

ЕЛЕКТРОТЕХНІКА

UDC 621.31:537.8

DOI

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ELECTROMAGNETIC INDUCTION AS A BASIS FOR UNCONVENTIONAL METHODS OF ELECTRICITY GENERATION

This article is devoted to a very relevant issue today, which will allow solving the energy needs of humanity, namely, alternative energy. However, it is not just traditional objects of non-traditional electric power that are considered, namely the possibilities of applying the basic law of electrical engineering - the principle of electromagnetic induction. The article reveals a whole aspect of the possibilities of generating electrical energy from renewable energy sources due to electromagnetic induction, such as floating generators of electrical energy, energy of tides and waves, kinetic energy of moving objects and magnetic generators.

The phenomenon of electromagnetic induction itself is also described, it is revealed, thanks to which properties electromagnetic induction has acquired great importance for science, because this phenomenon has gained practical application in many fields of industry and science, for example: radio engineering, medicine, energy, various household appliances, wireless transmission of electricity, modern communication technologies, etc. The special significance of the application of the principle of electromagnetic induction in the alternative energy of permanent magnets is revealed.

An overview of engineering developments already existing in the world, whose activity is based on the principle of electromagnetic induction, and which have already proven their practicality and energy efficiency, is made. It has been found that capital energy projects allow significant savings on financial costs of electricity generation, which makes it possible to obtain electricity from renewable energy sources.

The principle of operation of each unit already existing in the world is described separately, the principle of operation of which is based on electromagnetic induction. The method of applying this phenomenon in the work and structure of each of them for the production of electricity from inexhaustible, renewable energy sources is disclosed. Users of scientific information are also introduced to the structure and principle of operation of a magnetic generator, which belongs to developments in the field of electrical engineering and works on permanent magnets. The article emphasizes that such a permanent magnet generator can be used for room lighting, which is especially relevant in our current conditions, and it can also be used in light industry to power production process equipment.

As a result of the conducted research, the article focuses on the fact that the population's needs for energy resources will only grow, therefore such an important discovery as the principle of electromagnetic induction will allow engineers and scientists to implement even more progressive methods of generating electrical energy due to this phenomenon.

Key words: *electromagnetic induction, magnetic generator, kinetic energy, alternative energy, wave and tidal energy, floating generator, permanent magnets.*

Formulation of the problem. The issue of energy «abundance» has always been an acute one for humanity. Rising electricity prices and the exhaustion of natural resources are forcing us to make more active use of inexhaustible energy sources, but the

existing alternative energy methods cannot fully satisfy the growing needs of humanity for electricity, as our electricity needs far exceed the volume of electricity production, so we are constantly looking for new renewable energy sources.

It is appropriate to say that most alternative energy sources, such as solar, wind, tidal and geothermal energy, exist independently of human activity, but not all of these renewable energy sources are competitive for a number of reasons: some of them occupy a large area; require significant funds for installation and operation; affect the ecological state of the environment; and depend on geographical location and climatic conditions. Therefore, the search for new, more efficient engineering solutions to the energy problem never stops.

In contrast to all existing methods of generating electricity, electromagnetic induction is breaking records in alternative energy, which is the basis of the principle of operation of existing power generation plants and new ones, which are ingenious engineering ideas that allow you to get electricity from elementary things (kinetic energy of motion and a magnetic generator).

Analysis of latest research and publications.

The principle of electromagnetic induction is of utmost importance in electrical engineering and power generation, as evidenced by a number of scientific publications. For example, in his article [8], Hermann Hartel presents an alternative approach to electromagnetic induction based on the fundamental law of electrodynamics by Wilhelm Weber. It covers mutual induction, self-induction, parallel and antiparallel currents, as well as currents in one and the opposite direction. The author points out that both approaches lead to the same quantitative results, but the conceptual difficulties are quite different.

Electromagnetic induction is widely used in technical developments in various fields of knowledge, for example, there is a description of a study in medical diagnostics to increase the output power for a given ambient oscillating magnetic field, which is based on the principle of electromagnetic induction [10].

The following article contains information about the research that focuses on the construction of the generator and the evaluation of the device to determine its possible applications and future improvements, described in [5]. The generated energy can be used in numerous applications, such as powering and charging mobile devices, powering small LEDs and light bulbs.

Another publication is devoted to a study on the fundamental principle of electromagnetic induction and its application in generators and transformers [9]. This article highlights that a series of carefully planned experiments systematically investigates the relationship between changes in magnetic

fields and induced electromotive force (EMF), and that the data collected are consistent with theoretical expectations, confirm Faraday's laws by demonstrating a direct relationship between varying magnetic fields and induced EMF, and the graphical representation further illustrates a linear relationship between the rate of change of magnetic flux and induced EMF, in accordance with Faraday's second law. The implications of these findings extend to the functioning of generators and transformers, emphasizing the role of electromagnetic induction in converting mechanical energy into electrical energy and facilitating energy transmission [9].

The application of the properties of permanent magnets proves the real possibility of application of the role of an alternative energy source. This is discussed in publications on the operation of electric generators based on permanent magnets [11]. The author of this publication scientifically substantiates that the introduction of technical solutions based on permanent magnets will significantly reduce the expenditures on electric power.

The conversion of kinetic energy of movement into mechanical energy to generate electricity is described in a number of publications: paving energy generating tiles [2], the next publication [6] is devoted to the development of a road rib that can be designed in such a way that any vehicle, from a bicycle to a truck, passing over it will generate electricity, which will then be stored on the roadside in a battery and then used to power any electrical roadside device.

How the principle of electromagnetic induction is applied in the operation of tidal power plants is described in a number of papers: [1], [3], [4].

Aim of the article. The purpose of this article is to prove the prospects of electromagnetic induction in generating electricity, since such electricity is cheap, and only coils and magnets are required for the operation of any installation for generating electricity using electromagnetic induction, and the successful experimental confirmation of Faraday's laws only enriches our understanding of the basic principles of electromagnetism and their application in the real world.

The main part of the research. A conductor with an electric current is attracted to a magnet - this is according to Ampère's physical law for a conductor with an electric current in a magnetic field. Ampère called this effect electrodynamic interaction. Based on the results of Ampère's experiments, it was found that the modulus of Ampère's force F is proportional to the length of the conductor L and depends on its position in the magnetic field. To quantitatively

describe the effect of a magnetic field on a conductor with a current, a quantity called magnetic induction was introduced (Figure 1):

$$B = F_A / I \cdot L, \quad (1)$$

where B – magnetic induction, (T); F_A – Ampère's force, (N); I – current, (A); L – length of the conductor, (m).

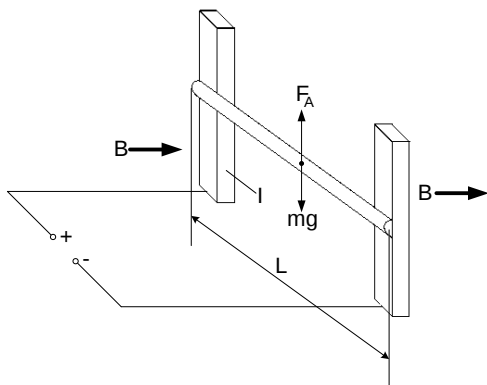


Fig. 1. Effects of the ampere force on a conductor with a current

Electromagnetic induction (Figure 2), which was discovered by Michael Faraday in 1831, is a phenomenon where any change in the magnetic flux that penetrates a closed current-carrying circuit results in an induction current in this circuit, the parameters of which depend on the rate of change in the magnetic flux.

Faraday discovered that the electromotive force that occurs in a closed conductive circuit is proportional to the rate of change of the magnetic flux through the surface bounded by this circuit.

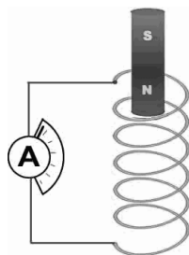


Fig. 2. The phenomenon of electromagnetic induction

It is well known that electric currents generate a magnetic field around them. The connection between the magnetic field and the current has given rise to numerous attempts to excite the current in a circuit using a magnetic field. This proves that in a closed conductive circuit, when the magnetic induction flux covered by this circuit changes, an electric current, which is called induction current, appears.

Based on the fundamental laws that characterize the properties of magnets, new technical solutions

are gaining momentum: renewable energy sources are emerging, with human knowledge and creativity contributing to their creation. It is these developments in unconventional energy based on the principle of electromagnetic induction that will be discussed below, but it should be noted that some of them are still in the research and development phase, and their technical and economic prospects are only being explored.

Electromagnetic induction is an important phenomenon in power engineering and has various applications. This phenomenon is also used in non-traditional electric power or in energy technologies that may look non-standard. One of the unconventional applications is the use of electromagnetic induction to obtain energy from various sources.

Take floating power generators as an example. Some concepts use floating structures moving in water to create vibrations that can then be used to create electrical energy through electromagnetic induction.

Another prominent example of the application of electromagnetic induction in non-conventional electricity is tidal and wave energy: some systems use the motion of tides and waves to generate oscillations that can be used to create electrical energy through electromagnetic induction.

Also kinetic energy of moving objects: the energy created by the movement of objects such as cars or bicycles, or the kinetic energy of human steps can be used to generate electrical energy through electromagnetic induction.

And finally, magnetic generators: invented and developed generators that use permanent magnets and electromagnets to create electrical energy.

Let's consider in more detail each of these types of application of electromagnetic induction for the generation of electrical energy.

Floating power generators are innovative systems that use the movement of water to generate electricity. The basic idea is that the movement of a flow, such as water, produces oscillations or mechanical motion that can be used to drive a generator of electricity.

The main components and principles of operation of floating power generators look something like this: first, it is a floating structure that can move relative to the water flow; secondly, a mechanism (it can be a wheel, turbine or other mechanical device) is placed on this floating structure, which reacts to the movement of the water flow. The mechanical movement generated by the movement of the flow is transmitted to the generator of electricity. A generator uses this mechanical motion to create rotational motion, which results in the generation of electrical energy. In some cases, a floating power generator may have a permanent energy storage element, such as a

battery or capacitor, to ensure a stable power supply when the flow becomes less intense.



Fig. 3. CorPower floating generator [8]

Floating generators are a breakthrough in unconventional electricity. They can be applied on different scales: from small mobile systems to large engineering solutions. This is only one approach to using the movement of water to generate electricity, and its implementation may vary depending on the specific project and operating conditions. For example, Sea Wave Energy Ltd (SWEL) has been working on a device that can generate energy using sea waves for more than a decade. The generator, named the Waveline Magnet, should provide decent production of clean energy at "ultra-low cost". For example, the Swedish company CorPower reported impressive results from tests of its full-scale floating generators in the Atlantic Ocean. These generators skillfully time their movements to amplify small waves while protecting themselves from dangerous storm conditions (Figure 3).

Waveline Magnet generators are long modular chains of plastic floats. Floats are located across the waves. Thus, the wave, passing under the chain, causes the modules to rise and fall.

The floats are not connected to each other, but are attached to the central longitudinal bar with the help of levers. Thanks to this, the whole structure resembles a spine with movable ribs. It is in this central part that generators are located, which convert the energy of movement into electricity (Fig. 4).



Fig. 4. Waveline Magnet floating generator [13]

The principle of electromagnetic induction using the energy of tides and waves can be implemented by a special system that uses the movement of water to create electrical energy. The basic idea is that the movement of water generates mechanical motion, which in turn is used to generate electrical energy through the principle of electromagnetic induction (Figure 5).

The main stages of this process are as follows:

The first is that the system must be located in an area with water's stream, this could be a coastal area with high tides or a place of intense waves. Further, the movement of the water leads to the mechanical movement of some parts of the installation, such as floats, fins or other mechanical elements. This movement can be caused by tides, waves, or a combination of these factors. The mechanical motion is then transmitted to the electricity generator. In this context, the generator can use electromagnetic induction – a change in the magnetic field during mechanical movement generates an electric current.



Fig. 5. The world's first tidal power plant, La Rance, France [5]

The generated electricity can be used to supply power to nearby consumers or transmitted through the power grid.

This method uses the relatively constant and predictable movement of water to create energy. Its effectiveness can depend on a number of factors, such as tidal intensity, wave patterns and installation design.

The principle of using the kinetic energy of moving objects to generate electrical energy through electromagnetic induction uses mechanisms based on a moving magnet and the joint use of Faraday's laws of electromagnetic induction.

The main stages of this process are as follows: an object with kinetic energy moves relative to another object or system, it can be a car, a bicycle, a train, the kinetic energy of human steps or any other moving object; a magnetic field is created in the area of the object's movement, this field can be created by a permanent magnet or other means; an inductor (coil)

is located near the moving object, which is connected to an electric generator; a change in the magnetic field that penetrates the coil generates an electric current in it, according to the laws of electromagnetic induction; the received electric current from the coil is fed to an electric power generator, the generator converts the mechanical energy received from the movement of the object into electric energy.

A striking example of the kinetic energy of moving objects is the energy-generating Pavegen paving slabs developed by engineer Lawrence Campbell-Cook.

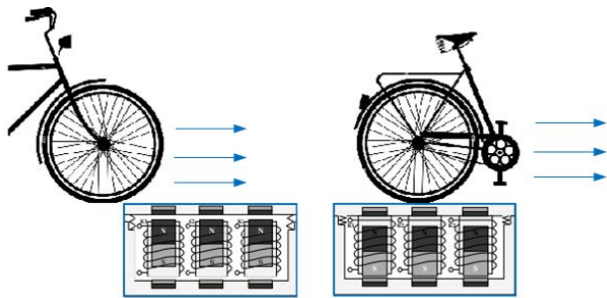


Fig. 6. The principle of operation of electric tiles

The tiles are made of a flexible, waterproof material derived from the recycling of used car tires, which makes them durable and resistant to abrasion. The tile body is made of special stainless steel. When pressed, the surface deflects by 5-10 mm, which activates an integrated converter to generate electricity. The converter technology is based on hybrid conversion, which includes the piezoelectric effect to generate electricity through deformation and electromagnetic induction. The only disadvantage is that it is inefficient to install it in places with low traffic. The principle of operation of low-power energy generating tiles is shown in Figure 6 [2].

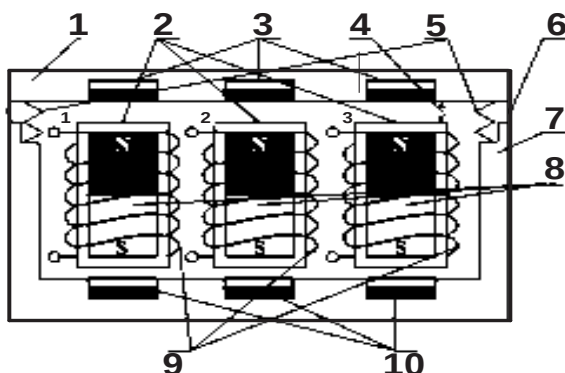


Fig. 7. Design of an electric generating tile [2, p. 69]

Figure 7 shows the design of the energy-generating tile: 1 – pressure cover; 2 – stator; 3 – neodymium magnets in the pressure cap; 4 – working stroke of the

pressure cover; 5 – springs; 6 – hermetic connection of the cover with the body; 7 – body; 8 – neodymium rotor magnets; 9 – stator coil winding (K1 – K3); 10 – neodymium magnets in the case; 11 – electric rectifier.

The resulting electrical energy can be used to power various devices or can be stored for later use, for example, in rechargeable batteries.

Consider a magnetic generator. Let's take a look at its components and principle of operation. The magnetic generator comprises a housing 1 made of a non-magnetic material, on which the cores and working windings 2 of the stator are fixedly mounted and uniformly distributed around the circumference, at least one core of the working winding 2 of the stator consists of an H-shaped magnetic circuit 3 and four bipolar permanent magnets 4, two of which are fixed on a rotor 5 made of a non-magnetic material, with a shaft 6 (Figure 8) [11, pp. 21-22].

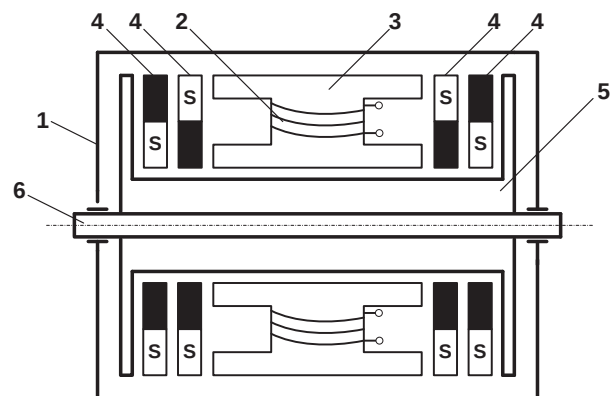


Fig. 8. Magnetic generator on permanent magnets [11, pp. 21-22]

The moving part of the generator is the rotor, which contains magnets or electromagnets. The rotor rotates around its axis. The stationary part of the generator surrounding the rotor is the stator, which contains the coils that play an important role in the process of generating electricity. The magnetic field changes, when the rotor rotates, which causes electromagnetic induction. The coils on the stator are subject to an alternating magnetic field, which generates an electric current in these coils.

In some magnetic generators, a commutator can be used to periodically change the direction of the current, i.e. to convert alternating current to direct current.

The interaction of the magnetic field, rotor and stator coils results in the induction of an electric current. This current can be output and used to power electrical appliances or stored in batteries for later use. It is important to note that such a generator

can use both permanent magnets and electromagnets powered by an electric current to generate a magnetic field.

Conclusion. Having reviewed the systems and devices designed to generate electrical energy, it can be concluded that the principle of electromagnetic induction is an extremely important discovery that has brought and will continue to bring great benefits to humanity in addressing its urgent needs.

As for the demand of the world's population for energy resources, it will not only remain extremely high, but will continue to grow, and there are unlikely to be sufficient resources to meet it, so from time to time there will be a need to look for new ways to generate electricity, and therefore there is a chance that scientists and engineers will invent even newer and more advanced ways to apply the principle of electromagnetic induction to generate electricity in large volumes.

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Антипчук Б.О., Лавріщев О.О., Новосилецький Ю.Л. ЕЛЕКТРОМАГНІТНА ІНДУКЦІЯ ЯК ОСНОВА НЕТРАДИЦІЙНИХ МЕТОДІВ ГЕНЕРАЦІЇ ЕЛЕКТРОЕНЕРГІЇ

Ця стаття присвячена досить актуальному питанню сьогодення, яке дозволить вирішити енергетичні потреби людства, а саме – альтернативній енергетиці. Проте, розглядаються не просто традиційні об'єкти нетрадиційної електроенергетики, а саме можливості застосування базового закону електротехніки – принципу електромагнітної індукції. У статті розкрито цілий аспект можливостей генерації електричної енергії з поновлювальних джерел енергії за рахунок електромагнітної індукції, таких як плаваючі генератори електричної енергії, енергія припливів та хвиль, кінетична енергія рухомих об'єктів та магнітні генератори.

Також описано саме явище електромагнітної індукції, розкрито, завдяки яким властивостям електромагнітна індукція набула величезного значення для науки, адже це явище набуло практичного застосування в багатьох галузях промисловості та науки, наприклад: радіотехніка, медицина, енергетика, різноманітні побутові прилади, безпроводна передача електроенергії, сучасні технології

комунікацій тощо. Розкрито особливе значення при застосуванні принципу електромагнітної індукції в альтернативній енергетиці постійних магнітів.

Зроблено огляд вже існуючих у світі інженерних розробок, діяльність яких базується на принципі електромагнітної індукції, та які вже довели свою практичність і енергетичну ефективність. З'ясовано, що капітальні енергетичні проекти дозволяють значно заощаджувати на фінансових витратах у генерацію електричної енергії, завдяки чому є можливість отримувати електрику з поновлювальних джерел енергії.

Описано принцип роботи вже існуючих у світі кожної установки окремо, принцип роботи яких базується на електромагнітній індукції. Розкрито методику застосування цього явища в роботі та структурі кожної з них для вироблення електрики з невичерпних, поновлювальних джерел енергії. Також ознайомлено користувачів наукової інформації з будовою та принципом роботи магнітного генератора, який відноситься до розробок в галузі електротехніки та працює на постійних магнітах. В статті зроблено акцент на те, що такий генератор на постійних магнітах можна застосовувати для освітлення приміщення, що особливо актуально в умовах нашого сьогодення, також його можна використовувати в легкій промисловості для живлення обладнання виробничих процесів.

Як підсумок проведеного дослідження, в статті зосереджено увагу на тому, що потреби населення на енергетичні ресурси будуть тільки зростати, тому таке важливе відкриття, як принцип електромагнітної індукції, дозволить інженерам та науковцям реалізувати ще більш прогресивні методи генерації електричної енергії за рахунок даного явища.

Ключові слова: електромагнітна індукція, магнітний генератор, кінетична енергія, альтернативна енергетика, енергія хвиль і припливів, плавучий генератор, постійні магніти.