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(54) **Compact power transformer in V-V for electrical traction**

(57) A power transformer (100) for electrical traction, comprising: a tank (3), and a single magnetic core (10) which is positioned inside the tank (3) and comprises one central leg (11) and two side legs (12, 13). A first phase

(20) comprises a primary winding (22) and a secondary winding (21) which are wound around one leg. A second phase (30) comprises a primary winding (32) and a secondary winding (31) which are wound around another leg.

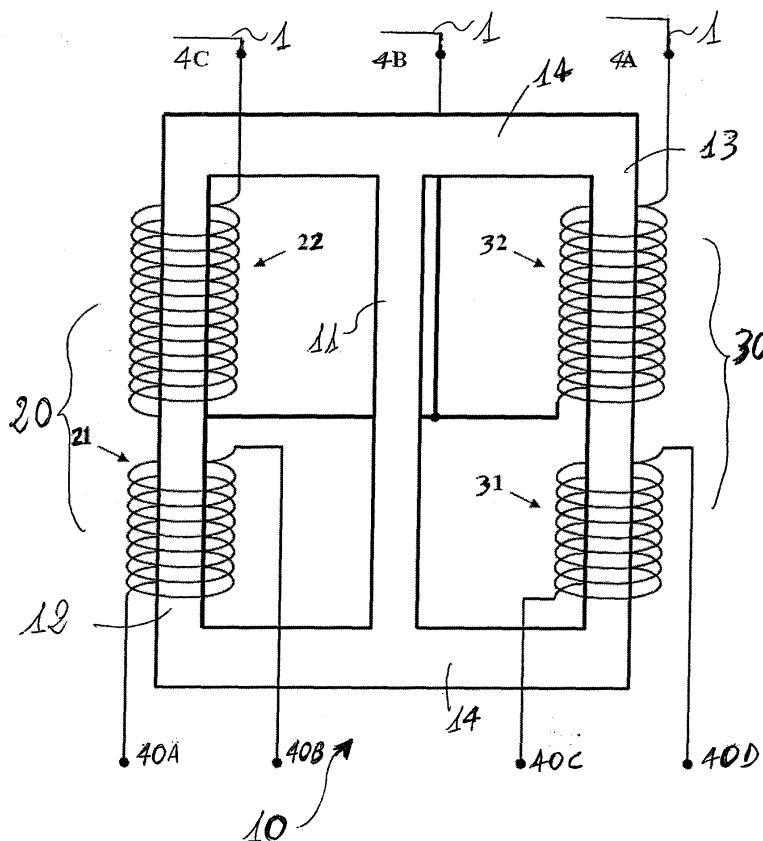


FIGURE 1

Description

[0001] The present invention relates to a compact power transformer for electrical traction. More particularly, the present invention relates to a compact power transformer in a V-V connection which is especially suitable for electrified railway traction systems and will be described by making reference to these systems without intending however to limit in any way its possible applications.

[0002] Voltage and current transformation equipments are well-known and used in the electricity sector to carry electric power from generator units to loads or end users.

[0003] Transferring electric power in an efficient way requires high voltage levels so as to reduce the current flowing through the lines and thus to minimise power losses associated to the energy transmission. Hence, this transportation of electric power is more efficient at high voltage, whereas consumption requires a lower voltage level, e.g. medium-voltage networks, for safety reasons. Therefore, electrical machinery is required to efficiently convert high-voltage power into medium or low-voltage power. These machines are called transformers.

[0004] In electrified traction applications, and in particular in railways traction systems, single-phase alternating current power systems are normally required, whereas alternating current power transmission systems are almost always three-phase.

[0005] There are different technical alternatives for three-phase input power voltage and single-phase output voltage transformers, depending on the way the windings associated to both voltage systems involved are connected.

[0006] In most cases, the so-called V-V connection system has been used in the past for this type of applications with quite effective results. More specifically, the aim of a transformer in a V-V connection for traction is to supply medium voltage power (in single-phase model) to railway equipments, taking it from a three-phase, high voltage power line. In its classic design, this type of connection uses two separate and distinct single-phase power transformers with windings connected as follows:

- the ends of the primary windings of each single-phase transformer are connected to two phases of the three-phase power system. Therefore, one of the ends of both windings will be connected to a common phase and the other to a different phase;
- the secondary windings of each single-phase transformer are connected in series and the connection point of both windings is normally earthed. Hence, there is an alternating single-phase voltage between the other ends of these secondary windings that is used to power the railway equipment.

[0007] The V-V connection provides single-phase power from a three-phase power network, causing only a slight imbalance in the latter network. It is also common

for one or both windings to include taps to adjust the output voltage. Finally, it is worth indicating that, due to the operation conditions of the railway equipment, the traction transformers are designed considering much more severe service conditions than a normal power transformer since they must withstand strong, short-term overloads and high electro-dynamic stress on the windings due to frequent current surges, etc.

[0008] Even though the power transformers used at present provide a good solution they still have some drawbacks which deserve improvements. In particular, one major drawback of known solutions resides in the fact that they use two independent single-phase transformers and therefore two independent magnetic circuits. In turn, these circuits have to be included either in two different hermetic tanks or in a single hermetic tank. In both cases, the end result is a cumbersome solution, in particular in terms of size and weight. This directly entails other shortcomings due to problems and costs of transportation and installation, as well as potential problems of maintenance and reliability since double components are used.

[0009] Hence, the main aim of the present invention is to provide a new power transformer for electrical traction which allows to overcome the above mentioned drawbacks, and in particular which is more compact, reliable and cheaper with respect to the existing prior art solutions.

[0010] This aim and others which will become apparent hereinafter are achieved by a power transformer for electrical traction, characterized in that it comprises:

- a tank;
- a single magnetic core which is positioned inside said tank and comprises three legs of which one leg is positioned centrally and two legs are positioned at the sides of the central leg;
- a first phase comprising a primary winding and a secondary winding which are wound around one of said three legs;
- a second phase comprising a primary winding and a secondary winding which are wound around another one of said three legs.

[0011] In a particularly preferred embodiment, the primary winding and the secondary winding of the first phase are wound around a first side leg, while the primary winding and the secondary winding of the second phase are wound around a second side leg.

[0012] Further characteristics and advantages will become apparent from the description of some preferred but not exclusive embodiments of a compact power transformer according to the invention, illustrated only by way of non-limitative examples with the accompanying drawing wherein:

Figure 1 schematically shows the layout of the windings and the magnetic circuit of the power transform-

er according to the present invention;

Figure 2 shows a side view of the compact transformer of Figure 1 in a V-V connection, ready for connection to an electrical power system;

Figure 3 illustrates the power transformer of figure 2 seen from the rear part;

Figure 4 is a top view of the power transformer of figures 2 and 3;

Figure 5 schematically shows a wiring diagram of the power transformer connections.

[0013] In the following description, the same reference numerals will be used to indicate in the various figures the same or equivalent components.

[0014] With reference to the above cited figures, the power transformer for electrical traction according to the present invention, globally indicated in figures 2-4 by the reference number 100, comprises a tank 3 containing the active part of the transformer, such as the magnetic circuit, the windings and their connections, and the on-load or off-load tap changer, according to customer requirements. This tank 3 may include also the parts necessary to move the transformer, such as wheels and corbels, to transport and lift it, and for its placement in the final location. An oil storage and preservation tank 5, usually indicated as the conservator, is also provided for containing the necessary oil to compensate for any variations of the volume of the oil contained in the main tank 3 which variations may be caused for example by changes in temperature. In figure 3 there are shown also the cooling parts 6 which are necessary to keep the oil temperature within the accepted levels and for dissipating any internal power loss of the transformer. In the embodiment illustrated, the cooling equipment 6 is made up of radiators and motor-fans. In figure 3 it is also illustrated an off-load tap changer wheel 7, and a control cabinet 8 from where a user of the machine can connect to the transformer protection and control equipment. Also an on-load tap changer can be provided.

[0015] Advantageously, in the power transformer 100 according to the invention, the magnetic circuit comprises a single magnetic core, which is indicated in figure 1 by the reference number 10 which is positioned inside the tank 3. As illustrated, the unique magnetic core 10 comprises three legs or limbs 11, 12, 13 of which one leg 11 is positioned centrally and two legs 12, 13 are positioned at the sides of the central leg 11. The legs 11, 12, 13 are connected to each other by means of yokes 14. A first phase 20 comprises a primary winding 22, e.g. a high-voltage winding, and a secondary winding 21, e.g. a medium-voltage winding, which are wound around one of the three legs 11, or 12, or 13. A second phase 30 comprises a primary winding 32, e.g. a high-voltage winding, and a secondary winding 31, e.g. a medium-voltage winding, which are wound around a different one leg 11, or 12, or 13.

[0016] As defined by international standards and common practices, the definition of high-voltage is hereby

meant to indicate voltage levels above 1 kV, while the definition of medium voltage is usually used to indicate a sub-range of such a high voltage range, i.e. voltage levels above 1 kV and up to 72 kV or even up to 100kV.

[0017] According to a preferred embodiment illustrated in figure 1, the primary winding 22 and the secondary winding 21 of the first phase 20 are wound around a first side leg, e.g. the side leg 12; in turn, the primary winding 32 and the secondary winding 31 of the second phase 30 are wound around the second side leg 13. The central leg 11 constitutes a return path for the magnetic flux circulating through the side legs 12, 13. In other words, in operation, in one side leg 12 of the transformer a magnetic flux corresponding to the phase-to-phase voltage is generated; this flux has a certain modulus and phase. On the other side leg 13 a magnetic flux is also generated with the same modulus - since it is also connected to phase-to-phase voltage and it is usually supposed that there is a balanced voltage system- and with a phase displacement of 120 degrees. With the properly selection of connections and directions of windings, the vectorial addition of both magnetic fluxes, which flows through the central leg 11, has the same modulus and a phase displacement of 240 degrees. Thus, through the three legs 11, 12, 13 the same amount of magnetic flux flows. In the side legs 12, 13 it is generated by the windings and in the central leg is due to their vector sum.

[0018] According to solutions which are well known and readily available to a person skilled in the art and thus not described herein in detail, the windings 22, 32, 21 and 31 in the side columns 12 and 13 can be designed according to traditional criteria associated to single-phase transformers in terms of insulation distances, current densities, etc. Their design can be conceived taking into account the special characteristics associated to traction transformers, such as heavy overloads, frequent surges that involve severe electro-dynamic requirements, etc.

[0019] As better illustrated in figure 2, the power transformer 100 comprises a first series of bushings 4 which are suitable for operatively interconnecting the first phase 20 and the second phase 30 with a power line, i.e. a high voltage three-phase power line schematically shown in figure 1 by the reference number 1. Further, the transformer 100 comprises a second series of bushings 40 which are suitable for operatively interconnecting the first phase 20 and second phase 30 with at least one electrical equipment (not illustrated in the figures), in particular with medium-voltage power systems.

[0020] The first series of bushings 4 comprises: a first high-voltage bushing 4C which is connected to the primary winding 22 of the first phase 20; a second high-voltage bushing 4A which is connected to the primary winding 32 of the second phase 30; and a third high-voltage bushing 4B which is connected to both the primary winding 22 of the first phase 20 and the primary winding 32 of the second phase 30. The high-voltage 4A, 4B, 4C are connected to the three-phase power line 1

and can be constituted for example by condenser-type high-voltage bushings.

[0021] In turn, the second series of bushings 40 comprises: a first bushing 40A and a second bushing 40B which are connected to the secondary 21 winding of the first phase; and a third bushing 40C and a fourth bushing 40D which are connected to the secondary phase 31 of the second phase 30. One of the bushings 40A or 40B which are connected to the secondary winding 21 of the first phase 20, e.g. the first bushing 40A is connected to earth; likewise, one of the third bushing 40C and the fourth bushing 40D which are connected to the secondary winding 31 of the second phase 30, i.e. the third bushing 40C is connected to earth.

[0022] Such bushings 40A-40D can be constituted for example by condenser-type ceramic bushings.

[0023] In this way, the primary or high-voltage windings 22 and 32 are connected in a V-V configuration, while the secondary or medium-voltage windings 21 and 31 are connected in series. Clearly, depending on the applications and/or specific needs, many other connection configurations are possible, in particular for the secondary windings.

[0024] Figure 5 shows the layout of the connections for the different windings forming the transformer in a V-V connection. The two single-phase high-voltage windings 22 are provided in this case with adjustment taps 23. The current transformers 24 on the medium-voltage output side can be seen, which are used to power the measuring and protection equipment in the substation where the transformer is installed.

[0025] In practice, it has been found that the power transformer according to the present invention fully achieves the intended aim giving several advantages with respect to prior art solutions. In fact, as previously described, the present power transformer 100 features a very compact design wherein all the windings are in a V-V connection and in a single magnetic circuit with a single one-body three-column magnetic core. Thanks to its compact configuration, the two-phase power transformer in V-V connection has an optimal design in terms of its weight and size and represents a significant improvement for new transformers in V-V connection (or the replacement of currently installed equipment), as it is cheaper than existing technical solutions that can be adopted for this type of connection. Hence, investments necessary for the manufacturing, purchase, and the space required for the transformer location are optimised. As an example of these achievements, for a 32 MVA power transformer with a primary voltage of 110 kV, the size of the machine can be reduced to approximately 6 metres in length, 5.7 metres in width and 5.1 metres in height. The total weight can be also reduced to approximately 75 tons and this can bring further advantages in the cost of transportation since for example, a transported weight for the heaviest part of up to 120 tons is considered suitable for road transport, while weights over this level require rail transportation.

[0026] As above indicated, the power transformer according to the invention is suitable for application in electrical traction and in particular for electrified railways power system. Thus the present invention also relates to an electrical power system, in particular an electrified railways traction power system, comprising:

- a power line, i.e. a high voltage power line 1;
- one or more electrical equipments suitable to be powered by said power line, comprising for example a one-phase medium-voltage power system; characterized in that it comprises a power transformer 100 as above described which is operatively connected between said power line and said one or more electrical equipments.

[0027] The power transformer thus conceived is susceptible of modifications and variations, all of which are within the scope of the inventive concept; all the details may furthermore be replaced with technically equivalent elements. For example, the bushings can be made according to a different construction or can be differently positioned or electrically connected. In practice, the materials used, so long as they are compatible with the specific use, as well as the dimensions, may be any according to the requirements and the state of the art.

Claims

1. A power transformer (100) for electrical traction, **characterized in that** it comprises:
 - a tank (3);
 - a single magnetic core (10) which is positioned inside said tank (3) and comprises three legs (11,12,13) of which one leg (11) is positioned centrally and two legs (12, 13) are positioned at the sides of the central leg (11);
 - a first phase (20) comprising a primary winding (22) and a secondary winding (21) which are wound around one of said three legs (11, 12, 13);
 - a second phase (30) comprising a primary winding (32) and a secondary winding (31) which are wound around another one of said three legs (11, 12, 13).
2. The power transformer (100) according to claim 1, **characterized in that** the primary winding (22) and the secondary winding (21) of said first phase (20) are wound around a first one (12, 13) of said side legs (12, 13).
3. The power transformer (100) according to claim 2, **characterized in that** the primary winding (32) and the secondary winding (31) of said second phase (30) are wound around a second one (13, 12) of said side legs (12, 13).

4. The power transformer (100) according to one or more of the previous claims, **characterized in that** said central leg (11) constitutes a return path for the magnetic flux circulating through said side legs (12, 13). 5

5. The power transformer (100) according to one or more of the previous claims, **characterized in that** it comprises a first series of bushings (4) for operatively interconnecting said first phase and said second phase with a power line. 10

6. The power transformer (100) according to one or more of the previous claims, **characterized in that** it comprises a second series of bushings (40) for operatively interconnecting said first phase and second phase with at least one electrical equipment. 15

7. The power transformer (100) according to claim 5, **characterized in that** said first series of bushing comprises a first high-voltage bushing which is connected to said primary winding of the first phase, a second high-voltage bushing which is connected to said primary winding of the second phase, and a third high-voltage bushing which is connected to both the primary winding of the first phase and the primary winding of the second phase. 20 25

8. The power transformer (100) according to claim 6, **characterized in that** said second series of bushings comprises a first bushing and a second bushing which are connected to the secondary winding of said first phase, and a third bushing and a fourth bushing which are connected to the secondary phase of said second phase. 30 35

9. The power transformer (100) according to claim 6, **characterized in that** one of said first and second bushings which are connected to the secondary winding of said first phase is connected to earth, and one of said third and fourth bushings which are connected to the secondary winding (31) of said second phase (30) is connected to earth. 40

10. An electrical power system for electrical traction comprising: 45
 - a power line;
 - one or more electrical equipments suitable to be powered by said power line, **characterized in that** it comprises a power transformer according to claim 1 which is operatively connected between said power line and said one or more electrical equipments. 50 55

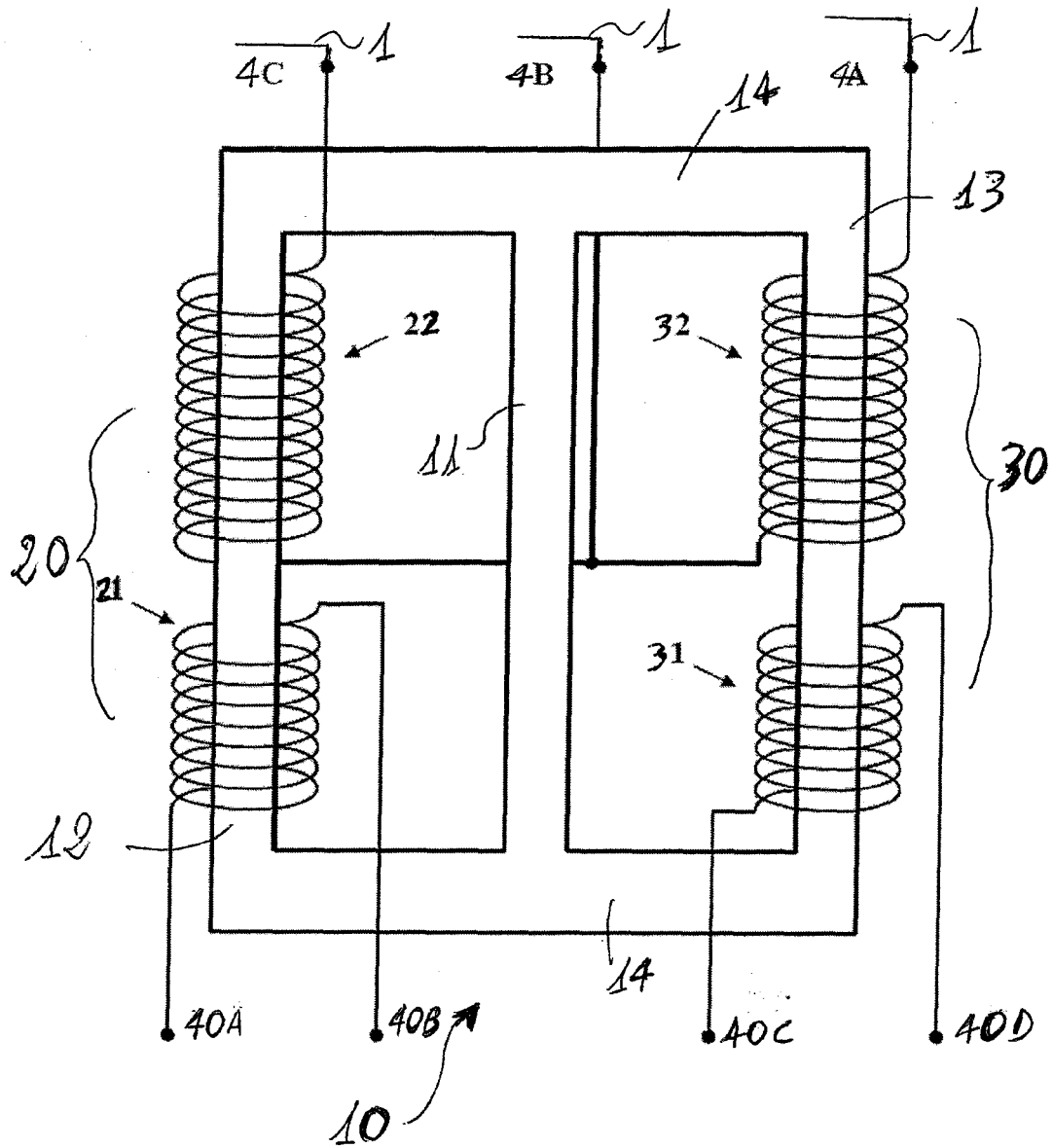


FIGURE 1

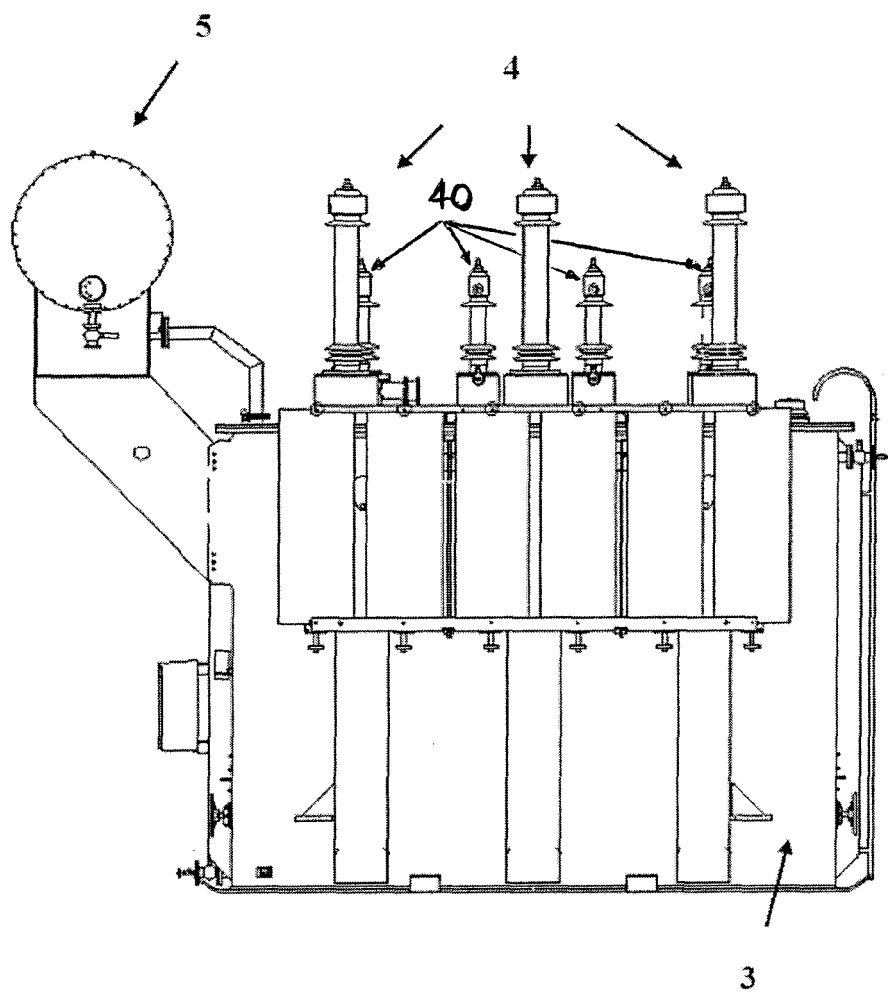


FIGURE 2

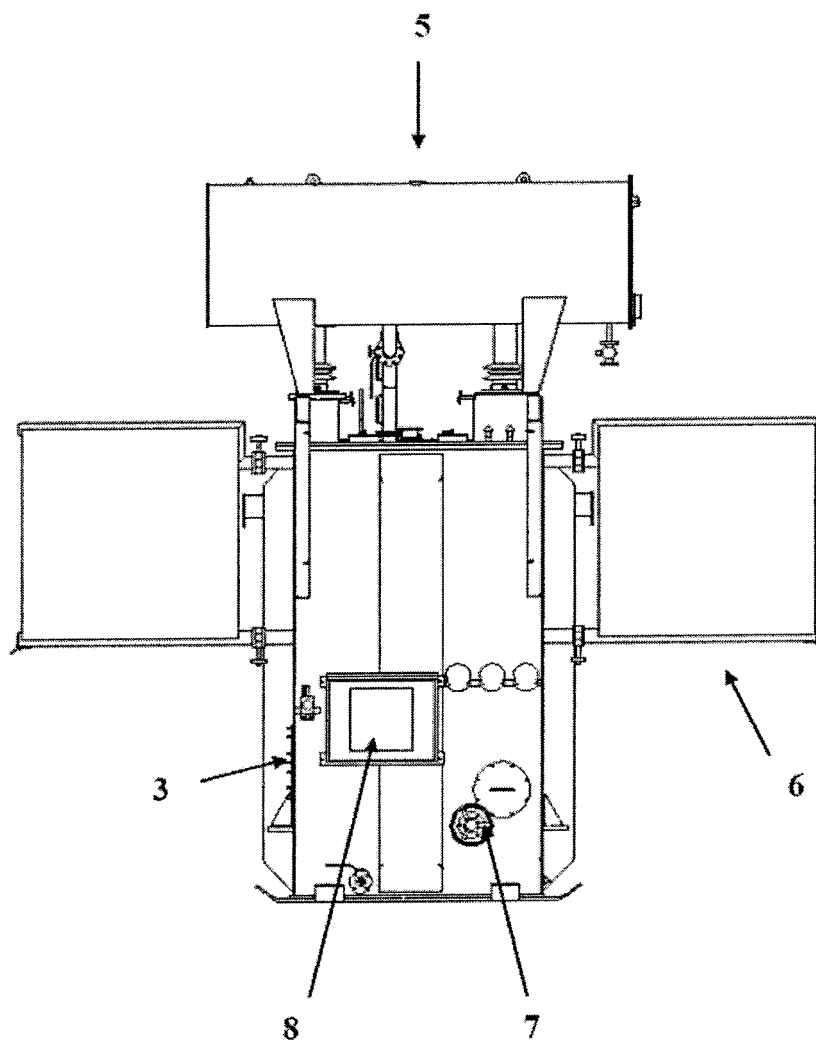


FIGURE 3

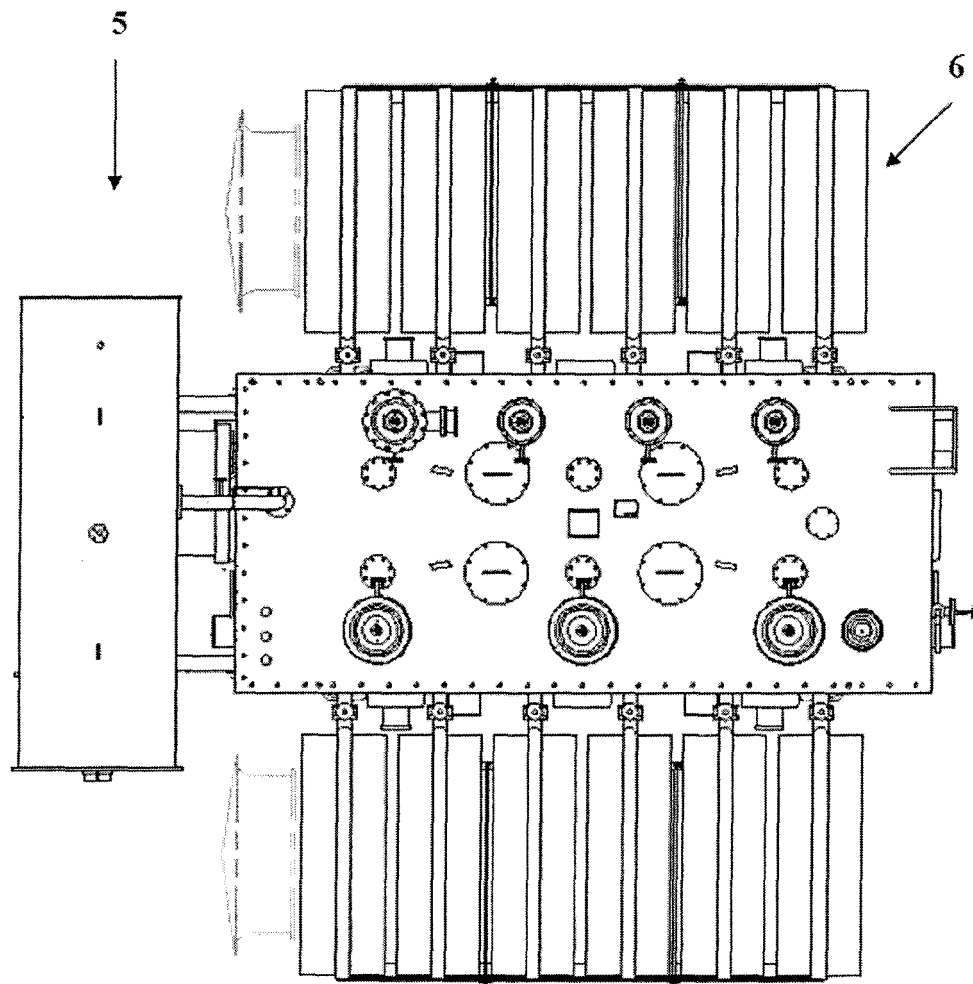


FIGURE 4

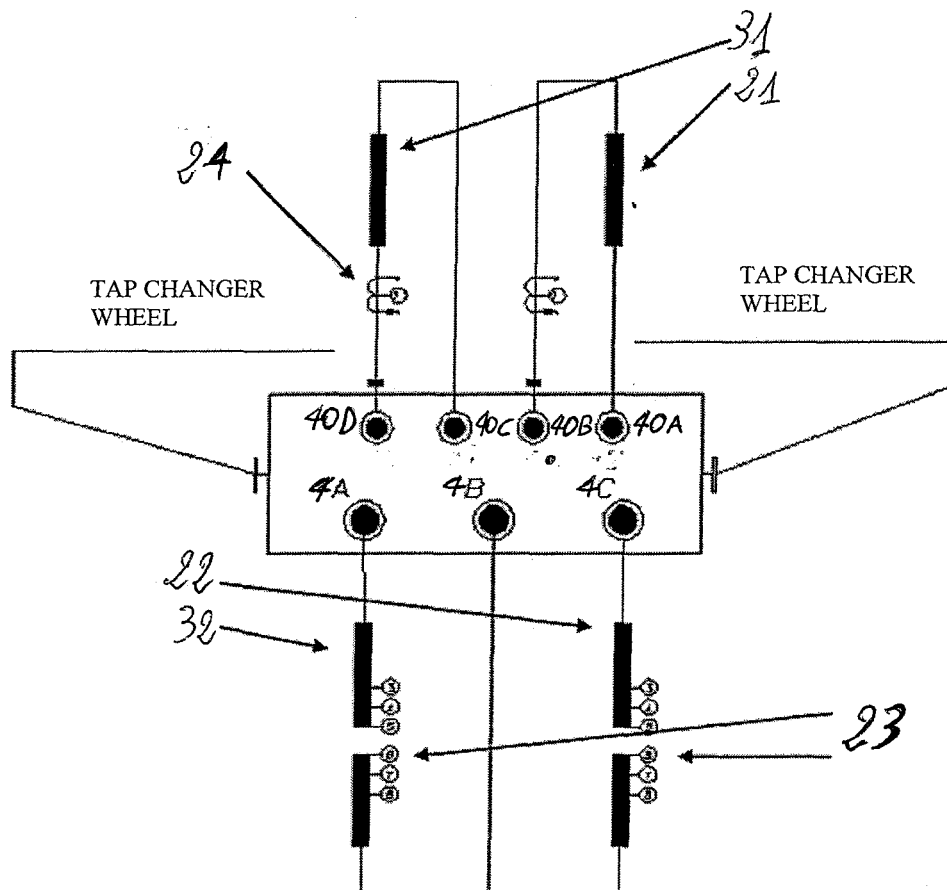


FIGURE 5



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EUROPEAN SEARCH REPORT

Application Number
EP 07 10 0680

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The present search report has been drawn up for all claims			
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**ANNEX TO THE EUROPEAN SEARCH REPORT
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