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Wireless selection of energy from high-voltage overhead electrical power transmission lines for power autonomous devices

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ABSTRACT: In the work has investigated the possibility of wirelessenergy selection from high-voltage overhead electrical power transmission line with help of aTesla flat coil, to be placingneartheelectricalline wire at a distance of tens of centimeters to two meters. For magnification the efficiency of energy selection using a Tesla coil, have proposed to be placing in the interval between the turns a ferromaterial with alargemagnetic permeability.The theoretically justified possibility of magnification the voltage on such a coil by many oftimes to voltages and powers, sufficientfor power supply of various low-power devices isshown.

Keywords: high-voltage power lines of industrial frequency, wireless extraction of energy, the innovative Tesla coil, autonomous devices

I. INTRODUCTION

High-voltage overhead electrical power transmission (OHL) lines have become widespread throughout the world to their cheapness and simplicity of realization.Currently, have a large number of autonomous devices, that perform various functions: control and measuring devices ofthe OHL, devices ofvideo surveillance, etc.,needing to recharge batteries or constant low-voltage power supply. Therefore, in conditions where whole "rivers" of electrical energy flow nearby, it is expedient to wirelessly way of selecting a small amount of electricity for your needs. Currents of hundreds of amperes flow through the wires of OHLand a sufficiently intense magnetic field is created around the wire, from which would you can be selected away a bit electrical energy to power autonomous devices[1].

The magnetic field of the high-voltage three-phase OHL

A dependence of the magnetic field induction in a not large removal from the extreme wire of a high-voltage three-phase OHL,calculated on developed previously on an analytical mathematical model [2,3], which are presented in Fig. 1.

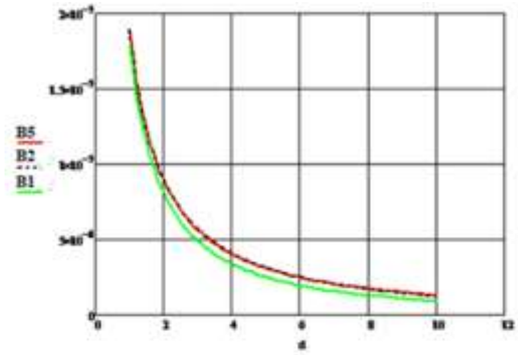

Fig. 1. 500 kV magistral overhead line, support PB2 - curve B5. Distribution overhead lines: 220 kV, support U-220-1+9 - curve B2 and overhead lines 110 kV, support 1P-110-1 - curve B1

At a distance of 2 meters from the extreme wire, the induction value for all views of OHL is about 10 µT at a current of 100 A, changing slightly with the type of support applied. The real currents in the OHL are significantly larger, they amount to several hundred amperes,respectively,and the induction of the magnetic field will be greater in the same number of times[4]. The distance tothe receiving coilcan be greatly smallerupto several tens of centimeters. In these cases, the induction, as can be seen from Fig.1,increasessharply.

Let's evaluate it the possibility take-off of a not large power from the OHL usingaTesla flat coil, between the turns of which there is a ferromaterial with high magnetic permeability (ferroorferrimagnet). Such coils can be placed near the wire of electrical lineor integrated into the body of be consuming ofan electrical energy of device.

Analysis of the possibility of selection ofpowerfrom the OHL a flat coilwithferromaterialofbetween the turns

The electrical circuit of the power take–off device is given in Fig. 2. Note that in this case, the load presents a device of converting a sinusoidal current with a frequency of 50 Hz to a direct current. For exception voltage losses on the inductance of the coil, the reactance of the load must have a capacitive character and therefore the entire two-pole connected to the EMF source is in resonant mode.

For analysis, choose a single-layer flat coil of a square forms (Fig.3) with a - is external and b - is internal dimensions, W - is winding pitch, d – is wire diameter, c = W - d– is distance between turns.

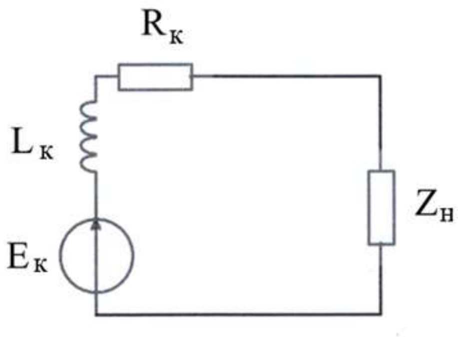

Fig. 2. Electrical diagram

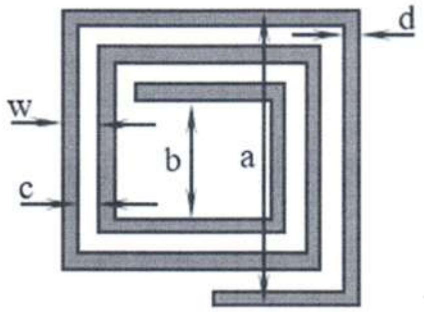

Fig. 3. Single layer flat coil

The value of the EMF of the coil $E_к$ according to the law of electromagnetic induction of Faraday is determined by the rate of change in the flux linkage of the coil Ψ with the magnetic field created by the OHL:

$$E_к = -\frac{d\Psi}{dt} = -2\pi f\Psi. \qquad (1)$$

Let's define the flux linkage Ψ of a flat square coil with a ferromaterial, is placed between the turns of the coil.

We will assume that the magnetic induction B and accordingly, the tension H in the air is constant on the surface of the coil and perpendicular to it. The section boundary is the air–

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ferromaterial are structurally design in such a way that the magnetic field strength from the air penetrates into the ferromaterial without loss.

The flux linkage of the coil Ψ is the sum of the flux linkages of all turns of the coil ψ_k, having a different magnitude, depended from what is inside the contour of the turn. With the number of turns of the coil N, have:

$$\Psi = \sum_{k=1}^{N} \psi_{\Pi k} + \sum_{k=2}^{N} \psi_{\phi k} + \psi_b = \mu_{\Pi} B \sum_{k=1}^{N} 4d \sum_{k=1}^{N} [b + 2W(n-1)] +$$

$$+\mu B \sum_{k=2}^{N} 4c \sum_{n=2}^{k} [b + 2d + 2W(n-1)] + \mu_b B b^2 \quad . \quad (2)$$

The magnitude of the inductance of a single-layer flat square-shaped coil with a ferromaterial, is calculated accordingly to the known approximate formula for a square coil [6], obtained for the relative magnetic permeability μ_r= 1:

$$L = 2{,}34 \mu_r N^2 \frac{\frac{a+b}{2}}{1+\frac{2{,}75(a-b)}{a+b}} \quad . \quad (3)$$

In our case, we have a nonuniformof magnetic properties filling of the coil space. Let us determine the average value of the relative magnetic permeability of the coil based on the equality of the flux linkages of a homogeneous coil and a coil with a ferromaterial$\Psi_0 = \Psi$. We will assume that the magnetic induction B in the coil is a constant value. Then the flux linkage of a homogeneous coil Ψ_0:

$\Psi_0 = \mu_{cp} BS$,(4)

Where

$S = \sum_{k=1}^{N} 4d \sum_{n=1}^{k} [b + 2W(n-1)] +$
k=2N4cn=2kb+2d+2Wn−1+b2 .

Flux linkage of a coil with a ferromaterialΨ:

$\Psi = BS_\mu$, (5)

where

$S_\mu = \mu_n \sum_{k=1}^{N} 4d \sum_{n=1}^{k} [b + 2W(n-1)] +$
μk=2N4cn=2kb+2d+2Wn−1 +μbb2 .

As a result, we get:

$\mu_{cp} = {}^{S_\mu}/_{S}$. (6)

Substitutinginto $\mu_r = \mu_{cp}$, we will determine the inductance of a coil with aferromaterial. This is an approximate estimate of the magnitude of the inductance, but it allows us to establish the influence of the material with high magnetic permeability on it.

Fig. 4 presents the results of calculations of the induced voltage and parameters of a coil from its step at relative magnetic permeabilityμ_r = 200and induction B = 10μTl.

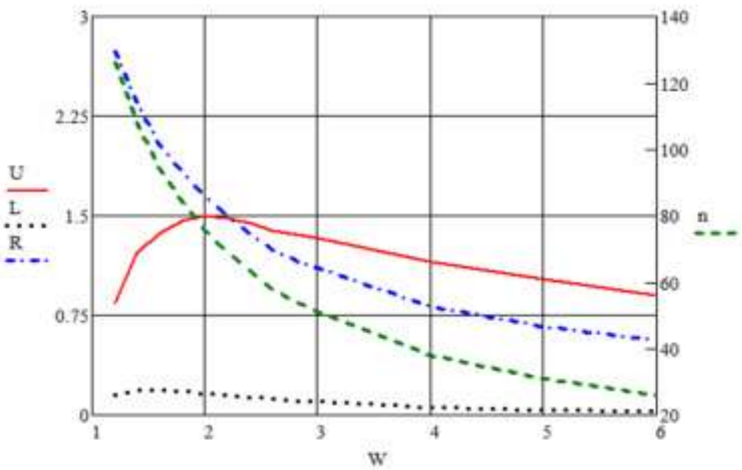

Fig. 4. Dependences of voltage on the coil U=Eк(V), its inductance L (H), active resistance R (Ohm) and the number of turns n on the pitch between turns W (mm) with a relative magnetic permeability of the ferro-ferrimagnet μ_r = 200, the diameter of the copper wire d = 1 mm and induction of magnetic field B = 10 μT

From those given in Fig. 4 results, it follows that the maximum of voltage is observed at W = 2mm, while U = 1,5V, and R = 1,65Ohm, L = 0,16H and N = 76. We will count these values as basic ones in further research.Noticing that in the absence of a ferromaterialU = 0,029 V.

The growth of voltage on the modified coil with a ferromaterial between turns occurs almost 100 times, respectively, the power grows by 100^2 = 10000 times.

In Fig.5 presents the results calculations of the voltage on the coil on the relative magnetic permeability of the ferromaterial.

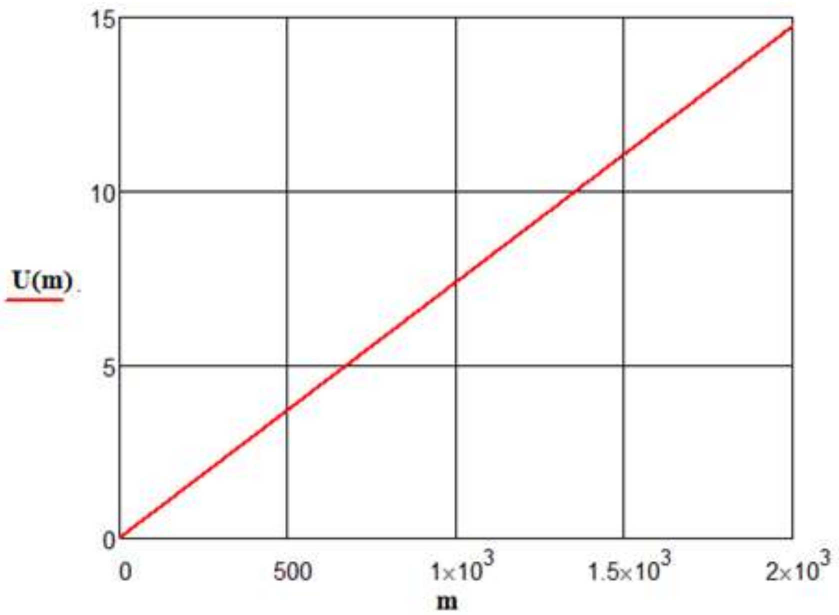

Fig. 5. Dependence of the voltage on the coil on the relative magnetic permeability of the ferro-ferrimagnet - μ_r (W = 2 mm)

The voltage growth in proportionlly to the magnitude ofμ and reaches almost 15V at μ = 2000. For today, the relative magnetic permeability of ferromaterials reaches tens of thousands or more.

On the fig. 6 presents the results of calculations of the voltage on the coil and its others parameters from internal dimension of the coil b at a fixed value of thestep.

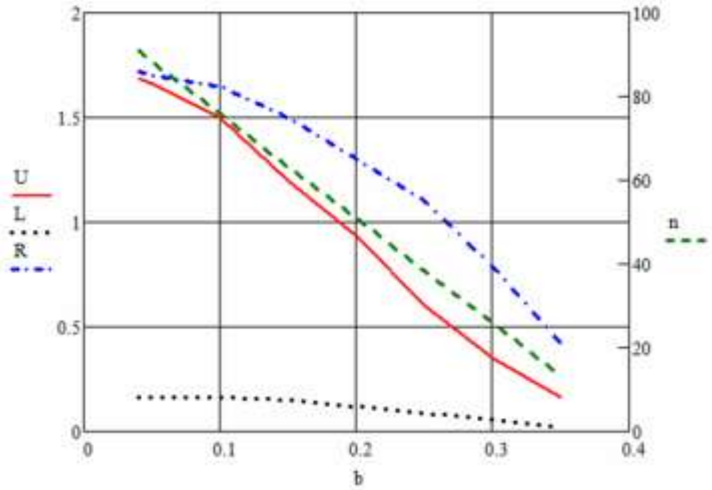

Fig. 6. Dependences of U, L, R, n on the internal size of the coil b at a fixed value of W = 2 mm

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A decrease of internal dimension b leads to an increase in the voltage of the coil at the cost an increase in the number of turns, but at the same time it is observed a significant grows in the resistance of the wire of the electrical lines.

On the fig. 7 presents the results of calculations of the influence of the filling factor of the step of the coil by a conductor on its voltage (the lower solid curve) and inductance, and theresistance of the coil isgiven in the same place.

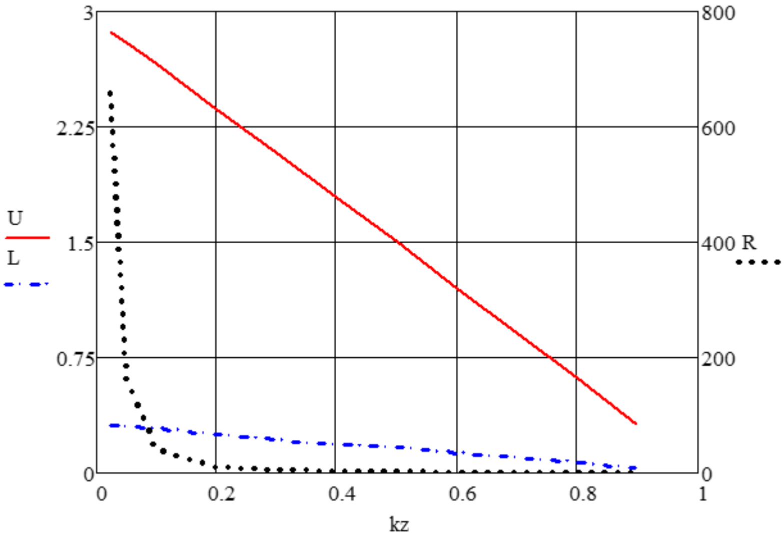

Fig. 7. Influence of the fill factor of the coil pitch with a conductor kz = d ⁄ W at a fixed value of W = 2 mm.

A decrease in the fill factor calling grows in the voltage of the coil due to an increase in the volume of the ferromaterial at a simultaneous while grows in its resistance.

II. CONCLUSION

Conducted investigation showed a possibility of the significantly increase in the efficiency of contactless selection of electricity from a high-voltage OHL with the help of flat single-layer coils, between the turns of which a ferromaterial with high magnetic permeability is put. Coils can be realized of metal having high conductivity and low weight. In the quality of the as a material between the turns ferrimagnetic, ferrite or foammaterial with high magnetic permeability can be applied.

As a result, contactless selection from anot largepower OHL or periodically recharging of the power accumulator batteriesof the technological device is possible. The application of similar flat coils is not limited only to the considered case energy selection by the technological devicesfrom OHL. They can be find applied in a charging stations, roads with wireless dynamic charging of electric vehicles, in the electric vehicles themselves, in the industrial robots, etc., as well as in RFID radio frequency identification systems to increase a range and reliability of the radio tag recognition.

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