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Electrical Transformers (Mini review)

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Abstract

The history of a new direction in transformer engineering is described. The operation of the new transformers is based on the principle of electromotive force induction in a winding with a magnetic circuit. With the new arrangement of the windings (or winding), together which perform the functions of the electrical and magnetic parts of the transformer, the windings (magnetic circuits) in one transformer are perpendicular to each other, and with mutual coverage of each other. This ensures the use of this principle of electromotive force induction. The materials that make up the transformer are used in a complex way: one material both for the manufacture of magnetic circuits and for the manufacture of electrical windings of the transformer. In this case, we can refuse copper. As a result, combined windings-magnetic cores can be made of a single material with sufficient electrical and magnetic properties, such as pure iron. For the complex use of the winding-magnetic core in a single-phase transformer, the "monkey knot" lineup is proposed.

Keywords: Power industry, Transformer, Technology, Assembly, Copper, Electrical steel, Economic effect, Assembly of transformers.

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1. Introduction

On examples of using the principle of electromotive force induction in a winding with a magnetic circuit, the evolution of transformer engineering is shown step by step.

The development of transformer engineering from the first works of Faraday, to modern designs of transformers, and further, to the immediate prospects of transformer technology is presented.

One of these new directions is based on the dual functional use of transformer materials, both electrically conductive and magnetic. This may lead to the use of chemically pure iron as both an electric current conductor and a magnetic flux conductor.

In the Cartesian coordinate system, each axis is perpendicular to the other two axes. This provides the use of electromotive force induction, on one axis, from the magnetic fields of the other two perpendicular axes. So for all three axes. Each of these axes has one transformer windings with mutual coverage of the other two windings. This is necessary to build a new three-phase transformer.

To use the principle of the Cartesian system for a single-phase transformer, one winding of this transformer, which is also a magnetic circuit, is laid according to the "monkey knot" type, which ensures the implementation of the principle of EMF induction in a coil with a magnetic circuit.

The transformer without a copper winding is not the final stage in the development of transformer engineering.

The direction of development of transformer engineering using the phenomenon of electromagnetic induction is not final. Only one branch is shown here.

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.

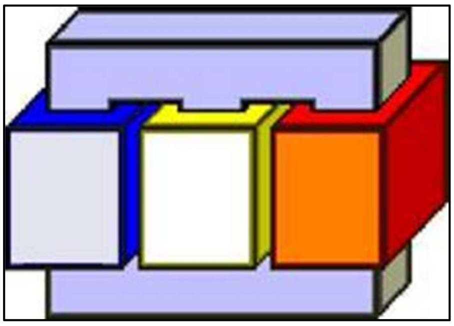
Cartesian coordinate system - ensuring mutual perpendicularity of electric currents and magnetic fluxes.

3. Three–phase transformer development path

Initially, the three–phase transformer was designed using the electromagnetic properties of materials such as the best electrical conductivity of copper and the best magnetic conductivity of iron. [1]

In our time, a three-phase transformer with a layout that has become traditional has become widespread (see Figure 1). In this and all subsequent figures, the individual phases (there are three in total) of transformers are depicted in different colors. In this case, the cross section of the magnetic circuits in such transformers is several times greater than the cross section of the winding.

Figure 1:

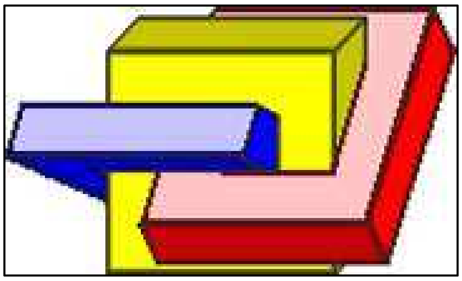


Source: Author.

If each winding of a transformer spans two other coils, then for each winding the other two windings will act as the cores of the transformer. If the transformer windings are made of iron, the cross section of which is several times larger than the cross section of the copper windings, then the electrical resistance of the windings will not change, since the electrical conductivity of iron is several times less than that of copper. In this case, the resulting windings will fully perform the functions of the magnetic cores of the transformer. [2]

This design is shown in Figure 2, [3, Figure 1].

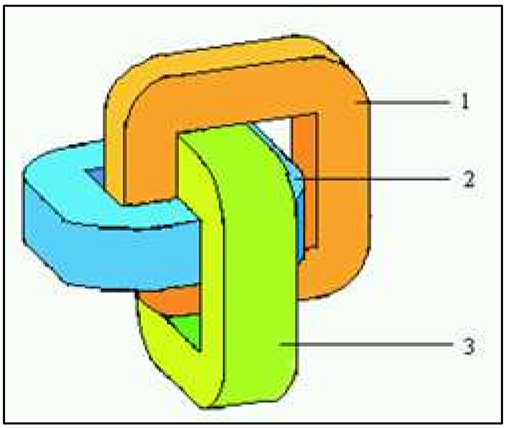
Figure 2: [3, Figure 1]



Source: Author.

If the transformer windings are positioned relative to each other at an angle other than 60° (120°), as in fig. 1, but 90° (see Fig. 3 [3]), then the efficiency of the transformer and the efficiency of using the magnetic cores of the transformer will increase.

Figure 3: [3, Figure 2]

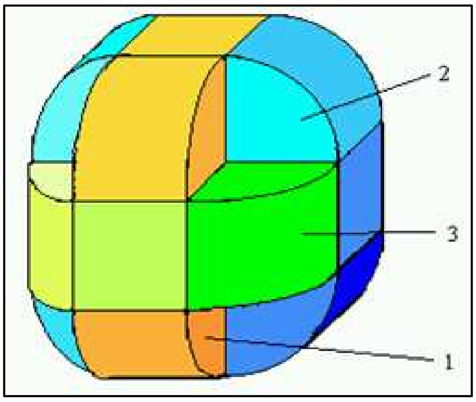


Source: Author.

Here 1, 2 and 3 are the transformer windings. They (1, 2 and 3) are the cores of this transformer. The Figure 4 shows the same positions: 1, 2 and 3.

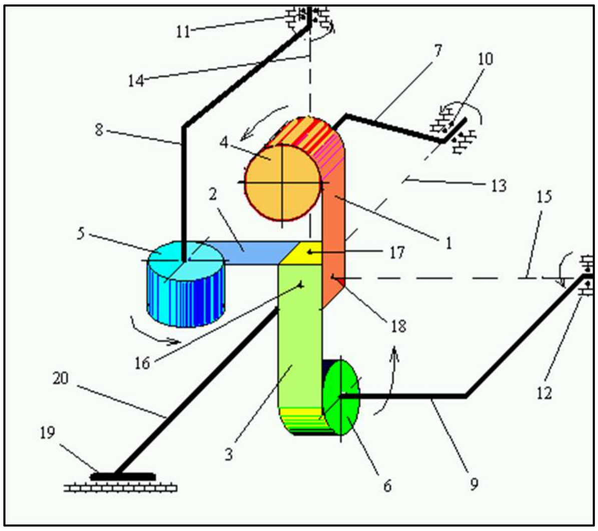
Figure 4 shows a transformer in which the electric windings (they are the magnetic cores of the transformer) are a single whole, that is, they are wound simultaneously, one turns of one winding to other turns of the other winding.

Figure 4: [3, Figure 3]



Source: Author.

Figure 5: Shows a diagram of a device for such winding. [3, Figure 4]

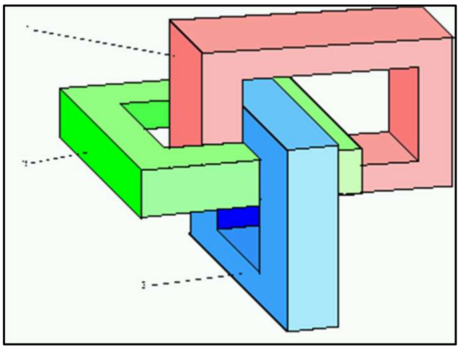


Source: Author.

Here 1, 2 and 3 are steel strips covered with insulation and wound in rolls 4, 5 and 6, respectively. Each roll rotates on an axis with rods 7, 8 and 9, respectively. Each rod is attached to shafts 10, 11 and 12, respectively. Axes 13, 14 and 15 of each shaft 10, 11 and 12, respectively, are directed to the middle of the faces 16, 17 and 18 of the Central technological cube, respectively. The cube is fixed on the base 19 by means of a rod 20, the axis of which passes through the largest diagonal of the cube. Shafts 10, 11 and 12 rotate synchronously. This ensures simultaneous winding of the transformer windings. [4]

To be able to use shuttles for winding transformers, the proposed transformer is made with additional gaps between the windings. These gaps are necessary for the passage of shuttles (See Figure 6. [3, Figure 5]).

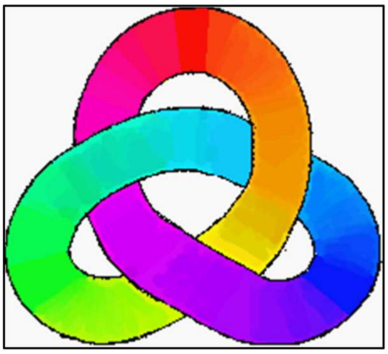
Figure 6:



Source: Author.

The single–phase transformer is also possible. Monkey's knot, known since time immemorial, is the design of such a single–phase transformer. (See Figure 7, [3, Figure 6]).

Figure 7:



Source: Author.

In such a transformer, the primary and secondary windings are parallel to each other and wrap around each other along the trajectory of the monkey knot.

The concentric system of transformer windings, tied in the form of a "monkey knot", has the following feature: each section of the winding is perpendicular to its other sections. This allows you to direct the electric current and magnetic flux through one ferromagnetic electrically conductive concentric winding system. In this case, the direction of the electric current always crosses the magnetic flux at an angle, and this is the condition for the transformer to work.

4. Perspectives

In the field of transformer engineering, such a solution will ensure the rejection of copper. Iron is sufficient for the production of transformers with such constitution.

Moreover, Figures 3, 6 and 7 show the configuration of the transformer, in which each winding covers two magnetic circuits, that is, the magnetic flux from each winding is divided into two flows and closed through two magnetic circuits. This reduces the magnetic load on each magnetic core by half, and will reduce the transformer by half.

5. History

In 1831, the English physicist and chemist Michael Faraday discovered the phenomenon of electromagnetic induction, which became the basis of electrical engineering. Electromagnetic induction is the occurrence of an electromotive force in a conductor when an external magnetic field changes. [5] [6]

On this basis, in the same 1831, M. Faraday first described the principle of the transformer, and further clarification followed in 1939. It was a single phase transformer. [7]

In 1889, a three–phase transformer with a copper winding and an iron magnetic core was proposed. [1]

In 1984, a three-phase transformer without copper winding was proposed, where steel windings and magnetically conductive cores, which were used both as windings and as magnetic circuits, together. [2]

In 2003, designs and methods for assembling them were proposed for three–phase transformers with higher efficiency, in which the conductive turns were perpendicular to the magnetically conductive cores. [4]

6. Conclusions

In transformers, the main (overwhelming) weight (and cross section) is magnetic cores. The resistivity of copper [8] is six times less than that of pure iron [9] [10]. Therefore, the total cross section of the iron winding of the proposed transformer will be six times larger than it would be if a copper winding was used. This indicates that the main calculation of the proposed transformer will be carried out according to the limitations of the magnetic circuit. In this case, the conductive winding will always be redundant.

Based on the fact that the designs of the proposed transformer have a feature: the division of the magnetic flux from each winding into two (see Figures 3 and 6), the magnetic circuit can be chosen two times smaller in cross section than in a conventional transformer.

If pure iron is chosen as the material for the manufacture of the winding–core of the proposed transformer, then the requirements for both high electrical conductivity and high magnetic permeability of the transformer material will be satisfied.

Making the core-winding of the transformer from pure iron will reduce the hysteresis. [11]

Making the core–winding of the transformer in the form of a wire (tape) wound on two other core–windings will ensure the suppression of eddy currents (Foucault currents). [12]

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