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Electrization of the Superconductive Windings, and Tori During the Introduction in Them of the Direct Currents

By F. F. Mende

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I. Introduction

It was already said, that Maxwell's equations do not include information about power interaction of the current carrying systems. In the classical electrodynamics for calculating such an interaction it is necessary to calculate magnetic field in the assigned region of space, and then, using a Lorentz force, to find the forces, which act on the moving charges. Obscure a question about that remains with this approach, to what are applied the reacting forces with respect to those forces, which act on the moving charges.

The concept of magnetic field arose to a considerable degree because of the observations of power interaction of the current carrying and magnetized systems. Experience with the iron shavings, which are erected near the magnet poles or around the annular turn with the current into the clear geometric figures, is especially significant. These figures served as occasion for the introduction of this concept as the lines of force of magnetic field. In accordance with third Newton's law with any power interaction there is always a equality of effective forces and opposition, and also always there are those elements of the system, to which these forces are applied. A large drawback in the concept of magnetic field is the fact that it does not give answer to that, counteracting forces are concretely applied to what, since magnetic field comes out as the independent substance, with which occurs interaction of the moving charges.

Is experimentally known that the forces of interaction in the current carrying systems are applied to those conductors, whose moving charges create magnetic field. However, in the existing concept of power interaction of the current carrying systems, based on the concepts of magnetic field and Lorentz force, the positively charged lattice, which is the frame of conductor and to which are applied the forces, it does not participate in the formation of the forces of interaction. That that the positively charged ions take direct part in the power processes, speaks the fact that in the process of compressing the plasma in transit through it direct current (the so-called pinch effect) it occurs the compression also of ions.

II. Electrization Of The Supercon ductive Windings And Tori During The Introduction In Them Of The Direct Currents

Let us examine power interaction between two parallel conductors (Fig. 1), along which flow the currents, within the framework the concept of the scalar-vector potential [1-7].

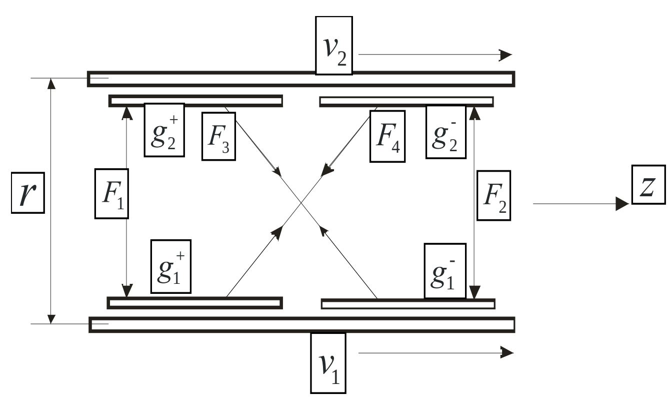

Fig. 1: Schematic of power interaction of the current carrying wires of two-wire circuit taking into account the positively charged lattice

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Let g_1^+ , g_2^+ and g_1^- , g_2^- - linear fixed (the positively charged lattice in the lower and upper conductors) and moving charges, moreover both conductors prior to the start of charges are electrically neutral. In Fig.1 the systems of the mutually inserted opposite charges for convenience in the examination are moved apart along the axis *z*. Subsystems with the negative charge (electrons) can move with the speeds v_1 and v_2 . The force of interaction between the conductors is equal to the sum of repulsive forces F_1 and F_2 (them we take with the minus sign) and attracting forces F_3 and F_4 (with the plus sign).

For the single section of the two-wire circuit of force, acting between the separate subsystems, will be written down

$$F_1 = -\frac{g_1^+ g_2^+}{2\pi\varepsilon r}, \quad F_2 = -\frac{g_1^- g_2^-}{2\pi\varepsilon r}\mathrm{ch}\frac{v_1 - v_2}{c}, \quad F_3 = \frac{g_1^- g_2^+}{2\pi\varepsilon r}\mathrm{ch}\frac{v_1}{c}, \quad F_4 = \frac{g_1^+ g_2^-}{2\pi\varepsilon r}\mathrm{ch}\frac{v_2}{c}. \tag{2.1}$$

Let us assume in (2.1) $g_2^+ = 0$ and $v_2 = 0$ (interaction of lower conductor with the current also of the fixed charge of upper conductor g_2^- without the lattice):

$$F_{\Sigma 2} = -g_1 g_2 v_1^2 \big/ \left(4\pi\varepsilon c^2 r\right).$$

It means, when current flows along the conductor, it loses electroneutrality and finds around itself the radial static electric field

$$E_\perp = -g_1 v_1^2 \big/ \left(4\pi\varepsilon c^2 r\right), \tag{2.2}$$

which is equivalent to appearance on the lower conductor of additional negative potential, which is, in turn, equivalent to appearance on this conductor of the additional specific static charge

$$g = -2 g_1 v_1^2 / c^2 . \tag{2.3}$$

This fact attests to the fact that the adoption of the concept of scalar- vector potential indicates the acknowledgement of the dependence of charge on the speed. However, up to now no one obtained experimental confirmation the validity of relationships (2.2) and (2.3).

When by Faraday and by Maxwell were formulated the fundamental laws of electrodynamics, to experimentally confirm relationship (2.2) it was impossible, since. the current densities, accessible in the usual conductors, are too small for the experimental detection of the effect in question. Thus, position about the independence of scalar potential and charge from the speed and the subsequent introduction of magnetic field they were made volitional way on the phenomenological basis.

Of current density, which can be achieved in the superconductors, make it possible to experimentally detect the electric fields, determined by relationship (2.2) [5, 6]. If such fields will be discovered, then this means that the scalar potential of charge depends on its relative speed.

Let us examine setting the experiment, which must give answer to the presented questions. The diagram of experiment is depicted in Fig. 2.

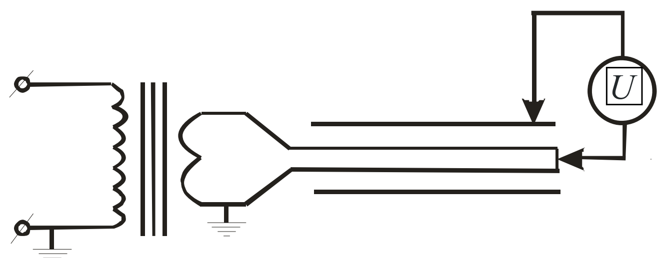

Fig. 2: Experimental confirmation of the dependence of the scalar potential of charge on its relative speed

If the folded in half superconductive wire (we will call its bifilar) to surround by the conducting cylinder and to introduce into it current in an induction manner, then in the case the dependence of charge on the speed the electrometer with the high internal resistance, connected between the cylinder and the wire, must show the presence of a potential difference. The noncontact induction introduction of current adapts with that purpose in order to exclude the presence of contact potential differences with the contact introduction of current. The difficulty of conducting this experiment consists in the fact that the input capacitance of the electrometer (usually several ten picofarads) it will be considerably more than the capacity between the bifilar loop and the cylinder. Since we measure not emf, but a potential difference, with the connection to this device of the input capacitance of electrometer the charge, induced on the cylinder to redistribute between both capacities. If we consider that an initial potential difference between the loop and the cylinder was U_1, and the capacity between them composed C_1, then with the connection between loop and cylinder of the

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additional tank of the electrometer C_2 a potential difference U_2 to be determined by the relationship:

$$U_2 = C_1 U_1 / (C_1 + C_2) = k_1 U_1 . \quad (2.4)$$

In the final analysis it turns out that in order to obtain a maximum voltage drop across electrometer itself should be increased the capacity between the loop and the cylinder, increasing the length of entire construction.

Let us begin from the determination of the expected effect the calculation of the parameters of the measuring system, intended for detecting the expected effect. On both sides from the plane layer of charges with the density n and by thickness λ is created the electric field

$$E_\perp = ne\lambda / (2\varepsilon_0).$$

Thus far this layer of charges does not move its electric field is completely compensated by the positive charges of lattice. But, when layer begins to move, is created additional electric field equal:

$$\Delta E \cong E_\perp v^2 / (2c^2). \quad (2.5)$$

The magnetic field on its surface of superconductor, equal to specific current, can be determined from the relationship

$$H = nev\lambda .$$

Let us substitute into (2.5) speed obtained from this relationship v:

$$\Delta E_\perp = H^2 / (2\varepsilon_0 ne\lambda c^2) = \mu_0 H^2 / (2ne\lambda).$$

To calculate the maximum expected value of the effect, the value of the critical field for H a given type of superconductor is taken as the quality.

Let us calculate the maximum magnitude of this effect for the case of superconductive niobium, after assuming $H_c = 1{,}5 \cdot 10^5 \ A/m$, $\lambda \cong 10^{-7}$ m, $n \cong 3 \cdot 10^{28} m^{-3}$, we obtain $\Delta E_\perp \cong 3V/m$. We will consider that the diameter of bifilar loop composes the doubled value of the diameter of the utilized superconductive wire with a diameter 0, 25 mm. If we take the diameter of the cylinder equal 10 mm, then a potential difference between the loop and the cylinder will comprise $U = \Delta E_\perp (d/2) \ln D(/d) \cong 3mV$. In this case the linear capacity of coaxial will comprise $C_0 = 15 \ pF/m$.

In the experiments was used the vibrating reed electrometer with a input capacitance ~ 60 pF and the sensitivity ~1mV. In order to ensure at least the same capacity of the coaxial (in this case a voltage drop across the capacity of electrometer after its connection to the coaxial it will be 1.5 mV) it is necessary to take the length of the coaxial of 4 meters of. Certainly, for the technical reasons it is difficult to cool this coaxial to helium temperatures and furthermore and effect itself proves to be insufficient for its reliable measurement. Therefore the magnitude of effect must be increased at least 100 times. This can be carried out, after increasing a quantity of central cores of coaxial, after bringing it to two hundred, for which to be required 400 meters of wire. Certainly, in this case it is necessary to increase the diameter of its cylindrical part. It is possible to again produce calculation, but use of an experimental model with the coaxial of this size nevertheless unacceptably in view of its unwieldiness, although the possibility of the precise calculation of the expected effect is the great advantage of this solution.

The not so much importantly precise agreement of calculated and experimental data, as to reliably reveal effect itself. Therefore experimental model was created according to another diagram. for the introduction of direct current into the winding was used the cooled to helium temperatures transformer with the iron core. Using as the secondary winding of transformer the superconductive winding, connected with the solenoid, it is possible without the presence of galvanic contacts to introduce current into it. In the transformer was used ring-shaped core made of transformer steel with a cross section 9 cm^2. The primary and secondary windings of transformer were wound by niobium-titanium wire with the copper coating and contained 150 and 10 turns respectively. Thus, transformer has a transformation ratio 15. Diameter of wire 2 mm. The secondary winding of transformer is connected in series with the solenoid with the small inductance, which is wound bifilar and contains 2448 turns of the same wire. The overall length of coil – 910 m. The ends of solenoid and secondary winding of transformer are welded with the aid of the laser welding. Solenoid is wound on the body from teflon resin. Inside and outside diameter of the winding of solenoid 35 and 90 mm of respectively, the width of the coil 30 mm. To the midpoint of solenoid is connected internal wiring of the coaxial, which emerges outside cryostat, the same coaxial is connected also to the screen of solenoid. The construction of low-inductive solenoid is shown in Fig. 3.

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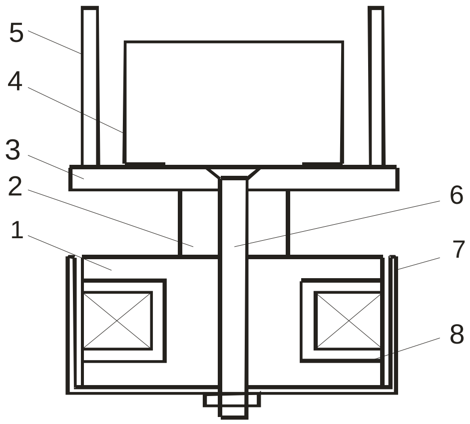

Fig. 3: Construction of the low-inductive superconductive solenoid

The following notations are used in the figure:1- aluminum body, 2 -teflon bushing, 3- teflon disk, 4- clamp, 5 - counter, 6- bolt, 7- copper screen, 8 - teflon body is eighth. Solenoid is wound on teflon body 8, which is concluded in aluminum body 1. Outside solenoid is surrounded by copper screen 7, which together with body 1 is the screen of solenoid. To body 1 by means of bolt 6 and teflon bushing 2 is fastened teflon disk 3, on which is installed clamp 4. The turns of the secondary winding of transformer cover clamp 4, through which, without concerning it, is passed the magnetic circuit of transformer. Entire construction is attached to the transformer by means of counters 5. Transformer together with the solenoid is placed in the tank of helium cryostat.

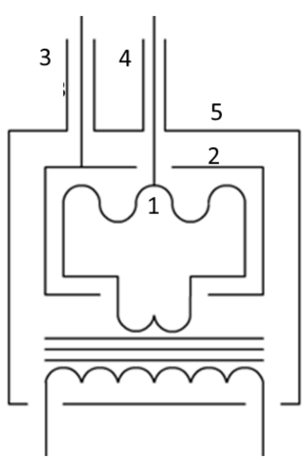

Fig. 4: Diagram of connection of the low-inductive solenoid

The diagram of the connection of coaxials to the solenoid is shown in Fig. 4.

In Fig. 4 are indicated: 1 - solenoid, 2 - screen of solenoid, 3, 4 - coaxials, 5 - common screen, which the helium tank is. Resistance between the grounded elements, the screen of solenoid and solenoid itself composes not less than 10^{14} Ohm. Capacities relative to the earth of the elements of the construction: coaxial 3 - 44 pF, coaxial 4 - 27 pF, capacity the screen- earth is 34 pF, capacity screen- solenoid is 45 pF. As the electrometer was used by capacitive vibrating reed electrometer with a input capacitance 60 pF and the input resistance 10^{14} Ohm.

This construction of the superconductive solenoid and surrounding screen makes it possible to establish the presence of effect itself without the precise electrodynamic calculation of electrostatic fields on around the solenoid.

With the measurements electrometer was connected directly to the screen by means of coaxial 4, and the midpoint of the superconductive solenoid by means of coaxial 3 was grounded. Current into the primary winding of transformer was introduced from the source of direct current, indication of electrometer in this case they did not depend on direction of flow. With the strengths of introduced current ~ 9 A occurred the spontaneous discharge of the indications of electrometer. This means that the current in the winding of solenoid reached its critical value, and winding converted to normal state. Iron core in this case seized magnetic flux, also, with the decrease of the current introduced into the solenoid, the curve of the dependence of the measured potential on the current was repeated, and potential reached its maximum value with current zero.

The dependence of the measured potential difference is given in Fig. 5

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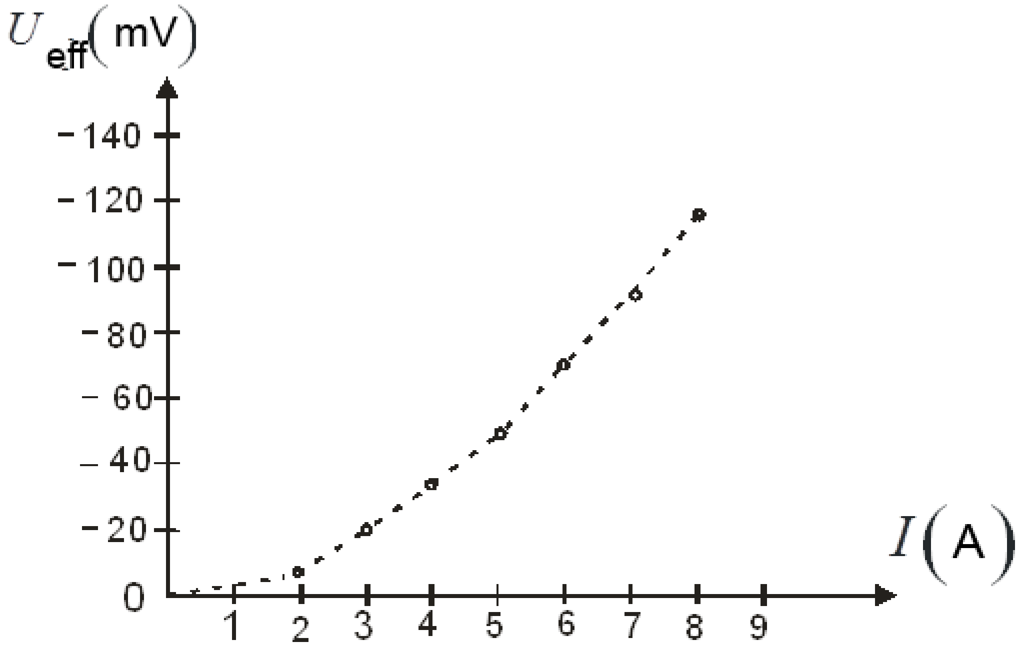

Fig. 5: Dependence of the given potential difference between the screen and the low-inductive solenoid on the current in its winding

Table 1: Experimental data are given in the table

$I(A)$	1	2	3	4	5	6	7	8
$I_1(A)$	15	30	45	60	75	90	105	120
$H(A/м)\cdot 10^4$	1.91	3.82	5.73	7.64	9.55	11.5	14.6	15.3
$-U_2(мB)$	-	2	6	10	15	21	27	35
$-U_1(мB)$	-	7	20	34	50	71	90	117
$U_{эф}/I^2(мB/A)$	-	1.75	2.22	2.13	2.00	1.94	1.84	1.83

In the first graph of table are given the values of the introduced current o I . In the second graph are given the values of the current I_1 in the winding of solenoid, calculated on the basis of the value of the transformation ratio of equal to 15. In this case it is assumed that in entire range of the introduced currents the magnetization of core remains proportional to current. In the third graph are given the values of magnetic fields on on the surface of the superconductive wires of winding. In the fourth - of the indication of electrometer. In the fifth - are given the effective values of a potential difference, which would be between the solenoid and the screen to the connection to the latter of the total capacitance of coaxial and electrometer. In the sixth - coefficient $k = U_{эф}/I^2$, which indicates the deviation of the obtained dependence on the quadratic law. The coefficient k_1 composed value 3.35, it was calculated, on the basis of the fact that the capacity between screen and solenoid of $C_1 =$ 45 pF, and the total capacitance C_2, connected to the capacity C_1 and which consists of the capacity of coaxial and capacity of electrometer, was equal to 111 pF. The root-mean-square relative deflection of the coefficient k from its average value equal to 1.93 composes 0.13, which gives relative root-mean-square error 7%. Thus, the obtained dependence between the current and the measured value of potential is very close to the quadratic law. It is also evident from the table that with the values of current in the conductors of solenoid on the order 120 A, the field strength on their surface reaches its critical value, which for the utilized superconductor composes $1.5 \cdot 10^5$ A/m, with which and is connected the discharge of the indications of electrometer with reaching of these currents. Thus,

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experimental results indicate that the value of scalar potential, and, therefore, also charge depends on speed.

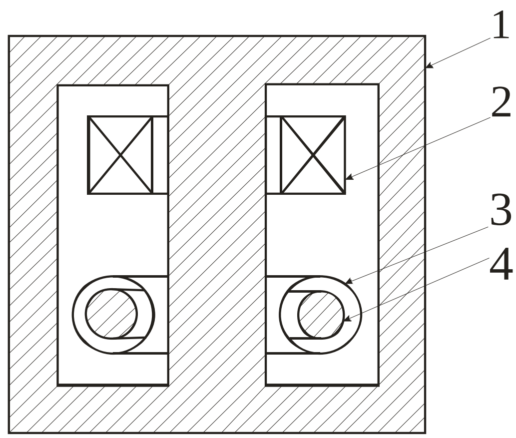

Fig. 6: Diagram of experiment with the superconductive torus

However in this diagram of experiment occurs the direct galvanic connection of electrometer to the superconductive solenoid. This can cause questions, but are not the reason for the appearance of a potential difference between the solenoid and the screen some contact phenomena in the place of the contact of wire, which connects electrometer with the solenoid? The experiments with the superconductive niobium torus were carried out for the answer to this question (Fig. 6).

If we inside the conducting screen arrange the second conducting screen, and between them let us connect electrometer, then charge when will appear inside the internal screen, a potential difference will appear between the internal and external screen. In the experiment, as external screen 1, the yoke of transformer, made from transformer steel, was used. On the central rod of this yoke was located primary winding with 2, wound by niobium-titanium wire, which contains 1860 turns. Torus-shaped metal screen 3, made from copper, was located on the same rod. Torus 4, made from niobium, was located inside this screen. The outer diameter of niobium torus was 76 mm, and internal 49 mm. Transformer was placed in the tank of helium cryostat and was cooled to the helium temperature, in this case the yoke of transformer and helium tank were grounded.

Direct current was induced during the introduction of direct current into the primary winding of transformer in the superconductive torus, and electrometer fixed the appearance between screen 3 and yoke of transformer a potential difference U . The constant value current in the superconductive torus 1860 times exceeded the current, introduced into the primary winding of transformer. The dependence U a potential difference of on the current I , introduced into the primary winding of transformer, it is shown in Fig. 7.

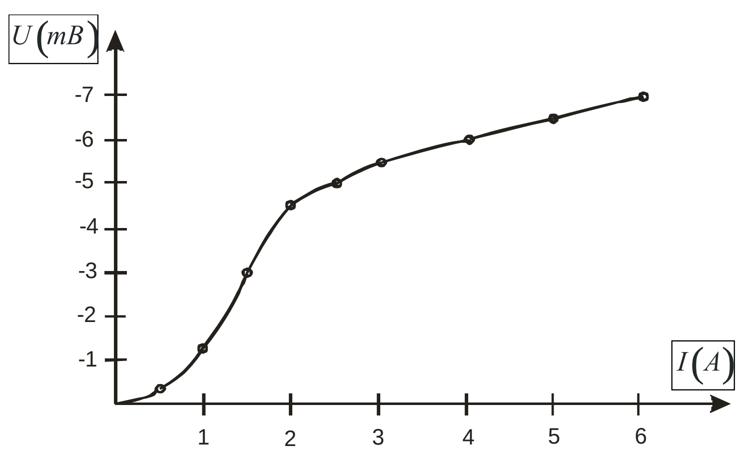

Fig. 7: Dependence of a potential difference boundary by screen 3 by the yoke of transformer 1 on the current, introduced into the primary winding of transformer

Data of the value of a potential difference are considerably less than for the superconductive wire winding, since. the surface of torus is considerably less than wire winding. The form of the dependence of a potential difference on the introduced current also strongly differs. Quadratic section is observed only in the very small initial section up to the values of currents into 2 amperes, introduced into the primary winding. Further this dependence is rectilinear with the small inclination toward the X-axis. It was not observed moreover of stalling the indications of electrometer in this case.

With which are connected such differences? In the case of wire solenoid the superconductive current is evenly distributed over the surface of wire and reaches its critical value in all its sections of surface simultaneously, with which and is connected the simultaneous passage of the entire winding of solenoid into the normal state, with the reaching in the wire of the critical value of current.

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In the case of torus the process of establishing the superconductive current on its surface occurs differently. That introduced into the direct current superconducting torus is very unevenly distributed over its surface. Maximum current densities occur on the internal surface of torus, and they are considerably less on the periphery. With this is connected the fact that the internal surfaces of torus begin to convert to normal state earlier than external. The process of passing the torus into the normal state occurs in such a way that with an increase of the current in the torus into the normal state pass the first interior and normal phase begins to be moved from the interior to the external. Process lasts until entire torus passes into the normal state. But why in this case up to the moment of passing the torus into the normal state does not occur the discharge of current, as it takes place in the case of wire solenoid? This niobium is connected with the fact that the superconductor of the second kind. This niobium is connected with the fact that the superconductor of the second kind, and it immediately abruptly does not convert to normal state, but he has the sufficiently significant region of current densities, with which it is in the mixed state, when Abrikosov's vortices penetrate inside the massive conductor. The circumstance that the indications of electrometer do not have a discharge of indications, he indicates that the superconductive torus is in the mixed state, but the presence of the vortex of the structures in it, which also present the superconductive currents, they lead to the fact that the torus ceases to be electrically neutral. From this it is possible to draw the conclusion that the vortices bear on themselves not only magnetic-flux quanta, but still electric charges.

With other direction of flow in the primary winding is repeated the dependence, similar to Fig. 7, but with strong hysteresis. This is connected with the fact that the vortices, which penetrated into the depths of the superconductor, they are attached on the stacking faults, falling into potential wells, that also leads to hysteresis.

Thus, the results of the carried out experiments unambiguously indicate the dependence of scalar potential and magnitude of the charge from their speed, which was predicted still in the work [8,9] and it is experimentally confirmed in the works [10,11]. All experiments indicated were carried out in the beginning of the 90's in LGC Scientific Research Institute of the cryogenic instrument manufacture FTINT NAN Ukraine.

III. Dynamic Potentials And The Field Of The Moving Charges

With the propagation of wave in the long line it is filled up with two forms of energy, which can be determined through the currents and the voltages or through the electrical and magnetic fields in the line. And only after wave will fill with electromagnetic energy all space between the generator and the load on it it will begin to be separated energy. I.e. the time, by which stays this process, generator expended its power to the filling with energy of the section of line between the generator and the load. But if we begin to move away load from incoming line, then a quantity of energy being if rated on it will decrease, since. the part of the energy, expended by source, will leave to the filling with energy of the additional length of line, connected with the motion of load. [12]. If load will approach a source, then it will obtain an additional quantity of energy due to the decrease of its length. But if effective resistance is the load of line, then an increase or the decrease of the power expendable in it can be connected only with a change in the stress on this resistance. Therefore we come to the conclusion that during the motion of the observer of those of relatively already existing in the line fields on must lead to their change. The productivity of this approach with the application of conversions of Galileo will be demonstrated in this chapter.

The fields, which are created in this inertial frame of reference(IFR) by the moving charges (for example, magnetic field around the moving charges) and by the moving sources of electromagnetic waves, let us name dynamic as already mentioned, in the classical electrodynamics be absent the rule of the conversion of electrical and magnetic fields on upon transfer of one inertial system to another. This deficiency removes special theory of relativity (SR), using instead of the conversions of Galileo conversions of Lorenz. With the entire mathematical validity of this approach the physical essence of such conversions up to now remains unexplained.

In this division will made attempt find the precisely physically substantiated ways of obtaining the conversions fields on upon transfer of one IFR to another, and to also explain what dynamic potentials and fields can generate the moving charges. First step in this direction, demonstrated into {1, 13}- the introduction of the symmetrical laws of magneto electric and electromagnetic induction, written in the form [14-18]:

$$\oint \mathbf{E}' d\mathbf{l}' = -\int \frac{\partial \mathbf{B}}{\partial t} d\mathbf{s} + \oint [\mathbf{v}\times\mathbf{B}] d\mathbf{l}'; \quad \oint \mathbf{H}' d\mathbf{l}' = \int \frac{\partial \mathbf{D}}{\partial t} d\mathbf{s} - \oint [\mathbf{v}\times\mathbf{D}] d\mathbf{l}' \qquad (3.1)$$

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or

$$\operatorname{rot}\mathbf{E}' = -\frac{\partial \mathbf{B}}{\partial t} + \operatorname{rot}[\mathbf{v}\times\mathbf{B}]; \quad \operatorname{rot}\mathbf{H}' = \frac{\partial \mathbf{D}}{dt} - \operatorname{rot}[\mathbf{v}\times\mathbf{D}]. \qquad (3.2)$$

For the constants fields on these relationships they take the form:

$$\mathbf{E}' = [\mathbf{v}\times\mathbf{B}]; \quad \mathbf{H}' = -[\mathbf{v}\times\mathbf{D}]. \qquad (3.3)$$

In relationships (3.1-3.3), which assume the validity of the Galileo conversions, stitched system and not stitched system values present fields and elements in moving and fixed IFR respectively. It must be noted, that conversions (3.3) earlier could be obtained only from the Lorenz conversions.

The relationships (3.1-3.3), which present the laws of induction, do not give information about how arose fields in initial fixed IFR. 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 (3.3) attest to the fact that in the case of relative motion of frame of references, between the fields $\mathbf{E}$ and $\mathbf{H}$ there is a cross coupling, i.e., motion in the fields $\mathbf{H}$ leads to the appearance fields $\mathbf{E}$ and vice versa. From these relationships escape the additional consequences, which were for the first time examined in the work [3]. If the charged rod has linear charge g, its electric field $E = g/(2\pi\varepsilon r)$ it diminishes according to the law $1/r$, where r - the distance from the central axis of rod to the observation point.

If we in parallel to the axis of rod in the field of begin to move with the speed of another IFR, then in it will appear the additional magnetic field of. If we now with respect to already moving IFR move third with the speed Δv, that already due to the motion in the field ΔH will appear additive to the electric field $\Delta E = \mu\varepsilon E(\Delta v)^2$, etc. Is obtained the number, which gives the value of electric field $E'_v(r)$ in moving IFR with reaching of speed $v = n\Delta v$, when $\Delta v \to 0$, and $n \to \infty$. In the final analysis, in moving IFR the value of dynamic electric field will prove to be more than in the initial, and depending on normal component $v_\perp$ charge rate to the vector, which connects the moving charge and observation point:

$$E'(r, v_\perp) = \frac{g\,\mathrm{ch}(v_\perp/c)}{2\pi\varepsilon r} = E\,\mathrm{ch}(v_\perp/c).$$

The electric field of a single charge is determined by the relation:

$$E'(r, v_\perp) = \frac{e\,\mathrm{ch}(v_\perp/c)}{4\pi\varepsilon r^2}.$$

The scalar 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. It is expressed as the scalar potential $\varphi(r)$ of fixed charge by the equality

$$\varphi'(r, v_\perp) = \frac{e\,\mathrm{ch}(v_\perp/c)}{4\pi\varepsilon r} = \varphi(r)\,\mathrm{ch}(v_\perp/c). \qquad (3.4)$$

Maximum value this potential has in the direction normal to the motion of charge itself. It determines even electric fields, induced by the accelerated charge.

It is analogous, we have for the case of moving the charge in the magnetic field:

$$H'(v_\perp) = H\,\mathrm{ch}(v_\perp/c).$$

where $v_\perp$ - speed normal to the direction of the magnetic field.

We will obtain this result by another method. Let us designate field variables in the fixed frame of reference without the prime, and in the mobile – with the prime. In the differential form let us write down the formulas of the mutual induction of electrical and magnetic fields on in the mobile frame of reference:

$$dH' = \varepsilon E' dv_\perp, \qquad (3.5)$$

$$dE' = \mu H' dv_\perp \qquad (3.6)$$

or, otherwise,

$$dH'/dv_\perp = \varepsilon E', \qquad (3.7)$$

$$dE'/dv_\perp = \mu H', \qquad (3.8)$$

where (3.7) it corresponds (3.5), and (3.8) it corresponds (3.6).

After dividing equations (3.7) and (3.8) on E H, we will obtain respectively:

$$\frac{d(H'/E)}{dv_\perp} = \varepsilon\frac{E'}{E}, \qquad (3.9)$$

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$$\frac{d\left(E'/E\right)}{dv_{\perp}}=\mu\frac{H'}{H}. \qquad (3.10)$$

Differentiating both parts (3.10), we have:

$$\frac{d^2\left(E'/E\right)}{d^2v_{\perp}}=\mu\frac{d\left(H'/E\right)}{dv_{\perp}}. \qquad (3.11)$$

After substituting (3.9) in (3.11), we will obtain:

$$\frac{d^2\left(E'/E\right)}{d^2v_{\perp}}=\mu\varepsilon\frac{E'}{E}. \qquad (3.12)$$

The function is the general solution (3.12) of differential equation

$$E'/E=C_2\,\mathrm{ch}\left(v_{\perp}/c\right)+C_1\,\mathrm{sh}\left(v_{\perp}/c\right), \qquad (3.13)$$

where c – the speed of light on Wednesday, C_1, C_2 – arbitrary constants.

Since with $v_{\perp}=0$ must be made $E'=E$, that from (3.13) we will obtain:

$$C_2=1. \qquad (3.14)$$

After substituting (3.14) in (3.13), we finally have the general solution, into which enters one arbitrary constant C_1:

$$E'/E=\mathrm{ch}\left(v_{\perp}/c\right)+C_1\,\mathrm{sh}\left(v_{\perp}/c\right).$$

Selecting $C_1=0$, we obtain

$$E'=E\,\mathrm{ch}\left(v_{\perp}/c\right).$$

In connection with to electromagnetic wave, introducing the parallel $E_{\uparrow}$, $H_{\uparrow}$ and normal $E_{\perp}$, $H_{\perp}$ speeds IFR of component fields on, we have [9]:

$$\begin{aligned}&\mathbf{E}'_{\uparrow}=\mathbf{E}_{\uparrow};\quad \mathbf{E}'_{\perp}=\mathbf{E}_{\perp}\,\mathrm{ch}\frac{v}{c}+\frac{Z_0}{v}\left[\mathbf{v}\times\mathbf{H}_{\perp}\right]\mathrm{sh}\frac{v}{c};\\&\mathbf{H}'_{\uparrow}=\mathbf{H}_{\uparrow};\quad \mathbf{H}'_{\perp}=\mathbf{H}_{\perp}\,\mathrm{ch}\frac{v}{c}-\frac{1}{vZ_0}\left[\mathbf{v}\times\mathbf{E}_{\perp}\right]\mathrm{sh}\frac{v}{c},\end{aligned} \qquad (3.15)$$

where $Z_0=\sqrt{\mu_0/\varepsilon_0}$ - impedance of free space, $c=1\big/\sqrt{\mu_0\varepsilon_0}$ - speed of light.

Conversions fields on (3.15) they are called the Mendeconversions.

Such means of the field of the moving charges they are characterized by from fields on fixed charges, that also leads to the electrization of the superconductive windings and tori, that also is confirmed experimental.

We will obtain these conversions by matrix method.

Let us examine the totality IFR of such, that IFRK_1moves with speed Δv relative to IFR KIFRK_2moves with the same speed Δv relative to $K_1$and so forth. If the module of speed Δv is small (compared to the speed of light c), then for the transverse components of the fields in IRFK_1K_2, we have:

$$\begin{aligned}&\mathbf{E}_{1\perp}=\mathbf{E}_{\perp}+\Delta\mathbf{v}\times\mathbf{B}_{\perp} &&\mathbf{B}_{1\perp}=\mathbf{B}_{\perp}-\Delta\mathbf{v}\times\mathbf{E}_{\perp}/c^2\\&\mathbf{E}_{2\perp}=\mathbf{E}_{1\perp}+\Delta\mathbf{v}\times\mathbf{B}_{1\perp} &&\mathbf{B}_{2\perp}=\mathbf{B}_{1\perp}-\Delta\mathbf{v}\times\mathbf{E}_{1\perp}/c^2\end{aligned} \qquad (3.16)$$

where of the field of and relate to current IFR. Directing the Cartesian axis of along, let us rewrite (3.17) in the components of the vector o

$$\Delta\mathbf{E}=\Delta\mathbf{v}\times\mathbf{B}_{\perp},\qquad \Delta\mathbf{B}=-\Delta\mathbf{v}\times\mathbf{E}_{\perp}/c^2, \qquad (3.17)$$

$$\Delta E_y=-B_z\Delta v,\qquad \Delta E=B_y\Delta v,\qquad \Delta B_y=E_z\Delta v/c^2 \qquad (3.18)$$

Relationship (3.18) can be represented in the matrix form

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

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

$$dU(v)/dv = AU(v) \qquad (3.19)$$

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

$$U' \equiv U(v) = \exp(vA)U, \qquad U = U(0). \qquad (3.20)$$

Here U - matrix column fields on in the system K, and U' - matrix column fields on in the system K'. Substituting (3.20) in the system (3.19), we are convinced, what U' is actually the solution of the system (3.19):

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

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

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

where o E - unit matrix with the size 4×4. It is convenient to write down for this matrix A in the unit type form

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

then

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

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

And the elements of matrix exponential curve take the form

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

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

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

$$\exp(vA)=\begin{pmatrix} I\,\mathrm{ch}(v/c) & -c\alpha\,\mathrm{sh}(v/c) \\ (\alpha\,\mathrm{sh}(v/c))/c & I\,\mathrm{ch}(v/c) \end{pmatrix}=\begin{pmatrix} \mathrm{ch}(v/c) & 0 & 0 & -c\,\mathrm{sh}(v/c) \\ 0 & \mathrm{ch}(v/c) & c\,\mathrm{sh}(v/c) & 0 \\ 0 & (\mathrm{ch}(v/c))/c & \mathrm{ch}(v/c) & 0 \\ -(\mathrm{sh}(v/c))/c & 0 & 0 & \mathrm{ch}(v/c) \end{pmatrix}.$$

Now we return to (3.20) and substituting there, we find

$$E'_y=E_y\,\mathrm{ch}(v/c)-cB_z\,\mathrm{sh}(v/c),\quad E'_z=E_z\,\mathrm{ch}(v/c)+cB_y\,\mathrm{sh}(v/c),$$
$$B'_y=B_y\,\mathrm{ch}(v/c)+(E_z/c)\mathrm{sh}(v/c),\quad B'_z=B_z\,\mathrm{ch}(v/c)-(E_y/c)\mathrm{sh}(v/c)$$

Or in the vector record

$$\mathbf{E}'_\perp=\mathbf{E}_\perp\,\mathrm{ch}\frac{v}{c}+\frac{v}{c}\mathbf{v}\times\mathbf{B}_\perp\,\mathrm{sh}\frac{v}{c},\quad \mathbf{B}'_\perp=\mathbf{B}_\perp\,\mathrm{ch}\frac{v}{c}-\frac{1}{vc}\mathbf{v}\times\mathbf{E}_\perp\,\mathrm{sh}\frac{v}{c} \qquad (3.21)$$

This is conversions (3.15)

IV. Conclusion

It was already said, that Maxwell's equations do not include information about power interaction of the current carrying systems. In the classical electrodynamics for calculating such an interaction it is necessary to calculate magnetic field in the assigned region of space, and then, using a Lorentz force, to find the forces, which act on the moving charges. Obscure a question about that remains with this approach, to what are applied the reacting forces with respect to those forces, which act on the moving charges. It is experimentally discovered, that when along the conductor flows the current, it loses electroneutrality and finds around itself radial static electric field; however, classical electrodynamics cannot explain this fact. In the article are given the experimental data, which attest to the fact that around the superconductive windings and the tori, into which is introduced direct current, is formed static electric field. This fact finds its explanation within the framework the concept of scalar- vector potential.

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