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Research paper

Step up transformer

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Abstract

The operation of new electrical step–up transformer is based on the principle of induction of electromotive force in an electrical conductor surrounded by a magnetic circuit. The new design of the transformer with a semiconductor secondary winding is presented. Such a transformer, for all its traditional simplicity, has an arbitrarily large transformation ratio.

Keywords: *Economic Effect; Power Industry; Semiconductor; Transformer; Technology.*

1. Introduction

Transformer, device that transfers electric energy from one alternating–current circuit to one or more other circuits, either increasing (stepping up) or reducing (stepping down) the voltage. [1]
Using examples of the use of the principle of EMF induction in an electrical conductor surrounded by a magnetic shell, the evolution of a step–up transformer and semiconductor effects in one device is shown step by step. The development of the transformer manufacturing and the manufacture of semiconductors from the first works of Michael Faraday [2] [3] and Thomas Johann Seebeck [4] to modern designs of step–up transformers and further, to the near future of transformer manufacturing is described.

1.1. History

In 1821, the effect of semiconductors was noticed for the first time. [4]
In 1827, the results of research and descriptions of electrical resistance were published. [5]
In 1831, the phenomenon of electromagnetic induction was discovered, which the basis of electrical engineering became. [6]
Electromagnetic induction is the occurrence of an electromotive force in a conductor when an external magnetic field changes, on this basis, was first described the principle of the transformer (1831). [7] [8]
Further clarification followed in 1833. It was a single phase transformer. [3]
In 1876, semiconductor–coated copper wires were manufactured. [9]
In 1885, transformers were described that began to be used to convert alternating current parameters. [10]
In 1891, the Tesla coil circuit was patented. This coil (Tesla transformer) made it possible to create a transformer with a significant transformation ratio. [11]
Despite the established traditions in the design and production of transformers, in 2003 a transformer was proposed with a different operating principle, based on the use of not the reactive component of the resistance of the transformer windings, but the active one. [12]
In 2021, the proposed operating principle of the new transformer was confirmed experimentally, namely, it was established that a conductive wire that has electrical resistance in an alternating electromagnetic field along the entire length of this wire is under voltage induced by this alternating electromagnetic field. This electrical voltage is equal to the geometric sum of voltage from the reactive and active components of the resistance of a given electrically conductive wire. [13]

2. Methods

The principle of electromagnetic induction in a transformer provides the induction of an electrical voltage in the coil of an electrical conductor by changing the magnetic field surrounding this coil. Using the phenomenon of electromagnetic induction to change the ratio of currents and voltages in the primary and secondary circuits in the construction of transformers. [3] [6]
Such changes in the ratio of currents and voltages in transformers are determined by the ratio of these physical quantities in the primary and secondary windings (transformation ratio). In turn, the values of these coefficients are determined by the ratio of the electrical resistances of the primary and secondary windings of this transformer. [3] [14]

The total electrical resistance (reactive and active – electrical impedance [15]), compared with only the reactance in the secondary winding of the transformer, increases the transformation ratio with a phase shift of induced currents and voltages.

2.1. Calculation formulas for a new transformer

The proposed transformer is similar to the design of a well–known transformer with a closed steel core of a magnetic flux conductor on which the primary and secondary copper windings are located. [16]
Such the transformer has the transformation ratio k :

$$k = \frac{U_1}{U_2} \tag{1}$$

Here U_1 is effective voltage value on the primary winding, U_2 is, similar, on the secondary winding.
Voltage U_2 is the result of the effective value of the electromotive force E induced in the secondary winding: [12]

$$U_2 = E = \sqrt{E_{\mathrm{L}}^2 + E_{\mathrm{R}}^2} = Kfw\Phi\sqrt{1 + \frac{1}{Q^2}} \tag{2}$$

Here E_{L} is inductive component from E, E_{R} is ohmic component of E , K=4.44 is coefficient, w is number of secondary winding turns, Φ is magnetic flux value, $Q = \frac{fL}{R}$ is winding quality factor [17], L is winding inductance, f is the operating frequency of the transformer, R is the ohmic resistance of the winding.
In transformers with copper windings, the active resistance of the windings R is negligibly small and the resistance of the windings is equal to the reactances of these windings U_1 and U_2 :

$$U_1 = E_1 = K\, f\, w_1\, \Phi \tag{4}$$

If in transformers with a secondary winding made of a semiconductor, the active resistance of the windings R_2 is a significant value, that is, Q is negligible in value:

$$U_2 = E_2 = K\, f\, w_2\, \Phi\, \frac{R_2}{fL_2} \tag{5}$$

Hence k for a transformer with a copper primary and semiconductor secondary winding is expressed by the formula:

$$k = \frac{K\, f\, w_1\, \Phi\, fL_2}{K\, f\, w_2\, \Phi\, R_2} \tag{6}$$

Or

$$k = \frac{w_1 L_2 f}{R_2 w_2} \tag{7}$$

When R is a significant value, k is much less than 1. Such a transformer is a step–up transformer and its k depends, to a large extent, on the active resistance R_2 of the secondary winding of the transformer.

3. Using this transformer

To get an idea of the capabilities of the new transformer, you should pay attention to the electrical conductivities of copper (the traditional material for the primary winding of a transformer) and the semiconductor material for the secondary winding. For copper, the electrical conductivity is 0.0175 (Ohm×mm^2/m), and for semiconductors this value is less by a factor of 10^2 to 10^{16}. This shows that a transformer with a semiconductor secondary winding can have a transformation ratio 10^{n} times greater than that of a similar transformer of a traditional design (with a copper secondary winding). In our case, n can be greater than 10. Thus, the transformation coefficient of the proposed transformer can have a fantastic value, for example, k =10^{12} (for a secondary winding made of quartz). This amazing property of the proposed transformer will ensure its use in creating high electrical voltages for the study of materials and substances, as well as for the ionization of gases (air), as well as for the operation of charged particle accelerators.
For the reliability of the design of the proposed transformer, and for the stability of the operation of this transformer, regardless of temperature changes, the secondary winding can be made of tungsten. [13]
The proposed transformer can replace electrostatic generators to produce large differences in electrical potential.
The efficiency of this transformer will not fall below 50% if the electrical resistance of the secondary winding is equal to the electrical resistance of the load. In this case, the transformation coefficient will be maximum.

4. Conclusion

Over the last century, the main efforts in the development of transformer manufacturing have been:

- Increasing the efficiency of the transformer,
- Reducing the cost of transformers while maintaining their efficiency and reliability.

The proposed solution will allow us to expand this list and pay attention to increasing the transformation ratio. This is achieved not by increasing the quality factor of the secondary winding of the transformer, but, on the contrary, by lowering this quality factor.

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