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(54) TRANSFORMER ARRANGEMENT

(57) Arrangement of a transformer with an output rectifier (30) comprising at least one primary winding (231) that consists of at least one segment made with several turns, wound at a suitable distance around the transformer axis (300), an iron core (236) electrically isolated from said primary winding, at least one secondary winding (233) electrically isolated from said primary winding and said iron core, comprising a first part (234) of said at least one secondary winding and a second part (235) of said at least one secondary winding, wherein both are wound at appropriate distances around the transformer axis (300), between which at least one primary winding coil is arranged, wherein said primary winding and said secondary winding overlap along the axis (500) in a part surrounded by an iron core and further, wherein the said primary winding and the said secondary winding in the part of the winding heads, which are not surrounded by the iron core, overlap only partially or do not overlap, which allows straight and short arrangement of the connections of an output rectifier in the direction of the axis (500).

As a result of the proposed transformer arrangement improved electromagnetic properties of the welding system are obtained, which provides a more homogeneous distribution of magnetic field in the iron core and a homogeneous distribution of electric currents in conductive parts, which affects the reduction of transformer power loss and operation with the higher frequency of the supply voltage. The arrangement of the secondary winding according to the present invention at the same time enables a much simpler production of the cooling of the welding transformer with output rectifier by liquid coolant by making bores of the adequate dimensions.

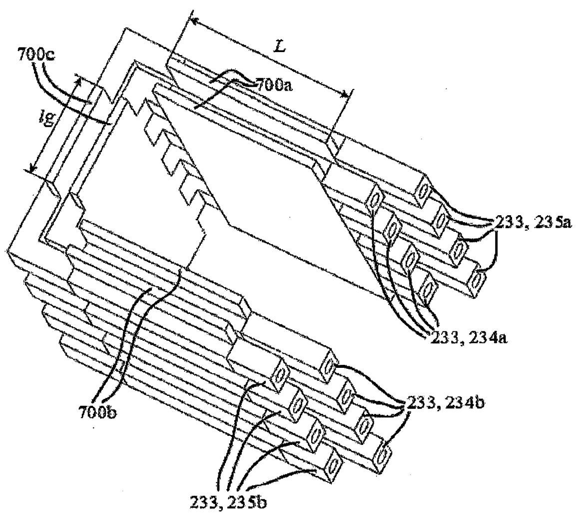


Fig. 7

EP 3 503 133 A1

Description

FIELD OF THE INVENTION

[0001] Electrical engineering; transformers; dc-dc converters

TECHNICAL PROBLEM

[0002] Technical problem solved by this invention is to provide a homogeneous distribution of the electric current in the windings of the transformer and the connecting elements, providing a sufficiently large surface on the side of the secondary winding, which is intended to connect an output rectifier and the connection of cooling, as well as to reduce the length of the straight connecting elements, which can be achieved by a proposed partial overlap of the primary and the secondary windings in the area of the so-called winding heads.

STATE OF THE ART

[0003] The known arrangements of high power industrial resistance spot welding systems used for sheet metal joining, among different applications also in the production of car bodies, have a unified structure comprising an input ac-ac converter for supplying a single-phase transformer with one primary and one secondary winding, where secondary winding is divided into two equal parts with the so-called center tap, and an output rectifier. The two power diodes of an output rectifier are connected with both parts of the secondary winding in a way to obtain the sufficiently high output dc welding current as the sum of two currents in both parts of secondary winding.

[0004] The conventional high power resistance spot welding systems with a dc welding current may differ from each other, while the base structure always includes an adequate voltage source, an input rectifier, a dc bus, an inverter, a single-phase welding transformer with a primary and secondary winding, which is divided into two equal parts with the so-called center tap, and output rectifier, wherein the two rectifier power diodes of an output rectifier are connected so that the dc welding current at the output is the sum of two rectified currents from each part of the secondary winding. The arrangements of an input rectifier and inverter, as well as a transformer and an output rectifier can be different. The primary side of the conventional welding transformer is usually supplied with a pulse width modulated (PWM) voltage with a constant switching period with a frequency of around 1 kHz, may be less or more, but for certain reasons it is bounded up and down. Existing manufacturers of resistance spot welding systems are using one or, exceptionally, several power diodes in each branch of an output rectifier, where relatively high currents in such power diodes with relatively high internal ohmic resistances results in relatively high Joule loss, hereinafter power loss. High power loss also occurs in massive connections between secondary winding and power diodes, which reduces the efficiency of the entire system.

[0005] A commonly known fact is that operation by increasing frequency of the PWM supply voltage at the same power of the transformer enables corresponding reduction of the transformer iron core cross-section area, which due to the reduction of dimensions automatically causes the corresponding reduction in the size of the windings and consequently the reduction of weight. It is also commonly known that the dc welding current at the output from an output rectifier decreases with increasing frequency of the supply voltage, which is analytically disclosed in reference DOI 10.1109/***TIE 2017***.2711549, IEEE. The inventors in the US2014/0321184A1 used the known fact and increased the frequency of the supply voltage to 10 kHz keeping a high value of secondary current 20 kA by separating a single secondary winding with a center tap and corresponding output rectifier into the ten smaller secondary windings with center tap and corresponding smaller output rectifiers, realized by MOSFET transistors, all ten secondary windings with output rectifiers connected in parallel. According to the claims in US2014/0321184A1, the increase in the number of parallel-connected secondary branches can either increase the value of the secondary welding current at the same frequency of the PWM power supply, or it can increase the frequency of PWM supply voltage by the maintaining unchanged value of the secondary welding current, which enables a suitable geometric reduction of the transformer, and therefore also a reduction of weight. The main disadvantage of the proposed concept in US2014/0321184A1 is the considerably increased complexity of the whole arrangement, which affects the cost and reliability of operation, although allows operation at significantly higher frequencies of PWM supply voltage.

[0006] A similar arrangement of a transformer with a parallel connection of a plurality of secondary winding coils and one common output rectifier is used in EP 2 749 373 A1. In this case, a so-called sandwich structure is used, in which a certain number of coils of primary winding are connected in serial and are positioned in such a way that placement of respectively connected secondary coils between the coils of primary winding is enabled. Such arrangement is very similar to the one used in US 7 978 040 B2, but comprises of several parallel connected coils of the secondary winding. The common characteristic of both arrangements is overlapping of the coils of the primary and secondary windings in the direction of the axis, which is parallel to the direction of the magnetic flux in the core of the transformer. The main disadvantage of these solutions is the different arrangement of the coil connections with the so-called positive side and the coil with the so-called negative side of the secondary winding, which causes a large difference in both sides and a highly non-homogeneous current distribution in one of the two sides of the secondary winding. The said arrangement of a transformer with a single primary coil and two coils or two parts of the secondary winding, where the coils are placed concentrically one above another, causes unwanted electromagnetic behavior of the entire system due to the geometric asymmetry.

[0007] A different way of coils overlap of the primary and secondary windings in an axis perpendicular to the direction of the magnetic flux in the transformer iron core is used in US 6 369 680 B1. The complete overlap of the primary winding made of thin electrically conductive metal strip material with coils of the secondary winding formed by an appropriate number of spirally wound layers of a thicker electrically conductive metal strip material are ensured, and the connection of the primary and secondary windings is carried out in a plane perpendicular to the direction of the magnetic flux in the transformer iron core. The disadvantage of the said design is a curved arrangement of connectors, which form electromagnetic loops with parts of the so-called winding heads and associated connecting plates, which increases the leakage inductances.

[0008] The weight of the transformer, which is designed for operation at the certain frequency of the supply voltage, can also be reduced by a certain change of construction in which the so-called sandwiched or pancake construction of the windings from the existing resistance spot welding systems in US 7 978 040 B2 is replaced by the so-called concentric cylindrical construction, as is done in EP 3 232 453 A1. Due to a good overlap of the primary and the secondary windings in such a cylindrical construction of the welding transformer, this arrangement ensures an excellent magnetic coupling between the individual windings of the transformer, which, in addition to transformer weight reduction and better cooling, can also improve efficiency and improves the electromagnetic properties of the transformer, thus achieving higher dynamics of operation of the welding system. However, the trade-off of such winding arrangement with a good overlap of windings is occurrence of a difficult realization of the corresponding connections for an output rectifier. Due to the arrangement of the connections, an extremely non-homogeneous distribution of currents in windings and connections occurs, which is particularly problematic at high values of secondary current. One of the main disadvantages of the transformer arrangement with an output rectifier in EP 3 232 453 A1 is therefore the arrangement of connections of secondary winding with an output rectifier, which form big electromagnetic loops and causes the increase of the corresponding leakage inductances, which have a predominant influence on the speed of change of the welding current. Moreover, the disadvantage is becoming more pronounced with the increase in the switching frequency of the supply voltage, which results in an even more pronounced decrease in the welding current amplitude. Distribution of the current in massive connection elements to an output rectifier at the nominal loading is very non-homogenous, which additionally increases the power loss.

DETAILED DESCRIPTION OF THE INVENTION

[0009] The proposed arrangement of the transformer, with a combination of best possible overlap of the comprising windings in the region of the transformer window and the partial overlap of the windings carried out outside the transformer window in the region of the so-callcd winding heads, shows a partially concentric tubular structure, and allows the electrical connection of an output rectifier including the cooling system with an adequate number of straight connections with a sufficiently large cross-section area, which makes it possible to ensure a homogeneous current distribution in windings and connections, and smaller corresponding leakage inductances. Choosing the appropriate number of straight connections and their position enables shorter paths for electrical currents, which can reduce the power loss in the windings. Due to the shorter paths and more appropriate arrangement of connections, cooling realization is also easier.

[0010] In the described way, using the complete overlap of the primary and secondary windings in the iron core window of the transformer, where this is most needed, due to the improvement of the electromagnetic properties of the transformer, and partial overlap of the windings carried out in the area of the so-called winding heads, the above presented technical problem of reduction of the non-homogenous current densities distribution in a different parts of the transformer and the problem of the lack of the sufficient connection cross-section area for the realization of electrical connections of the secondary winding with an output rectifier including a cooling, which in the case of the use of perfect overlap of the primary and secondary windings presented in EP 3 232 453 A1, represents a key technical limitation.

[0011] By a transformer arrangement with a partial overlap of the primary and secondary windings in the area of so-called winding heads, a compact design of the transformer is achieved, which enables a homogeneous current distribution in all parts of the transformer as well as use of straight and short connections with a sufficient large cross-section area to connect an output rectifier. It is also possible to achieve higher output powers of the welding transformer than in the existing solutions available on the market.

[0012] The present invention relates to the arrangement of a transformer in the sense of a different construction of the primary and secondary windings, whereby the arrangement of the secondary windings ensures complete overlap of the parts of the primary and secondary windings in the transformer's window, while in the part of the so-called winding heads of the primary and the secondary windings, they overlap only partially, which makes it easier to carry out the connections for an output rectifier, which at the same time become also the elements of the individual secondary winding heads. The modified version of the two turns of secondary winding enables the necessary change of the magnetic and electrical properties of the welding system, and thus enables the achievement of a homogeneous distribution of electrical currents in different parts of the transformer windings and electrical connections and consequently reduces the power loss in the transformer and increases the ability to supply the primary side of the transformer with the voltages with a higher frequency by maintaining the output welding current. The arrangement of the secondary winding according to the present invention at the same time enables a much easier arrangement of the water-cooling of the welding transformer by making the straight sections of the cooling channels of the corresponding dimensions. With implementation of cooling of transformers of smaller powers, the cooling can be replaced by an air-cooling, which additionally simplifies the structure of the transformer.

[0013] The object of the present invention relates to the improvement of the realization of suitably strong and robust electrical connections at suitable locations and the realization of suitable cooling channels for cooling with a liquid coolant medium. The change in the transformer arrangement in accordance with the present invention reduces the technological complexity of the transformer production and at the same time allows integration, i.e., installation of the rectifier devices of an output rectifier in the winding heads of the two parts of the secondary winding.

[0014] The rectifier devices of an output rectifier may be a power diodes or transistors, due to relatively low voltages and high currents, preferably MOSFET transistors. Also only a two power diodes can be used, as is the case with existing industrial solutions.

[0015] The transformer according to the present invention provides the completely straight connections without electrical loops for connecting an output rectifier to the secondary winding, which enables reduction of the respective inductances and ensures a homogeneous distribution of the currents across the entire cross-section area of these connections, In addition, these connections are short and easy to implement, which reduces electrical losses.

ARRANGEMENT OF THE WELDING TRANSFORMER WITH A PARTIALY OVERLAP OF WINDINGS

[0016] The invention is graphically illustrated by figures, which are forming a part of the present application, and represent:

According to the present invention, Figure 1 shows a block diagram of the arrangement of the existing high-power ac-dc converters.

[0017] According to the present invention, Figure 2 shows an electrical circuit diagram of existing welding transformers with an integrated output rectifier.

[0018] According to the present invention, Figure 3 shows a transformer arrangement with an integrated output rectifier.

[0019] According to the present invention, Figure 4 shows the arrangement of the transformer.

[0020] According to the present invention, Figure 5 shows the arrangement of a transformer with a look in cross-section A-A in Figure 4.

[0021] According to the present invention, Figure 6 shows the arrangement of the windings in Figure 4.

[0022] According to the present invention, Figure 7 shows the arrangement of a secondary winding of the welding transformer.

[0023] In the following, the invention is described by meanss of individual arrangements.

[0024] A block diagram of a resistance spot welding system is shown in Figure 1 and is denoted as a whole by a number **100.** A resistance spot welding system comprises of a voltage source **101,** an input rectifier **102,** and a dc link with a filter **103,** an input inverter **104,** and a welding transformer with a built-in output rectifier **105,**

[0025] The electrical circuit diagram of the transformer with an integrated output rectifier is schematically shown in Figure 2 and is as a whole denoted by a number **200.** The arrangement of the transformer includes a primary circuit **210** and a secondary circuit **220,** which are linked with a transformer **230,** The primary winding **231** with the number of turns N_1 of the transformer **230** is connected to the primary circuit **210** and is supplied with the primary voltage u_1 **232.** The secondary winding **233** has $N_2 + N_3$ turns and is composed of two identical parts or elements **234** and **235,** where, for the sake of symmetry, the number of turns is the same $N_3 = N_2$. The primary and the secondary winding **231, 233** of the transformer are magnetically linked - connected by an iron core **236,** which can be carried out differently. The primary voltage **232** is pulse width modulated - PWM in different ways.

[0026] The secondary circuit **220** contains two rectifier devices, **237** and **238,** which can be either power diodes or adequate transistors, preferably MOSFET transistors. In the secondary circuit **220** are marked *A*1 **239,** the center tap *A2* **240,** which with the connection to point *A6* **244** represent one of the load terminals with the voltage u_2 **245,** the point *A4* **242,** where are added the currents from the rectifier devices **237** and **238** and *A*4 **242,** which with the connection represent the second terminal point *A*5 **243** for connection of the load.

[0027] Structure of the transformer with a built-in output rectifier to be protected is shown in Figure 3, which is denoted as a whole by number **30.** The rectifier devices **237** and **238** of an output rectifier are mounted in the winding head of the first part of the secondary winding **234** and the winding head of the second part of the secondary winding **235.** The first head of the secondary turn **234** is an element **239** with a rectifier device **237,** which is mounted between **239** and the element **242** on which the connection **243** is carried out, and comprises of the corresponding number of parallel-connected rectifier devices in the form of power diodes, or transistors, preferably MOSFET transistors. The first head of the secondary turn **235** represent an element **241,** so that a rectifier device **238** is mounted between the element **241** and the element **242** on which the terminal point **243** is implemented, comprising the corresponding number of parallel-connected rectifier devices in the form of power diodes, or transistors, preferably MOSFET transistors. The parallel connected power diodes, or transistors, preferably MOSFET transistors, which as a whole represent the rectifier devices **237** and **238,** can be also replaced by only two power diodes, as it is the case with the conventional version of the welding system described in US 7 978040 B2. Around the iron core **236** of the transformer, a primary winding **231** is arranged. The secondary terminal points A5 and *A6* arc according to Fig. 3 placed above and below, but they could be placed anywhere else. However, output terminal points *A*5 and *A*6 may be both also below or both above or anywhere else. Instead of so-called shell-type construction with two iron cores **236** shown in Figure 3, each of the two cores **236** are comprising two C-segments, the so-called core-type construction of transformer could have just a single iron core **236** with two C-segments, having the same iron core cross-section area as that one with the two iron cores.

[0028] All windings **231, 233** in Figure 3 are electrically isolated between each other and electrically isolated from the iron core **236.**

[0029] Figure 4 shows the arrangement of a transformer that is the subject of the invention. The primary winding **231,** as indicated in Figure 5, is made with a rectangular wire with a cross-section *a* x *b,* where α is a thickness and *b* is a wire width, concentrically wound around the transformer axis **300.** A secondary winding **233** is also wound around the transformer axis **300** and/or an iron core, where on the right and on the left side of the axis **300** on the places, where the primary winding and both parts of the secondary winding do not completely overlap, the well-visible straight parts **234a, 234b, 235a** and **235b,** which allow simple connection of an output rectifier and the cooling, where the round bores **410** can be used for the cooling. The arrangement of the transformer in Figure 4 comprises of four connecting points for the beginnings and ends of the two parts of the secondary winding **233,** otherwise, it is also possible to make a transformer with at least one or more surfaces to connect an output rectifier and the cooling. With the implementation of cooling of transformers of smaller powers, the cooling can be replaced with an air-cooling, which additionally simplifies the structure of the transformer. All windings **231, 233** in Figure 4 are electrically isolated between each other, and are electrically isolated from the iron core **236.**

[0030] Figure 5 shows the transformer from Figure 4 in a cross-section A-A. In the present arrangement of the transformer, the primary winding **231** is divided into the three segments, wherein the first segment lies at a distance rp1 and is in the presented arrangement formed of three successive layers of rectangular wires, the second segment lies at a distance rp2 and is in the presented arrangement also formed of three successive layers of rectangular wires, while the third segment is located at a distance rp3 and is in the presented arrangement also formed of three successive layers of rectangular wires, all of said distances relative to the transformer axis **300.** In the present configuration in Figure 5 are, due to the three successive layers of rectangular wires in each segment, the thicknesses p1, p2 and p3 of the individual segments of the primary winding the same, but it could also be different, if there would be a different number of layers in each segment.

[0031] Secondary winding **233** comprises of two parts **234** and **235,** wherein the first part **234** is concentrically wound around the transformer axis **300** at the distance rs1, while the second part **235** is wound at a distance rs2 around the transformer axis **300.** The extensions of the rectangular shape with cooling bores **410** in parts **234a, 234b** , **235a,** and **235b** are located at distances h1, h2, h3 and h4 from the lower edge **430** in the direction of the axis **300** with the cross-section *f* x *d*.

[0032] In the described arrangement in both parts of the secondary winding **234a, 234b, 235a** and **235b** appear empty spaces with the sizes h1 x p3 and h1 x p2, in which are placed the second and third segment of the primary winding **231.** Inside the two windows of the transformer **420** with dimensions *j* x *h* in the length of the iron core *L* along an axis **500,** which is perpendicular to the axis 300, the first segment of the primary winding and both parts of the secondary winding overlap, the second and third segment of the primary winding also overlap with the first segment of the primary winding, and the overlap of first and second part of the secondary winding with the second and third segment of the primary winding is also in five places, while in four places the overlap is just partial, which enables realization of a straight and short connections of an output rectifier in the direction of the axis **500.**

[0033] Areas of both parts of the secondary winding without overlap in the extension areas in the transformer window in length *L* with bores **410** allow the proper realization of the connections for an output rectifier and the cooling by a liquid coolant.

[0034] The dimensions of extensions of the rectangular shape in Figure 5 are the same, therefore *d* = s1 = s2 = s3 = s4, but these can be also completely different, only the symmetry must be applied in respect to the axis **300.** In the case of extreme choice when *c* = *f*, the extensions disappear and with them also the bores for a liquid cooling, and in this case cooling must be carried out differently, for example with air. The bores **410** are typically designed for liquid cooling, but they can be used for a screwing as well.

[0035] All the windings **231, 233** in Figure 5 are electrically isolated from one another, and electrically isolated from the iron core **236.**

[0036] Figure 6 shows an assembled set of primary winding **231** and secondary winding **233** with a separately marked parts **235a, 235b, 234a,** and **234b,** where four partial overlapping parts between the primary and secondary windings are clearly seen in the right side, which is not relevant from the point of view of the transformer operation. It is important to ensure overlap of the windings in the remaining three-quarters of the primary and secondary windings. The primary winding is carried out with a rectangular wire with a cross-section *a* x *b*, but it could also be made with a round wire or wire, which includes parallel-connected round wires or a combination of a rectangular wire and a round wire. All the windings in Figure 6 are electrically isolated from one another, and electrically isolated from the iron core **236.**

[0037] Figure 7 shows the first and the second part **234** and **235** of the secondary coil **233** with four straight extensions, which allow easy connection of an output rectifier and cooling with the liquid coolant. Although the individual parts of the first and the second part of a secondary coil **234** and **235** in Figure 7 consist of several parts, it is possible to produce both parts in a single piece, which also significantly improves electrical properties. Figure 7 also shows the massive parts **700a, 700b** of the two parts of the secondary winding **233,** which are along the axis **500** in the length of the iron core L surrounded by an iron corc, and at the same time ensure overlap of the windings in the described area. Similarly, the solid parts **700c** ensure a complete overlap of the windings in the major part of the winding head of the first and second part of the secondary winding in the length *l*g, while in the smaller part of the winding heads remains without overlap. All the windings **231, 233** in Figure 7 are electrically isolated from one another, and are electrically isolated from the iron corc **236,**

[0038] The values of parameters *a, b, c, d, f, g, h,j, k* in Figure 5 depend on the desired output power of the welding transformer by maintaining the same cooling intensity, while the values of *L* and *e* in Figures 4 and 5 depend on the frequency of the supply voltage of the primary winding.

[0039] According to the present invention, the transformer arrangement **30** provides a homogeneous distribution of the magnetic fields in an iron core of the transformer **236,** which reduces the phenomenon of the unwanted saturation in an iron core. The said arrangement of the transformer with an output rectifier also provides a homogeneous distribution of currents in conductive parts of the windings and a very short distance for connecting an output rectifier, which provides a better system efficiency than the proposed arrangement described in EP3 232 453 A1. With the proposed arrangement, it is also possible to achieve higher values of output welding current under the same operating conditions.

[0040] The arrangement of the transformer in Figure 4 shows a partial overlap of the primary winding **231** with a secondary winding **233** only in the so-called winding heads on the left side of the transformer, without overlap of the windings heads on the right site of the transformer. Without any change of the electromagnetic advantages of the proposed transformer arrangement, a similar system of partial overlap of the primary winding **231** with the secondary winding **233** can also be used for the so-called winding heads on the opposite side, which is, according to Figure 4, on the right side of the transformer. In this case, the right-lying rectifier device **238** in Figure 3 can be moved to the opposite left side of the transformer, while the arrangement of the overlap of the primary and secondary windings along the axis **500** in length *L,* remains unchanged.

Claims

1. A transformer arrangement (30), comprising:

at least one primary winding (231), comprising at least one segment, each segment of the primary winding comprising a plurality of layers, each layer of primary winding comprising a plurality of turns wound around the transformer axis (300), and each segment of the primary winding located at an appropriate distance from the transformer axis (300); an iron core (236), electrically isolated from a said primary winding; at least one secondary winding (233), electrically isolated from a said primary winding and from a said iron core, said iron core surrounding said primary and said secondary winding, comprising at least one secondary winding (233), wherein each secondary winding comprises at least two parts wound around the transformer axis (300) in the distance of the corresponding part of the secondary winding, both distances from the transformer axis (300), the first segment of the primary winding and the first part of the secondary winding not overlap or overlap only partially in a certain area of a total length along the axis (400), which is perpendicular to the transformer axis (300), and wherein the first segment of the primary and all parts of the secondary winding overlap along the transformer axis (300), and each subsequent possible segment of the primary winding positioned in the direction of the axis (400) between the other possible parts of secondary winding and wound around the transformer axis (300) in the distance of the respective segment of the primary winding from the transformer axis (300) or as the last segment in this way, that any possible second and any possible further segment of the primary winding does not overlap completely in the respective length of that part of the secondary winding along the transformer axis (300), which creates empty spaces between the segments of any possible second and any further subsequent segment of the primary winding along the axis (400) in the same line, providing for adequate empty space for making straight and short connections of two parts of secondary winding along the axis (500).

2. Transformer arrangement (30) according to claim 1, wherein the individual part of the secondary winding in the areas of the empty spaces between any second or any further segment of the primary winding can be widened to form a sufficiently large surface to connect the secondary winding with an output rectifier.

3. Arrangement of the transformer (30) according to claim 1, wherein the number of empty spaces for carrying out the connections in any possible second or any further segment of the primary winding along the transformer axis (300) can be at least one or more, wherein the empty spaces arc located at any distance from (430) along the transformer axis (300).

4. Transformer arrangement (30) according to claim 1, comprising one primary winding (231) and a secondary winding (233), electrically isolated from said primary winding and from said iron core, comprising first part of said secondary winding and a second part of said secondary winding, where both of them are wound around the transformer axis (300) at adequate distances, between which at least one segment of said primary winding is arranged, wherein the said primary winding and said secondary winding overlap along the axis (500) in the part surrounded by an iron core and further wherein the overlap of the first segment of the primary winding with two parts of the secondary winding in said length is complete, while the overlap of the second and third segment of the primary winding with the first and second part of the secondary winding remains complete only at those positions, where the two parts of the secondary winding are not widespread, while an overlap in the widespread parts of two parts of the secondary winding with the second and the third part of the primary winding is limited, which enables the arrangement of a straight and short connections along the axis (500) for connection of an output rectifier and connection of a cooling system.

5. Transformer arrangement (30) according to claim 1, wherein a said primary winding and a said secondary winding in the part of the winding heads, which are not surrounded by an iron core, overlap only partially or do not overlap.

6. Transformer arrangement (30) according to claim 1, wherein the part (234) of the secondary winding (234) can be produced in one piece without joints, and wherein the part (235) of the secondary coil (233) can be produced in one piece without joints.

7. Transformer arrangement (30) according to claim 1, wherein the rectangular cross-section extensions with the dimensions *f* x *d* may be intended either for bores (410) for the flow of the coolant or for a screwing connection,

8. Transformer arrangement (30) according to claim 1, wherein an element (239) is connected to the straight connecting terminals (235a) of the second part of the secondary winding (233) without additional connections, which also represents the winding head on the right side of the second part (235) of the secondary winding (233) and a part of an output rectifier.

9. Transformer arrangement (30) according to claim 1, wherein the elements (239) and (241) are directly connected to the straight connecting terminals of the two parts of winding (233), which are already a part of an output rectifier and represent one of the heads of the secondary winding (233).

10. Transformer arrangement (30) according to claim 1, wherein an element (240) is connected to the straight connecting terminals of the two parts of the secondary winding (233), which represents the center tap between the two parts of the secondary winding.

11. Transformer arrangement (30) according to claim 1, wherein, due to the adequate rectangular shapes of the two parts of secondary windings, it is possible to make straight bores (410) for the flow of the coolant.

12. Transformer arrangement (30) according to claim 1, wherein both parts of the secondary winding (233) can also be produced without suitable extensions for performing cooling, if the cooling of the transformer is not necessary.

13. Transformer arrangement (30) according to claim 1 may have arrangement of output terminals *A*5 and *A6* anywhere.

14. Transformer arrangement (30) of claim 1, wherein the primary winding may also be made with a round wire or wire, comprising several parallel-connected round wires or a combination of a wire with a rectangular cross-section *a* x *b* and a round wire.

15. Transformer arrangement (30) according to claim 1, wherein the rectifier devices (238) can also be moved to the opposite side of the transformer using a similar system of limited overlap of the primary winding (231) with the secondary winding (233) in the part of the winding heads, whereas the overlap of primary and secondary windings remain unchanged along the axis (500) in length *L,* where the windings are surrounded by the iron core (236).

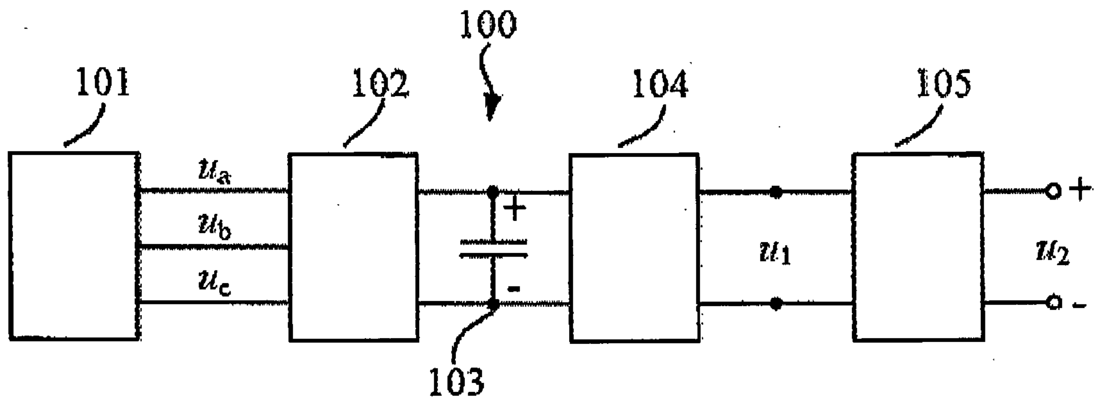
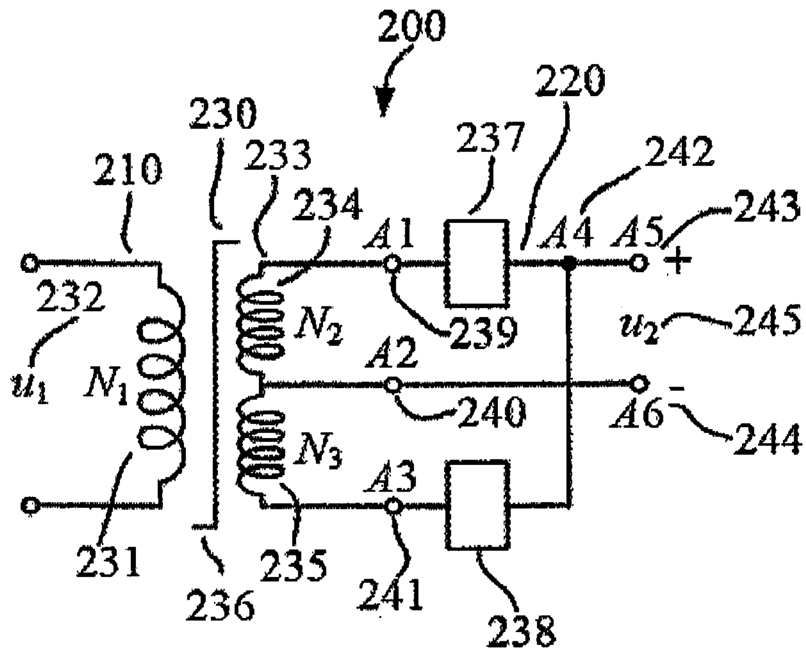

100
101
102
104
105
u_a
u_b
u_c
+
-
u_1
u_2
+
-
103

Fig. 1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A1
A4
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-
A6
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N_3
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241
236
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Fig. 2

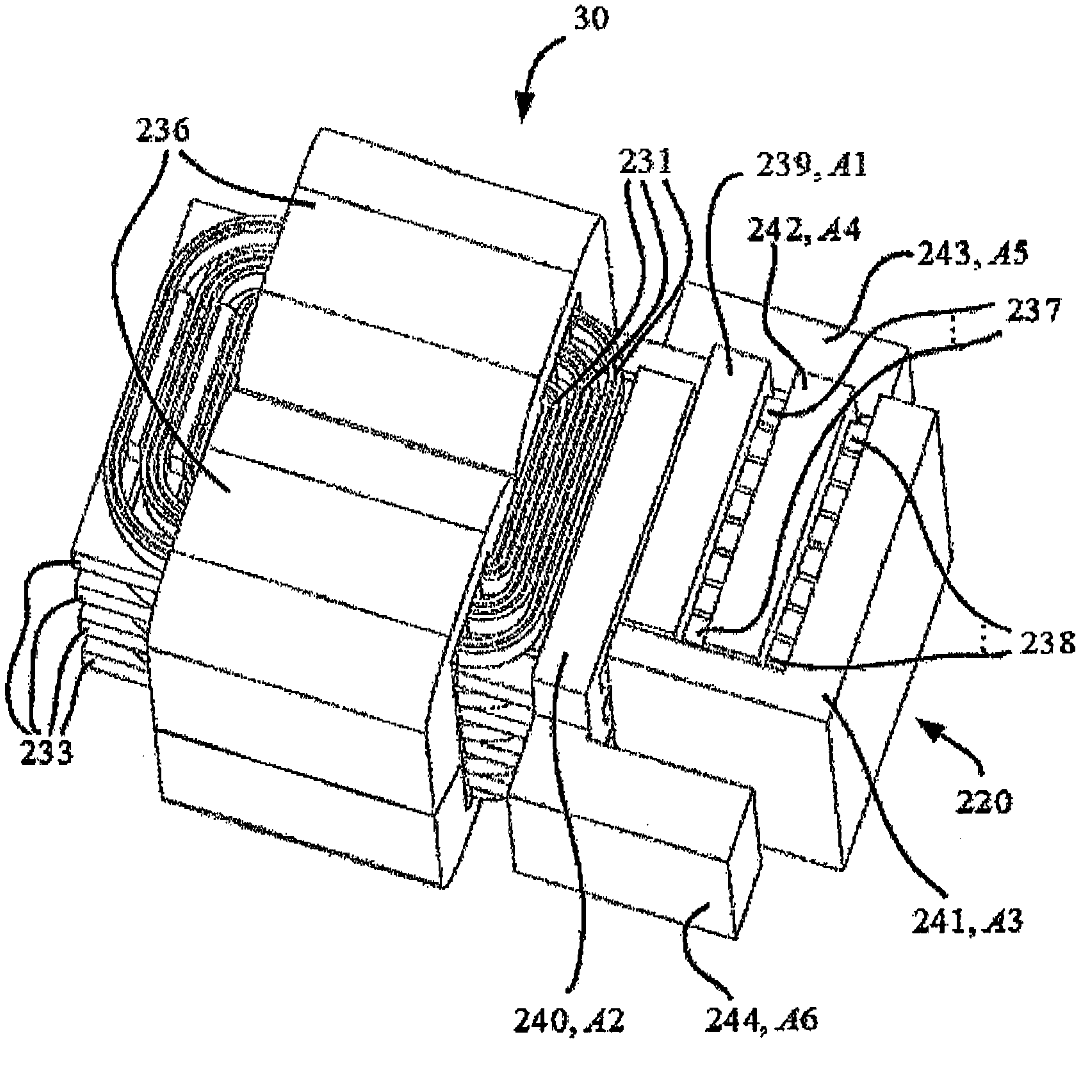
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Fig. 3

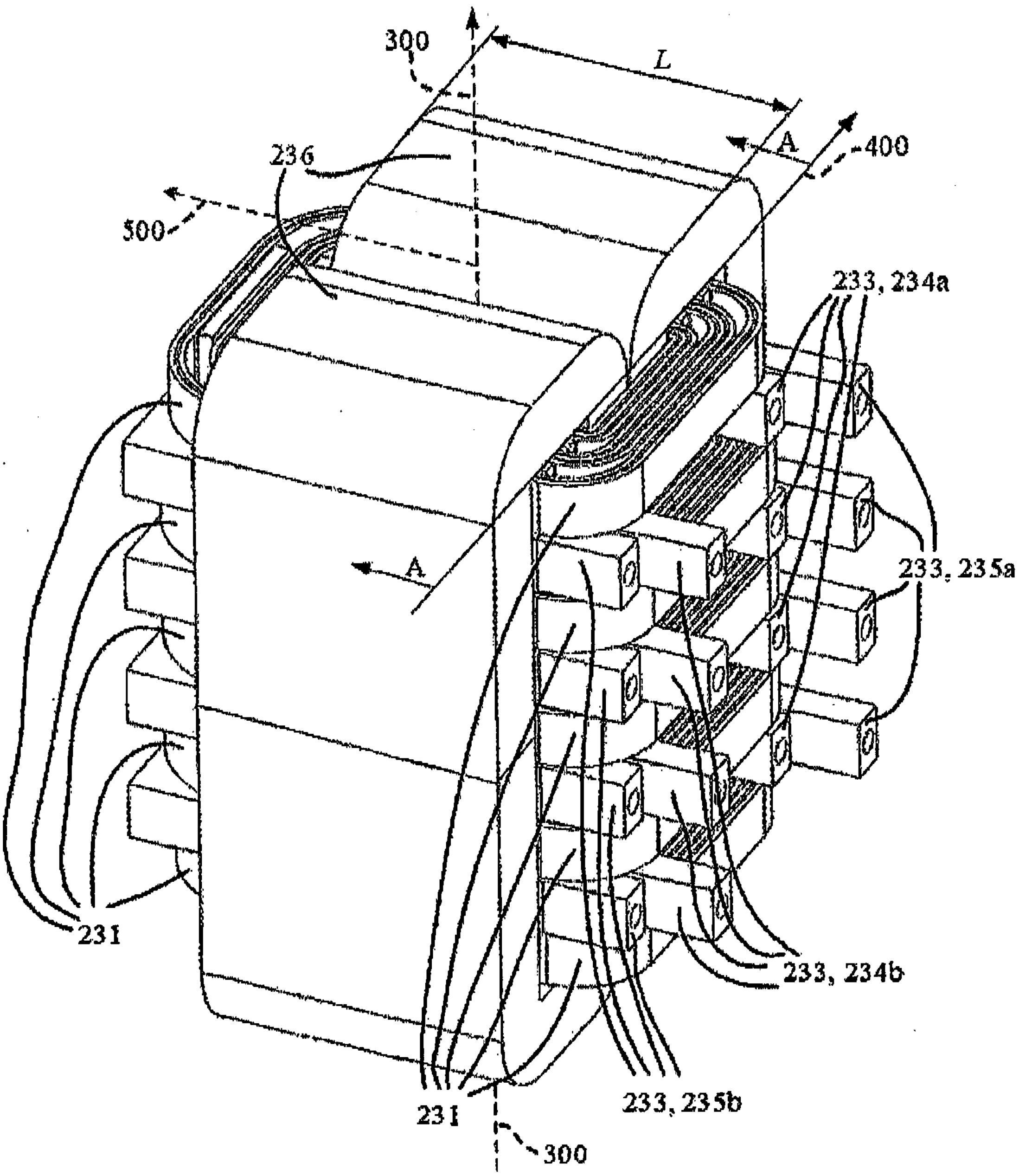
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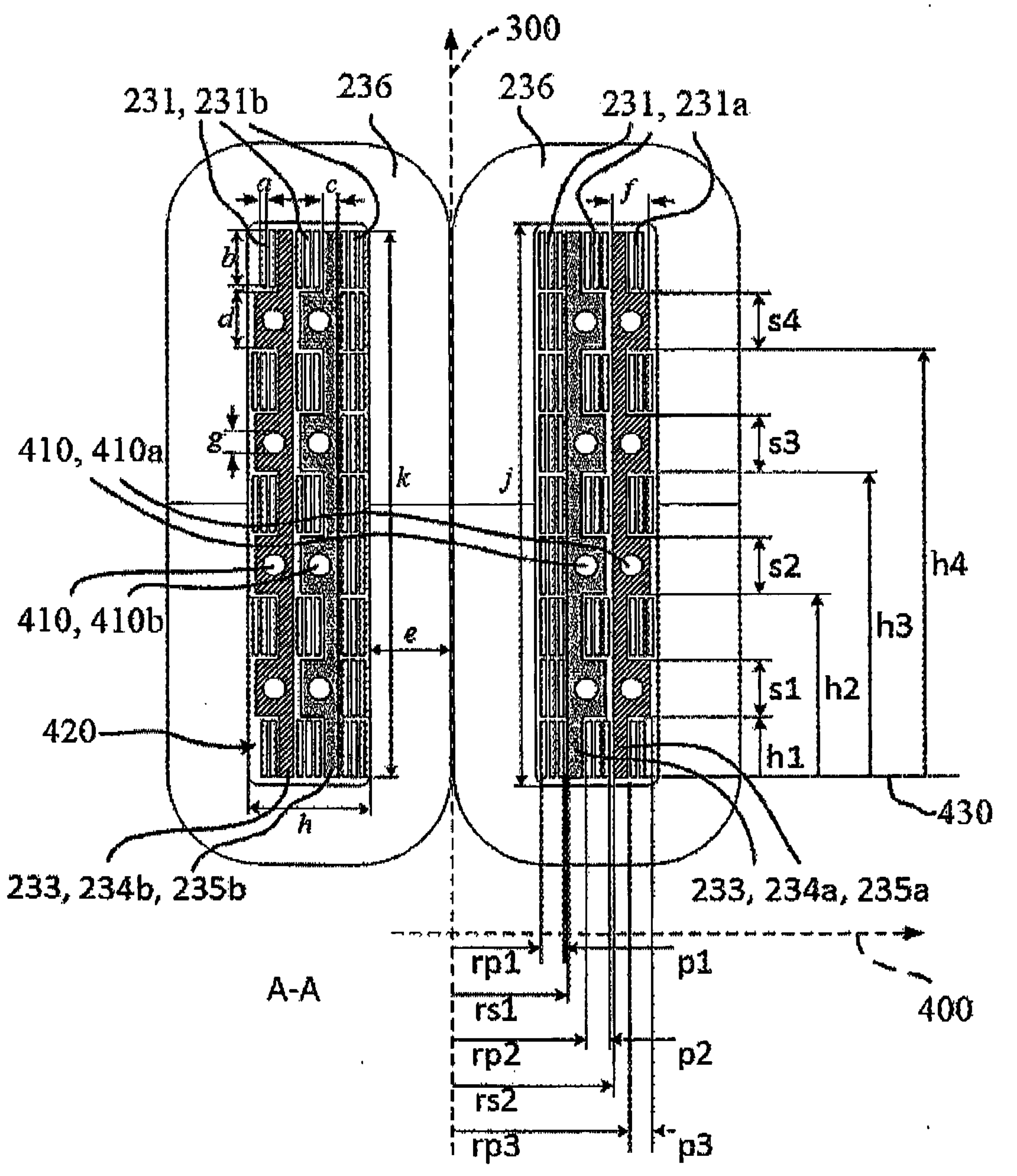
Fig. 4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410, 410b
k
j
e
420
430
h
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rp2
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rs2
rp3
p3
400
A-A

Fig. 5

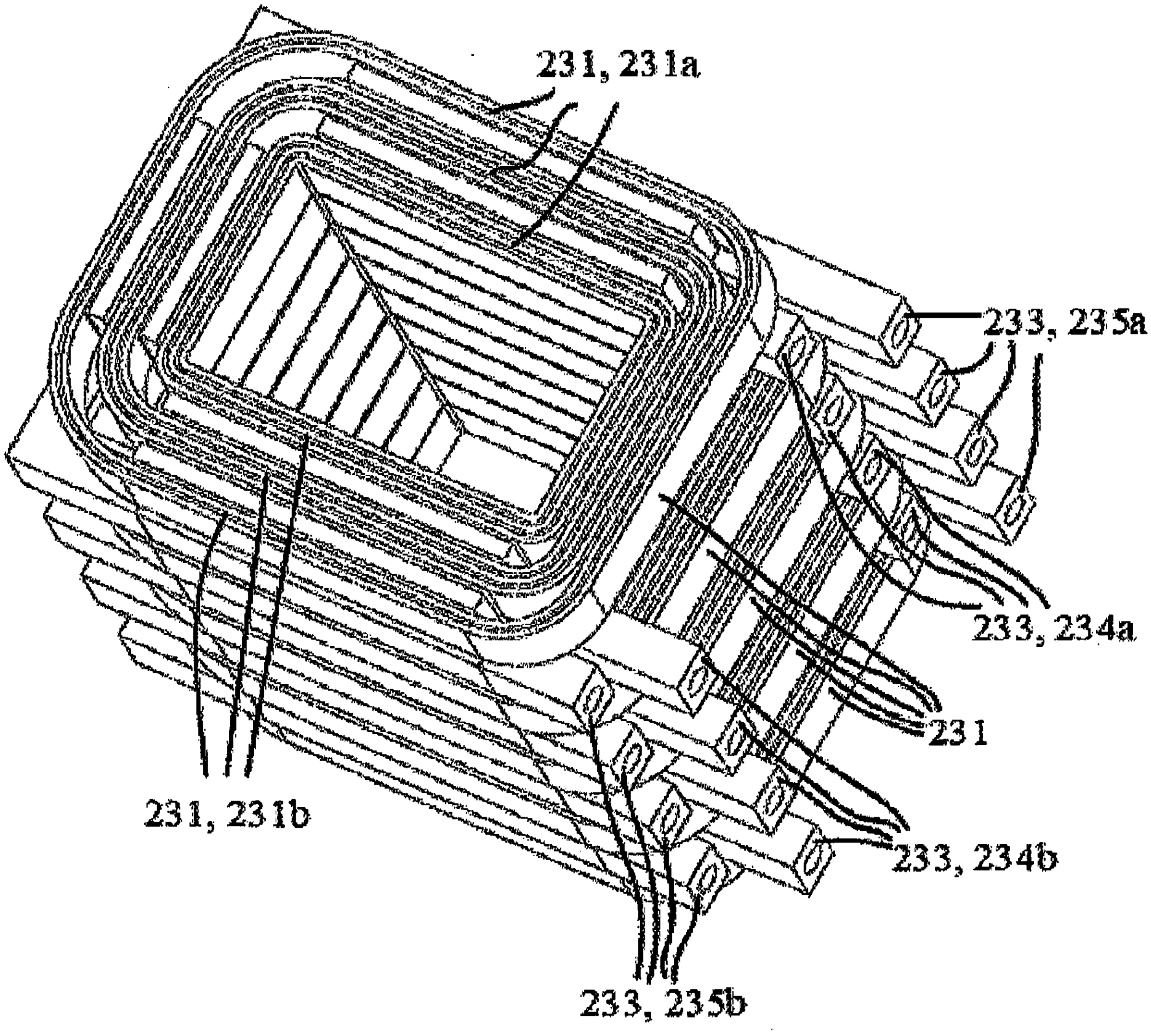

Fig. 6

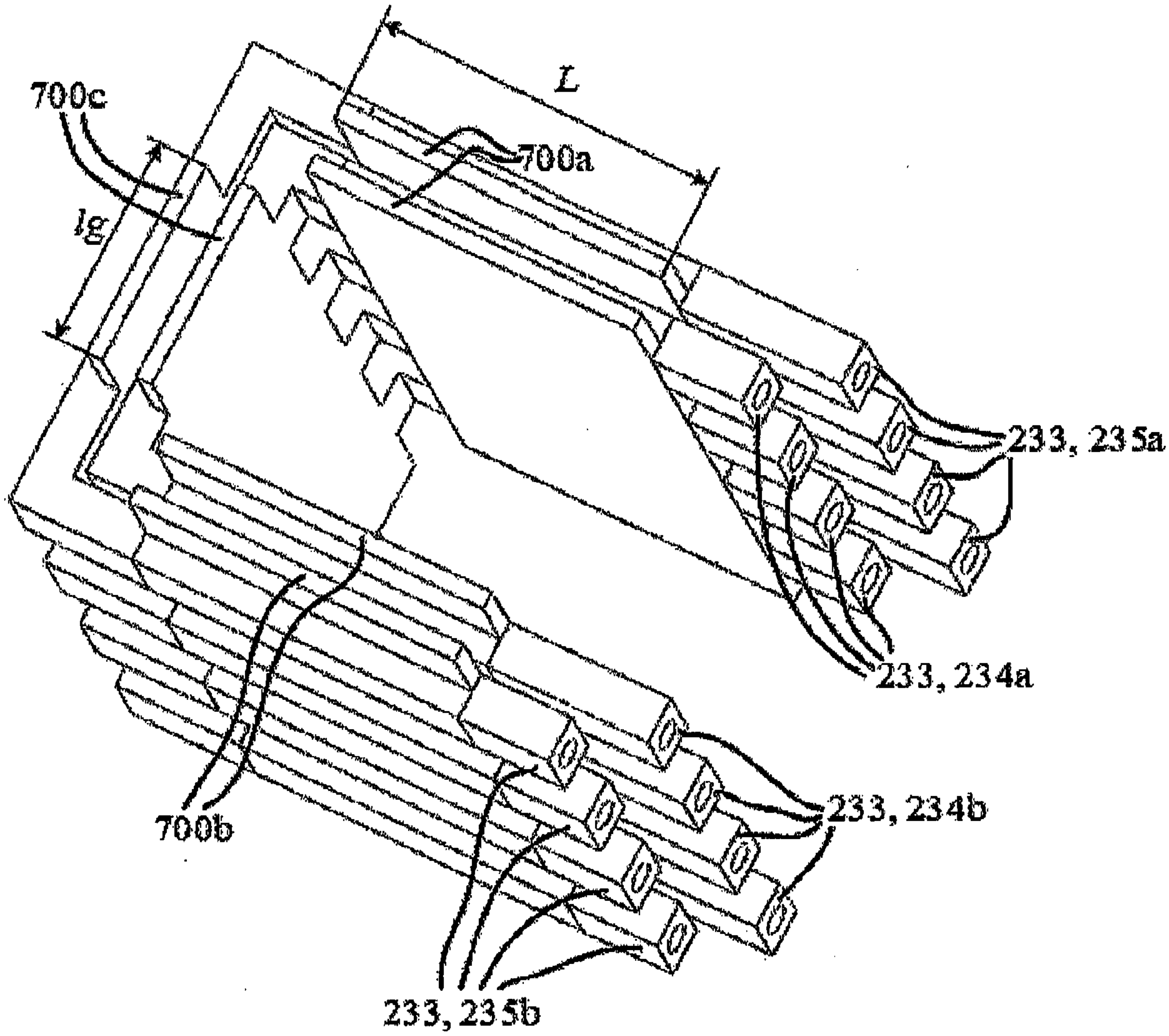

Fig. 7

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EUROPEAN SEARCH REPORT

Application Number
EP 18 00 0967

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 5 160 820 A (TSUJII GEN [JP] ET AL) 3 November 1992 (1992-11-03) * abstract *; figures 3-6 * * column 4, line 49 - column 5, line 23 * -----	1-15	INV. H01F27/16 H01F27/28 H01F27/40 B23K11/24
X	JP H06 38223 U (.) 20 May 1994 (1994-05-20) * paragraphs [0001] - [0012]; figures 1-6 * -----	1-9, 11-15	
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			H01F B23K

The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
Munich	6 May 2019	Reder, Michael

CATEGORY OF CITED DOCUMENTS

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