Faraday's Paradox & its Solution

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This paper presents the results of our study of the Faraday paradox. It shown that conventional measurement methods in principle do not allow experimentally solve the problem of field rotation. The method of measuring the EMF we developed using field-effect transistor with insulated shutter, allowed us to prove that the rotation of the magnet is not equivalent to the rotation of the conductor around the magnetic field does not rotate with the magnet and therefore when, magnet and disc rotate together, the EMF is induced not in the wires of the measuring circuit, but only in the rotating disk.

1. Introduction

In 1831, Michael Faraday discovered a paradox: a voltmeter connected by sliding contacts to a copper disk shows voltage, not only when the disk rotates near a stationary magnet, but also when the magnet rotates with the disk. The following question arose: Where and how is the EMF induced - by the field in the rotating disk, or by the field in the fixed measuring circuit? That is a question that many researchers have so far tried unsuccessfully to answer arose: whether equivalent the rotation of the disk to the rotation of the magnet and whether the field rotates with the magnet or remains stationary [1-9]. Einstein began his article "On the Electrodynamics of Moving Bodies" with the statement that "the electrodynamic interaction between a magnet and a conductor with current ... depends only on the relative motion of the *conductor and magnet*" [10] Supporters of SRT still claim that uni-polar induction is a relativistic Effect.

2. The Cause of the Faraday Paradox

The Faraday paradox arose from the fact that conventional measuring devices do not allow us to determine where the EMF is induced - in the disk of a unipolar generator or in a measuring circuit. In order to measure the induced EMF, a voltmeter with sliding contacts is connected to a rotating disk with **two** wires. As a result of this, the rotating disk and the fixed wires form a closed contour in which the voltmeter is connected simultaneously to two branches of the contour - to a rotating disk and to a fixed measuring circuit.

In the simplest case, when the disk rotates and the magnet is stationary, the EMF is obviously induced only in the disk and the voltmeter connected to it by sliding contacts shows exactly this EMF (Fig. 1a).

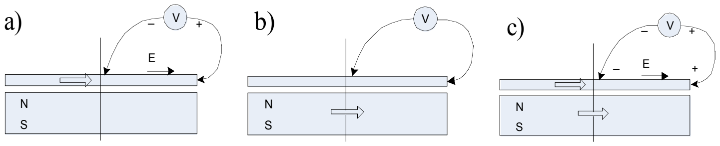

Figure 1.

The problem occurs when only the magnet rotates (Fig. 1b) or when the magnet and the disk rotate together (Fig. 1c). So, in the case of Fig. 1b, the voltmeter shows zero, but this may be because the field does not rotate and the EMF is simply not induced anywhere, or because the field rotates and therefore an equal opposing EMF is induced in the disk and in the measuring wires. In the case of Fig. 1c, the voltmeter shows the EMF, but it may be the emf that is induced in he rotating disk if the field does not rotate, or it is the EMF that is induced only in the fixed wires of the measuring circuit, if the field rotates.

In both of these cases, it is impossible to say for certain where the EMF is induced, since the voltmeter, although it is connected to the disc, shows not only the EMF of the disc, but the emf of the circuit consisting of the disc and the measuring wires.

Figure 2 shows that no attempt to somehow 'remove' the wires from the magnet field can eliminate the generation of EMF in them, since the same EMF is induced on the section of the mn wire as on the km section of the disk.

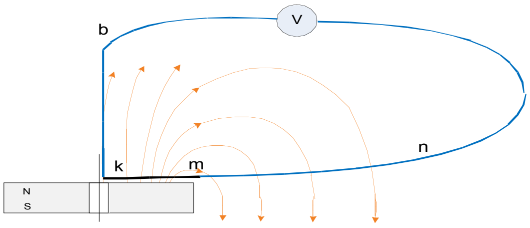

Figure 2.

One can eliminate the EMF generation in one of the wires if you take it away from the disk, strictly along the axis of rotation of the magnet (segment kb). We used this fact to create the field rotation detector described below. However, it is basically impossible to exclude emf generation in both wires simultaneously.

The concept of the circuit and the Faraday formula $E = wd\Phi / dt$ are not sufficient for the study of a unipolar generator. This formula works perfectly in all practical cases: when analyzing transformers, electromagnets, various sensors and all electrical machines, both direct and alternating current, but it turns out to be useless when analyzing unipolar devices. But in order to understand the physical meaning of the processes, it is necessary to consider each conductor separately in the circuit and use the formula for determining the EMF, E = BLV, where B is the field induction, l is the conductor length, V is the linear velocity of motion. This is well illustrated by the example of a sensor with a wire loop laid in the road surface, which gives a signal to open the gate or to switch the traffic light when a carhits it. But this sensor does not feel when a bicycle enters the circuit. Because is the weight of the bike not enough to change the quality of the circuit? Of course, but this is not entirely true. The same sensor works fine if the bike doesn't just run into the circuit, but turns out to be exactly above the groove in which the wire is laid. And this happens because it is not the circuit that actually works, but the conductors that make up this circuit. Therefore, all our studies were carried out taking into account the EMF E = BLV, induced in each individual conductor, and not in the abstract Faraday 'contour'.

3. Conductor Motion Sensor Development Relative to the Axial Magnet Field

When we researched Faraday paradox, the main goal of our research was the development of a measuring device: in order to resolve the paradox, it was necessary to find a way to measure the induced EMF separately in a rotating disk or in the measuring wires.

3.1 Conductor shielding

Our first attempt to create such a measuring device was to use a measuring loop one branch of which was shielded from the magnetic field and did not create counter-EMF (Fig. 3)

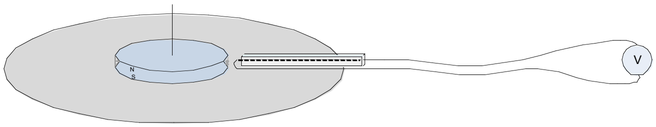

Figure 3.

The loop is fixed on a plastic disk which you can manually quickly rotate at some angle around the axis of the magnet. In the absence of a shield in both branches of a loop moving relative to the field, the same EMF is induced and the voltmeter shows a zero. We supposed that if one branch is shielded, the EMF induced in it should decrease or become equal to zero, and the device should see the difference in EMF. If it turned out that such a loop sensor responds to motion relative to the field, it could be used to detect a rotating field: if the field rotates, the sensor located near the rotating magnet should produce an EMF. Lack of EMF would prove that the field does not rotate.

However, this idea turned out to be erroneous and it turned out to be impossible to create such a sensor, because in the course of these studies we found an effect unknown to us: ferromagnetic shield that reliably protects the conductor from changing magnetic field, does not protect against EMF in the case when shielded conductor rotates relative to the axial magnet.

The most effective is the shield in which steel plates divert the field from the conductor (Fig.4). A Hall sensor placed inside such shield shows that when the magnet approaches, there is practically no field inside the shield. The reed switch placed inside this shield also does not work.

Figure 4.

However, when a conductor with such shield rotates relative to an axial magnet, in both cases — when the conductor is placed in the shield or when there is no shield — the same EMF is induced in the conductor.

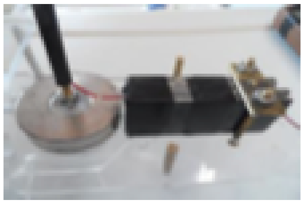

Figure 5.

In Figure 5, when a conductor with a shield is quickly turned, the EMF is induced on a section of a conductor moving over a magnet, but the same opposite EMF is induced on a section of a wire placed inside the shield and the resulting EMF of the circuit is zero. According to this scheme, we tested a variety of shields and in all cases the voltmeter showed no signal.

During these studies, we discovered another effect: with an increase in the magnet rotation speed, its induction B decreases and already at a rotation speed of 3000 rpm, at different points near the magnet, this decrease amounts to several percent

3.2 Detector with field effect transistor

To prove that when the axial magnet rotates, its field does not rotate and remains stationary relative to the inertial frame, we succeeded with the help of the detector developed by the field-effect transistor with an insulated gate, which allowed us to unambiguously determine that the induced EMF is induced only in the disk, and is not induced in the fixed measuring wires.

We managed to create such a detector, using our idea of measuring the potential with a voltmeter connected 'at one end'.

Такой детектор нам удалось создать, использовав нашу идею измерения потенциала с подключением вольтметра «одним концом»:

A single conductor feeds the potential of the point at which we want to detect an electric charge to the gate of the field-effect transistor, which is the first amplification stage; then the signal is amplified by an operational amplifier and fed to a voltmeter.

3.3 The principle of operation of the detector

When the disk rotates relative to a fixed axial magnet, it induces an EMF E = BLV. Under the action of this EMF, depending on the direction of rotation, the electrons shift to the axis of rotation or to the edge of the disk. When the disk is rotated by hand near the neodymium magnet, the potential difference between the center of the disk and its edge is fractions or units of millivolts.

If the electrons are displaced, for example, to the center of the disk, this means that a negative potential is created at point m in Fig. 6.

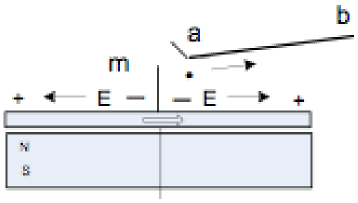

Figure 6.

We were able to detect this potential using a MDP transistor (an insulated gate field-effect transistor) using its main property - a very large input resistance.

If to connect an additional conductor **ab**, which is connected with the gate of the transistor, to the charged point m, the charge of point m decreases, since a part of theb charge flows to th.ae gate. But since the charge on the gate changes, a signal appears at the output of mthe cascade on the MDP transistor, which is then amplified by the operational amplifier and fed to a voltmeter. Obviously, the charge of point m decreases the smaller, +EE+ the more massive the copper disk, the shorter the conductor **ab** and the larger the input resistance of the transistor.

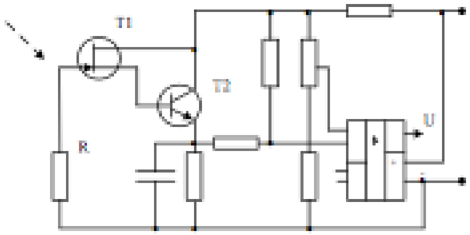

Figure 7.

Since the connection of the measuring probe (conductor ab) greatly changes the charge at point m, the voltage at the amplifier output is not proportional to the EMF of the disk. That is, this detector does not measure the EMF, but only allows you to determine the fact whether the EMF is induced in the disk or in the drive.

The amplifier has a large gain and therefore the detector is very sensitive to interference. But since we are only interested in the DC signal, the main noise, which is the AC noise, is suppressed simply by introducing flexible negative feedback (capacitive OS).

Multimeter 10039S as an EMF Detector

To detect the EMF induced in a rotating or stationary disk, as well as in conductor moving near a magnet or fixed, even a conventional multimeter type 10030S allows, because its input resistance is large enough to detect the presence of induced EMF in unipolar generator.

Fig. 8 shows an extremely simple setup, in which we, rotating the disk with our hand, carried out many measurements with the help of this multimeter.

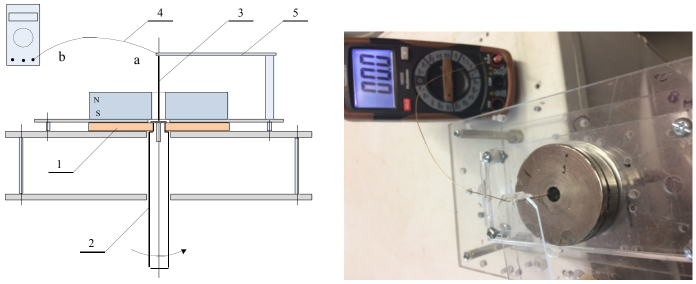

Figure 8.

The aluminum disk 1 with a thickness of 5 mm is fixed on the shaft 2. A fixed neodymium magnet with a diameter of 50 mm is located above the disk. The potential formed in the center of the disk is transmitted hrough a fixed needle 3, and a short thin conductor ab (4), to the multi-meter. The needle is held in a vertical position with a plastic stop 5. The detector probe moves away from the center of the disk along the axis of the magnet and therefore no EMF is induced in it. The amplifier responds to the potential that is created only by the EMF induced in the drive.

At the moment when the shaft begins to rotate by hand, an EMF of about 0.2–0.4 milli-volts arises on the disk (we can see the same value of EMF by connecting this or another device to the disk with two conductors). The multi-meter shows the values of the EMF, close to 0.2-0.4 mV only at the moment when the rotation starts and the EMF appears, but then, when the charges drain from the disk, the signal becomes equal to zero. That is, due to the fact that the input impedance of the detector is not infinitely large, it actually reacts, not to the EMF itself, but to its derivative - the signal at the output of this detector appears only when the induction EMF changes. But this signal is quite enough to claim that the emf is induced in the disk.

Similarly, this detector can measure the potential of the inner end of a conductor rotating around a magnet. When the **conductor rotates above fixed magnet** (Fig.9, a), an EMF is induced in it. The detector connected to the end drawn along the axis of rotation (at the point m) sees this EMF and generates a signal.

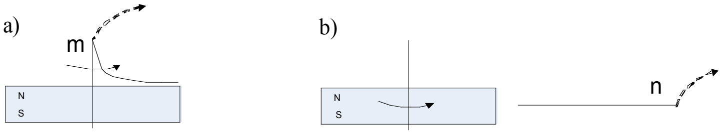

Figure 9.

An EMF is induced in conductor when it passes a motionless magnet or rotates by hand at some angle around fixed magnet. Detector connected to one end of a conductor confidently responds to the changes of potential.

However, in the case when the conductor (or disk) is stationary and the **magnet rotates**, **the detector does not produce any signal either when the magnet accelerates or at a constant rotational speed**, which unequivocally proves the motionless field.

The signal of detector also **turns out to be zero** if the disk is fixed in the setup of Fig. 8 and the **magnet is rotated** - the rotating magnet does not induce an EMF in a fixed disk since the **fiekd does not rotate**.

?. Conclusion

The field-effect transistor detector developed by us made it possible to determine exactly where the EMF is induced in a unipolar generator - in a disk or in a measuring circuit, and to prove that the EMF

* is induced only in the disk when it rotates relative to a stationary or rotating magnet, but is not induced either in a fixed disk or in a fixed measuring circuit, when only the magnet rotates.
* This made it possible to unambiguously solve the Faraday paradox and conclude that the rotation of the magnet is not equivalent to the rotation of the conductor and that the field does not rotate with the magnet, but remains motionless relative to the inertial frame, just as the orbits of satellites launched from the Earth remain stationary rather than rotate with the Earth. The nonequivalence of the movements of the magnet and the conductor proves that unipolar induction is not a relativistic effect but has a purely classical explanation.

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