Backup thermoelectric sources of electric energy

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Abstract. The article presents the rationale for the use of thermoelectric systems to provide backup power supply for actuators and automation systems for engineering systems of multistory buildings. The experiments were carried out using the developed stand, which modulated the parameters of the engineering systems of multi-storey buildings. The stand consists of a NEPS-100-220-0.03-UHL4 heating element and a CoolerMasterI30 cooler, the temperature on the sides of the thermoelectric module is controlled by a TPM-2 thermostat using a solid-state relay, the thermoelectric power value is recorded by an OVEN IMS device. F1, the electrical load is set by the resistance bridge. Temperature control of thermoelectric elements, hot and cold sides of a thermoelectric module, as well as sources of "heat" and "cold" is carried out by thermocouples, the data is recorded by the TPM138 meter-regulator. As a result of the work carried out, it was found that with the help of new technical solutions it is possible to increase the temperature on the heat exchange sides of thermoelectric modules and bring their technical parameters to the area of maximum efficiency. When organizing thermoelectric systems, it will be possible to provide backup power to the equipment used in heat points of multi-storey buildings.

1. Introduction

The process of automation of engineering systems should be mandatory for all buildings and structures, because, firstly, it is convenience and comfort, and secondly, energy saving. The main equipment of engineering systems, like the automation system itself, cannot work without electrical energy. Recently, much attention has been paid to alternative energy sources, which cannot completely replace traditional energy sources, but can ensure the stability of energy supply, compensate for network congestion during peak hours and can serve as a backup source of energy in an emergency. For these purposes, mainly use renewable resources, in the form of solar energy, wind, heat of the Earth [1]. In the period of negative temperatures, when the bulk of the energy is consumed, it becomes necessary to reliably provide electrical energy for engineering equipment [2]. It is enough to imagine the classic picture in the Irkutsk region of the last century, when the temperature drops below -30 °C. The period of negative temperatures for our region is quite long. Utilities of multi-storey buildings faced this situation and, as always, were not ready for overloads in electric networks. This was especially noticeable when energy services began to carry out “fan-shaped” outages. Despite the fact that thermal energy was supplied to houses in the required amount, the microclimate parameters in multi-storey buildings sharply worsened, and the upper floors were left without water supply. It turns out that automation can still work on internal batteries, and pumps, fans, valves and other actuators of
engineering systems cannot work without electricity. Installing wind generators and solar panels on
the roof of a multi-story building and transferring energy to the basement is very expensive. Installing
a diesel or gasoline generator in the basement, taking additional measures to prepare a room for the
storage and operation of fire hazardous materials, as well as constantly monitoring this room are also
an expensive pleasure.

We conduct our research in the field of thermoelectric energy, energy that is generated due to the
temperature difference between thermoelectric contacts that are located on opposite surfaces of
thermoelectric modules. The more one side heats up or the other cools down, the more electricity is
generated and the greater the temperature difference, the higher the efficiency of thermoelectric
soldering. The temperature difference present in engineering systems does not allow thermoelectric
modules to work with maximum efficiency. The design of thermoelectric modules assumes internal
heat losses, which are comparable to external losses, especially in the low temperature region [3].

An effective method of reducing internal heat loss is to use heat exchangers. An analysis of
scientific publications in this area showed [4-7] that the use of various designs of heat exchangers
significantly affects the efficiency of thermoelectric modules, simplifies the design of thermoelectric
systems and reduces cost. In addition, these designs allow the use of a natural resource in the form of
external cold air, which is especially effective in the winter period, precisely at a time when there is a
need for backup energy sources.

2. Materials and methods
The efficiency of thermoelectric systems is influenced by many factors, one of which is the proper
organization of heat removal. It must be taken into account that the temperature gradient in technical
systems is in a certain boundary interval when thermoelectric modules cannot work with maximum
efficiency. Mostly engineering systems are in stationary mode, their parameters change rather slowly
over a long period of time. Accordingly, when installing a thermoelectric system, the power will be
distributed from the radiators to the surrounding space, described by the following formula:

\[ P = k_i \tau_{ss0} F \]  

(1)

\[ P = k_i \tau_{ss0} F \tau_{ss0} = \frac{P}{k_i \times F} \]  

(2)

\[ k_i \] - coefficient heat transfer W/m² K.

\[ \tau_{ss0} = T_s - T_0 \] - the excess of the steady-state temperature of the heater over the environment °C.

For time t from engineering K systems thermoelectric power station it is passed to the system energy,
where

\[ Gcd \tau \] - heating of the radiator, and the value of \[ F \tau \] assigned to the environment Wednesday,
\[ G \] - mass radiator weight, kg. \( c \) - specific gravity thermal conductivity \( J / kg \cdot degree \);
\[ F \] - heat transfer area radiator height, m²; \( \tau \) - excess temperature.

Heat balance equation:

\[ P dt = Gcd \tau + F kT \tau dt \]  

(3)

For steady state temperatures this is an equation purchases next view:

\[ \delta T = \frac{P}{F_k} \left( 1 - \exp \left[ \frac{F_k \tau}{G_c} \right] \right) \]  

(4)

or:

\[ \delta T = \frac{P}{F_k} \]  

(5)
To analyze and evaluate the performance of thermoelectric systems, depending on the temperature gradient and the amount of generated energy, we developed a stand, shown in Figure 1.

Testing of thermoelectric modules was carried out at this stand, where the temperature parameters that are present in engineering systems were modulated. For experiments, the thermoelectric module (1) is placed using heat-conducting paste on a metal heating element (2) of the NEPS-100-220-0.03-UHL4 brand. The radiator from an air-cooled personal computer (3) of the brand CoolerMasterI30 is mounted on top of the thermoelectric module. The temperature on the sides of the thermoelectric module is controlled by the temperature controller TPM-2 using a solid state relay (5, 6). The thermopower value under load, which is set by the resistance bridge (7), is recorded by the OWEN device of the IC-F11.SCH1 brand (8), and the voltage value, current consumption and power are also monitored. The temperature of the thermoelectric elements, the hot and cold sides of the thermoelectric module, as well as the sources of “heat” and “cold” are controlled by thermocouples (9), the data are recorded by the TPM138 meter-controller. Data from all devices via the interface (11) is sent to a personal computer (12).

![Figure 1. Stand for evaluation efficiency thermoelectric devices systems.](image)

3. Research result

The analysis of literature data showed that there is practically no research into emergency supply of thermal stations with electric energy using alternative energy sources. We found that research in this area is not getting enough attention. In our region and other regions of our country in severe winters it is impossible to maintain housing without quality heating and water supply. High-quality operation of engineering systems is provided by additional drives controlled by automatic control systems, with minor malfunctions in electrical networks, serious problems arise during the operation of buildings.

Due to the fact that the temperature range that is present in engineering systems does not always allow the efficient use of thermoelectric modules as backup energy sources, therefore, scientists do not conduct research in this area. Our studies show that for the use of thermoelectric modules it is necessary to implement a number of technical solutions. First of all, should be considered mind that the area of thermoelectric modules is small. The material through which thermal energy is transmitted has a small mass and, accordingly, a small heat capacity. When forming a thermoelectric system, the mutual influence of the heat exchange sides affects the material, which is a source of heat or cold. Secondly, we propose using a natural resource in as of outside air to generate electrical energy. The minimum temperature that is present in engineering systems is in the range of 10 to 15 °C, and if use...
a duct system to circulate outdoor air, in winter the average temperature is in the range of minus 15 to 30 °C, this means that the temperature gradient can be increased with of 50-70°C to 80-100°C. In figure 2 shows the graphs of the generated voltage by the thermoelectric module depending on the temperature gradient and depending on the load. The graphs show that with a small temperature gradient a lower voltage is generated, which is obvious. In addition, the graphs show that with a higher temperature gradient, the voltage changes much less during an electrical load. In fact, the applied technical solutions bring thermoelectric modules into a cost-effective range of electricity production.

Figure 2. Graphs of the generated voltage by the thermoelectric module depending on the temperature gradient and depending on the load: 1- without loads; 2- s load 22 Ohm.; 3 - with load 7 Ohms.

In figure 3 shows graphs of changes in the generated power of the thermoelectric module. The graph shows that at a load of 7 ohms, the thermoelectric module generates energy of more than 3 watts. This value is recommended for charging batteries when working with solar panels, and this suggests that thermoelectric modules can be integrated into an existing service designed for solar energy.

Figure 3. Charts changes generated capacity thermoelectric equipment plugins: 1 - with load 22 Ohms.; 2-with load 7 Ohms.
Further studies in this direction showed that the creation of thermoelectric systems from several thermoelectric modules with a capacity of up to 200 W into a hot water supply system does not have a significant effect on consumers, since during operation heat is inevitably lost through pipe walls, fittings, and structural elements. The ratio of the amount of energy spent on heating water for a hot water supply system to the amount of converted energy does not exceed 1%, and the average coefficient of heat loss per square meter of an uninsulated pipeline for high-rise buildings is 12 watts / (m²K), respectively, the amount of converted energy is comparable with the error of the total losses in the pipeline.

In modern residential buildings, a storage tank and a circulation pump are installed in the hot water system, which provides the necessary pressure and circulation, which mix the cooled and heated water. To reduce money and energy costs, the heating units of modern residential buildings are equipped with automatic equipment that regulates the pressure in the hot water supply system and ensures that the circulation pump is switched on in the absence of water intake and the temperature drops below the normalized value. Field tests of the hot water supply system showed that the 600 W circulation pump installed in the residential building worked for no more than 2 hours during the day, respectively, the daily consumption was no more than 1200 W / day. After changing the design of the thermoelectric generator, the cold side of the thermoelectric module was transferred from the cold water pipeline to the radiator, as a result of which the generated emf increased by an average of 30%. This is only possible during a period of time when the temperature outside is negative. At the same time, our studies showed that the total energy consumption spent on hot water supply and lighting decreases by about the same amount [8,9].

In multi-storey buildings of modern buildings, the generated EMF from thermoelectric generators is constant. In old buildings, the magnitude of the generated EMF from thermoelectric generators is characteristic of peak hours of consumption of hot and cold water by the population. During hours when there is no active consumption of water, these houses have to wait a long time until there is no water. During the hours when active water intake is carried out, the pressure in the system does not meet the existing requirements, respectively, residents do not receive the required amount of water.

Our previous studies on the use of thermoelectric generators in hot and cold water supply systems have shown the promise of this direction [10,11]. During the experiments, a thermoelectric module was installed between the pipelines of hot and cold water supply, the generated voltage was enough to use it in LED lamps. The generated power when using automatic devices is sufficient to illuminate common areas, including stairwells, basements and surrounding areas.

4. Discussion and conclusions

From the above data it can be seen that the technical parameters provided by the thermoelectric generator coincide with the parameters necessary to ensure the operation of the circulation pump and LED lighting devices. Considering the fact that similar parameters are present in the ventilation system, sewage system and other engineering systems, it can be argued that it is possible to create an alternative power supply system, the power of which will be enough to provide energy to all devices, managing the operation of a heat point.

If look at this problem on the other hand, the proposed technical solutions for using thermoelectric generators can be used not only as an emergency or backup power source, but also as a stable DC source for powering automation devices in Smart Home systems or other devices engineering systems.

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