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# Unipolar Induction in the Concept of the Scalar-Vector Potential

F. F. Mende <sup>α</sup> & A. S. Dubrovin <sup>ο</sup>

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## I. INTRODUCTION

The unipolar induction was discovered still By faradeem almost 200 years ago [1], but in the classical electrodynamics of final answer to that as and why work some constructions of unipolar generators, there is no up to now. Is separately incomprehensible the case, when there is a revolving magnetized conducting cylinder, during motion of which between the fixed contacts, connected to its axis and generatrix, appears emf. Is still more incomprehensible the case, when together with the cylindrical magnet revolves the conducting disk, which does not have galvanic contact with the magnet, but fixed contacts are connected to the axis of disk and its generatrix. In some sources it is indicated that the answer can be obtained within the framework special relativity (SR), but there are no concrete references, as precisely SR explain the cases indicated. Let us show that the concrete answers to all these questions can be obtained within the framework the concept of scalar- vector potential. This concept, obtained from the symmetrical laws of induction, assumes the dependence of the scalar potential of charge and pour on it from the charge rate.

## II. CONCEPT OF SCALAR-VECTOR POTENTIAL

The Maxwell equations do not give the possibility to write down fields in the moving coordinate systems, if fields in the fixed system are known [2]. This

problem is solved with the aid of the Lorenz conversions, however, these conversions from the classical electrodynamics they do not follow. Question does arise, is it possible with the aid of the classical electrodynamics to obtain conversions fields on upon transfer of one inertial system to another, and if yes, then, as must appear the equations of such conversions. Indications of this are located already in the law of the Faraday induction. Let us write down Faraday:

$$\oint \vec{E}' d \vec{l}' = - \frac{d \Phi_B}{d t} \quad (2.1)$$

As is evident in contrast to Maxwell equations in it not particular and substantive (complete) time derivative is used.

The substantial derivative in relationship (2.1) indicates the independence of the eventual result of appearance emf in the outline from the method of changing the flow, i.e. flow can change both due to the local time derivative of the induction of and because the system, in which is measured , it moves in the three-dimensional changing field . The value of magnetic flux in relationship (2.1) is determined from the relationship

$$\Phi_B = \int \vec{B} d \vec{S}' \quad (2.2)$$

where the magnetic induction  $\vec{B} = \mu \vec{H}$  is determined in the fixed coordinate system, and the element  $d \vec{S}'$  is determined in the moving system. Taking into account (2.2), we obtain from (2.1)

$$\oint \vec{E}' d \vec{l}' = - \frac{d}{d t} \int \vec{B} d \vec{S}', \quad (2.3)$$

and further, since  $\frac{d}{d t} = \frac{\partial}{\partial t} + \vec{v} \text{ grad}$  , let us write down [3-6]

$$\oint \vec{E}' d \vec{l}' = - \int \frac{\partial \vec{B}}{\partial t} d \vec{S} - \int [\vec{B} \times \vec{v}] d \vec{l}' - \int \vec{v} d \vec{v} \cdot \vec{B} d \vec{S}' \quad (2.4)$$

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In this case contour integral is taken on the outline  $d\vec{l}'$ , which covers the area  $d\vec{S}'$ . Let us immediately note that entire following presentation will be conducted under the assumption the validity of the Galileo conversions, i.e.,  $d\vec{l}' = d\vec{l}$  and  $d\vec{S}' = d\vec{S}$ . From relationship (2.6) follows

$$\vec{E}' = \vec{E} + [\vec{v} \times \vec{B}]. \quad (2.5)$$

If both parts of equation (2.6) are multiplied by the charge, then we will obtain relationship for the Lorentz force

$$\vec{F}'_L = e \vec{E} + e [\vec{v} \times \vec{B}]. \quad (2.6)$$

Thus, Lorentz force is the direct consequence of the law of magnetoelectric induction.

For explaining physical nature of the appearance of last term in relationship (2.5) let us write down  $\vec{B}$  and  $\vec{E}$  through the magnetic vector potential  $\vec{A}_B$ :

$$\vec{B} = \text{rot } \vec{A}_B, \quad \vec{E} = -\frac{\partial \vec{A}_B}{\partial t}. \quad (2.7)$$

Then relationship (2.5) can be rewritten

$$\vec{E}' = -\frac{\partial \vec{A}_B}{\partial t} + [\vec{v} \times \text{rot } \vec{A}_B] \quad (2.8)$$

and further

$$\vec{E}' = -\frac{\partial \vec{A}_B}{\partial t} - (\vec{v} \nabla) \vec{A}_B + \text{grad } (\vec{v} \vec{A}_B) \quad (2.9)$$

The first two members of the right side of equality (2.9) can be gathered into the total derivative of vector potential on the time, namely:

$$\vec{E}' = -\frac{d \vec{A}_B}{d t} + \text{grad } (\vec{v} \vec{A}_B). \quad (2.10)$$

From relationship (2.9) it is evident that the field strength, and consequently also the force, which acts on the charge, consists of three parts.

First term is obliged by local time derivative.

The sense of second term of the right side of relationship (2.9) is also intelligible. It is connected with a change in the vector potential, but already because charge moves in the three-dimensional changing field of this potential. Other nature of last term of the right side of relationship (2.9). It is connected with the presence of

potential forces, since. potential energy of the charge, which moves in the potential field  $\vec{A}_B$  with the speed  $\vec{v}$ , is equal  $e (\vec{v} \vec{A}_B)$ . The value  $e \text{grad } (\vec{v} \vec{A}_B)$  gives force, exactly as gives force the gradient of scalar potential.

Taking rotor from both parts of equality (2.10) and taking into account that  $\text{rot grad} = 0$ , we obtain

$$\text{rot } \vec{E}' = -\frac{d \vec{B}}{d t}. \quad (2.11)$$

If there is no motion, then relationship (2.11) is converted into the Maxwell first equation. Relationship (2.11) is more informative than Maxwell equation

$$\text{rot } \vec{E} = -\frac{\partial \vec{B}}{\partial t}.$$

Since in connection with the fact that  $\text{rot grad} = 0$ , in Maxwell equation there is no information about the potential forces, designated through  $e \text{grad } (\vec{v} \vec{A}_B)$ .

Let us write down the amount of Lorentz force in the terms of the magnetic vector potential:

$$\vec{F}'_L = e \vec{E} + e [\vec{v} \times \text{rot } \vec{A}_B] = e \vec{E} - e (\vec{v} \nabla) \vec{A}_B + e \text{grad } (\vec{v} \vec{A}_B) \quad (2.12)$$

Is more preferable, since the possibility to understand the complete structure of this force gives.

Faraday law (2.2) is called the law of electromagnetic induction, however this is terminological error. This law should be called the law of magnetoelectric induction, since the appearance of electrical fields on by a change in the magnetic caused fields on.

However, in the classical electrodynamics there is no law of magnetoelectric induction, which would show, how a change in the electrical fields on, or motion in them, it leads to the appearance of magnetic fields on. The development of classical electrodynamics followed along another way. Ampere law was first introduced:

$$\oint \vec{H} d \vec{l} = I, \quad (2.13)$$

where  $I$  is current, which crosses the area, included by the outline of integration. In the differential form relationship (2.13) takes the form:

$$\text{rot } \vec{H} = \vec{j}_\sigma, \quad (2.14)$$

where  $j_\sigma$  is current density of conductivity.

Maxwell supplemented relationship (2.14) with bias current

$$\text{rot } \vec{H} = \vec{j}_\sigma + \frac{\partial \vec{D}}{\partial t}. \quad (2.15)$$

If we from relationship (2.15) exclude conduction current, then the integral law follows from it

$$\oint \vec{H} d\vec{l} = \frac{\partial \Phi_D}{\partial t}, \quad (2.16)$$

where  $\Phi_D = \int \vec{D} d\vec{S}$  the flow of electrical induction.

If we in relationship (2.16) use the substantial derivative, as we made during the writing of the Faraday law, then we will obtain [1-10]:

$$\oint \vec{H}' d\vec{l}' = \int \frac{\partial \vec{D}}{\partial t} d\vec{S} + \oint [\vec{D} \times \vec{v}] d\vec{l}' + \int \vec{v} d\vec{v} \vec{D} d\vec{S}'. \quad (2.17)$$

In contrast to the magnetic fields, when  $\text{div} \vec{B} = 0$ , for the electrical fields on  $\text{div} \vec{D} = \rho$  and last term in the right side of relationship (2.8) it gives the conduction current of and from relationship (2.7) the Ampere law immediately follows. In the case of the absence of conduction current from relationship (2.17) the equality follows:

$$\vec{H}' = \vec{H} - [\vec{v} \times \vec{D}]. \quad (2.18)$$

As shown in the work [2], from relationship (2.18) follows and Bio-Savara law, if for enumerating the magnetic fields on to take the electric fields of the moving charges. In this case the last member of the right side of relationship (2.17) can be simply omitted, and the laws of induction acquire the completely symmetrical form [6]

$$\begin{aligned} \oint \vec{E}' d\vec{l}' &= -\int \frac{\partial \vec{B}}{\partial t} d\vec{S} + \oint [\vec{v} \times \vec{B}] d\vec{l}' \vec{H} \\ \oint \vec{H}' d\vec{l}' &= \int \frac{\partial \vec{D}}{\partial t} d\vec{S} - \oint [\vec{v} \times \vec{D}] d\vec{l}' \vec{H}' \end{aligned} \quad (2.19)$$

or

$$\begin{aligned} \text{rot} \vec{E}' &= -\frac{\partial \vec{B}}{\partial t} + \text{rot} [\vec{v} \times \vec{B}] \\ \text{rot} \vec{H}' &= \frac{\partial \vec{D}}{\partial t} - \text{rot} [\vec{v} \times \vec{D}] \end{aligned} \quad (2.20)$$

For dc fields on these relationships they take the form:

$$\begin{aligned} \vec{E}' &= [\vec{v} \times \vec{B}] \\ \vec{H}' &= -[\vec{v} \times \vec{D}] \end{aligned} \quad (2.21)$$

In relationships (2.19-2.21), which assume the validity of the Galileo conversions, prime and not prime

values present fields and elements in moving and fixed inertial reference system (IS) respectively. It must be noted, that conversions (2.21) earlier could be obtained only from the Lorenz conversions.

The relationships (2.19-2.21), which present the laws of induction, do not give information about how arose fields in initial fixed IS. They describe only laws governing the propagation and conversion fields on in the case of motion with respect to the already existing fields.

The relationship (2.21) attest to the fact that in the case of relative motion of frame of references, between the fields  $\vec{E}$  and  $\vec{H}$  there is a cross coupling, i.e. motion in the fields  $\vec{H}$  leads to the appearance fields on  $\vec{E}$  and vice versa. From these relationships escape the additional consequences, which were for the first time examined in the work.

The electric field  $E = \frac{g}{2\pi\epsilon r}$  outside the charged long rod with a linear density  $g$  decreases as  $\frac{1}{r}$ , where  $r$  is distance from the central axis of the rod to the observation point.

If we in parallel to the axis of rod in the field  $E$  begin to move with the speed  $\Delta v$  another IS, then in it will appear the additional magnetic field  $\Delta H = \epsilon E \Delta v$ . If we now with respect to already moving IS begin to move third frame of reference with the speed  $\Delta v$ , then already due to the motion in the field  $\Delta H$  will appear additive to the electric field  $\Delta E = \mu \epsilon E (\Delta v)^2$ . This process can be continued and further, as a result of which can be obtained the number, which gives the value of the electric field  $E'_v(r)$  in moving IS with reaching of the speed  $v = n\Delta v$ , when  $\Delta v \rightarrow 0$ , and  $n \rightarrow \infty$ . In the final analysis in moving IS the value of dynamic electric field will prove to be more than in the initial and to be determined by the relationship [7]:

$$E'(r, v_\perp) = \frac{gch \frac{v_\perp}{c}}{2\pi\epsilon r} = Ech \frac{v_\perp}{c}.$$

If speech goes about the electric field of the single charge  $e$ , then its electric field will be determined by the relationship:

$$E'(r, v_\perp) = \frac{ech \frac{v_\perp}{c}}{4\pi\epsilon r^2},$$

where  $v_\perp$  is normal component of charge rate to the vector, which connects the moving charge and observation point.

Expression for the scalar potential, created by the moving charge, for this case will be written down as follows:

$$\varphi'(r, v_{\perp}) = \frac{ech \frac{v_{\perp}}{c}}{4\pi\epsilon r} = \varphi(r) ch \frac{v_{\perp}}{c}, \quad (2.22)$$

where  $\varphi(r)$  is scalar potential of fixed charge. The potential  $\varphi'(r, v_{\perp})$  can be named scalar-vector, since it depends not only on the absolute value of charge, but also on speed and direction of its motion with respect to the observation point. Maximum value this potential has in the direction normal to the motion of charge itself. Moreover, if charge rate changes, which is connected with its acceleration, then can be calculated the electric fields, induced by the accelerated charge.

During the motion in the magnetic field, using the already examined method, we obtain:

$$H'(v_{\perp}) = Hch \frac{v_{\perp}}{c}.$$

where  $v_{\perp}$  is speed normal to the direction of the magnetic field.

If we apply the obtained results to the electromagnetic wave and to designate components fields on parallel speeds IS as  $E_{\uparrow}$ ,  $H_{\uparrow}$ , and  $E_{\perp}$ ,  $H_{\perp}$  as components normal to it, then with the conversion fields on components, parallel to speed will not change, but components, normal to the direction of speed are converted according to the rule

$$\begin{aligned} \vec{E}'_{\perp} &= \vec{E}_{\perp} ch \frac{v}{c} + \frac{v}{c} \vec{v} \times \vec{B}_{\perp} sh \frac{v}{c}, \\ \vec{B}'_{\perp} &= \vec{B}_{\perp} ch \frac{v}{c} - \frac{1}{vc} \vec{v} \times \vec{E}_{\perp} sh \frac{v}{c}, \end{aligned} \quad (2.23)$$

$$\Delta U = AU \Delta v \begin{pmatrix} 0 & 0 & 0 & -1 \\ 0 & 0 & 1 & 0 \\ 0 & 1/c^2 & 0 & 0 \\ -1/c^2 & 0 & 0 & 0 \end{pmatrix} U = \begin{pmatrix} E_y \\ E_z \\ B_y \\ B_z \end{pmatrix}$$

If one assumes that the speed of system is summarized for the classical law of addition of velocities, i.e. the speed of final IS  $K'=K_N$  relative to the initial system  $K$  is  $v=N\Delta v$ , then we will obtain the matrix system of the differential equations of

$$\frac{dU(v)}{dv} = AU(v), \quad (2.27)$$

where  $c$  is speed of light.

Conversions fields (2.23) they were for the first time obtained in the work [8].

However, the iteration technique, utilized for obtaining the given relationships, it is not possible to consider strict, since its convergence is not explained. Let us give a stricter conclusion in the matrix form [7].

Let us examine the totality IS of such, that IS  $K_1$  moves with the speed  $\Delta v$  relative to IS  $K$ , IS  $K_2$  moves with the same speed  $\Delta v$  relative to  $K_1$ , etc. If the module of the speed  $\Delta v$  is small (in comparison with the speed of light  $c$ ), then for the transverse components fields on in IS  $K_1, K_2, \dots$  we have:

$$\begin{aligned} \vec{E}'_{1\perp} &= \vec{E}_{\perp} + \Delta \vec{v} \times \vec{B}_{\perp} & \vec{B}'_{1\perp} &= \vec{B}_{\perp} - \Delta \vec{v} \times \vec{E}_{\perp} / c^2 \\ \vec{E}'_{2\perp} &= \vec{E}'_{1\perp} + \Delta \vec{v} \times \vec{B}'_{1\perp} & \vec{B}'_{2\perp} &= \vec{B}'_{1\perp} - \Delta \vec{v} \times \vec{E}'_{1\perp} / c^2 \end{aligned} \quad (2.24)$$

Upon transfer to each following IS of field are obtained increases in  $\Delta \vec{E}$  and  $\Delta \vec{B}$

$$\Delta \vec{E} = \Delta \vec{v} \times \vec{B}_{\perp}, \quad \Delta \vec{B} = -\Delta \vec{v} \times \vec{E}_{\perp} / c^2, \quad (2.25)$$

where of the field  $\vec{E}_{\perp}$  and  $\vec{B}_{\perp}$  relate to current IS. Directing Cartesian axis  $x$  along  $\Delta \vec{v}$ , let us rewrite (4.7) in the components of the vector

$$\Delta E_y = -B_z \Delta v, \quad \Delta E = B_y \Delta v, \quad \Delta B_y = E_z \Delta v / c^2. \quad (2.26)$$

Relationship (2.26) can be represented in the matrix form

with the matrix of the system  $v$  independent of the speed  $A$ . The solution of system is expressed as the matrix exponential curve  $\exp(vA)$ :

$$U' \equiv U(v) = \exp(vA)U, \quad U = U(0), \quad (2.28)$$

here  $U$  is matrix column fields on in the system  $K$ , and  $U'$  is matrix column fields on in the system  $K'$ . Substituting (2.28) into system (2.27), we are convinced, that  $U'$  is actually the solution of system (2.27):

$$\frac{dU(v)}{dv} = \frac{d[\exp(vA)]}{dv} U = A \exp(vA) U = AU(v).$$

It remains to find this exponential curve by its expansion in the series:

$$\exp(va) = E + vA + \frac{1}{2!}v^2 A^2 + \frac{1}{3!}v^3 A^3 + \frac{1}{4!}v^4 A^4 + \dots$$

where  $E$  is unit matrix with the size  $4 \times 4$ . For this it is convenient to write down the matrix  $A$  in the unit type form

$$A = \begin{pmatrix} 0 & -\alpha \\ \alpha/c^2 & 0 \end{pmatrix}, \quad \alpha = \begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix}, \quad 0 = \begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix}.$$

then

$$A^2 = \begin{pmatrix} -\alpha^2/c^2 & 0 \\ 0 & -\alpha/c^2 \end{pmatrix}, \quad A^3 = \begin{pmatrix} 0 & \alpha^3/c^2 \\ -\alpha^3/c^4 & 0 \end{pmatrix},$$

$$A^4 = \begin{pmatrix} \alpha^4/c^4 & 0 \\ 0 & \alpha^4/c^4 \end{pmatrix}, \quad A^5 = \begin{pmatrix} 0 & -\alpha^5/c^4 \\ \alpha^5/c^6 & 0 \end{pmatrix} \dots$$

And the elements of matrix exponential curve take the form

$$[\exp(vA)]_{11} = [\exp(vA)]_{22} = I - \frac{v^2}{2!c^2} + \frac{v^4}{4!c^4} - \dots,$$

$$[\exp(vA)]_{21} = -c^2 [\exp(vA)]_{12} = \frac{\alpha}{c} \left( \frac{v}{c} I - \frac{v^3}{3!c^3} + \frac{v^5}{5!c^5} - \dots \right),$$

$$E'_y = E_y ch \ v / c - cB_z sh \ v / c,$$

$$E'_z = E_z ch \ v / c + cB_y sh \ v / c,$$

$$B'_y = B_y ch \ v / c + (E_z/c) sh \ v / c,$$

$$B'_z = B_z ch \ v / c - (E_y/c) sh \ v / c$$

or in the vector record

$$\vec{E}'_{\perp} = \vec{E}_{\perp} ch \ \frac{v}{c} + \frac{v}{c} \vec{v} \times \vec{B}_{\perp} sh \ \frac{v}{c},$$

$$\vec{B}'_{\perp} = \vec{B}_{\perp} ch \ \frac{v}{c} - \frac{1}{vc} \vec{v} \times \vec{E}_{\perp} sh \ \frac{v}{c},$$
(2.29)

This is conversions (2.23).

### III. UNIPOLAR INDUCTION IN THE CONCEPT OF THE SCALAR-VECTOR POTENTIAL

Let us examine the case, when there is a single long conductor, along which flows the current. We will as before consider that in the conductor is a system of the mutually inserted charges of the positive lattice  $g^+$  and free electrons  $g^-$ , which in the absence current neutralize each other (Fig.1).

where  $I$  is the unit matrix  $2 \times 2$ . It is not difficult to see that  $-\alpha^2 = \alpha^4 = -\alpha^6 = \alpha^8 = \dots = I$ , therefore we finally obtain

$$\exp(vA) = \begin{pmatrix} Ich \ v/c & -csh \ v/c \\ (ash \ v/c)/c & Ich \ v/c \end{pmatrix} =$$

$$\begin{pmatrix} ch \ v/c & 0 & 0 & -csh \ v/c \\ 0 & ch \ v/c & csh \ v/c & 0 \\ 0 & (ch \ v/c)/c & ch \ v/c & 0 \\ -(sh \ v/c)/c & 0 & 0 & ch \ v/c \end{pmatrix}.$$

Substituting there  $\exp(vA)$ , we find

$$E^+ = \frac{g^+}{2\pi\epsilon r}. \quad (3.1)$$

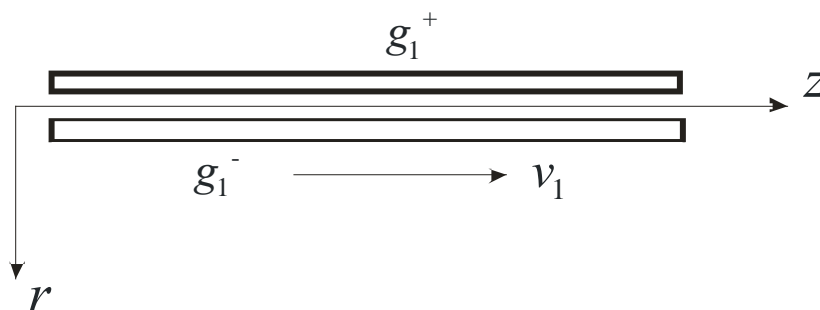


Fig. 1 : Section is the conductor, along which flows the current.

We will consider that the direction of the vector of electric field coincides with the direction  $r$ . If electronic flux moves with the speed, then the electric field of this flow is determined by the equality

$$E^- = -\frac{g^-}{2\pi\epsilon r} ch \frac{v_1}{c} \cong -\frac{g^-}{2\pi\epsilon r} \left( 1 + \frac{1}{2} \frac{v_1^2}{c^2} \right) \quad (3.2)$$

Adding (3.1) (3.2), we obtain:

$$E^- = -\frac{g^- v_1^2}{4\pi\epsilon c^2 r}$$

This means that around the conductor with the current is an electric field, which corresponds to the negative charge of conductor. However, this field has insignificant value, since in the real conductors. This field can be discovered only with the current densities, which

can be achieved in the superconductors, which is experimentally confirmed in works.

Let us examine the case, when very section of the conductor, on which with the speed  $v_1$  flow the electrons, moves in the opposite direction with speed  $v$  (Fig. 2). In this case relationships (3.1) and (3.2) will take the form

$$E^+ = \frac{g^+}{2\pi\epsilon r} \left( 1 + \frac{1}{2} \frac{v^2}{c^2} \right), \quad (3.3)$$

$$E^- = -\frac{g^-}{2\pi\epsilon r} \left( 1 + \frac{1}{2} \frac{(v_1 - v)^2}{c^2} \right) \quad (3.4)$$

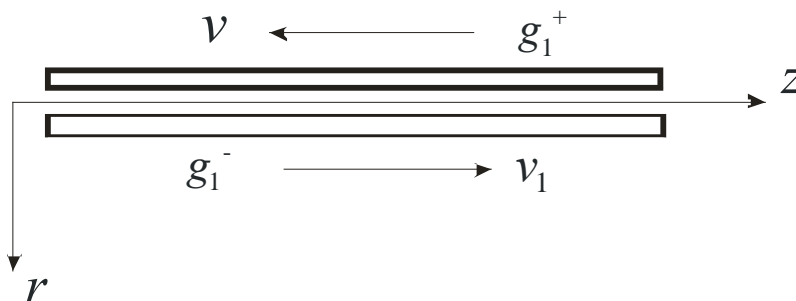


Fig. 2 : Moving conductor with the current

.Adding (3.3) and (3.4), we obtain:

$$E^+ = \frac{g}{2\pi\epsilon r} \left( \frac{v_1 v}{c^2} - \frac{1}{2} \frac{v_1^2}{c^2} \right) \quad (3.5) \quad E^+ = \frac{g v_1 v}{2\pi\epsilon c^2 r} \quad (3.6)$$

In this relationship as the specific charge is undertaken its absolute value. since the speed of the mechanical motion of conductor is considerably more than the drift velocity of electrons, the second term in the brackets can be disregarded. In this case from (3.5) we obtain

The obtained result means that around the moving conductor, along which flows the current, with respect to the fixed observer is formed the electric field, determined by relationship (3.6), which is equivalent to appearance on this conductor of the specific positive charge of the equal

$$g^+ = \frac{gv_1v}{c^2}.$$

If we conductor roll up into the ring and to revolve it then so that the linear speed of its parts would be equal  $v$ , then around this ring will appear the electric field, which corresponds to the presence on the ring of the specific charge indicated. But this means that the

revolving turn, which is the revolving magnet, acquires specific electric charge on wire itself, of which it consists. During the motion of linear conductor with the current the electric field will be observed with respect to the fixed observer, but if observer will move together with the conductor, then such fields will be absent.

As is obtained the unipolar induction, with which on the fixed contacts a potential difference is obtained, it is easy to understand from Fig. 3.

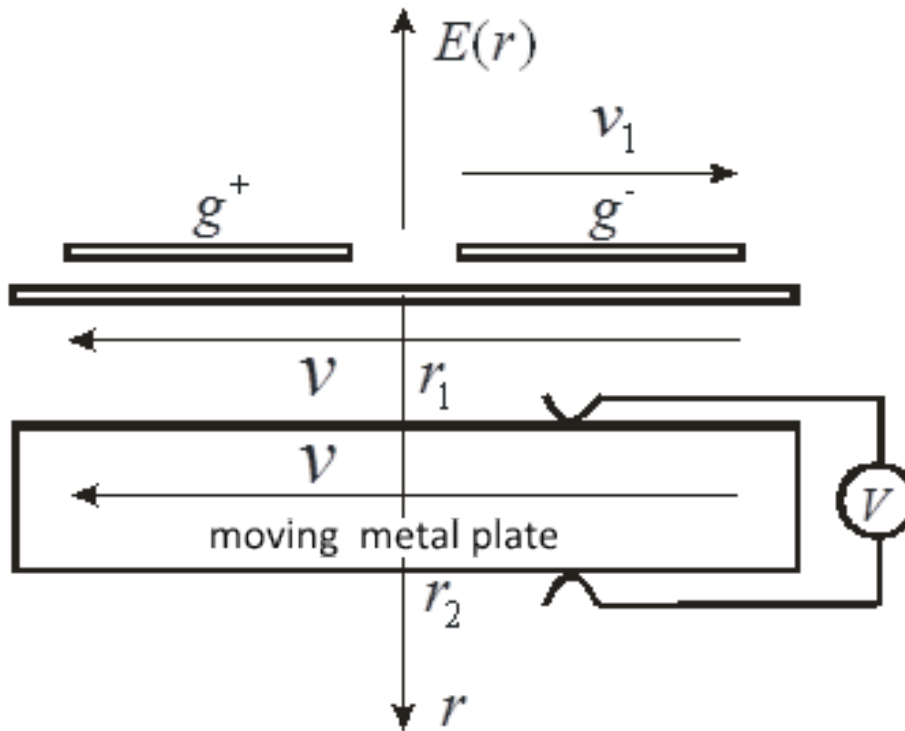


Fig. 3 : Diagram of formation emf. unipolar induction.

We will consider that  $r_1$  and  $r_2$  of the coordinate of the points of contact of the tangency of the contacts, which slide along the edges of the metallic plate, which moves with the same speed as the conductor, along which flows the current. Contacts are connected to the voltmeter, which is also fixed. Then, it is possible to calculate a potential difference between these contacts, after integrating relationship (3.6):

$$U = \frac{gv_1v}{2\pi\epsilon c^2} \int_{r_1}^{r_2} \frac{dr}{r} = \frac{gv_1v}{2\pi\epsilon c^2} \ln \frac{r_2}{r_1}.$$

But in order to the load, in this case to the voltmeter, to apply this potential difference, it is necessary sliding contacts to lock by the cross connection, on which there is no potential difference indicated. But since metallic plate moves together with the conductor, a potential difference is absent on it. It serves as that cross connection, which gives the possibility to convert this composite outline into the source emf with respect to the voltmeter.



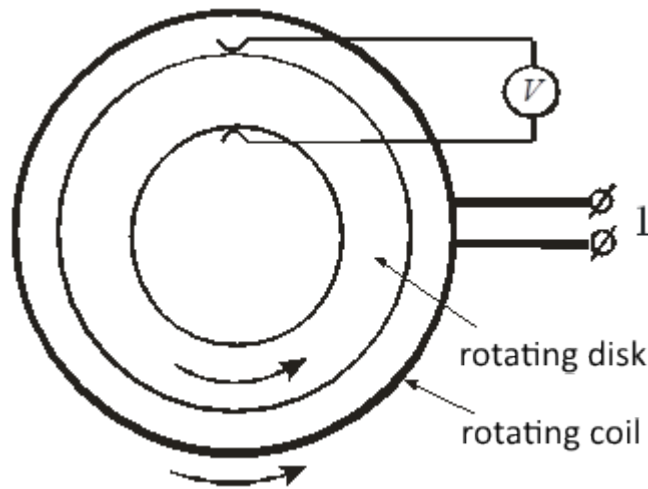


Fig. 4 : Schematic of unipolar generator with the revolving turn with the current and the revolving conducting ring.

Now it is possible wire to roll up into the ring (Fig. 4) of one or several turns, and to feed it from the current source [9-11]. Moreover contacts 1 should be derived on the collector rings, which are located on the rotational axis and to them joined the friction fixed brushes. Thus, it is possible to obtain the revolving magnet. In this magnet should be placed the conducting disk with the opening, which revolves together with the turns of the wire, which serves as magnet, and with the aid of the fixed contacts, that slide on the generatrix of disk, tax voltage on the voltmeter. As the limiting case it is possible to take continuous metallic disk and to

connect sliding contacts to the generatrix of disk and its axis. Instead of the revolving turn with the current it is possible to take the disk, magnetized in the axial direction, which is equivalent to turn with the current, in this case the same effect will be obtained.

Different combinations of the revolving and fixed magnets and disks are possible.

The case with the fixed magnet and the revolving conducting disk is characterized by the diagram, depicted in Fig. 5, if the conducting plate was rolled up into the ring.

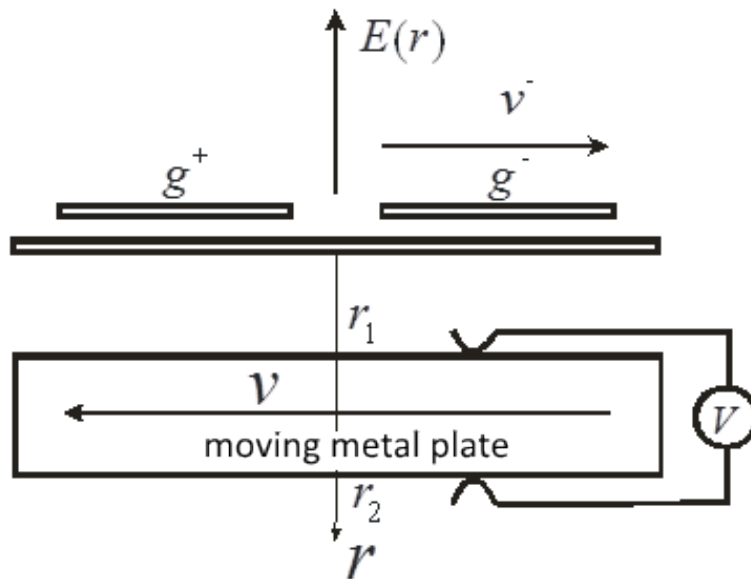


Fig. 5 : Case of fixed magnet and revolving disk.

In this case the following relationships are fulfilled:

The electric field, generated in the revolving disk by the electrons, which move along the conductor, is determined by the relationship

$$E^- = -\frac{g^-}{2\pi\epsilon r} ch \frac{v_1 - v}{c} = -\frac{g^-}{2\pi\epsilon r} \left( 1 + \frac{1}{2} \frac{(v_1 - v)^2}{c^2} \right),$$

and by the fixed ions

$$E^+ = \frac{g^+}{2\pi\epsilon r} ch \frac{v}{c} = \frac{g^-}{2\pi\epsilon r} \left( 1 + \frac{1}{2} \frac{v^2}{c^2} \right).$$

The summary tension of electric field in this case will comprise

$$E_{\Sigma} = \frac{g}{2\pi\epsilon r} \left( \frac{v v_1}{c^2} \right),$$

and a potential difference between the points  $r_1$  and  $r_2$  in the coordinate system, which moves together with the plate, will be equal

$$U = \frac{g(r_2 - r_1)}{2\pi\epsilon r} \left( \frac{v v_1}{c^2} \right).$$

Since in the fixed with respect to the magnet of the circuit of voltmeter the induced potential difference is absent, the potential difference indicated will be equal by the electromotive force of the generator examined. As earlier moving conducting plate can be rolled up into the disk with the opening, and the wire, along which flows the current into the ring with the current, which is the equivalent of the magnet, magnetized in the end direction.

Thus, the concept of scalar-vector potential gives answers to all presented questions.

#### IV. CONCLUSION

The unipolar induction was discovered still Faraday almost 200 years ago, but in the classical electrodynamics of final answer to that as and why work some constructions of unipolar generators, there is no up to now. Let us show that the concrete answers to all these questions can be obtained within the framework the concept of scalar-vector potential. This concept, obtained from the symmetrical laws of induction, assumes the dependence of the scalar potential of charge and pour on it from the charge rate. The symmetrization of the equations of induction is achieved by the way of their record with the use by substantial derivative. Different the schematics of unipolar generators are given and is examined their operating principle within the framework of the concept of scalar-vector potential.

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