# ANNOTATION

of dissertation for the Philosophy Doctor (PhD) degree in specialty "6D071900 – Radioengineering, electronics and telecommunications" by Issimova Aigerim on the topic "**A device for converting mechanical vibration into an electrical signal**"

The dissertation is devoted to the study of a system for converting vibrational energy into electrical energy using an electromagnetic generator. The vibration generator converts mechanical vibrations into electrical signals. The main objective of the work is to develop an efficient system capable of converting vibration signals into electric current. The study examines the fundamental principles of electromagnetic generators and the mechanisms of vibrational energy conversion into electricity. Various types of electromagnetic generators and their applications in modern technology are described.

To achieve this goal, a system consisting of two permanent magnets and a coil was developed. An experimental study was conducted to evaluate the system's performance. The experiment was carried out within a frequency range from 2 Hz to 600 Hz, covering both low-frequency and high-frequency signals. The output signal waveform was recorded using an oscilloscope. The results demonstrated that the system efficiently converts vibration signals into electrical energy with high efficiency, and the harvester prototype can operate with broadband signals. A theoretical model of the system was developed, along with computer modeling that fully describes the harvester's operation. Numerical calculations were performed using Python. It was shown that parameters such as the recovery coefficient and self-induction play a crucial role in the effective operation of the electromagnetic energy harvesting system. Thus, the developed system can be used in various fields where vibrational energy needs to be converted into electricity, such as modern medicine (for powering sensors and various devices), as well as in industry for automation and control systems.

**Relevance of the dissertation theme**

In the past decade, extensive research has been conducted on the development of vibration energy harvesters for the Internet of Things (IoT). This is due to advances in ultra-low-power (ULP) circuit technology and the growing demand for wireless sensors. Modern wireless sensor nodes (WSN) typically use electrochemical batteries as a power source. However, conventional batteries have a limited lifespan (up to 15 years when operating at milliwatt-level currents). In some cases, replacing such batteries is either too complex or too expensive. Renewable energy sources such as solar radiation, thermal energy, and wind energy are well-studied and applicable for outdoor use. However, most of these sources are highly dependent on weather conditions and generate significantly less power indoors. This makes vibration energy harvesters a viable alternative, as vibrations are widely present in real-world environments. These devices convert mechanical oscillations into electricity. Vibration

energy harvesters are generally categorized as piezoelectric, electrostatic, and electromagnetic, depending on their operating principles, each with its own advantages and disadvantages. In recent years, vibration-based energy harvesting has been regarded as a promising technology and has attracted significant research interest due to its durability and high energy density. These qualities are crucial for power sources in wireless sensor networks used in medicine, environmental monitoring, and modern electronic products. Most vibration energy accumulators (VEUs) are designed based on a specific conversion mechanism: piezoelectric, electrostatic, electromagnetic, or triboelectric. Significant progress has been made in recent years in developing energy harvesting solutions to power wireless sensors and create self-powered systems. This not only addresses challenges related to high wiring costs and the logistical difficulties of battery replacement but also aligns with global trends toward renewable and sustainable solutions. As the importance of specialized sensors in industrial complexes continues to grow, so will the need for autonomous power supplies for such devices. Fortunately, waste energy from machinery or the environment—such as thermal energy, magnetic and electric fields, and mechanical energy—can be harvested to power sensor nodes using energy harvesting (EH) technologies. This approach significantly extends the lifespan of sensor nodes, reduces system maintenance costs, and prevents environmental pollution from battery disposal. Despite the availability of such energy sources, challenges remain in developing efficient energy harvesters that are well-suited to various vibrational environments.

**The putpose of the research**

The development of a prototype energy-efficient device for converting mechanical vibrations into electrical energy and the investigation of its characteristics.

**The object of the research**

An electromagnetic system that collects energy from vibrational oscillations, consisting of two permanent and freely moving magnets and a coil.

**The subject of the research**

The dependence of electromotive force (EMF) on the frequency of mechanical oscillations.

**Research methods**

1. Experimental investigation of the electromagnetic vibration signal system.
2. Theoretical analysis of magnet movement under mechanical influence.
3. Computer modeling of the system.

**Research objectives**

1. Development of a harvester prototype based on two permanent and freely moving magnets.

2. Creation of an experimental setup for studying the dependence of the EMF value generated by the coil on the external vibration signal.

3. Conducting experiments on the prepared setup.

4. Creating a mathematical model describing the frequency dependence of the generated energy.

5. Conducting numerical modeling and comparing its results with experimental data.

6. Studying the possibility of using the developed system in Internet of Things (IoT) systems to provide autonomous power supply for wireless sensors and monitoring devices.

**Scientific novelty of the work:**

1. An improved prototype of an electromagnetic converter has been developed, including a small-sized and freely moving magnet, which ensures high sensitivity of the system to external vibration effects.

2. During the experiments, the operating frequency of the prototype was determined, and it was found that the device has a broadband spectrum of operation, which makes it universal for various operating conditions.

3. A detailed mathematical model has been developed that allows predicting the dependence of the amount of generated electrical energy on the frequency of mechanical vibrations and the characteristics of the system.

4. The conducted studies confirmed that the proposed device can be effectively used in autonomous power supply systems for IoT sensors, providing a stable power supply without the need for traditional power sources.

**The main provisions for defense:**

1. Development and creation of a prototype converter based on the interaction of two permanent magnets freely moving in a magnetic field;

2. Creation of an experimental setup for determining the dependence of the EMF value generated along the device on the external vibration force, as well as conducting experiments;

3. Creation of a mathematical model describing the frequency dependence of the magnitude of electrical energy generated by an electromagnetic converter device. Numerical computer solution of the quantities described by the created mathematical model, as well as verification of the compliance of the results of the mathematical and computer models with the experimental results.

4. Application of an electromagnetic converter consisting of two freely moving magnets in Internet of Things systems.

**Theoretical and practical importance of the disserttion**

The results of the thesis make it possible to create a prototype of an electromagnetic vibration energy converter capable of converting the vibration energy of the environment. And the electromagnetic oscillation energy converter device can be used to power sensors from a power source and with autonomous power supply during monitoring. These theoretical principles can be used when calculating indicators in vibration energy conversion systems.

**The reliability and validity of the results**

The reliability of the results achieved in the dissertation work is confirmed by the presence of publications in local journals recommended by the Committee for Quality Assurance in Science and Higher Education of the Ministry of Science and Higher

Education of the Republic of Kazakhstan, in foreign journals included in the Web of Science (Clarivate Analytics, USA) and Scopus (Elsevier, Netherlands) databases, and in the proceedings of international conferences, as well as consistency with the results of other authors.

**The personal contribution of the author**

The author fully participated in the following research projects at all stages of the dissertation work: creating a prototype of a device for converting the energy of electromagnetic oscillations, preparing a stand for instruments necessary for conducting research, as well as conducting experimental research. It was carried out jointly with the supervisor when approving the tasks and work plan, constructing a mathematical model, calculating the computer model and analyzing the results.

**Publications**

3 scientific publications have been published on the topic of the dissertation, including 1 article in a scientific publication recommended by the Committee for Education and Science of the Republic of Kazakhstan, 1 article in the European Conference, 1 article in scientific publications included in the international information resources Scopus. In addition, there is 1 copyright certificate for the result of the work.

**Articles with a high impact factor in publications included in the Thomson Reuters database or the international scientific database Scopus:**

1. Kurt E., Issimova A., Medetov B. A wide-band electromagnetic energy harvester //Energy. – 2023. – T. 277. – C. 127693. Quartile: Q1

**Publication recommended by the Committee for Education and Science of the Republic of Kazakhstan:**

1. Исимова А.Т., Толегенова А.А., Курт Е., Медетов Б.Ж. Екі тұрақты магниттен құрастырылған электр тогының генераторы // Вестник КазНИТУ. – 2020. - №1. – С. 190 – 196

**Conference publications**

1. Kurt E., Issimova A., Medetov B. Algebraic modeling of a new elecrtomagnetic mechanical vibration energy harvester // European conference on renewable energy system. – Istambul, 2020. – p. 221-226

**Certificate of authorship**

Исимов А.Т., Медетов Б.Ж. Екі тұрақты магниттен құрастырылған электр тогының генераторы // Авторлық куәлік, 2023. №37045

**The scope and structure of the dissertation**

The dissertation consists of an introduction, 3 sections, a conclusion and a list of sources used from 110 titles, contains 88 pages of basic computer text, including 45 figures, 51 formulas and 5 tables