Physical nature of vector potential

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Abstract

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$$I = \frac{Ut}{L},$$

where L - inductance of solenoid.

Consequently, magnetic field with this interpretation for entire elongation of solenoid will increase synchronous. However, so whether this in reality? In order to be dismantled at this, let us examine a question about how swelling current in the shortened out section of long line will if line (Fig. 1) to short out at a distance z_1 rel.un. of beginning, then summary the inductance of line will compose the value

$L_\Sigma = z_1 L_0 = z_1 \dfrac{a}{b}\mu_0$. If we connect to the line dc power supply, in it will begin to be extended the wave of the voltage $I = \dfrac{U}{Z}$ and current U as shown in Fig. 1 The wave of stress in its right part has the transition section z_2, which is named the front of the wave of stress. This section corresponds to the transit time $\tau = \dfrac{z_2}{c}$, for which the voltage of the source, connected to the line, attains its nominal value.

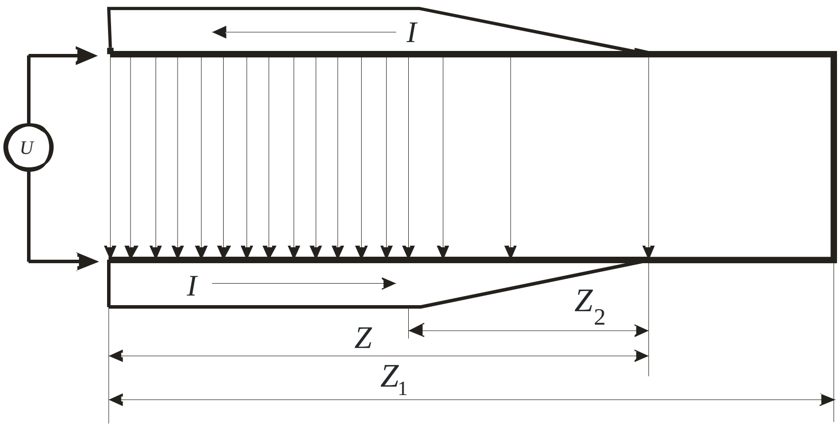

Fig. 1. Propagation of the current wave and voltage in the long line.

Specifically, in this transition section proceeds the acceleration of the charges from the zero speed in its beginning, to the values necessary for creating the rated current in the line, whose value is determined by the relationship of . To this section is applied the voltage of the power source. In this case it is accepted that during the voltage transient increases according to the linear law (although in the general case it can increase according to any other law). It is accepted also that the time of this transient process is considerably less than the time, for which the front of stress passes along the line to one side. The interval z_2 corresponds to the transient process, which is connected with the inertia properties of the device, which connects the voltage source to the line. It is assumed that $z_1 \gg z_2$.

Earlier has already been indicated that solution of problems interactions of the moving charges in the classical electrodynamics are solved by the introduction of the magnetic field or vector potential, which are fields by mediators. To the moving or fixed charge action of force can render only electric field. Therefore natural question arises, and it is not possible whether to establish the laws of direct action, passing fields the mediators, who would give answer about the direct interaction of the moving and fixed charges. This approach would immediately give answer, also, about sources and places of the application of force of action and reaction. Using scalar-vector potential for resolution of questions of power interaction of the current carrying systems, we already showed that precisely this approach gives the possibility to understand the structure of such forces and place of their application. Let us show that application of scalar- vector potential gives the possibility to establish the straight laws of the induction, when directly the properties of the moving charge without the participation of any auxiliary pour on they give the possibility to calculate the electrical induction fields, generated by the moving charge.

Let us examine the diagram of the propagation of current and voltage in the section of the long line, represented in Fig. 1. In this figure the wave front occupies the section of the line of the long z_2, therefore, the time of this transient process equally $t = \frac{z_2}{c}$. This the very are thing time, for which the voltage on incoming line grows from zero to its nominal value. The duration of this transient process is adjustable, and it depends on that, in which law we increase voltage on incoming line, now we will attempt to understand, from where is taken that field strength, which forces charges in the conductors, located near the current carrying elements of line, to move in the direction opposite to the direction of the motion of charges in the primary line. This exactly are that question, to which, until now, there is no physical answer. Let us assume that voltage on incoming line grows according to the linear law also during the time Δt it reaches its maximum value U, after which its increase ceases. Then in line itself transient process engages the section $z_1 = c\Delta t$. Let us depict this section separately, as shown in Fig. 2. In the section z_1 proceeds the acceleration of charges from their zero speed (more to the right the section z_1) to the value of speed, determined by the relationship

$$v = \sqrt{\frac{2eU}{m}} \ ,$$

where e and m - charge and the mass of current carriers, and U - voltage drop across the section z_1. Then the dependence of the speed of current carriers on the coordinate will take the form:

$$v^2(z) = \frac{2e}{m}\ \frac{\partial U}{\partial z} z\,. \qquad (1)$$

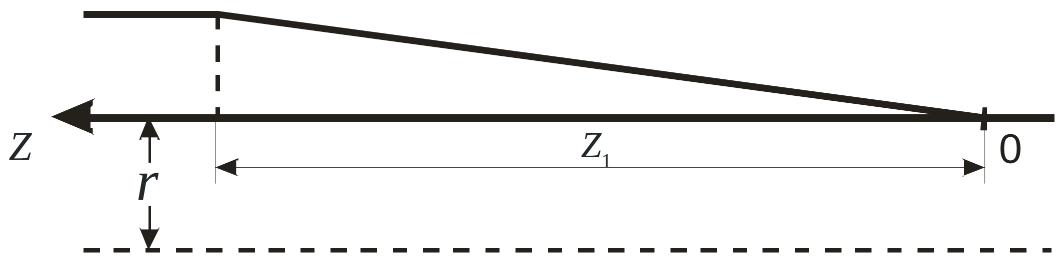

Fig. 2. Current wavefront, which is extended in the long line.

Since we accepted the linear dependence of stress from the time on incoming line, the equality occurs

$$\frac{\partial U}{\partial z} = \frac{U}{z_2} = E_z\,,$$

where E_z - field strength, which accelerates charges in the section z_1. Consequently, relationship (1) we can rewrite

$$v^2(z) = \frac{2e}{m} E_z z\,.$$

Using for the value of scalyar-vector potential the relationship

$$\varphi(r, v_\perp) = \frac{ech\frac{v_\perp}{c}}{4\pi\varepsilon r}\,,$$

and taking only first two members of expansion in the series of hyperbolic cosine, let us calculate scalar potential as the function z on a certain distance r from the line

$$\varphi(z)=\frac{e}{4\pi\,\varepsilon_0 r}\left(1+\frac{1}{2}\;\frac{v^2(z)}{c^2}\right)=\frac{e}{4\pi\,\varepsilon_0 r}\left(1+\frac{eE_z z}{mc^2}\right). \qquad (2)$$

For the record of relationship (2) are used only first two members of the expansion of hyperbolic cosine in series.

Using the formula $E=-grad\,\varphi$, and differentiating relationship (2) on z, we obtain

$$E_z{}'=-\frac{e^2E_z}{4\pi\,\varepsilon_0 rmc^2}, \qquad (3)$$

where $E_z{}'$ - the electric field, induced at a distance r from the conductor of line. Near E we placed prime in connection with the fact that calculated field it moves along the conductor of line with the speed of light, inducing in the conductors surrounding line the induction currents, opposite to those, which flow in the basic line. The acceleration of , tested by the charge of in the field of , is determined by the relationship of . Taking this into account from (3) we obtain

$$E_z{}'=-\frac{ea_z}{4\pi\,\varepsilon_0 rc^2}\;. \qquad (4)$$

thus, the charges, accelerated in the section of the line z_1, induce at a distance r from this section the electric field, determined by relationship (4). Direction of this field conversely to field, applied to the accelerated charges. Thus, is obtained the law of direct action, which indicates what electric fields generate around themselves the charges, accelerated in the conductor. This law can be called the law of electro-electrical induction, since it, passing fields mediators (magnetic field or vector potential), gives straight answer to what electric fields the moving electric charge generates around itself. This law gives also answer about the place of the application of force of interaction between the charges. Specifically, this relationship, but not Farrday law, we must consider as the fundamental law of induction, since. specifically, it establishes the reason for the appearance of induction electrical pour on around the moving charge. In what the difference between the proposed approach and that previously existing consists. Earlier we said that the moving charge generates vector potential, and the already changing vector potential generates electric field. Relationship (4) gives the possibility to exclude this intermediate operation and to pass directly from the properties of the moving charge to the induction fields. Let us show that relationship it follows from this and the introduced earlier phenomenologically vector potential, and, therefore, also magnetic field. Equality (4) we can rewrite

$$E_z{}' = -\frac{e}{4\pi\,\varepsilon_0 r c^2}\frac{\partial v_z}{\partial t} = -\mu\frac{\partial A_H}{\partial t},$$

from where, integrating by the time, we obtain

$$A_H = \frac{e v_z}{4\pi r}.$$

This relationship corresponds to the determination of vector potential. It is now evident that the vector potential is the direct consequence of the dependence of the scalar potential of charge on the speed. The introduction also of vector potential and of magnetic field this is the useful mathematical device, which makes it possible to simplify the solution of number of electrodynamic problems, however, one should remember that by fundamentals the introduction of these pour on it appears scalar-vector potential.