

THERMOELECTRIC GENERATORS, PROBLEMS AND WAYS TO INCREASE THEIR EFFICIENCY

¹S. F. Ergashev, ²D. T. Mamadiyeva, ³M. Yu. Khasanova

Fergana Polytechnic Institute¹, Tashkent University of Information Technologies Fergana Branch^{2,3}

ABSTRACT

The article analyzes the design features, technological problems, methodology for calculating the technical and energy indicators of solar thermoelectric generators. Ways to improve the most important properties of semiconductor material and energy efficiency of a thermoelectric generator are also given.

Key words and phrases: *thermoelectric generator, solar thermoelectric system, technical and energy indicators, K.U.A., thermo-EMF, thermopile.*

The development of a thermoelectric method for converting energy is characterized by a surge in scientific and technical research and engineering developments at the beginning of the second half of the 20th century, followed by a decline in scientific and technical activity by the end of the century. This was due to both technical and technological difficulties that arose in the practical implementation of the thermoelectric method for converting energy, and the successes and advantages of alternative directions (machine, photoelectric methods for generating electricity, compression based on freons - for producing cold). [1,2,3]

However, the accumulated positive experience of long-term practical operation of various thermoelectric devices and the emergence of new, more efficient semiconductor materials - on the one hand, a long service life, multifunctionality, low cost - on the other, in the light of modern problems and promising tasks of small-scale power engineering, today they raise the question of the need revising priorities and highlighting areas of application, where the advantages of thermoelectricity can make it a determining factor when choosing a device for generating electricity [5,7,9].

TYPES OF THERMOELECTRIC GENERATORS USED

- Fuel: heat from fuel combustion (natural gas, oil, coal). Radioisotope: heat from decay of isotopes (decay is not controlled and work is determined by half-life).
- Nuclear: the heat of an atomic reactor (uranium-233, uranium-235, plutonium-238, thorium), as a rule, there is a thermoelectric generator - the second and third conversion stages.
- Solar: heat from solar collectors (mirrors, lenses, heat pipes).
- Utilization: heat from any sources that emit waste heat (exhaust and furnace gases, etc.).

The current state of the energy sector, along with the improvement of traditional methods of energy conversion, is characterized by the search for alternative ways based on the use of solar energy, utilization of waste heat, rejection of polluting methods, etc. One of the ways to use thermoelectric converters to convert heat into electricity is to install a battery of thermal modules in heating installations for household use (heating boilers, hot water installations, warm air generators, etc.), while no costs for heating and cooling the thermopile are required. This will increase their autonomy and reliability, primarily in places of permanent or temporary power outages. Similar devices can be used in catalytic heat generators operating on the combustion of both high-calorie and low-calorie fuels, as well as various wastes containing combustible components. The latter circumstance, as well as the small size and rather high mobility of such installations, together with the possibility of simultaneous production of electricity without resorting to the help of gasoline-electric or other units, can make such installations attractive to various consumers - from agricultural producers to departments of the Ministry of Emergency Situations.

A solar thermoelectric generator is a modification of a solar power plant that converts solar energy into electrical energy.

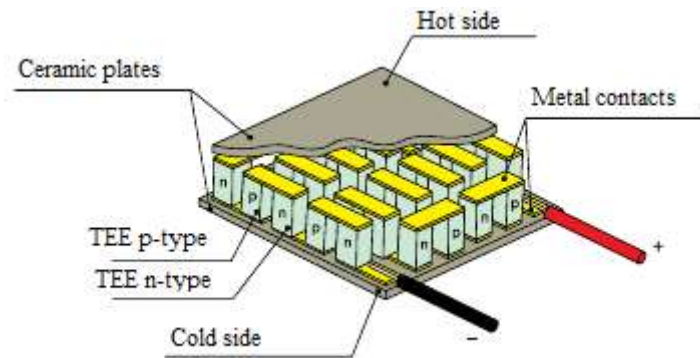
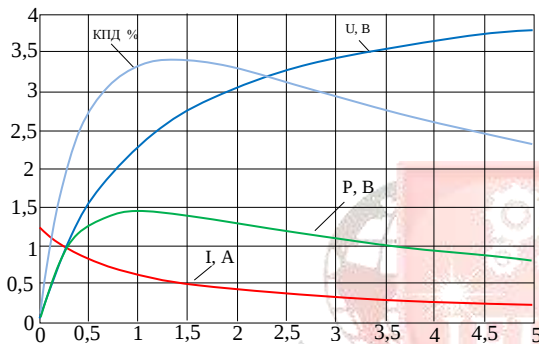


Fig. 1. Sectional view of the thermoelectric generator.



Example of dependence of TEG characteristic on load resistance [2]

The structure consists of a thermoelectric generator (Fig. 1), a system that concentrates the energy of solar radiation, a system that monitors the movement of the Sun, and a mechanical support. The solar concentrator increases the density of the solar thermal flux that passes through the thermoelement. The density is also increased with the help of heat-conducting plates with an area larger than the cross-section of the thermoelement. The properties of the thermoelement semiconductors determine the efficiency of the solar thermoelectric generator.

According to the method of density concentration,

solar thermoelectric generators are optical and panel. Solar thermoelectric generators are used to provide energy to devices with low power, no more than a few hundred watts (for example, spacecraft, some agricultural devices).

Basic formulas and ratios for determining the parameters of TEG [4,8,12]

In order to create a temperature difference on the sides of the generator module, it is necessary to bring the heat flux Q_h to its hot side and remove the heat flux Q_c from the cold side, and their difference, according to the law of conservation of energy, will be the generated electric power P .

$$P = Q_h - Q_c \quad (2)$$

On an external load - the TEG creates a voltage U on the internal resistance of the generator:

$$U = E_{1234} - I \times R, \\ \text{или } I \times R_m = E_{1234} - I \times R, \quad (3)$$

Amperage I in the circuit is determined by the expression:

$$I = \frac{2N \times \alpha \times \Delta T}{R + R_n} = \frac{2N \times \alpha \times \Delta T}{R(1 + m)}, \quad (4)$$

где $m = R_n / R_0$. (5)

The voltage across the load is:

$$U = I \times R_n = 2N \times \alpha \times \Delta T \frac{m}{(1+m)^2} \quad (6)$$

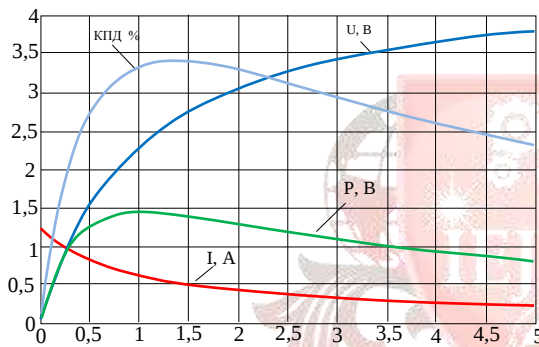
The power supplied to the external circuit can be calculated using the following formula:

$$P = I \times U = \frac{(2N \times \alpha)^2 \times \Delta T^2}{R} \times \frac{m}{(1+m)^2} \quad (7)$$

:

The efficiency of the thermoelectric is estimated by the coefficient of useful action:

$$\eta = P / Q_h \quad (8)$$



Example of dependence of TEG characteristic on load resistance.

To ensure the efficient operation of the TGM, it is necessary to ensure the maximum permissible temperature difference between the sides of the module; for this, heat must be supplied to one side of it (Q_h), and on the other, it is necessary to ensure effective removal of heat energy (Q_c). The electrical power at the load is directly proportional to the square of the temperature difference ΔT :

$$P = Q_h - Q_c = I^2 \times R_H \sim \Delta T^2 \quad (9)$$

To achieve maximum power, the electrical resistance of the load must be equal to the internal resistance of the generator module under operating conditions.

Choosing the parameter m in a certain way, you can change the efficiency, while the electrical power that can be obtained from the thermoelectric generator will change (Fig ...). The maximum power from the TEG can be obtained when the external and internal loads are equal, and the maximum efficiency is achieved at $m = 1.3-1.4$.

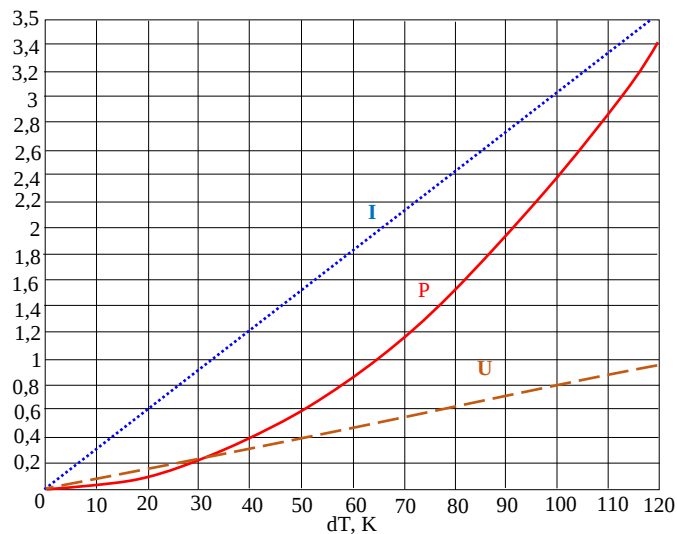


Fig. 3. Graph of current I (A), voltage U (B) and power P (W) versus the temperature difference between the hot and cold sides of the generator module. [18]

For thermoelectric generators, semiconductor thermoelectric materials are used, which provide the highest coefficient of conversion of heat into electricity. The list of substances with thermoelectric properties is quite large (thousands of alloys and compounds), but only a few of them can be used to convert thermal energy.

Due to the complexity of the physical processes occurring in thermoelectric materials, today there is no thermoelectric material that fully satisfies the industry with its properties.

The most important properties of a semiconductor material for thermoelectric generators are [7,9]:

- Coefficient of useful action: the highest possible efficiency;
- Manufacturability: the possibility of any types of processing;
- Cost: absence of rare elements in the composition or their smaller amount, sufficient raw material base.
- High coefficient of thermo-EMF
- Low content of toxic elements (for example: lead, bismuth, tellurium, selenium) or their inert state (in the composition of alloys);

Ways to develop and improve Coefficient of useful action [5,7,9]

- Effective thermoelectric material:
- Conversion efficiency, thermo-EMF, plasticity, thin-film design.
- Unification of units adapted for different applications.
- Wide temperature range to utilize high potential heat and therefore increase the convertible heat output.

Thus, the relevance of the use of thermoelectricity for scientific, industrial and domestic purposes does not weaken, passing from the stage of scientific research to experimental design and practical implementation of specific technical solutions. At the same time, taking into account the design features of thermal modules in combination with various heat and power devices, the task of choosing the optimal characteristics of thermopiles is constantly becoming more complicated due to the need to take into account both previously identified side factors and the appearance of additional effects due to the design features of a particular device.

LITERATURE

1. Ioffe A.F. Energy bases of thermoelectric batteries from semiconductors. M., From the Academy of Sciences of the USSR, 1950
2. Thermoelectrics and their applications. Reports of the VI interstate seminar. FTI them. A.F. Ioffe, St. Petersburg., 1999
3. R.V. Kovalsky Engineering methods for calculating thermoelectric generators. M., Science, 1990.
4. Ioffe A.F. Semiconductor thermoelements. M. - L., From - in the Academy of Sciences of the USSR, 1960
5. Burshtein A.I. Physical basis for calculating semiconductor thermoelectric devices. Moscow: Fizmatgiz, 1962.
6. Moyzhes B.Ya. Influence of the temperature dependence of the parameters of materials on the efficiency of thermoelectric generators and refrigerators.-FTT, 1960, 2, No. 4.
7. Kotyrlo G.K., Lobunets Yu.N. Calculation and design of thermoelectric generators and heat pumps. Directory. Kiev, "Naukova Dumka", 1980.
8. Iordanishvili E.K. Thermoelectric power supplies. M., Soviet radio, 1968
9. Thermoelectric materials and converters. Per. from English A.M. Braginsky et al., -M.: Mir, 1964.
10. Stilbans L.S. About switching of semiconductor thermoelements. ZhTF, 1957, 27, No. 1.
11. Naer VA Influence of contact electrical and thermal resistances on the characteristics of semiconductor batteries. ZhTF, 1965, No. 1.
12. Shulman F., Nucleonics, 1963, Vol.21, # 9.
13. Okhotin A.S., Efremov A.A., Okhotin V.S., Pushkarsky A.S. Thermoelectric generators.-M., Atomizdat, 1976
14. Pozdnyakov B.S., Koptelov E.A. Thermoelectric power engineering. M., Atomizdat, 1974
15. R.V. Kovalsky Generalized dependencies for determining the optimal operating mode of a thermoelectric generator. Izvestia of the USSR Academy of Sciences, Energy and Transport, 1970, No. 3, p. 160.
16. Novikov A.I. Improving the efficiency of the solar thermoelectric battery. IFZh, t. 74, No. 1, 2001
17. A.I. Novikov Thermoelectric power source for the spacecraft power supply system. Sat. reports of the VII Interstate Seminar "Thermoelectrics and Their Applications", FTI im. A.F. Ioffe RAS, St. Petersburg, 2000
18. P. Shostakovsky Thermoelectric Alternative Energy Sources Components and Technologies No. 12, 2010
19. Sulaymonov Husanboy Mannopovich 2020. Mathematikal model of calclation parabola-cylindirical solar hot water systems of industrial enterprises. International Journal on Integrated Education. 3, 9 (Sep. 2020), 33-38. DOI: <https://doi.org/10.31149/ijie.v3i9.584>
20. Zaylobidinovich P. B. et al. Spectrum of the short circuit photo current of CdTe, CdTe: inphotololatic films depending on the temperature //European science review. – 2018. – T. 1. – №. 11-12. – С. 108-110.
21. Рахимов Рустам Хакимович, Эргашев Сирожиддин Фаязович, Абдурахмонов Султон Мукармович, and Нигматов Улугбек Журакузиевич. "Автоматизированная компьютерная

система измерения производительности солнечных водонагревателей с порционной подготовкой горячей воды" Computational nanotechnology, no. 1, 2017, pp. 23-26.

22. Mamadieva, D T.; Nurmatov, O R.; Raxmonov, T I.; Sulaymonov, Kh M.; and Yuldashev, N Kh (2019) "The effect of mechanical deformation on the photovoltaic properties of semiconductor polycrystalline film structures CdTe: Sn," Scientific-technical journal: Vol. 2 : Iss. 3 , Article 1
23. Rakhmonov, T I.; Siddikov, R U.; and Mirzaaxmedov, A (2021) "Influence of mechanical deformation on the photo-voltaic properties of thin polycrystalline CdTe, CdSe, CdS films manufactured by portional evaporation in vacuum," Scientific-technical journal: Vol. 4 : Iss. 3 , Article 2.
24. Sulaymonov, X M. and Yuldashev, N Kh (2020) "Elektric conductivity and strain sensitivity of semiconductor polycrystalline thin films," Scientific-technical journal: Vol. 3 : Iss. 1 , Article 6.
25. Sulaymonov, Kh. M.; Yuldashev, N. Kh.; Mamatov,, O. M.; and Mamadieva, D. T. (2020) "Edge absorption spectra of heavily doped polycrystalline PbTe: Pb and PbTe: te films," Scientific-technical journal: Vol. 24 : Iss. 2 , Article 10. <https://uzjournals.edu.uz/ferpi/vol24/iss2/10>

