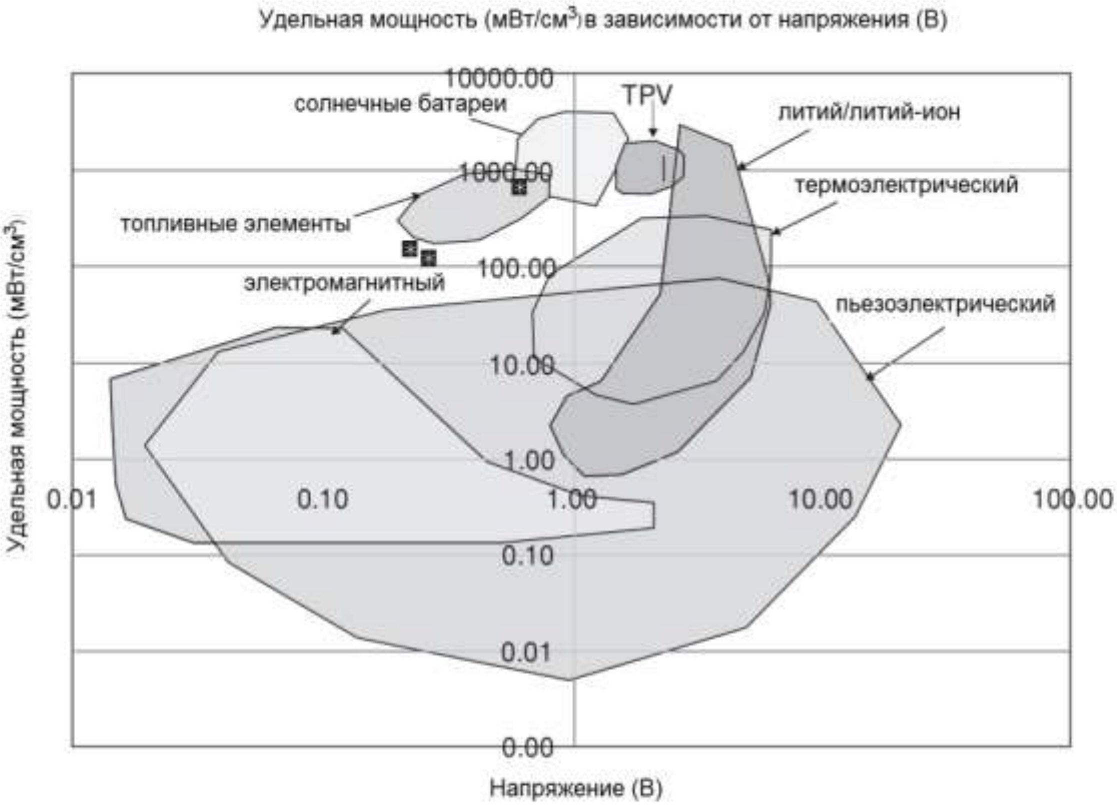
Among the existing methods of energy conversion methods where solar cells are used, the TP effect, piezo-transformations, are good for portable portable devices that do not require a large amount of energy [2].

http://dx.doi.org/10.17770/het2018.22.3638

Initially, piezoelements do not have a complex design, unlike a turbine. Secondly, piezoceramic elements can be located in a closed housing. Finally, piezo-based devices do not require additional power supplies for energy conversion.

During the last decade, attention has been drawn to obtaining energy from vibration [4]. The motive for conducting research in this direction is to reduce the power requirements of microelectronic components, such as wireless sensors, which are used in passive and active monitoring systems. The ultimate goal of such studies is the development of power systems for such microelectronic devices by using the energy of vibration present around. If this can be done, the requirements for the availability of external power supplies, as well as the need for constant costs for periodic battery replacement and chemical processing of batteries can be reduced.

The main advantage of piezoelectric materials for obtaining energy (in comparison with the other two conversion mechanisms) is a large specific power, which can be obtained with their help, as well as ease of use. The specific power in comparison with the voltage shown in picture 1 shows that the area of piezoelectric energy production occupies a large area of the figure, and the specific power is comparable with the specific power of thin-film and thick-film lithium-ion batteries and thermoelectric generators.



Picture 1. Specific power versus voltage for various regenerative and lithium / lithium-ion power sources

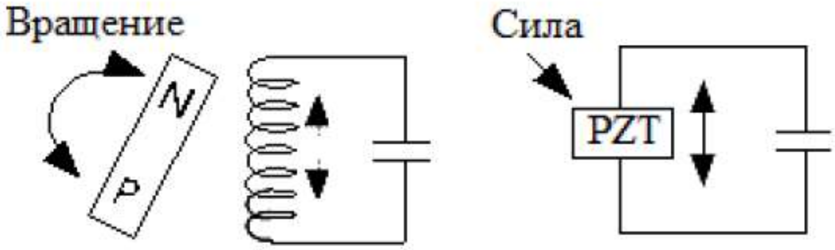
As can be seen in picture 1, the output voltage for electromagnetic power generation devices is usually very small, and a multi-step boost is often required to obtain the voltage level required to charge the consumer device. In a piezoelectric device, the required voltage level can be obtained directly from the piezoelectric element. In the electrostatic power generating device, an input voltage or charge is needed, which must be applied to create relative oscillatory motion of the capacitor elements and to obtain an alternating output voltage.

On the other hand, the output voltage of the piezoelectric device is determined by the properties of the material, which eliminates the need for an external voltage source.

Charge generation from a piezoelectric material

Electromagnetic generators use electromagnetic forces to move free electrons in the coil of a permanent magnet of the rotator. Piezoelectric material, which is used as a non-conductive material, does not have free electrons, so electrons can not freely flow through the material [2]. Since piezoceramics do not have free electrons, they consist of crystals that have many "constant" electrons. These constant electrons can move slightly under the action of an external force, that is, there is a deformation of the crystals. This small movement of electrons changes the state of equilibrium of neighboring materials and creates an electrical force. This force will push, and pull electrons to the electrodes of the piezoelectric crystal.

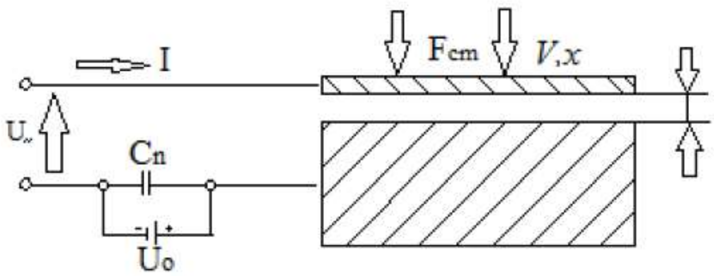
Magnetic and piezoelectric generators work the same way (picture 2). Magnetic generators use mechanical energy to change the magnetic field. This changing field creates the power to move free electrons. In the generator, piezoelectric, free electrons move, changing the electric field "inside" the crystal.



Picture 2. Electromagnetic generator and piezoelectric generator

Static action on the piezoelectric transducer

By analogy with electromagnetic systems, an electrostatic converter can be made reversible and linear by its polarization by a constant electric field. The scheme of the polarized converter is shown in picture 3 .



Picture 3. Polarized electrostatic converter

The polarization voltage U_0 is connected to the electrodes in series with an alternating voltage $U_{\sim}$. The capacitance C_n, the shunting source of the polarizing voltage, is chosen from the condition $C_n >> C$, which makes it possible not to distinguish between the voltage $U_{\sim}$ and the variable component of the voltage acting between the electrodes.

As can be seen from Figure 7, when voltage $U_{\sim}$ between the electrodes is applied to the converter, the voltage $U_0 + U_{\sim}$ is applied, therefore, we find the required force of attraction

$$F_{xm} = \frac{\varepsilon\varepsilon_0 S}{2\delta^2}(U_0 + 2U_п U_0 + U_п^2)$$

For a polarized electrostatic converter, when the linearity condition ($U_0 >> U_\sim$) is satisfied, the exciting electrostatic force is directly proportional to the applied electric stress $U_\sim$, and the relationship between the force and the voltage is independent of the frequency of the oscillations.

Mathematical modeling of a piezoelectric generator

The task of modeling is the creation of a static piezo generator with increased electric power, in comparison with existing analogues, as well as the use of free energy of vibration of various industrial, construction, road and household structures.

Mathematical modeling of piezo-generators is a promising direction for the development of autonomous power supplies for microelectronic devices and remote sensors that attract the attention of researchers in various fields of technology, including materials science.

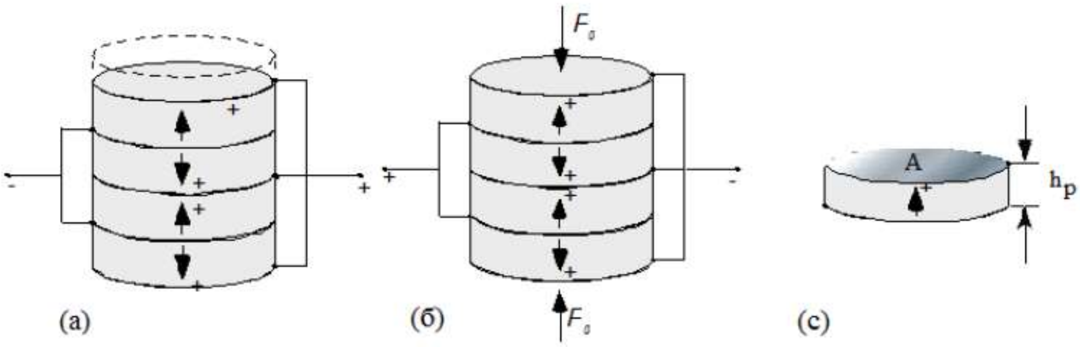
In the early stages, researchers used models with lumped parameters with one mechanical degree of freedom to describe a system similar to that shown in picture 4. The use of a lumped parameter model is justified, since the electrical part already contains lumped parameters: a capacitor representing the internal capacitance of piezoceramics , and a resistor that displays the external load resistance. Consequently, it remains only to obtain concentrated parameters representing the mechanical part so that mechanical equilibrium and electrical equations with lumped parameters would be related to the basic equations of the piezoeffect, and a transformation relation could be established. This was done in and . Although modeling in lumped parameters allows one to get an initial idea of the problem with simple expressions, this approximation is nevertheless limited to one vibrational mode, and it does not take into account some important aspects of the displayed physical system, such as vibration modes and the exact distribution of deformations, on the electrical response.

Since beam piezo generators are excited mainly at the point of attachment of the base, in the literature on piezo generators a widely used approach is based on the use of lumped parameters [5]. This approach is applied both for modeling and for the study of regimes.

The task is solved due to the fact that the static generator of piezoelectric energy contains a piezoelectric transducer, in parallel with which a resistor, a rectifier, a storage capacitor and an output regulating electronic circuit are connected. Also, the proposed generator is provided with a lever and is made in the form of a sectioned converter, the sections of which are electrically connected to each other, and each section consists of one or more piezoelectric elements glued to each other and electrically connected to each other.

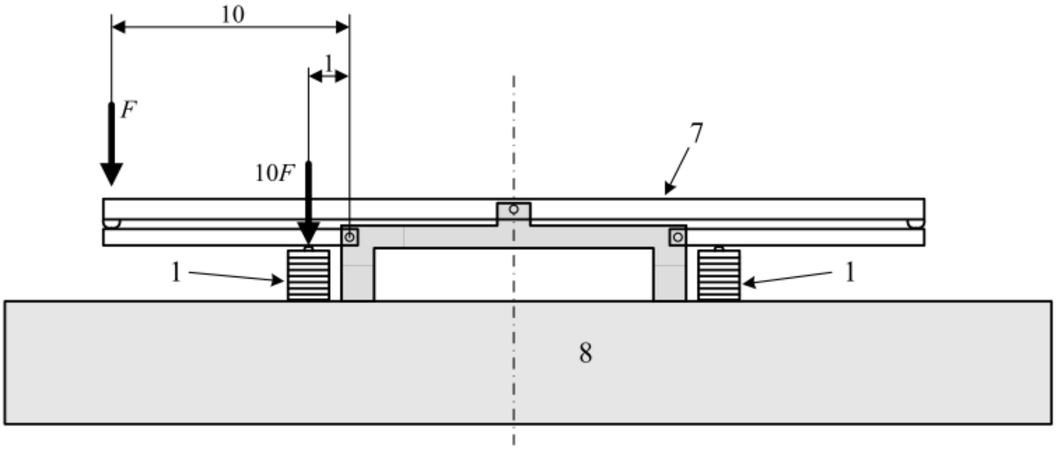
The technical result achieved is an increase in the power of the piezoelectric generator and the output voltage, an increase in the electric charge generated by the piezoelectric generator, a decrease in the generator's own electrical capacity and the possibility of using free energy.

However, taking into account all the qualities of piezoceramics, the piezoelectric element can not create large deformations. Large deformations are created only at a very high electric field strength. In the case of small dimensions of the piezoelectric element and the smallness of the deformation values at simultaneously large electric field values, a brittle material can not be used to generate a voltage. To overcome this drawback, the piezoelements are fastened together. The piezoelectric column is made from a large number of thin piezoelectric plates, which are glued together and connected in parallel. The direction of the force and polarization of such devices is the same - 33. As a result of the gluing, the productivity is increased N times, where N is the number of piezoelectric layers. For this reason, a piezoelectric rod transducer in the form of a column is the most common among the "power generation" devices. The disadvantages of such devices are the inadmissibility of transverse effects due to the brittleness of the ceramic and the relatively small volume of piezoelements.



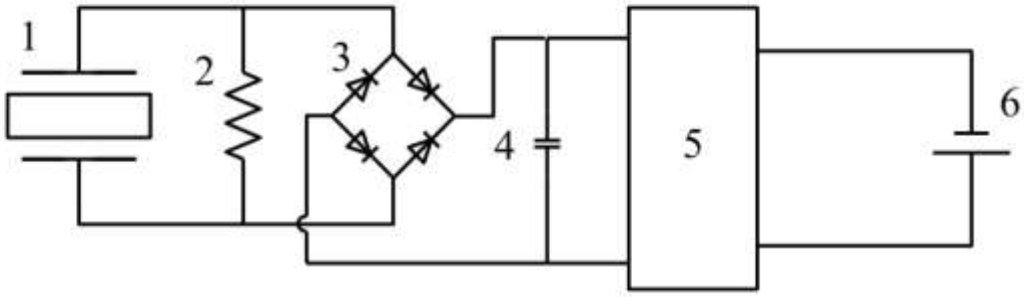
Picture 4. Scheme of the connection of piezoelectric elements taking into account the polarization direction of the plates in a static generator: (a) rod stretching; (b) compression of the rod; (c) one piezoelectric element of thickness h p.

A rod consisting of connected piezoelectric elements can only be compressed in the longitudinal direction, as shown in picture 4, i.e. creating longitudinal deformations. The application of force can lead to both stretching and compression of the rod. This means that the generation of electricity is not possible with transverse deformations, that is, if there are any lateral forces, the piezoelectric generator must convert them into longitudinal actions.



Picture 5. Nonlinear piezoelectric transducer

Picture 5 shows one possible piezotransformer implementations utility model "Nonlinear piezoelectric transducer" [6] which is adapted partitioned, wherein the sections are mechanically connected to each other in series, so all the sections subjected to equal force, and each section comprises one or more piezoelectric elements glued to each other and electrically connected to each other in series or in parallel, depending on how the output voltage and which output resistance r generators of retrieve.



Picture 6. Schematic of a static piezoelectric generator

The piezoelectric generator (Picture 6) has two or more piezo transducers 1, a resistor 2, a rectifier 3, a storage capacitor 4, a circuit controlling the charge of the battery 5 and a battery.

The piezoelectric transducer 1 (Picture 6) is made in the form of a sectioned foot consisting of a set of polarized rectangular piezoelements combined in a section. Structurally, the piezoelements are connected in series, so that each piezoelement is under the same load, and the mechanical compression stress in each piezoelement is the same. The mechanical load on the transducer exceeds the external force (for example, the weight of a person or car) F in the ratio of the arms of lever 7 (the figure shows an example in which this ratio is 10). The mechanical stress in the piezoelectric element (in Pascals) is equal to the ratio of the load in Newtons to the cross-sectional area in m2. The middle of the non-linearity region for piezoceramics, for example of the type CTC-19, is of the order of magnitude of 100 MPa. Therefore, to achieve this voltage with an external force F of, for example, 100 kG (i.e., about 1000 N), with a lever arm ratio of 1:10, the cross section of the piezoelectric element should be approximately 1 cm 2 [6].

The piezoelectric elements inside each section, as well as the sections between themselves, are electrically connected in series or in parallel, depending on what voltage and what power is required from the converter. The converter as a whole densely lies on the base 8 (Picture 5). Thus, the converter can withstand without destroying large static and dynamic loads.

The output voltage of the converter through the terminating resistor 2 is fed to the input of the rectifier 3, and then the rectified voltage is applied to the input of the storage capacitor 4. After the storage capacitor through the electronic control circuit 5, the voltage is applied to the input of the battery 6.

Principle of operation of a static piezoelectric generator

The generator works as follows: the converter is attached to a vibrating element of a building, industrial, household or road structure. The converter can be located on the basis of the type of plate (8 - in Picture 5), which can either fit snugly, for example, to the element of the building structure, or to the floor, or to the roadway, or to the vibrating surface. As a result of the static external action on the piezoelectric element or vibration, as a result of the direct piezoelectric effect at the output of the transducer (Picture 6), an alternating voltage arises that is applied to the resistor 2 and then to the rectifier 3. After rectification, the electric charge accumulates on the storage capacitor 4, then enters the circuit 5, which controls the battery charge. The energy of the charged battery is used by the consumer. Thus, the free energy of external influence, or the vibration of various objects, is used.

Achieved technical result:

1. Increase the power of the piezoelectric generator;
2. The use of free energy of external influence, or vibration of various industrial, construction, road and household structures to generate electricity;
3. Saving or receiving electricity in places where it is not available.

Conclusion

This work is devoted to the review and application of a piezoelectric generator of a static type.

This generator can be a small independent power source for various types of electronics, as it converts energy.

The developed static piezo generator contains a lever and an electric converter, which is made in the form of a piezoceramic column, the elements of which are electrically connected in parallel with each other. Also, the generator is equipped with a resistor, a rectifier, a storage capacitor, a circuit controlling the charge of the capacitor and the battery.

The converter is located on the base, or attached to objects subject to vibration, and generates electrical energy due to the energy of the external force, or the vibration of the object to which it is attached. The lever also performs the function of strengthening the external influence.

The use of the devices presented in this work is possible to reduce the energy consumption of primary information systems (sensors) and to ensure their autonomous operation during practically unlimited time due to the energy of environmental vibrations. In addition, the solution of problems related to strength characteristics can be continued under conditions of a nonlinear stress-strain state.

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