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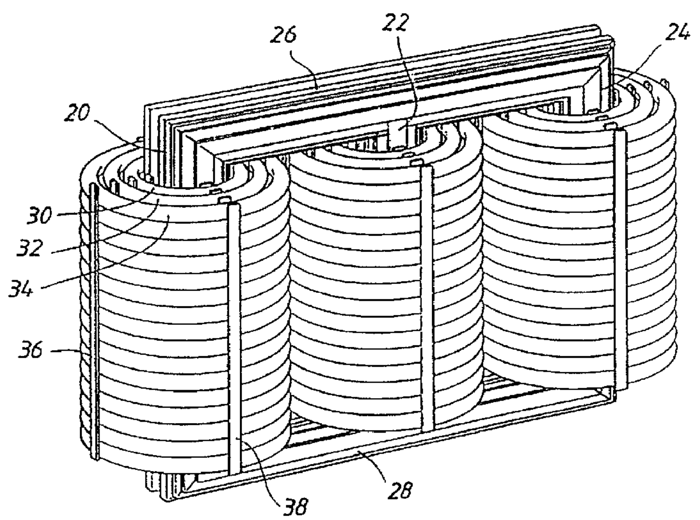
(54) **TRANSFORMATEUR A COURANT CONTINU/REACTEUR**
(54) **A DC TRANSFORMER/REACTOR**



(57) Cette invention se rapporte à un transformateur à courant continu/réacteur, qui comprend un circuit magnétique, lequel est constitué par un noyau magnétique et par au moins un enroulement. Cet enroulement contient au moins un conducteur transporteur de courant. Chaque enroulement comprend également un système isolant, constitué d'une part par au moins deux couches semi-conductrices, dont chacune constitue essentiellement une surface équipotentielle, et d'autre part par un isolant solide placé entre ces deux couches.

(57) The present invention relates to a DC transformer/reactor comprising a magnetic circuit, wherein the magnetic circuit comprises a magnetic core and at least one winding. The winding comprises at least one current-carrying conductor. Each winding comprises also an insulation system, which comprises on the one hand at least two semiconducting layers, wherein each layer constitutes substantially an equipotential surface, and on the other hand between them is arranged a solid insulation.

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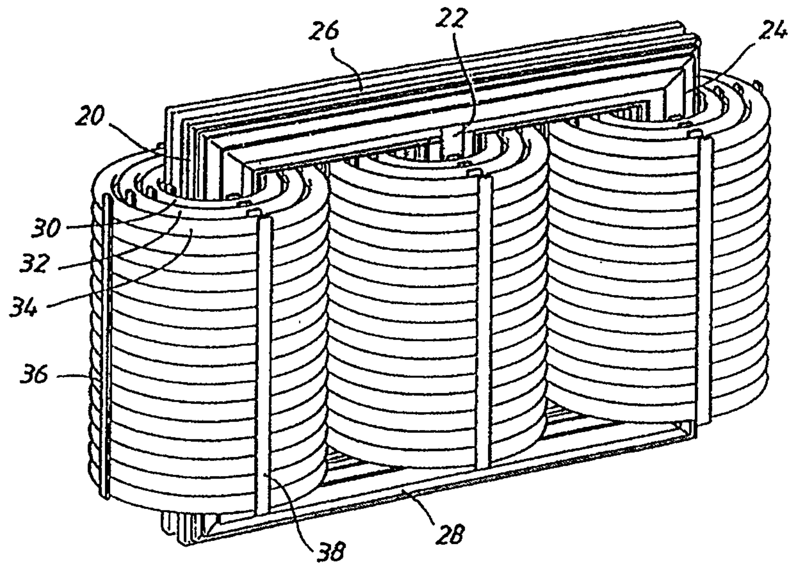

(57) Abstract

The present invention relates to a DC transformer/reactor comprising a magnetic circuit, wherein the magnetic circuit comprises a magnetic core and at least one winding. The winding comprises at least one current-carrying conductor. Each winding comprises also an insulation system, which comprises on the one hand at least two semiconducting layers, wherein each layer constitutes substantially an equipotential surface, and on the other hand between them is arranged a solid insulation.

A DC TRANSFORMER/REACTOR

Technical field of the invention

The present invention relates to a DC transformer/ reactor in accordance with the introductory part of claim 1.

The DC transformers/reactors have a rating power ranging from several hundred kVA to 1000 MVA and above with a rating voltage from 3-4 kV to very high transmission voltages, up to the order of 1 MV.

Background of the invention

In order to describe a DC transformer/reactor according to the invention a description of a conventional power transformer will be given.

Reference may be made, for example, to the following well known literature.

The J & P Transformer Book, A Practical Technology of the Power Transformer, by A. C. Franklin and D. P. Franklin, published by Butterworths, edition 11, 1990.

Regarding the internal electrical insulation of windings, etc., the following can be mentioned:

Transformerboard, Die Verwendung von Transformerboard in Grossleistungstransformatoren by H. P. Moser, published by H. Weidman AG, CH-8640 Rapperswil.

The latter publication has been published by the insulation manufacturer Weidman in Switzerland and belongs to the basic literature of every transformer manufacturer.

From a purely general point of view, the primary task of a power transformer is to allow exchange of electric energy between two or more electrical systems of, normally, different voltages with the same frequency.

A conventional power transformer comprises a transformer core, in the following referred to as a core, often of laminated oriented sheet, usually of silicon iron. The core comprises a number of core limbs, connected by yokes which together form one or more core windows.

Transformers with such a core are often referred to as core transformers. Around the core limbs there are a number of windings which are normally referred to as primary, secondary and control windings. As far as power transformers are concerned, these windings are practically always concentrically arranged and distributed along the length of the core limbs. As a rule the core transformer has circular coils and a tapered leg section to utilize the window space as well as possible.

In addition to core type transformers there are shell type transformers. These are often designed with rectangular coils and a rectangular core limb section.

Conventional power transformers, in the lower part of the above-mentioned power range, are sometimes designed with air cooling to carry away the unavoidable inherent losses. For protection against contact, and possibly for reducing the external magnetic field of the transformer, it is then often provided with an outer casing provided with ventilating openings.

Most of the conventional power transformers, however, are oil-cooled. One of the reasons therefor is that the oil has the additional very important function as insulating medium. An oil-cooled and oil-insulated power transformer is therefore surrounded by an external tank on which, as will be clear from the description below, very high demands are placed.

Normally, means for water-cooling of the coil are provided.

The following part of the description will for the most part refer to oil-filled power transformers.

The windings of the transformer are formed from one or several series-connected coils built up of a number of series-connected turns. In addition, the coils are provided with a special device to allow switching between the terminals of the coils. Such a device may be designed for changeover with the aid of screw joints or more often with the aid of a special changeover switch which is operable in the vicinity of the tank. In the event that changeover can take place for a transformer under voltage, the changeover switch is referred to as an on-load tap changer whereas otherwise it is referred to as a de-energized tap changer.

Regarding oil-cooled and oil-insulated power transformers in the upper power range, the breaking elements of the on-load tap changers are placed in special oil-filled containers with direct connection to the transformer tank. The breaking elements are operated purely mechanically via a motor-driven rotating shaft and are arranged so as to obtain a fast movement during the switching when the contact is open and a slower movement when the contact is to be closed. The on-load tap changers as such, however, are placed in the actual transformer tank. During the operation, arcing and sparking arise. This leads to degradation of the oil in the containers. To obtain less arcs and hence also less formation of soot and less wear on the contacts, the on-load tap changers are normally connected to the high-voltage side of the transformer. This is due to the fact that the currents which need to be broken and connected, respectively, are smaller on the high-voltage side than if the on-load tap changers were to be connected to the low-voltage side. Failure statistics of conventional oil-filled power transformers show that it is often the on-load tap changers which give rise to faults.

In the lower power range of oil-cooled and oil-insulated power transformers, both the on-load tap changers and their breaking elements are placed inside the tank. This means that the above-mentioned problems with degradation of the oil because of arcs during operation, etc., effect the whole oil system.

From the point of view of applied or induced voltage, it can broadly be said that a voltage which is stationary across a winding is distributed equally onto each turn of the winding, that is, the turn voltage is equal on all the turns.

From the point of view of electric potential, however, the situation is completely different. One end of a winding is normally connected to ground. This means, however, that the electric potential of each turn increases linearly from practically zero in the turn which is nearest the ground potential up to a potential in the turns which are at the other end of the winding which correspond to the applied voltage.

This potential distribution determines the composition of the insulation system since it is necessary to have sufficient insulation both between adjacent turns of the winding and between each turn and ground.

The turns in an individual coil are normally brought together into a geometrical coherent unit, physically delimited from the other coils. The distance between the coils is also determined by the dielectric stress which may be allowed to occur between the coils. This thus means that a certain given insulation distance is also required between the coils. According to the above, sufficient insulation distances are also required to the other electrically conducting objects which are within the electric field from the electric potential locally occurring in the coils.

It is thus clear from the above description that for the individual coils, the voltage difference internally between physically adjacent conductor elements is relatively low whereas the voltage difference externally in relation to other metal objects - the other coils being included - may be relatively high. The voltage difference is determined by the voltage induced by magnetic induction as well as by the capacitively distributed voltages which may arise from a connected external electrical system on the external connections of the transformer. The voltage types which may enter externally comprise, in addition to operating voltage, lightning overvoltages and switching overvoltages.

In the current leads of the coils, additional losses arise as a result of the magnetic leakage field around the conductor. To keep these losses as low as possible, especially for power transformers in the upper power range, the conductors are normally divided into a number of conductor elements, often referred to as strands, which are parallel-connected during operation. These strands must be transposed according to such a pattern that the induced voltage in each strand becomes as identical as possible and so that the difference in induced voltage between each pair of strands becomes as small as possible for internally circulating current components to be kept down at a reasonable level from the loss point of view.

When designing transformers according to the prior art, the general aim is to have as large a quantity of conductor material as possible within a given area limited by the so-called transformer window, generally described as having as high a fill factor as possible. The available space shall comprise, in addition to the conductor material, also the insulating material associated with the coils, partly internally between the coils and partly to other metallic components including the magnetic core.

The insulation system, partly within a coil/winding and partly between coils/windings and other metal parts, is normally designed as a solid cellulose- or varnish-based insulation nearest the individual conductor element, and outside of this as solid cellulose and liquid, possibly also gaseous, insulation. Windings with insulation and possible bracing parts in this way represent large volumes which will be subjected to high electric field strengths which arise in and around the active electromagnetic parts of the transformer. To be able to predetermine the dielectric stresses which arise and achieve a dimensioning with a minimum risk of breakdown, good knowledge of the properties of insulating materials is required. It is also important to achieve such as surrounding environment that it does not change or reduce the insulating properties.

The currently predominant insulation system for high-voltage power transformers comprises cellulose material as the solid insulation and transformer oil as the liquid insulation. The transformer oil is based on so-called mineral oil.

The transformer oil has a dual function since, in addition to the insulating function, it actively contributes to cooling of the core, the winding, etc., by removal of the loss heat of the transformer. Oil cooling requires an oil pump, an external cooling element, an expansion coupling, etc.

The electrical connection between the external connections of the transformer and the immediately connected coils/windings is referred to as a bushing aiming at a conductive connection through the tank which, in the case of oil-filled power transformers, surrounds the actual transformer. The bushing is often a separate component fixed to the tank and is designed to withstand the insulation requirements being made, both on the outside and the inside of the tank, while at the same time it should withstand the current loads occurring and the ensuing current forces.

It should be pointed out that the same requirements for the insulation system as described above regarding the windings also apply to the necessary internal connections between the coils, between bushings and coils, different types of changeover switches and the bushings as such.

All the metallic components inside a power transformer are normally connected to a given ground potential with the exception of the current-carrying conductors. In this way, the risk of an unwanted, and difficult-to-control, potential increase as a result of capacitve voltage distribution between current leads at high potential and ground is avoided. Such an unwanted potential increase may give rise to partial discharges, so-called corona, Corona may be revealed during the normal acceptance tests, which partially occurs, compared with rated data, increased voltage and frequency. Corona may give rise to damage during operation.

The individual coils in a transformer must have such a mechanical dimensioning that they may withstand any stresses occurring as a consequence of currents arising and the resultant current forces during a short-circuit process. Normally, the coils are designed such that the forces arising are absorbed within each individual coil, which in turn may mean that the coil cannot be dimensioned optimally for its normal function during normal operation.

Within a narrow voltage and power range of oil-filled power transformers, the windings are designed as so-called sheet windings. This means that the individual conductors mentioned above are replaced by thin sheets. Sheet-wound power transformers are manufactured for voltages of up to 20-30 kV and powers of up to 20-30 MW.

The insulation system of power transformers within the upper power range requires, in addition to a relatively complicated design, also special manufacturing measures to utilize the properties of the insulation system in the best way. For a good insulation to be obtained, the insulation system shall have a low moisture content, the solid part of the insulation shall be well impregnated with the surrounding oil and the risk of remaining "gas" pockets in the solid part must be minimal. To ensure this, a special drying and impregnating process is carried out on a complete core with windings before it is lowered into a tank. After this drying and impregnating process, the transformer is lowered into the tank which is then sealed. Before filling of oil, the tank with the immersed transformer must be emptied of all air. This is done in connection with a special vacuum treatment. When this has been carried out, filling of oil takes place.

To be able to obtain the promised service life, etc., pumping out to almost absolute vacuum is required in connection with the vacuum treatment. This thus presupposes that the tank which surrounds the transformer is designed for full vacuum, which entails a considerable consumption of material and manufacturing time.

If electric discharges occur in an oil-filled power transformer, or if a local considerable increase of the temperature in any part of the transformer occurs, the oil is disintegrated and gaseous products are dissolved in the oil. The transformers are therefore normally provided with monitoring devices for detection of gas dissolved in the oil.

For weight reasons large power transformers are transported without oil. In-situ installation of the transformer at a customer requires, in turn, renewed vacuum treatment. In addition, this is a process which, furthermore, has to be repeated each time the tank is opened for some action or inspection.

It is obvious that these processes are very time-consuming and cost-demanding and constitute a considerable part of the total time for manufacture and repair while at the same time requiring access to extensive resources.

The insulating material in conventional power transformers constitutes a large part of the total volume of the transformer. For a power transformer in the upper power range, oil quantities in the order of magnitude of several tens of cubic metres of transformer oil are not unusual. The oil which exhibits a certain similarity to diesel oil is thinly fluid and exhibits a relatively low flash point. It is thus obvious that oil together with the cellulose constitutes a non-negligible fire hazard in the case of unintentional heating, for example at an internal flashover and a resultant oil spillage.

It is also obvious that, especially in oil-filled power transformers, there is a very large transport problem. Such a power transformer in the upper power range may have a total oil volume of several decades of cubic metres and may have a weight of up to several hundred tons. It is realized that the external design of the transformer must sometimes be adapted to the current transport profile, that is, for any passage of bridges, tunnels, etc.

The following problem areas regarding conventional oil-filled power transformers will briefly be summarized:

A conventional oil-filled power transformer

- comprises an outer tank which is to house a transformer comprising a transformer core with coils, oil for insulation and cooling, mechanical bracing devices of various kinds, etc. Very large mechanical demands are laced on the tank, since, without oil but with a transformer, it shall be capable of being vacuum-treated to practically full vacuum. The tank requires very extensive manufacturing and testing processes and the large external dimensions of the tank also normally entail considerable transport problems;

- normally comprises a so-called pressure-oil cooling. This cooling method requires the provision of an oil pump, an external cooling element, an expansion vessel and an expansion coupling, etc.;

- comprises an electrical connection between the external connections of the transformer and the immediately connected coils/windings in the form of a bushing fixed to the tank. The bushing is designed to withstand any insulation requirements made, both regarding the outside and the inside of the tank;

- comprises coils/windings whose conductors are divided into a number of conductor elements, strands, which have to be transposed in such a way that the voltage induced in each strand becomes as equal as possible to neighbouring strands in order to minimize induced voltage between neighbouring strands;

- comprises an insulation system, partly within a coil/winding and partly between coils/windings and other metal parts which is designed as a solid cellulose- or varnish-based insulation nearest the individual conductor element and, outside of this, solid cellulose and a liquid, possibly also gaseous, insulation. In addition, it is extremely important that the insulation system exhibits a very low moisture content;

- comprises as an integrated part an on-load tap changer, surrounded by oil and normally connected to the high-voltage winding of the transformer for voltage control;

- comprises oil which may entail a non-negligible fire hazard in connection with internal partial discharges, so-called corona, sparking in on-load tap changers and other fault conditions;

- comprises normally a monitoring device for monitoring gas dissolved in the oil, which occurs in case of electrical discharges therein or in case of local increases of the temperature;
- comprises oil which, in the event of damage or accident, may result in oil spillage leading to extensive environmental damage.

The DC transformers/reactors also have the additional problem, that the electric field is a superposition of an A field and of a DC field. The magnetic flux through the core may further contain a dc component leading to quite large designs.

Summary of the invention

The object of the present invention is to solve the above mentioned problems and to provide a DC transformer/reactor wherein all space outside the cable screens are essentially potential free. This object is achieved by providing the DC transformer/reactor, defined in the introductory part of claim 1, with the advantageous features of the characterizing part of said claim.

Accordingly, the winding of the DC transformer/reactor comprises at least one current-carrying conductor, and each winding comprises an insulation system, which comprises on the one hand at least two semiconducting layers, wherein each layer constitutes substantially an equipotential surface, and on the other hand between them is arranged a solid insulation.

A very important advantage of the present invention, as defined in Claim 1, is that the use of the special winding makes it possible to obtain a DC transformer/reactor with optimal design regarding the thermal, electric and mechanic design. This results in space reduction between windings with different DC potential, space reduction between windings with DC potential and the core and possible compensation of the air gaps at 50/60 Hz by a compensation winding loaded with a capacitor. This will reduce the size, especially of reactors.

Brief description of the drawings

Embodiments of the invention are described hereafter, in association with the accompanying drawings in which:

Figure 1 shows the parts included in the current modified standard cable;

Figure 2 shows a transmission scheme;

Figure 3 shows the electrical field distribution around a winding in a conventional transformer/ reactor;

Figure 4 shows a DC transformer/reactor in accordance with the present invention;

Figure 5 shows a reactor with a compensated air gap according to the present invention;

Figure 6 shows an isometric view of another embodiment of a DC transformer incorporating an improved air gap arrangement; and

Figure 7 shows the circuit diagram of an integrated arrangement for transformation of high electric power from one DC voltage level to another DC voltage level in accordance with the present invention.

Detailed description of Embodiments

An important condition for being able to manufacture a transformer/reactor in accordance with the description of the invention is to use for the winding a conductor cable with an extruded electrical insulation comprising a semiconducting layer both at the conductor and at the casing. Such cables are available as standard cables for other power engineering fields of use. As described under the summary of the invention, however, an improved embodiment of such a standard cable will be used as a winding. To be able to describe an embodiment, a short description of a standard cable will first be made. The internal current-carrying conductor comprises a number of strands. Around the strands there is a semiconducting inner casing. Around this semiconducting inner casing, there is an insulating layer of extruded insulation. An example of such an extruded insulation is PEX or, alternatively, so-called EP rubber. This insulating layer is surrounded by an external semiconducting layer which, in turn, is surrounded by a metal shield and a sheath. Such a cable will be referred to below as a power cable.

A preferred embodiment of the improved cable is shown in Figure 1. Accordingly cable 1 is described in the figure as comprising a current-carrying conductor 2 which comprises both transposed non-insulated and insulated strands. Electromechanically transposed, extruded insulated strands are also possible. There is an inner semiconducting layer 3 around the conductor which, in turn, is surrounded by an extruded insulation layer 4. This layer is surrounded by an external semiconducting layer 5. The cable used as a winding in the preferred embodiment has no metal shield and no external sheath.

Figure 2 shows a transmission scheme. In this figure there is disclosed a transformer including two serie connected, phase-shifted valve bridges 6, 7, wherein the valves are diode valves.

Figure 3 shows the electrical field distribution around a winding in a conventional DC transformer/reactor. In figure 3 there is disclosed a winding 8 wound around a core 9. The reference numeral 10 represents equipotential lines of the electrical field distribution of a conventional winding when the lower part of the winding is on earth potential. The design and the placement of a winding in relation to the core is mainly determined by the electrical field distribution in the core window.

Figure 4 shows a DC transformer/reactor in accordance with the present invention. In figure 4 there is disclosed a three-phase laminated core transformer. The core comprises in a conventional manner, three core legs 20, 22, and 24 and the connecting yokes 26 and 28. In the disclosed embodiment both the core legs and the yokes have tapered sections. The DC transformer comprises three concentrical winding turns 30, 32, and 34. The innermost winding turn 30 can represent the primary winding and the two other winding turns 32 and 34 can represent the secondary winding. The DC transformer also comprises spacing rails 36 and 38 with some different functions. The spacing rails 36 and 38 can be made by isolating material, which functions as a certain space between the concentric winding turns for cooling, bracing. It shall be pointed out that the DC transformer disclosed in figure 4, as opposed to the transformer disclosed in figure 3, will not present any electrical fields outside the cables of the windings.

Figure 5 shows a principle sketch of a reactor for DC plants with a compensated air gap in accordance with the present invention. The reactor comprises a magnetic core 60 and a winding 62 comprising a cable in accordance with figure 1. The reactor also comprises an air gap 64 in the core 60. Air gap means in this context any way to achieve a zone with lowered permittivity in the magnetic main flux. The reactor also comprises a compensation winding 66 which is capacitively loaded with a capacitor 68.

Another way of achieving this zone with lowered permittivity in the magnetic main flux is by reducing the air gap length, e.g. by dividing the air gap into a series of smaller air gaps in order to limit the radial components of the magnetic flux. Yet another way of achieving this zone with lowered permittivity in the magnetic main flux is to use another material than air, wherein the material has a relative permeability μ_r which satisfies the expression $1 \leq \mu_r \leq \mu_{core}$.

Figure 6 shows an isometric view of another embodiment of a DC transformer incorporating an improved air gap arrangement. The magnetic core structure with an orthogonal or radial air gap for low acoustic noise is shown in fig. 3. This three-legged magnetic core is comprised by an essentially rectangular one-piece outer member 30 having opposing side sections 30s and end sections 30e, and by a cylindrical center member 31 that is continuous in the longitudinal direction. A pair of aligned circular apertures or openings 32 are machined into the two outer member end sections 30e, or alternatively the rectangular outer member is pressed into this shape. The opposite ends of cylindrical center member 31 respectively extend into aligned circular apertures 32 to thereby define at either end a radial magnetic air gap of constant predetermined length that is further circumferentially continuous and uninterrupted. A non-magnetic spacer 33 is mounted in the magnetic air gap space between each end section 30e and the respective end of center member 31 to maintain the radial air gap and support the center member. A winding assembly wound directly on the center member or on a toothed split bobbin, is placed about the center member in the window areas 35 provided between outer and center members 30 and 31. If desired, spacer 33 at one end can be eliminated and a zero air gap provided at that end.

Figure 7 shows the circuit diagram of an integrated arrangement for transformation of high electric power from one DC voltage level to another DC voltage level.

A DC/DC power transformer is provided which is an arrangement for direct transformation of high electric power from one DC voltage level to another DC voltage level without an intermediate AC voltage network. The DC voltage is today basically used for transmission of high electric power at long distances. The DC voltage level for these transmissions are of the order of several 100 kV. The DC/DC power transformer allows several DC voltage levels to be used by connecting DC networks with different voltages. The principle for this arrangement is that the valve windings (43, 45) from one or several converter transformers (47) are connected to two valve bridges, which generate opposing cyclically variating magnetic flows in the transformer cores (44). One of the valve bridges is operated as an inverter (42) and the other as a rectifier (46) and in this manner the power is transformed from one DC voltage level (U_{d1}) to another (U_{d2}). At high voltage levels the leakage inductances in the transformers will be high for conventional transformers as a consequence of the large insulation distances and therefore special arrangements must be made in order to commutate the magnetic energy from one phase of the transformer to another without creating great losses.

A DC transformer in accordance with the present invention can be made with very low leakage inductances.

The DC transformer/reactor in accordance with the present invention can e.g. be a HVDC or MVDC transformer/reactor.

The invention is not limited to the embodiments described in the foregoing. It will be obvious that many different modifications are possible within the scope of the following claims.

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AMENDED CLAIMS

1. A DC transformer/reactor comprising a magnetic circuit, wherein the magnetic circuit comprises a magnetic core and at least one winding, **characterized in** that the winding comprises at least one current-carrying conductor and each winding comprises an insulation system, which comprises on the one hand at least two semiconducting layers, wherein each layer constitutes substantially an equipotential surface, and on the other hand between them is arranged a solid insulation.

2. A DC transformer/reactor according to claim 1, **characterized in** that at least one of said semiconducting layers has in the main equal thermal expansion coefficient as said solid insulation.

3. A DC transformer/reactor according to claim 2, **characterized in** that the potential of the inner one of said layers is essentially equal to the potential of the conductor.

4. A DC transformer/reactor according to claim 2 or 3, **characterized in** that an outer one of said layers is arranged in such a way that it constitutes an equipotential surface surrounding the conductor.

5. A DC transformer/reactor according to claim 4, **characterized in** that said outer layer is connected to a specific potential.

6. A DC transformer/reactor according to claim 5, **characterized in** that said specific potential is ground potential.

7. A DC transformer/reactor according to any one of claims 1, 2, 3, 4, 5, or 6, **characterized in** that at least two of said layers have substantially equal thermal expansion coefficients.

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8. A DC transformer/reactor according to any of the previous claims, **characterized in** that the current-carrying conductor comprises a number of strands, only a minority of the strands being non-isolated from each other.

9. A DC transformer/reactor according to any one of the preceding claims, **characterized in** that each of said two layers and said solid insulation is fixed connected to adjacent layer or solid insulation along substantially the whole connecting surface.

10. A DC transformer/reactor comprising a magnetic circuit, wherein the magnetic circuit comprises a magnetic core and at least one winding, **characterized in** that the winding comprises a cable (1) comprising at least one current-carrying conductor (2),

- each conductor (2) comprises a umber of strands,
- around said conductor (2) is arranged an inner semiconducting layer (3),
- around said conductor (2) is arranged an inner semiconducting layer (3),
- around said inner semiconducting layer (3) is arranged an insulating layer (4) of solid insulation, and
- around said insulating layer (4) is arranged an outer semiconducting layer (5).

11. A DC transformer/reactor according to claim 10, **characterized in** that said cable also comprises a metal shield and a sheath.

12. A DC transformer/reactor according to Claim 11, **characterized in** that the cable has a diameter comprised in the approximate interval 20-250 mm and a conductor are comprised in the approximate interval 80-3000 mm^2.

13. A DC transformer/reactor according to any of Claims 1-12, **characterized in** that windings on different potentials are wound in direct contact to each other.

14. A DC transformer/reactor according to any of Claims 1-13, **characterized in** that a winding on DC potential versus the core is wound directly on, or very near the core.

15. A DC transformer/reactor according to any of Claims 1-14. **characterized in** that the magnetic circuits exposed for DC magnetisation comprise at least one zone with lowered permittivity in the magnetic main flux.

16. A DC transformer/reactor according to Claim 15, **characterized in** that the zone with lowered permittivity is accomplished with an air gap arranged in said core.

17. A DC transformer/reactor according to claim 15, **characterized in** that the zone with lowered permittivity is accomplished with a series of small air gaps arranged in said core.

18. A DC transformer/reactor according to claim 15, **characterized in** the zone with lowered permittivity is accomplished with a gap arranged in said core, wherein said gap is made of a material with a relative permeability, μ_r, which satisfies the expression $1 \leq \mu_r \leq \mu_{core}$.

19. A DC transformer/reactor according to any of Claims 15-18, **characterized in** that said core comprises an essentially rectangular outer member having opposing side sections and connecting end sections and further comprises a cylindrical center member that is continuous in the longitudinal direction, said core end sections having a pair of aligned circular apertures extending completely there through into which opposite ends of said cylindrical center member extend to define between at least one end

section and the respective end of said center member a radial magnetic air gap of constant predetermined length for controlling the permeability of said core.

20. A DC transformer/reactor according to any of Claims 16, 17, or 19, **characterized in** tat each air gap is compensated by a capacitively loaded compensation winding.

21. A DC transformer/reactor according to any of Claims 1-20, **characterized in** that said transformer/ reactor also comprises a housing including at least thyristor valve.

22. A DC transformer/reactor according to Claim 21, **characterized in** that all of said thyristor valves are of the integrated type.

23. A DC transformer/reactor comprising a magnetic circuit, wherein the magnetic circuit comprises a magnetic core and at least one winding, **characterized in** that the winding comprises at least one current-carrying conductor, and also comprising an insulation system, which comprises at least two semiconducting layers, wherein each layer constitutes substantially an equipotential surface, which insulation system in respect of its thermal and electrical properties permits a voltage level in said HVDC transformer/reactor exceeding 36 kV.

24. An integrated back-to-back station, **characterized in** that said station comprises two transformers/groups of DC transformers according to any of Claims 1-23.

25. An integrated arrangement for transformation of high electric power from one DC voltage level to another DC voltage level, **characterized in** that said arrangement comprising a DC transformer according to any of Claims 1-23, wherein the DC transformer comprising first valve windings and second valve windings, wherein the first valve windings are connected to a first valve bridge and the second valve windings are connected to a second valve

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bridge, whereby the first valve bridge is operated as an inverter and the second valve bridge is operated as a rectifier.

26. An integrated arrangement according to Claim 25, **characterized in** that said first valve bridge comprising at least one six-pulse inverter bridge which includes a plurality of self-commutated thyristors and further comprising a plurality of diodes, each diode being connected antiparallel to a self-commutated thyristor, and said second valve bridge comprising a six-pulse rectifier bridge which includes a plurality of diode valves.

27. A DC transformer/reactor according to Claim 13 or 14, **characterized in** that the cable is specially adapted for mixed voltage.

28. A reactor for DC plants according to Claim 20, **characterized in** that said compensation winding is loaded with a variable capacitance so as to be able to vary the inductance of the reactor.

29. A DC transformer/reactor according to any of Claims 10-22, 27, **characterized in** that said outer semiconducting layer (5) is cut in a number of parts, each of which is connected to ground potential.

30. A DC transformer/reactor according to any of Claims 1-22, 27, and 29, **characterized in** that the DC transformer/reactor also comprising at least one sensor/transducer for monitoring and diagnostics.

Fig. 1

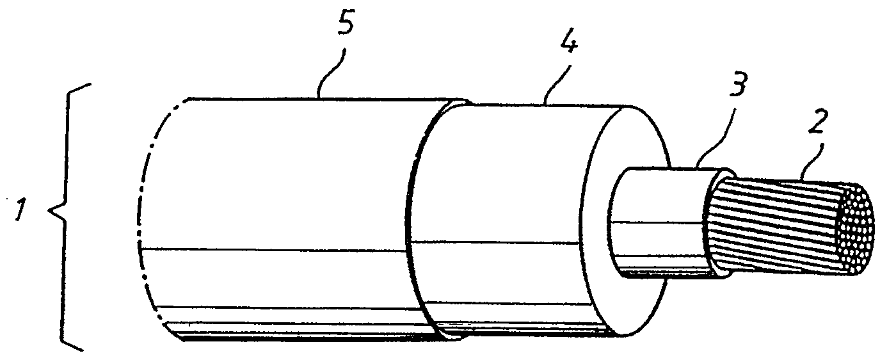

Fig. 2

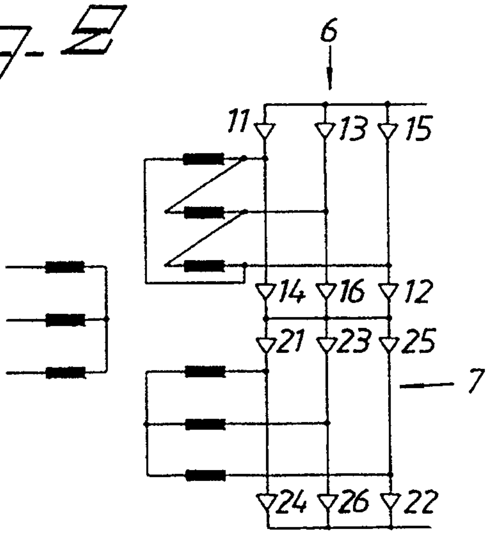

Fig. 3

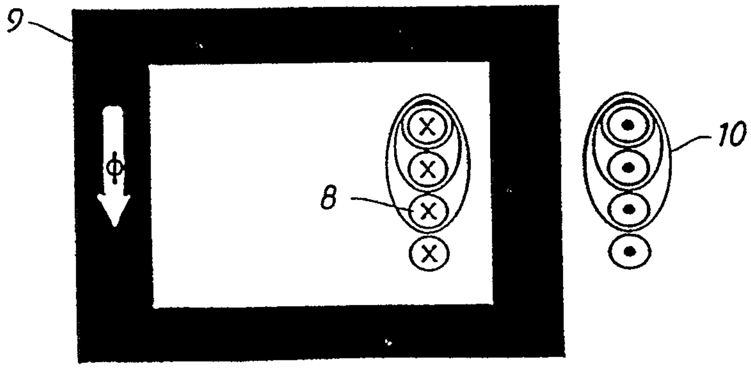

Fig. 4

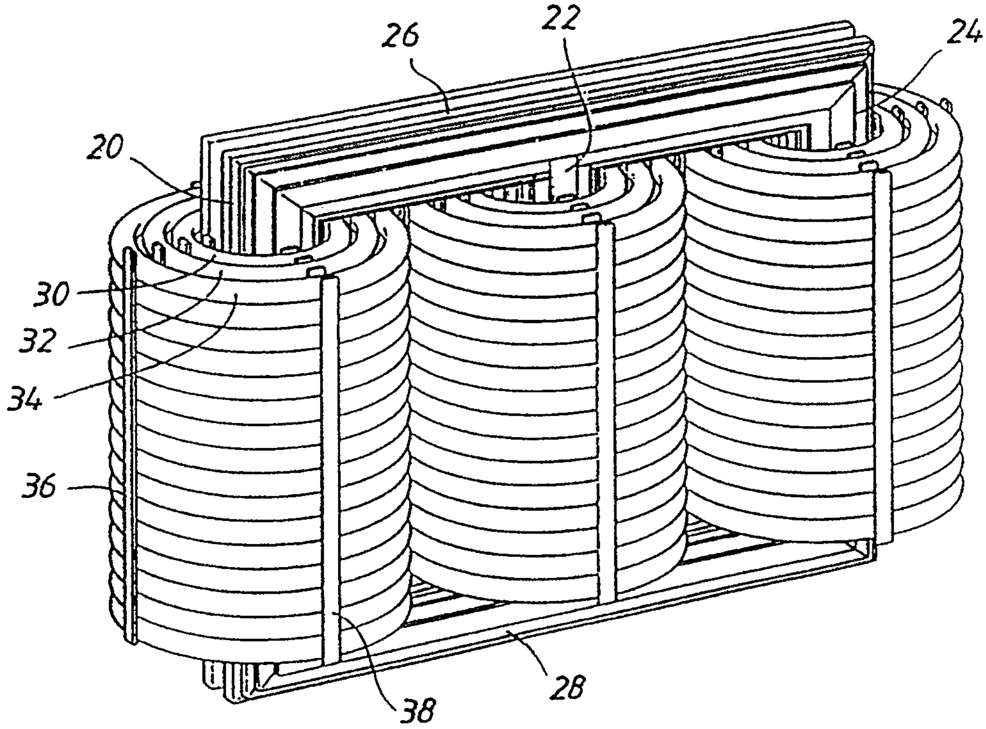

Fig. 5

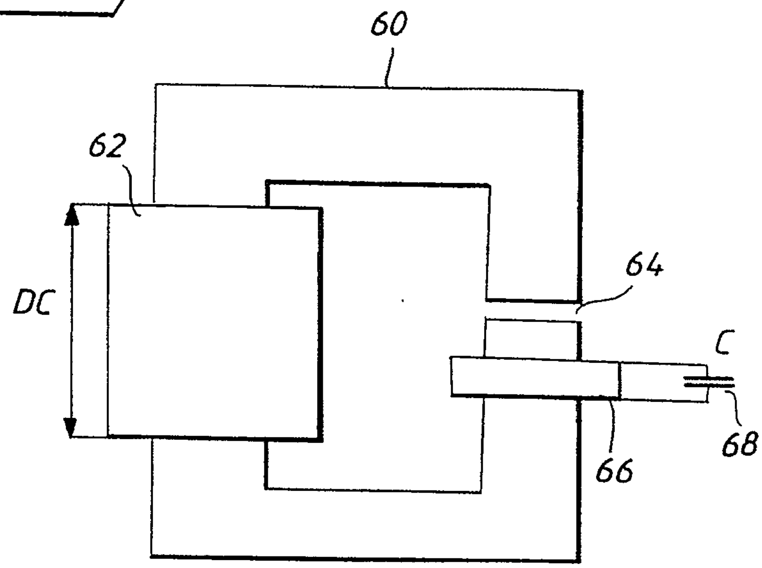

Fig. 6

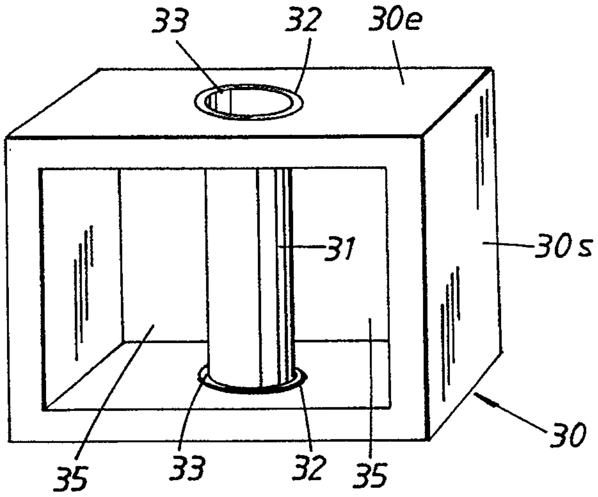
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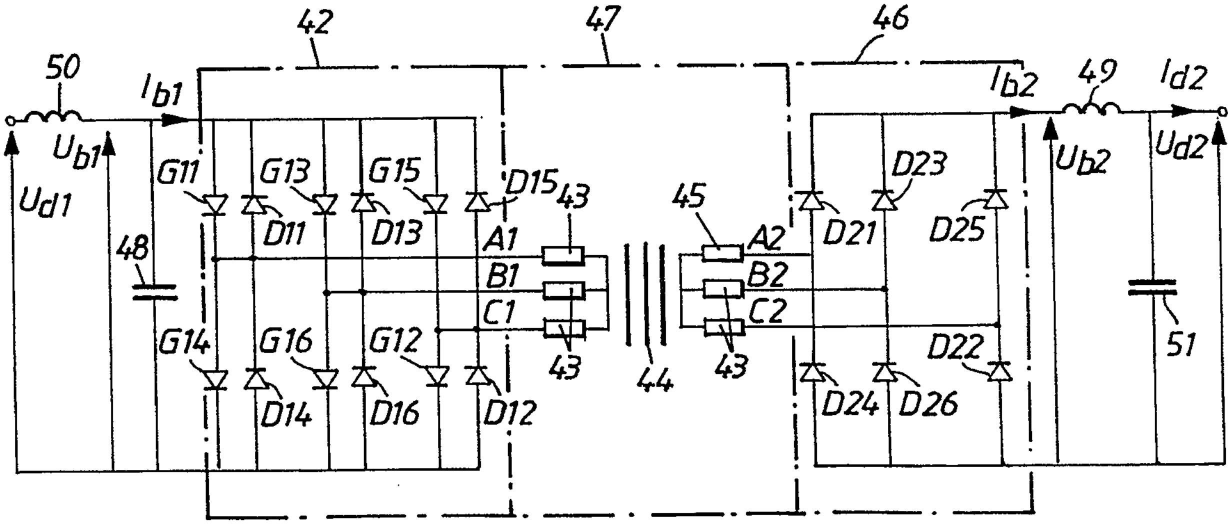
Fig. 7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A2
D21
D23
D25
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B1
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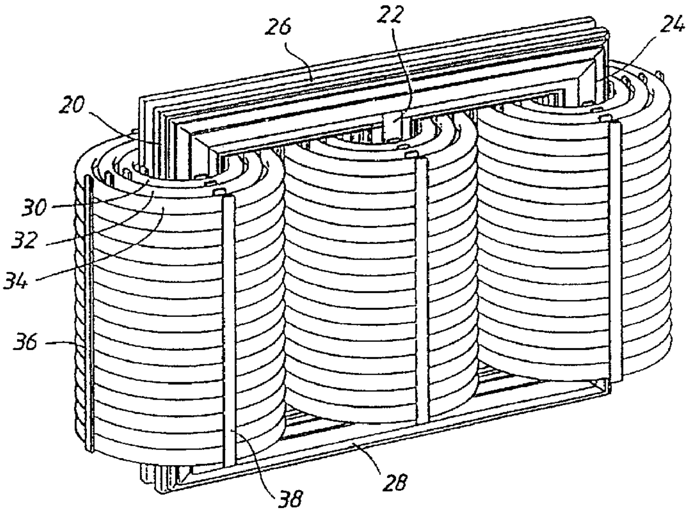

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