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(54) **High voltage DC system.**

(57) ABSTRACT: A high voltage DC system (100) is disclosed, comprising a high voltage DC device (10) exhibiting a change of electric potential hi longitudinal direction (L) during operation from a first end portion (12) of the high voltage DC (10) device to a second end portion (13) of the high voltage DC device (10), and an enclosure. The enclosure comprises a tubular insulating body (20) having at least one an electrically insulating enclosure wall (21a, 21b); and at least one resistive field grading layer (40) on at least a part of a surface (22a, 22b, 23a, 23b) of the insulating enclosure wall (21a, 21b). The field grading layer has (40) a non-linear resistive behavior. A first part of the field grading layer (40) is connected to the first end portion (12) of the high voltage DC device (10). The field grading layer (40) extends essentially continuously from the first end portion (12) to the second end portion (13). (Fig- 1)
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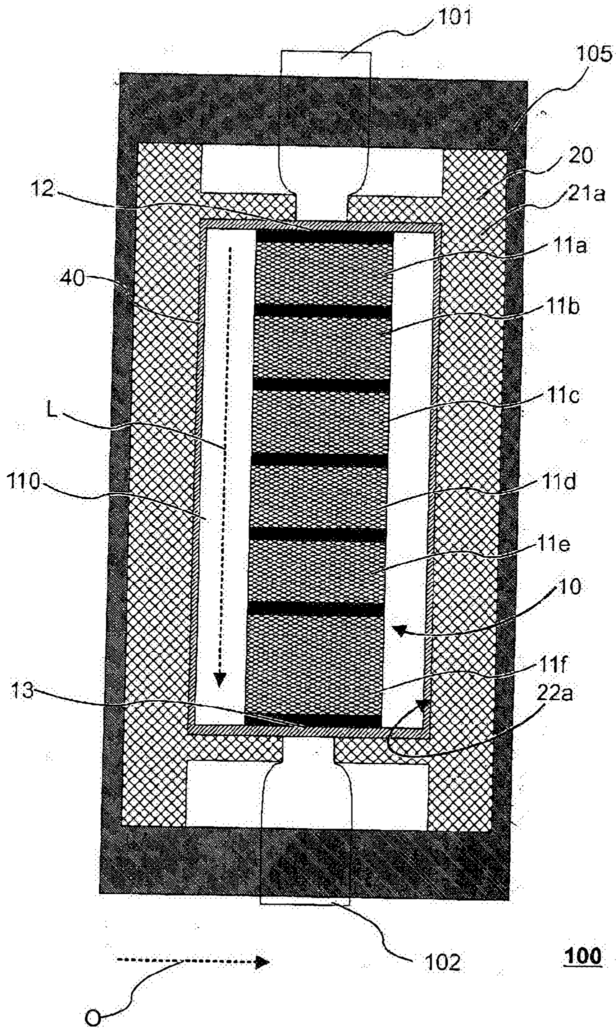

Fig. 1

High voltage DC system

Technical Field

The disclosure relates generally to a high voltage DC system. Further embodiments relate to the use of a high voltage DC system in insulating a high voltage DC device operable or operating with a DC voltage applied to it.

Background art

High voltage systems are particularly desirable when system loss has to be reduced. For example, when frequency converters, drives etc. are operated at a high voltage, less current is needed when the same power is desired. Conventional high voltage systems comprise a high voltage device for which a proper insulation has to be ensured. Common insulation technologies include, for example, composite insulations, which employ different insulation materials.

In particular, when a high voltage DC device (HVDC device) is used in a high voltage DC system (HVDC system), the DC field distributions in equipment with a composite insulation can become disadvantageous. For example, very large field enhancements can occur due to large resistivity ratios between the different insulation materials. Field enhancement may include, for example, local field enhancements, short-term capacitive field enhancements and/or transient field enhancements.

Furthermore, the different insulation materials are strongly sensitive to various parameters; thus, the field distribution is often not robust.

Conventional technology includes a technique, which makes use of field grading materials. Some field-grading materials exhibit a resistance behavior, which is non-linear. The conductivity of a non-linear resistive field grading material is dependent on the electric field. It has a comparatively low conductivity for the case, that the applied electric field is low; when the electric field strength increases, also the conductivity increases.

With the conventional field grading arrangements, in particular in HVDC systems, a robust DC field distribution can hardly be achieved. Thus, the conventional field grading is often unreliable, particularly in DC applications.

It is therefore desirable to provide a reliable, robust HVDC system with an improved DC field distribution.

Brief Summary of the Invention

In view of the above, a high voltage DC system according to claim 1 is provided. Furthermore, a use of a high voltage DC system according to claim 16 is provided. Further aspects, advantages, and features of the present disclosure are apparent from the dependent claims, the description, and the accompanying drawings.

According to one aspect of the disclosure, a high voltage DC system is provided, comprising a high voltage DC device exhibiting a change of electric potential in longitudinal direction during operation from a first end portion of the high voltage DC device to a second end portion of the high voltage DC device; an enclosure comprising a tubular insulating body having at least one an electrically insulating enclosure wall; at least one resistive field grading layer on at least a part of a surface of the insulating enclosure wall; wherein the field grading layer has a non-linear resistive behavior, wherein a first part of the field grading layer is connected to the first end portion of the high voltage DC device, wherein the field grading layer extends essentially continuously from the first end portion to the second end portion.

According to a further aspect of the disclosure, the use of a high voltage DC system as disclosed herein is provided. According to the use, the high voltage DC system is used in insulating the high voltage DC device operable or operating with a DC voltage applied to it.

The high voltage DC system according to embodiments described herein enables an advantageous DC field distribution along the HVDC device and/or prevents a harmful field asymmetry in particular for capacitive fields, which may e.g. occur during transient events such as impulse type signals etc.

With the high voltage DC system according to embodiments described herein, several effects can be obtained which allow for a robust and reliable operation.

Brief Description of the Drawings

The subject matter of the disclosure will be explained in more detail with reference to preferred exemplary embodiments, which are illustrated in the accompanying drawings.

In the drawings:

Fig. 1 shows a schematic sectional side view of a high voltage DC system according to an embodiment of the present disclosure;

Fig. 2 shows a schematic sectional side view of parts of a high voltage DC system according to another embodiment of the present disclosure;

Fig. 3 shows a schematic sectional side view of parts of a high voltage DC system according to yet another embodiment of the present disclosure;

Fig. 4 shows a schematic sectional side view of parts of a high voltage DC system according to yet another embodiment of the present disclosure;

Fig. 5 shows a schematic sectional side view of a high voltage DC system according to yet another embodiment of the present disclosure;

Fig. 6 shows a schematic side view of parts of a high voltage DC system according to yet another embodiment of the present disclosure; and

Fig. 7 shows a schematic top view of parts of a high voltage DC system according to yet another embodiment of the present disclosure.

Detailed Description of the Embodiments

In the following, various aspects and features of embodiments of the disclosure are described. It is intended that each of the aspects and features, whether described in the context of a particular embodiment or not, can be combined with any other aspect or feature.

In the drawings and the description of the embodiments, in principle, identical or corresponding parts are provided with the same reference numerals. The description relating to the same reference numerals shall be applicable to any embodiment unless otherwise specified.

For convenience, in the embodiments of Figs. 2, 3, and 4, only a part of the high voltage DC system 100 (to be described further below) is shown. This is, however, not to be understood as limiting, and it is understood that the parts omitted from Figs. 2, 3, and 4 are usually provided also in those embodiments.

Fig. 1 shows a sectional side view of a high voltage DC system 100 (in the following, referred to as HVDC system 100). The HVDC system 100 comprises a high voltage DC device 10 (in the following, referred to as HVDC device 10) and an enclosure which accommodates at least parts of the HVDC device 10.

As understood herein, "high voltage" refers to a rated voltage above about 20 kV or above 30 kV. Typically, the voltages are even higher, e.g. above 100 kV or above 150 kV. It is understood that the high voltage refers to a potential difference between the terminals, e.g. external terminals, of the HVDC system 100 and/or to a potential difference between the terminals, e.g. internal terminals, of the HVDC device 10.

The HVDC device 10 extends between a first end portion 12 thereof to a second end portion 13 thereof. Typically, the HVDC device 10 is substantially entirely accommodated by the enclosure of the HVDC system 100 in between the first end portion 12 and the second end portion 13. The direction of extension between the first end portion 13 and the second end portion 13 defines a longitudinal direction L, which is indicated in Fig. 1 by means of an arrow.

During operation, the HVDC device 10 exhibits a change of electric potential in the longitudinal direction L. Typically, a voltage drop occurs at the HVDC device 10 from the first end portion 12 to the second end portion 13. Voltage drop is not to be understood as limiting the direction of change of the electric potential and may thus be a negative value as well. In typical embodiments, one of the first end portion 12 and the second end portion 13 is on ground potential, while the other one is on high voltage potential. Examples for a HVDC device 10, which are not to be understood as limiting, are power converters, stacks of DC capacitors etc.

The enclosure comprises a tubular insulating body 20. Typically, the insulation body 20 extends in the longitudinal direction L. As used herein, the term "tubular" is not to be understood as being limited to a circular cross section; rather a tubular cross section refers to the topology and not necessarily to the geometry, and it also includes, for example, square or rectangular cross sections.

The tubular insulating body 20 comprises, for example, an electrically insulating material like a polymer or a ceramic material, but is not limited thereto. Typically, the tubular insulating body 20 essentially consists of the polymer or a ceramic material. An outer surface of the tubular insulating body 20 may be provided with an outer electrically grounded surface, e.g. a grounded encapsulation. In the case of an outer grounded surface, the tubular insulating body

20 is adapted to reliably insulate the voltage at the first end portion 12 and the second end portion 13 having the highest potential difference to ground.

The tubular insulating body 20 has at least one electrically insulating enclosure wall 21a, 21b. At least one resistive field-grading layer 40 is provided on at least a part of a surface 22a, 22b, 23a, 23b of the insulating enclosure wall 21a, 21b. In the embodiment according to Fig. 1, the field-grading layer 40 is provided on an inner surface 22a of the insulating enclosure wall 21a. The field-grading layer 40 may, for example, be provided as a coating, thereby realizing a cost-efficient solution.

The field-grading layer 40 exhibits non-linear resistive properties. The conductivity of the non-linear resistive field-grading layer 40 is dependent on the electric field. It has a comparatively low conductivity for the case, that the applied electric field is low; when the electric field strength increases, also the conductivity increases. Typically, in case the electric field is sufficiently low, the field grading layer 40 exhibits an insulating behavior; and in case the electric field is sufficiently high, the field grading layer 40 exhibits a conducting behavior. The transition between non-conductive to conductive is typically substantially instantaneous. By way of example, the field-grading layer 40 may exhibit a "switching-type" property, wherein the transitional range of the field strength from the non-conductive state to the conductive state is comparatively narrow.

A first part of the field-grading layer 40 is connected to the first end portion 12 of the high voltage DC device 10. That is, a first part of the field-grading layer 40 is brought to substantially the same electric potential as the first end portion 12. An electrical connection of the first end portion 12 of the high voltage DC device 10 is passed through to the outside. Typically, the first end portion 12 is provided with a first terminal, which is led to the outside of the HVDC device 100 via a first bushing 101. Thus, typically, the voltage applied to the first terminal is substantially the same voltage as that of the first end portion 12 of the HVDC device 10 and also substantially the same voltage as that of the first part of the field-grading layer.

The field grading layer 40 extends essentially continuously from the first end portion 12 to the second end portion 13. That is, the field-grading layer 40 is provided along substantially the entire extension of the HVDC device 10 in the longitudinal direction. The term "substantially the entire extension" may include, for example, that the field-grading layer 40 is provided along more than 95% of the entire extension of the HVDC device 10 in the longitudinal direction, preferably along more than 98% of the entire extension of the HVDC device 10 in the longitudinal direction. Thus, the field-grading layer 40 covers, with a clearance, substantially the entire elongation of the HVDC device 10 in the longitudinal direction L.

An extension of the field-grading layer 40 along substantially the entire extension of the HVDC device 10 may help to homogenize the electric field occurring along the HVDC device 10 and may avoid or reduce undesired field peaks.

In the embodiment of Fig. 1, the field-grading layer 40 is depicted as changing the direction in a plane containing the first end portion 12 and in a plane containing the second end portion 13 to respectively extend in a plane perpendicular to the longitudinal direction L, in addition to the longitudinal extension. Such an arrangement may be helpful to ensure a connection with the first end portion 12 or the second end portion 13, respectively. However, the shown arrangement is not to be understood as limiting, and the connection of the first part of the field grading layer 40 to the first end portion 12 and/or connection of the second part of the field grading layer 40 to the second end portion 13 can be made by other means than extending the whole layer 40 to the respective connection point.

In some embodiments, a second part of the field-grading layer 40 is connected to the second end portion 13 of the HVDC device 10. That is, a second part of the field-grading layer 40 is brought to substantially the same electric potential as the second end portion 13. An electrical connection of the second end portion 13 of the high voltage DC device 10 is passed through to the outside. Typically, the second end portion 13 is provided with a second terminal, which is led to the outside of the HVDC device 100 via a second bushing 102. Thus, typically, the voltage applied to the second terminal is substantially the same voltage as that of the second end portion 13 of the HVDC device 10 and also substantially the same voltage as that of the second part of the field-grading layer.

That is, according to typical embodiments described herein, the field grading layer 40 extends along substantially the whole longitudinal extension of the tubular insulating body, and it is connected to the high voltage potential at one of the first end portion 12 and the second end portion, and connected to ground potential at the other one of the first end portion 12 and the second end portion. This may help to further homogenize the electric field occurring along the HVDC device 10 and may reduce undesired field peaks even further.

Reference is made to Fig. 4, which shows a schematic sectional side view of parts of a high voltage DC system according to another embodiment of the present disclosure.

In some embodiments, the field-grading layer 40 has different non-linear resistive characteristics in at least two different sections 41, 42, 43, 44 thereof when seen in the direction of the longitudinal direction L. That is, according to some embodiments described herein, the non-linear characteristics of the field-grading layer 40 differ in at least two sections of the field-grading layer 40, the sections being arranged at different distances from the first end portion 12 in the longitudinal direction. The sections 41, 42, 43, 44 each extend in the longitudinal direction and are typically interconnected with one another. An interconnection of the sections 41, 42, 43, 44 may also be secured by providing an integrally formed field-grading layer 40 comprising at least two sections 41, 42, 43, 44 with different non-linear resistive characteristics. A distance of a section 41, 42, 43, 44 is typically the longitudinal distance of its center from the reference point, e.g. from the first end portion 12.

The different non-linear resistive characteristics in the at least two different sections 41, 42, 43, 44 can be achieved in various ways. For example, different amounts and/or concentrations of field grading materials within the field-grading layer 40 can be employed.

In typical embodiments, in a field grading layer 40 having different non-linear resistive characteristics in at least two different sections 41, 42, 43, 44 thereof, the thickness of the field grading layer 40 varies in the longitudinal direction L. As shown in the exemplary embodiment of Fig. 4, each section 41, 42, 43, 44 has a corresponding thickness 51, 52, 53, 54. The thickness is typically the extension of the corresponding section 41, 42, 43, 44 of the field-grading layer 40 in the direction of a plane perpendicular to the longitudinal direction. In the exemplary case, but not by way of limitation, of a circular tube forming the tubular insulating body 20, the direction of the plane perpendicular to the longitudinal direction is the radial direction of the tubular insulating body 20.

In the embodiment of Fig. 4, the thickness gradually decreases from a first thickness 51 of the first section 41 over a second thickness 52 of the second section 42 and a third thickness 53 of the third section 43 to a fourth thickness 54 of the fourth section 44. However, this is only to be understood as an example, and more or less sections than four sections 41, 42, 43, 44 may be provided, each or some of them having different thicknesses. Likewise, the thicknesses of some of the sections may be the same or substantially the same, while others are different from one another.

In order to vary the thickness 51, 52, 53, 54, the field-grading layer 40 may comprise a combination of sub-layers each having essentially the same thickness, wherein the amount of sub-layers in each of the sections 41, 42, 43, 44 determines the respective thickness 51, 52, 53, 54.

In typical embodiments, the HVDC device 10 comprises two or more device units 11a, 11b, 11c, 11d, 11e, 11f that are stacked and interconnected to one another. Typically, the interconnection is a series type connection. The interconnection between the device units 11a, 11b, 11c, 11d, 11e, 11f is typically a galvanic connection. The device units 11a, 11b, 11c, 11d, 11e, 11f typically comprise one or more of active components and passive components. Examples of active components are, but not limited to, power converter modules, such as modular-multi-level-converter modules, each or some of which may comprise a power semiconductor module, a gate drive unit, a control electronics unit. Examples of passive components are, but not limited to, capacitors, coolers, bus bars. In the drawings, the device units 11a, 11b, 11c, 11d, 11e, 11f are depicted schematically with a contact-type interconnection in black color.

Each device unit 11a, 11b, 11c, 11d, 11e, 11f may be a low voltage device. As used herein, "low voltage" refers to a rated voltage of, for example, several kilovolts, typically more than 1 kV or more than 2 kV. A stack of device units 11a, 11b, 11c, 11d, 11e, 11f forming the HVDC device 10 is commonly referred to as a pile.

Typically, the HVDC device 10 comprises multiple device units which are stacked in the direction between the terminals, e.g. between the bushings. Such a stack of device units normally extends in the longitudinal direction L, i.e. the direction between the terminals, and typically, the extension of the HVDC device 10 in the longitudinal direction is greater than the extension in the orthogonal direction, e.g. in the circumferential direction. However, the present disclosure is not limited to this example, and a HVDC 10 device with a comparatively extension in the longitudinal direction with respect to the orthogonal direction is also comprised by this disclosure.

In the stack or pile, the voltage drops across each of the single device units 11a, 11b, 11c, 11d, 11e, 11f, resulting in an overall voltage drop across the HVDC device 10. Thus, according to the embodiment, each of the device units 11a, 11b, 11c, 11d, 11e, 11f exhibits a partial voltage drop during operation.

In the stack of device units 11a, 11b, 11c, 11d, 11e, 11f, one or more of the configurations disclosed herein may help preventing harmful field asymmetries, in particular during AC transient events, and/or may help to shape a specific DC field distribution along the stack.

In some embodiments, the HVDC device 10 comprises a voltage divider at least at one of the interconnected device units 11a, 11b, 11c, 11d, 11e, 11f. In the embodiment, the voltage divider typically comprises a capacitive and/or a resistive voltage divider. A voltage divider may help to equalize and/or to stabilize the partial voltage drops across each of the device units 11a, 11b, 11c, 11d, 11e, 11f. A capacitive voltage divider may be effective for AC fields, such as transient events like surges etc. A transient event may, for example, occur during type testing with a switching surge pulse. A resistive voltage divider may be effective for DC fields, such as those occurring during normal operation of the HVDC device 10. With the field-grading layer 40 extending essentially continuously from the first end portion 12 to the second end portion 13, undesired field peaks may be further reduced.

Reference is made to Fig. 5, which shows a schematic sectional side view of a high voltage DC system according to another embodiment of the present disclosure.

In some embodiments, the HVDC device 10 comprises at least one intermediate connection 15a, 15b, 15c, 15d electrically connecting a predetermined one of the device units 11a, 11b, 11c, 11d, 11e, 11f with the field-grading layer 40. The intermediate connection 15a, 15b, 15c, 15d is provided in between the first end portion 12 and the second end portion 13. The intermediate connection 15a, 15b, 15c, 15d may, for example, comprise at least one electrical conductor and/or at least one nonlinear resistive field-grading element. An intermediate connection 15a, 15b, 15c, 15d may further help to support a resistive voltage division. Furthermore, the intermediate connection 15a, 15b, 15c, 15d may serve as a spacer. Typically, the intermediate connection 15a, 15b, 15c, 15d is orthogonal longitudinal direction L, ensuring the shortest distance between the respective device unit and the field-grading layer 40. This may further equalize and/or stabilize the electric field.

Typically, one or more intermediate connections 15a, 15b, 15c, 15d are provided, each corresponding to a predetermined one of the device units 11a, 11b, 11c, 11d, 11e, 11f. Predetermination may be made, for example, taking into account the expected electric potential and/or the expected electric field strength at the respective device unit 11a, 11b, 11c, 11d, 11e, 11f. By way of example and not by limitation, the predetermined one or ones of the device units 11a, 11b, 11c, 11d, 11e, 11f are those at which the highest field strengths are expected in the stack.

In an exemplary embodiment, the HVDC device 10 has different non-linear resistive characteristics in at least two different sections 41, 42, 43, 44 thereof when seen in the direction of the longitudinal direction L, as further described herein, and the HVDC 10 comprises also two or more device units 11a, 11b, 11c, 11d, 11e, 11f which are stacked and interconnected to one another, as further described herein. According to the exemplary embodiment, the different non-linear resistive characteristics in the at least two different sections 41, 42, 43, 44 may be realized by different thicknesses 51, 52, 53, 54, as described herein. Also, according to the exemplary embodiment, the HVDC device 10 comprising the at least two interconnected device units 11a, 11b, 11c, 11d, 11e, 11f may comprise a voltage divider at least at one of the interconnected device units 11a, 11b, 11c, 11d, 11e, 11f and/or at least one intermediate connection 15a, 15b, 15c, 15d, as described herein.

Further, according to the present embodiment, each section 41, 42, 43, 44 of the field grading layer 40 corresponds to each one of the device units 11a, 11b, 11c, 11d, 11e, 11f, and the non-linear resistive characteristics of the field grading layer 40 in the sections 41, 42, 43, 44 are respectively adjusted to the voltage drop of the corresponding device unit 11a, 11b, 11c, 11d, 11e, 11f.

In order to address a specific longitudinal field distribution, the adjusted non-linear resistive characteristics of the field-grading layer 40 in the sections 41, 42, 43, 44 may help to avoid a flashover. In addition, the adjusted non-linear resistive characteristics of the field-grading layer 40 in the sections 41, 42, 43, 44 may help to address a particular longitudinal potential distribution. For example, in the case that a grounded part of the HVDC system 100 is present around the HVDC device 10, a longitudinal potential distribution determines the radial field in the insulation. The adjusted non-linear resistive characteristics of the field-grading layer 40 in the sections 41, 42, 43, 44 may help to control the radial field.

Referring to Fig. 4, an example is shown according to the present embodiment, wherein four device units 11a, 11b, 11c, 11d are provided in the HVDC device 10. This is, however, only an example and is not to be understood as a limitation to four device units 11a, 11b, 11c, and 11d. According to the present example, the non-linear resistive characteristics of the field-grading layer 40 in the sections 41, 42, 43, 44 are respectively adjusted to the voltage drop of the corresponding device unit 11a, 11b, 11c, 11d.

That is, according to the present embodiment, the non-linear resistive characteristics of the field-grading layer 40 in the sections 41, 42, 43, 44 are adapted to equalize and/or to stabilize the different electric field strengths that occur in the respective corresponding parts of the HVDC system 100. For example, the field strength is the highest in the topmost part of Fig. 4, i.e. along the device unit 11a. Therefore, the non-linear resistive characteristics of the field-grading layer 40 in the corresponding section 41 are adjusted such that the comparatively high electric field strength is equalized and/or stabilized reliably. Likewise, the field strength is the lowest in the lowermost part of Fig. 4, i.e. along the device unit 11d. In addition, here, the non-linear resistive characteristics of the field-grading layer 40 in the corresponding section 44 are adjusted such that the comparatively high electric field strength is equalized and/or stabilized reliably.

Reference is made again to Fig. 1 and to Figs. 2, each showing a schematic sectional side view of parts of a high voltage DC system according to embodiments of the present disclosure.

According to the exemplary embodiment shown in Fig. 1, the field-grading layer 40 is provided on the inner surface 22a of the insulating enclosure wall 21a. A field grading layer 40 provided on the inner surface 22a of the insulating enclosure wall 21a may particularly be useful if the enclosure comprises a grounded outer part, e.g. a grounded encapsulation, at its outside.

However, as shown in Fig. 2, the field grading layer 40 may also be provided, in addition to or alternatively to the inner surface 22a of the insulating enclosure wall 21a, on the outer surface 23a of the insulating enclosure wall 21a. This is particularly useful when the enclosure does not comprise a grounded part.

As shown in Fig. 3, the tubular insulating body 20 may also comprise at least two concentrically arranges insulating enclosure walls 21a, 21b. According to the present embodiment, and in addition to or alternatively to providing the field grading layer 40 on an outermost surface or an innermost surface of the insulating enclosure walls, the field grading layer 40 may also be provided in between the insulating enclosure walls 21a, 21b. That is, according to the present embodiment, the field-grading layer 40 may also be sandwiched between multiple insulating enclosure walls 21a, 21b, for example, but not limited to, sandwiched between two insulating enclosure walls 21a, 21b.

It is also possible to provide the field grading layer 40 partially on the outer surface, partially on the inner surface and/or partially sandwiched in between the insulating enclosure walls 21a, 21b. The parts are typically interconnected to one another and extend, as a resulting total field grading layer 40, essentially continuously from the first end portion 12 to the second end portion 13.

According to typical embodiments, the field grading layer 40 comprises one or more of the group of: coated mica pigments; antimony-doped tin oxide; coated glass; coated ceramic; carbon black; graphene; graphene oxide; zinc oxide; tin oxide; varistor ceramic rings. Varistor ceramic rings may be in the form of stacked annular discs having a field grading behavior. Typically, the non-linear resistive material of the field-grading layer 40 comprises or essentially consists of microvaristor particles of one or more of the mentioned materials. Microvaristor particles may have very sharp switching transitions and a high nonlinearity. Typically, the particles have a size in the range of < 100 μm, preferably of < 60 μm and are readily available from known companies. The non-linear resistive material or materials may be present as such. They may also be the filler part of a filled polymer material, e.g. a filling material in a matrix of a polymer material. One example is a filler material in a matrix of polymer comprising a thermoplastic, elastomeric or duroplastic, i.e. a thermosetting polymer.

Reference is made to Figs. 6 and 7, each showing a schematic sectional view of a high voltage DC system according to embodiments of the present disclosure. In Fig. 6, a sectional side view is shown, as in Figs. 1 to 5. In contrast, Fig. 7 shows a sectional top view.

According to typical embodiments, the tubular insulating body 20 comprises a plurality of body segments 25a, 25b that are stacked in the longitudinal direction such that field grading layer segments 45a, 45b of the field grading layer 40 that respectively correspond to the insulating body segments 25a, 25b are electrically interconnected to one another. The body segments 25a, 25b may, for example, be tubular segments such as cylinder-shaped segments, which can be stacked around the HVDC device 10 when mounting the HVDC system 100. The stacking direction (i.e., the direction of combining or separating the body segments 25a, 25b) is indicated in Fig. 6 by a double arrow. The body segments 25a, 25b may be regarded as adapters in a modular concept.

Such a modular concept may be specifically advantageous when adapting a field-grading concept to different HVDC devices 10, for example different stacks of HVDC device units. That is, for example, the stack of insulating body segments 25a, 25b may be adapted to the specific needs of a particular stack of HVDC device units, e.g. due to a specific longitudinal field distribution (avoiding a flashover) and/or due to a longitudinal potential distribution. The stack of insulating body segments 25a, 25b may also be adapted to the dimensions (e.g., different elongations) of the HVDC device 10 and/or according to an expected characteristic of the electric field along the HVDC device 10 during operation thereof.

Some or all of the insulating body segments 25a, 25b may comprise an interconnection part, which is mechanically and/or electrically complementary to a corresponding interconnection part of another one of the insulating body segments 25a, 25b. The interconnection parts are typically equipped each with an electrical contact member. The electrical interconnection of the field-grading layer 40 may be ensured, for example, by providing a contact interface as the electrical contact member at each of the body segments 25a, 25b. The contact interface may optionally be treated to enhance the electrical contact properties, e.g. by way of metallization.

Additionally or alternatively, according to typical embodiments, the tubular insulating body 20 comprises at least two shell parts 26a, 26b, the shell parts 26a, 26b being separable and, in the mounted state, respectively adjacent to one another at respective longitudinal joint surfaces such that field grading layer parts 46a, 46b of the field grading layer 40 that respectively correspond to the shell parts 26a, 26b are electrically interconnected to one another. The shell parts 26a, 26b – i.e. the shell halves in the case of two shell parts 26a, 26b – can thus be wrapped around the HVDC device 10 when mounting the HVDC system 100. Such a concept may be specifically advantageous when assembling the HVDC system 100. The combining direction (i.e., the direction of combining or separating the shell parts 26a, 26b) is indicated in Fig. 7 by a double arrow.

The electrical interconnection of the field-grading layer 40 may be ensured, for example, by providing the longitudinal joint at least partially with a contact interface at each of the shell parts 26a, 26b. The contact interface may optionally be treated to enhance the electrical contact properties, e.g. by way of metallization.

It is emphasized that the tubular insulating body 20 comprising a plurality of body segments 25a, 25b and/or the tubular insulating body 20 comprising at least two shell parts 26a, 26b can advantageously be combined with any of the other embodiments described herein, leading to a flexible and/or modular concept which can easily be adapted to HVDC systems 100 with different HVDC devices 10, at the same time facilitating the assembly of the HVDC system 100.

According to typical embodiments, the field grading layer 40 extends in the longitudinal direction L along the high voltage DC device 10 and also extends, in the vicinity of the first end portion 12 and/or in the vicinity of the second end portion 13, in a direction O of a plane P1, P2 orthogonal to the longitudinal direction L, wherein the field grading layer 40 comprises a rounded portion 47, 48 at a transition between the directions. A rounded portion 47, 48, as shown for example in Fig. 5, may help to further equalize and/or stabilize the electric field occurring in the HVDC system 10, avoiding substantially harmful field strength peaks.

According to typical embodiments, the field grading layer 40 is provided along a full circumference in at least one cross-section orthogonal to the longitudinal direction L of the high voltage DC device 10, preferably wherein the field grading layer 40 is provided along a full circumference essentially along the entire extension the high voltage DC device 10 in the longitudinal direction L thereof. That is, according to the present exemplary embodiment, the field-grading layer 40 is not interrupted in the circumferential direction around the whole HVDC device 10. This may help to further equalize and/or stabilize the electric field.

According to typical embodiments, the enclosure is adapted for gas-insulated accommodation of the HVDC device 10. In typical HVDC applications, the HVDC device 10 is gas-insulated for reducing the risk of dielectric breakdown along the insulation path. In Figs. 1 through 5, a gas insulation space 110 is shown which may be filled with an insulation gas. A common example for an insulation gas employed in HVDC insulation is, but not limited to, SF_6. The dielectric properties of the insulation gas are more advantageous than those of ambient air and may lead to a size reduction of the HVDC system 100. The HVDC device 10 is thus surrounded by a solid material. For example, the tubular insulating body 20 may also serve as a gas-tight (gas-insulated) accommodation according to the embodiment.

One of the tasks of ensuring a reliable DC insulation in a gas-insulated HVDC system 10, in addition to reducing the risks of dielectric breakdown in the gas, is to reduce flashover along gas-solid insulation surfaces. With the configuration of one or more of the embodiments disclosed herein, an advantageous field control may be achieved particularly in a gas-insulated HVDC system 100, reducing the breakdown and flashover risk while also reducing the overall dimensions of the HVDC system 100.

Also part of this disclosure is the use of any one of the HVDC system 100 as described herein in insulating the HVDC device 10 which is operable or which is operating with a DC voltage applied to it. Typically, the use is with a HVDC device 10 having a high DC voltage applied to it, e.g. a voltage of above 20 kV or above 30 kV or above 100 kV.

Although the invention has been described based on some preferred embodiments, those skilled in the art should appreciate that those embodiments should by no way limit the scope of the present invention. Without departing from the spirit and concept of the present invention, any variations and modifications to the embodiments should be within the apprehension of those with ordinary knowledge and skills in the art, and therefore fall in the scope of the present invention, which is defined by the accompanied claims.

List of reference numerals

100 high voltage DC system

101 first bushing

102 second bushing

105 casing

110 gas insulation space

10 high voltage DC device

11a, 11b, 11c, 11d, 11e, 11f device unit

15a, 15b, 15c, 15d intermediate connection

L longitudinal direction

P orthogonal direction

P1, P2 plane

12 first end portion

13 second end portion

101 first bushing

102 second bushing

20 tubular insulating body

22a, 22b inner surface

23a, 23b outer surface

21a, 21b enclosure wall

25a, 25b body segment

26a, 26b shell part

40 field grading layer

47, 48 rounded portion

45a, 45b field grading layer segment

46a, 46b field grading layer part

41 first section

42 second section

43 third section

44 fourth section

51 first thickness

52 second thickness

53 third thickness

54 fourth thickness

PATENTANSPRÜCHE 93028

1. Hochspannungs-DC-System (100), umfassend:
eine Hochspannungs-DC-Einrichtung (10), die während des Betriebs eine Veränderung des elektrischen Potenzials in Longitudinalrichtung (L) von einem ersten Endbereich (12) der Hochspannungs-DC-Einrichtung (10) zu einem zweiten Endbereich (13) der Hochspannungs-DC-Einrichtung (10) zeigt;
ein Gehäuse, umfassend:
einen röhrenförmigen Isolierkörper (20) mit mindestens einer isolierenden Gehäusewand (21a, 21b);
mindestens eine resistive Feldsteuerungsschicht (40) auf zumindest einem Teil einer Fläche (22a, 22b, 23a, 23b) der isolierenden Gehäusewand (21a, 21b);
wobei die Feldsteuerungsschicht (40) ein nichtlineares Verhalten hat,
wobei ein erster Teil der Feldsteuerungsschicht (40) mit dem ersten Endbereich (12) der Hochspannungs-DC-Einrichtung (10) verbunden ist,
wobei die Feldsteuerungsschicht (40) im Wesentlichen durchgehend von dem ersten Endbereich (12) zu dem zweiten Endbereich (13) verläuft.

2. Hochspannungs-DC-System (100) nach Anspruch 1,
wobei ein zweiter Teil der Feldsteuerungsschicht (40) mit dem zweiten Endbereich (13) der Hochspannungs-DC-Einrichtung (10) verbunden ist.

3. Hochspannungs-DC-System (100) nach einem der vorhergehenden Ansprüche,
wobei die Feldsteuerungsschicht (40) verschiedene nicht-lineare resitive Eigenschaften in mindestens zwei verschiedenen Abschnitten (41, 42, 43, 44) davon bei Betrachtung in der Longitudinalrichtung (L) hat.

4. Hochspannungs-DC-System (100) nach Anspruch 3,
wobei die Dicke (51, 52, 53, 54) der Feldsteuerungsschicht (40) in Longitudinalrichtung (L) variiert.

5. Hochspannungs-DC-System (100) nach einem der vorhergehenden Ansprüche, wobei die Hochspannungs-DC-Einrichtung (10) mindestens zwei zusammengeschaltete Einrichtungseinheiten (11a, 11b, 11c, 11d, 11e, 11f), optional mindestens zwei in Reihe zusammengeschaltete Einrichtungseinheiten (11a, 11b, 11c, 11d, 11e, 11f) umfasst, wobei jede der Einrichtungseinheiten (11a, 11b, 11c, 11d, 11e, 11f) während des Betriebs einen teilweisen Spannungsabfall zeigt.

6. Hochspannungs-DC-System (100) nach Anspruch 5, wobei die Hochspannungs-DC-Einrichtung (10) einen Spannungsteiler an zumindest einer der Einrichtungseinheiten (11a, 11b, 11c, 11d, 11e, 11f) umfasst, wobei der Spannungsteiler typischerweise einen kapazitiven und/oder einen resistiven Spannungsteiler aufweist.

7. Hochspannungs-DC-System (100) nach Anspruch 5 oder 6, die ferner mindestens eine Zwischenverbindung (15a, 15b, 15c, 15d) umfasst, die elektrisch eine vorbestimmte der Einrichtungseinheiten (11a, 11b, 11c, 11d, 11e, 11f) mit der Feldsteuerungsschicht (40) verbindet, wobei sich die Zwischenverbindung (15a, 15b, 15c, 15d) zwischen dem ersten Endbereich (12) und dem zweiten Endbereich (13) befindet.

8. Hochspannungs-DC-System (100) gemäß einer Kombination von einem der Ansprüche 3 und 4 mit einem der Ansprüche 5 bis 7, wobei jeder Abschnitt (41, 42, 43, 44) der Feldsteuerungsschicht (40) jeder der Einrichtungseinheiten (11a, 11b, 11c, 11d, 11e, 11f) entspricht, wobei die nichtlinearen resistiven Eigenschaften der Feldsteuerungsschicht (40) in den Abschnitten (41, 42, 43, 44) jeweils an den Spannungsabfall der korrespondierenden Einrichtungseinheit (11a, 11b, 11c, 11d, 11e, 11f) angepasst sind.

9. Hochspannungs-DC-System (100) nach einem der vorhergehenden Ansprüche, wobei die Feldsteuerungsschicht (40) auf der inneren Fläche (22a, 22b) der isolierenden Gehäusewand (21a, 21b) vorgesehen ist, und/oder wobei die Feldsteuerungsschicht (40) auf der äußeren Fläche (23a, 23b) der isolierenden Gehäusewand (21a, 21b) vorgesehen ist.

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10. Hochspannungs-DC-System (100) nach einem der vorhergehenden Ansprüche, wobei der röhrenförmige Isolierkörper (20) mindestens zwei konzentrisch angeordnete isolierende Gehäusewände (21a, 21b) umfasst, wobei die die Feldsteuerungsschicht (40) zwischen den Gehäusewänden (21a, 21b) angeordnet ist.

11. Hochspannungs-DC-System (100) nach einem der vorhergehenden Ansprüche, wobei die Feldsteuerungsschicht (40) eines oder mehrere der folgenden Gruppe umfasst: beschichtete Glimmerpigmente, antimondotiertes Zinnoxid, beschichtetes Glas, beschichtete Keramik, Kohlenruß, Graphen, Graphenoxid, Zinkoxid, Zinnoxid; Varistor-Keramikringe.

12. Hochspannungs-DC-System (100) nach einem der vorhergehenden Ansprüche, wobei der röhrenförmige Isolierkörper (20) mindestens eines der folgenden umfasst:

eine Mehrzahl von Körpersegmenten (25a, 25b), die in Longitudinalrichtung (L) gestapelt sind, so dass Feldsteuerungsschichtsegmente (45a, 45b) der Feldsteuerungsschicht (40), die jeweils zu den isolierenden Körpersegmenten (25a, 25b) korrespondieren, elektrisch miteinander verschaltet sind; und

mindestens zwei Schalenteile (26a, 26b), wobei die Schalenteile (26a, 26b) trennbar sind und, im montierten Zustand, jeweils aneinander an jeweiligen longitudinalen Stoßflächen aneinandergrenzen, so dass Feldsteuerungsschichtteile (46a, 46b) der Feldsteuerungsschicht (40), die jeweils zu den Schaltenteilen (26a, 26b) korrespondieren, elektrisch miteinander verschaltet sind.

13. Hochspannungs-DC-System (100) nach einem der vorhergehenden Ansprüche, wobei die Feldsteuerungsschicht (40) in der Longitudinalrichtung (L) entlang der Hochspannungs-DC-Einrichtung (10) verläuft und ebenfalls, in der Nähe des ersten Endbereichs (12) und/oder in der Nähe des zweiten Endbereichs (13), in einer Richtung (O) einer Ebene (P1, P2) orthogonal zu der Longitudinalrichtung (L) verläuft,

wobei die Feldsteuerungsschicht (40) einen abgerundeten Bereich (47, 48) an einem Übergang zwischen den Richtungen umfasst.

14. Hochspannungs-DC-System (100) nach einem der vorhergehenden Ansprüche, wobei die Feldsteuerungsschicht (40) entlang eines vollen Umfangs in zumindest einem Querschnitt orthogonal zu der Longitudinalrichtung (L) der Hochspannungs-DC-Einrichtung (10) vorgesehen ist, wobei vorzugsweise die Feldsteuerungsschicht (40) entlang eines vollen Umfangs entlang eines vollen Umfangs im Wesentlichen entlang der Gesamtausdehnung der Hochspannungs-DC-Einrichtung (10) in deren Longitudinalrichtung (L) vorgesehen ist.

15. Hochspannungs-DC-System (100) nach einem der vorhergehenden Ansprüche, wobei das Gehäuse zum gasisolierten Aufnehmen der Hochspannungs-DC-Einrichtung (10) angepasst ist.

16. Verwendung eines Hochspannungs-DC-Systems (100) nach einem der vorhergehenden Ansprüche für die Isolierung der Hochspannungs-DC-Einrichtung (10), die mit einer daran angelegten DC-Spannung betreibbar ist oder betrieben wird.

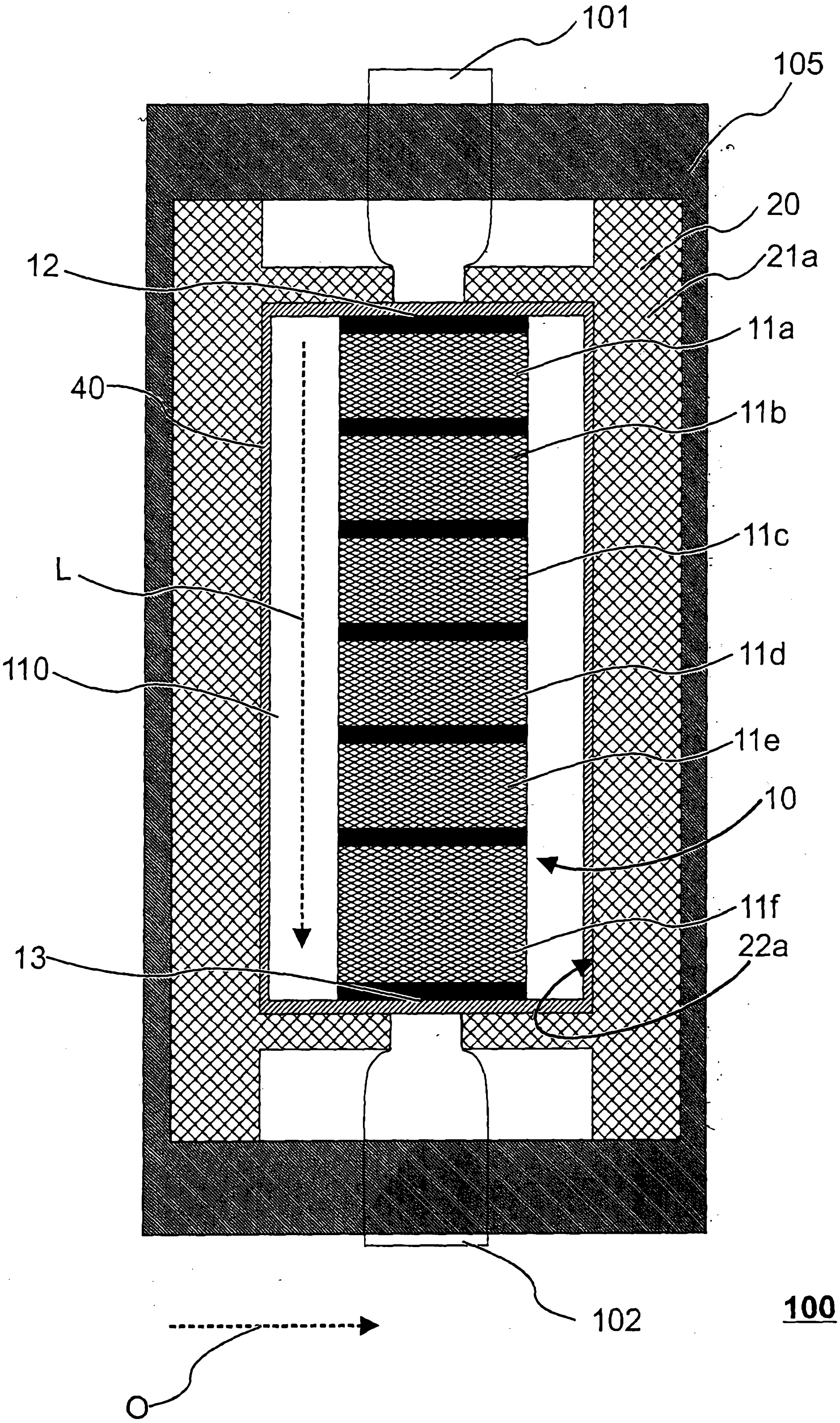
101
105
20
21a
12
11a
40
11b
11c
L
110
11d
11e
10
11f
22a
13
102
100
O

Fig. 1

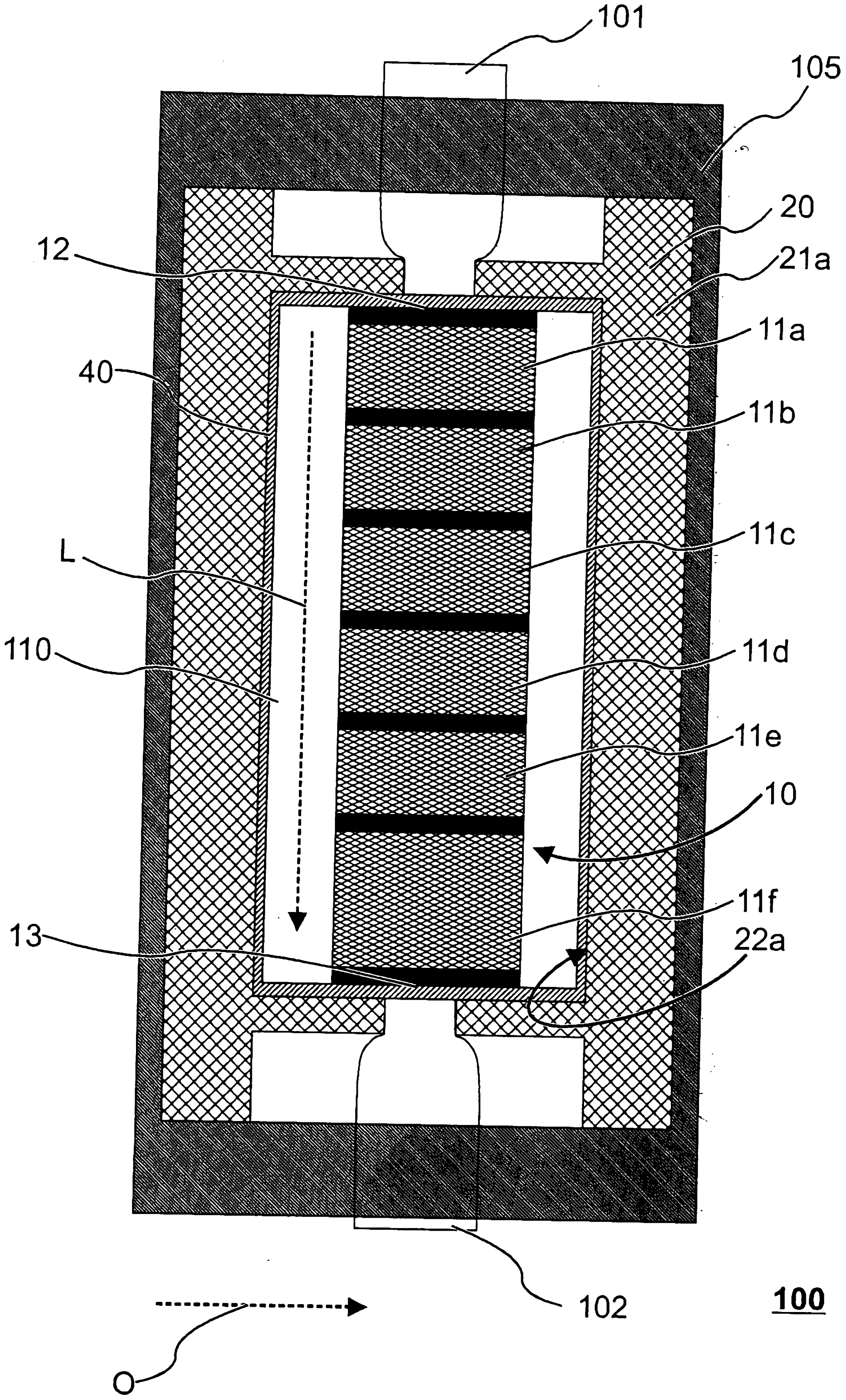
101
105
20
21a
12
11a
40
11b
L
11c
110
11d
11e
10
11f
22a
13
102
100
O

Fig. 1

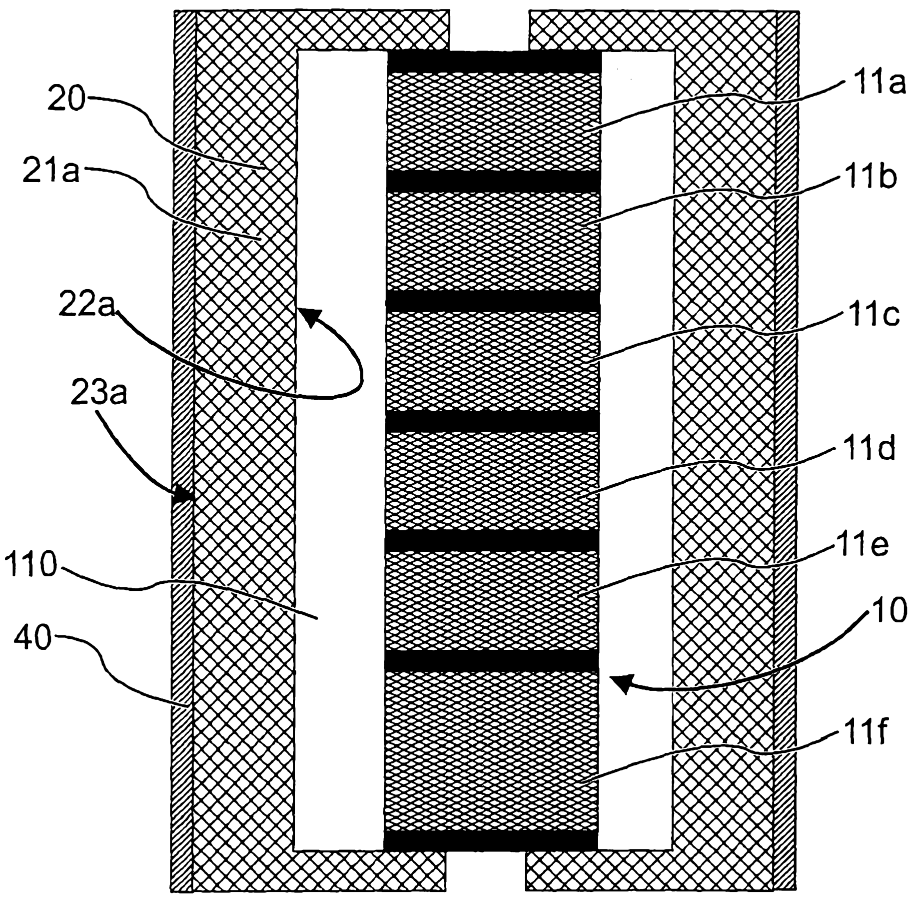

Fig. 2

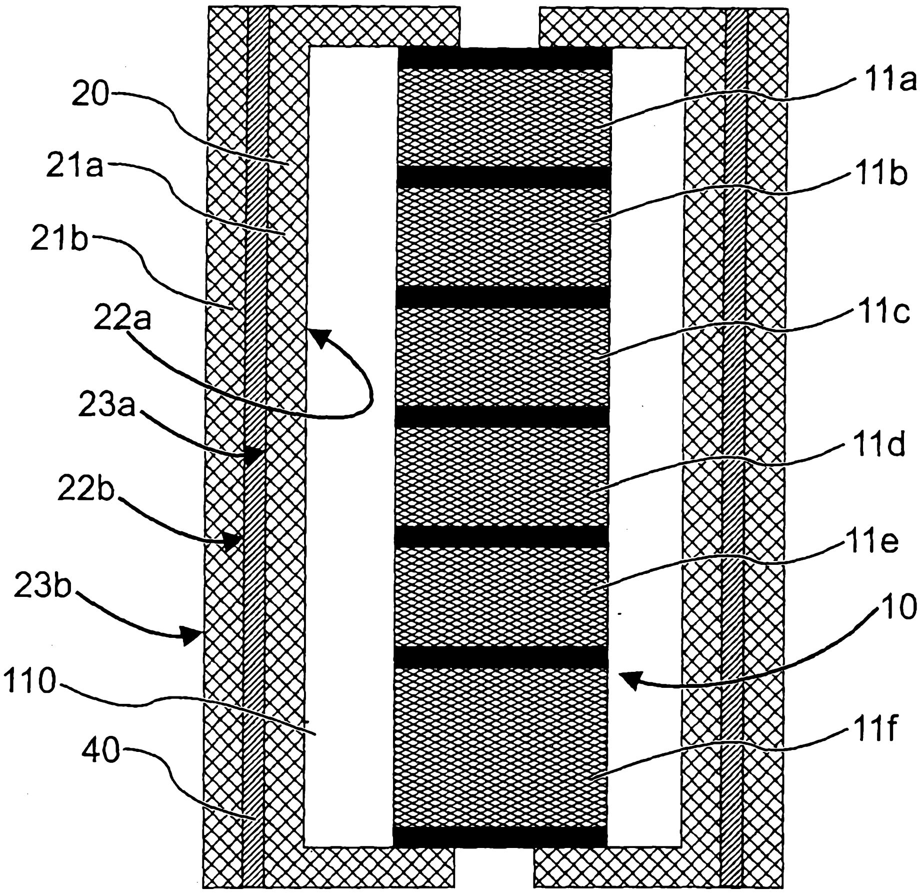

Fig. 3

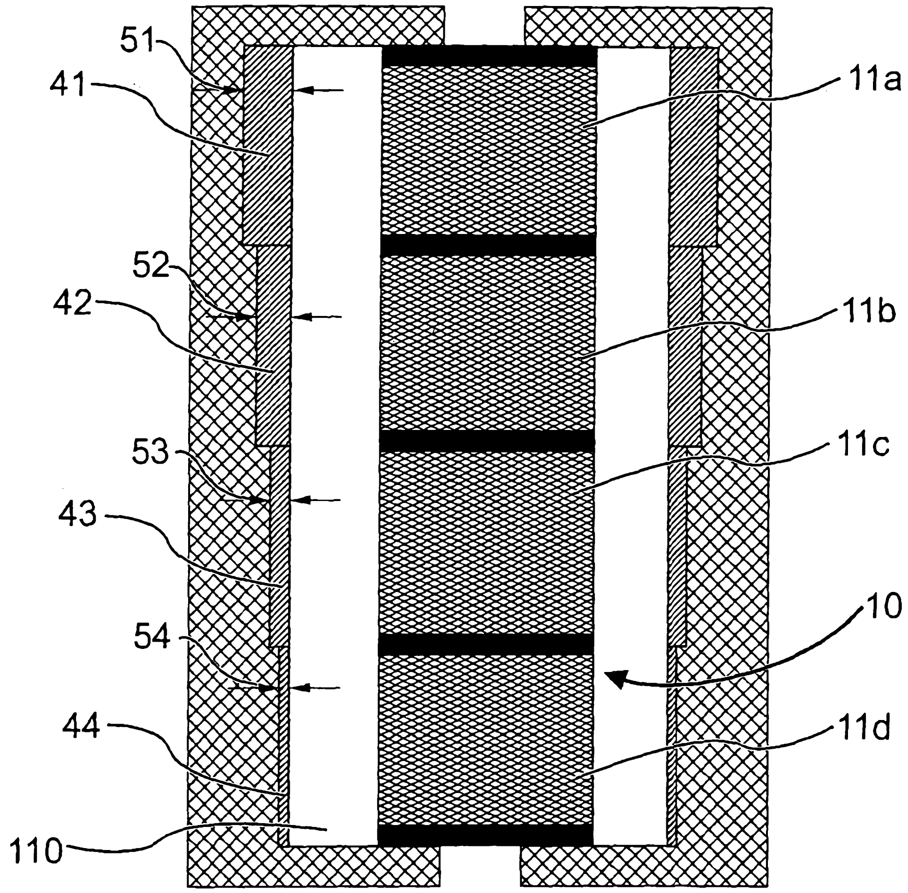

Fig. 4

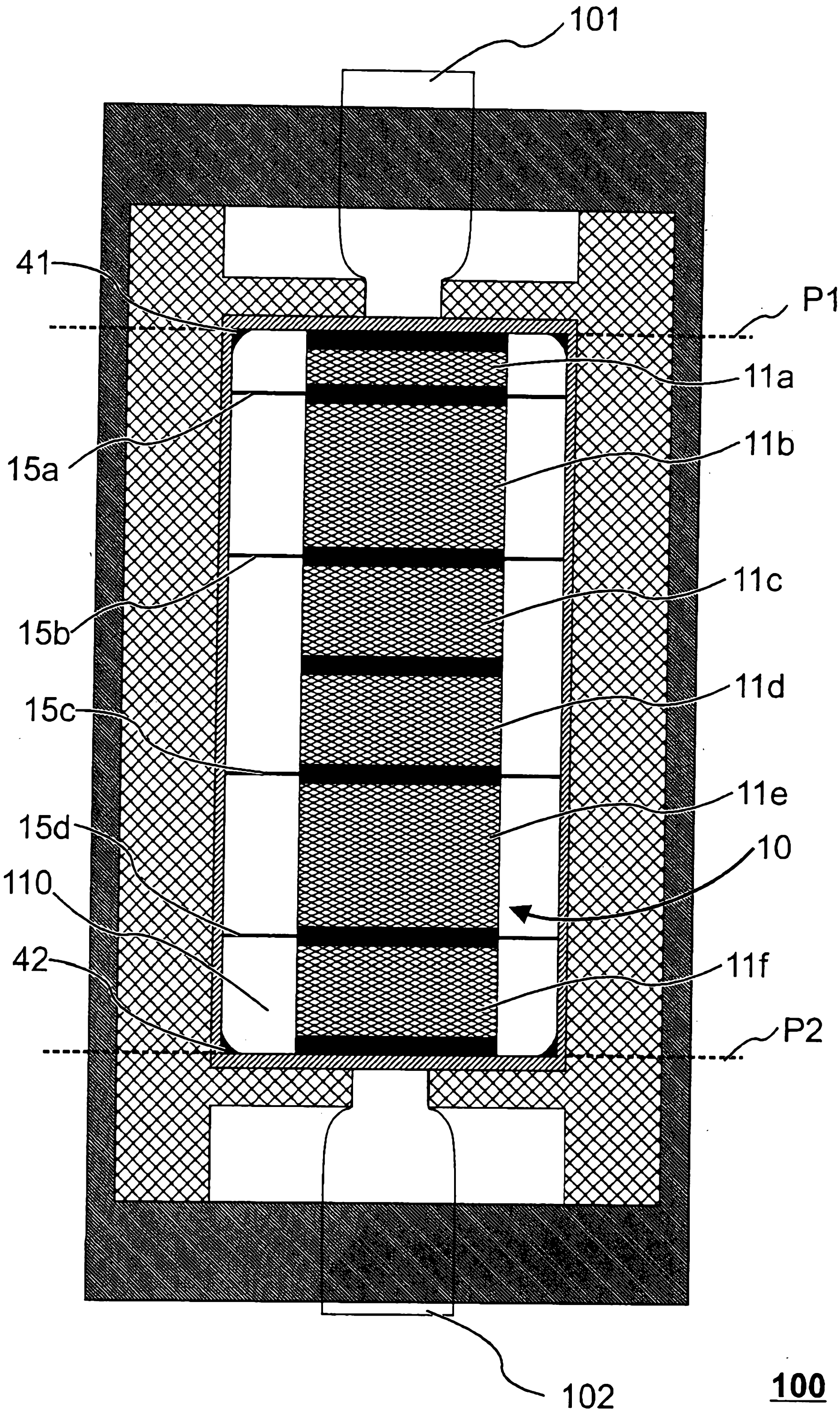
101
41
P1
11a
15a
11b
15b
11c
15c
11d
11e
15d
10
110
42
11f
P2
102
100

Fig. 5

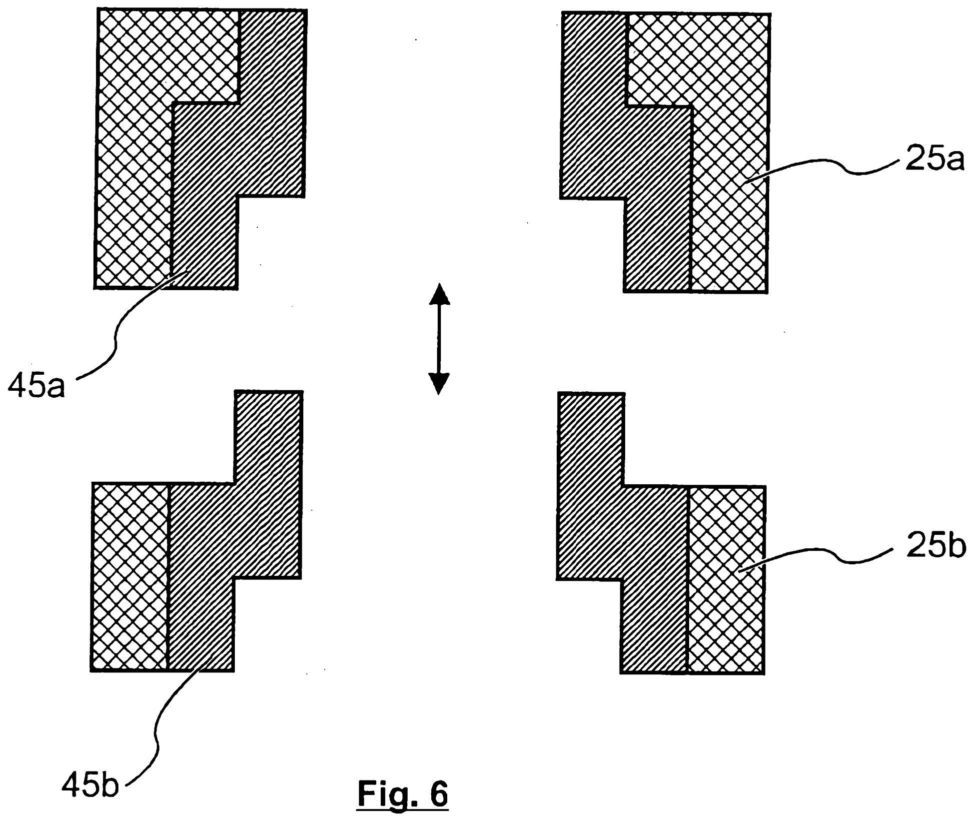

Fig. 6

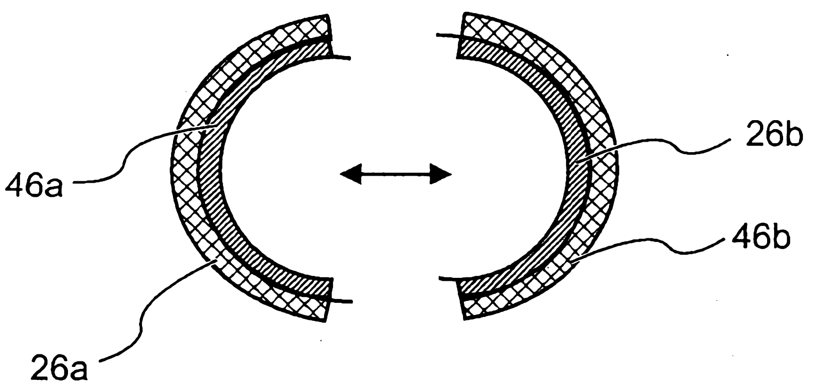

Fig. 7

ABSTRACT

A high voltage DC system (100) is disclosed, comprising a high voltage DC device (10) exhibiting a change of electric potential in longitudinal direction (L) during operation from a first end portion (12) of the high voltage DC (10) device to a second end portion (13) of the high voltage DC device (10), and an enclosure. The enclosure comprises a tubular insulating body (20) having at least one an electrically insulating enclosure wall (21a, 21b); and at least one resistive field grading layer (40) on at least a part of a surface (22a, 22b, 23a, 23b) of the insulating enclosure wall (21a, 21b). The field grading layer has (40) a non-linear resistive behavior. A first part of the field grading layer (40) is connected to the first end portion (12) of the high voltage DC device (10). The field grading layer (40) extends essentially continuously from the first end portion (12) to the second end portion (13).

(Fig. 1)

LE GOUVERNEMENT
DU GRAND-DUCHÉ DE LUXEMBOURG
Ministère de l'Économie
et du Commerce extérieur

National Application Number

LO 1327
LU 93028

SEARCH REPORT

in accordance with Article 35.1 a)
of the Luxembourg law on patents
dated 20 July 1992

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
Y	WO 2016/008518 A1 (ABB TECHNOLOGY LTD [CH]) 21 January 2016 (2016-01-21) * page 1, lines 17-19 * * page 8, lines 16-19 * * page 9, lines 14-20 * * page 12, lines 11-18 * * page 12, line 26 - page 13, line 5 * * page 13, lines 17-30 * * page 16, lines 17-24; figure 2 * -----	1-16	INV. H05K7/14 H01L25/11
Y	US 2002/070428 A1 (BERNHOFF HANS [SE] ET AL) 13 June 2002 (2002-06-13) * paragraphs [0013] - [0015] * * paragraphs [0034] - [0037] * * paragraphs [0045] - [0046] * * figures 3,4,7 * -----	1-16	
A	WO 2015/132128 A1 (ABB TECHNOLOGY AG [CH]) 11 September 2015 (2015-09-11) * paragraph [0039] * -----	1-16	

TECHNICAL FIELDS SEARCHED (IPC)

H05K
H01L
H02M

The present search report has been drawn up for all claims

1

	Date of completion of the search	Examiner
	9 December 2016	Pantelakis, P

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C55)

ANNEX TO THE SEARCH REPORT ON LUXEMBOURG PATENT APPLICATION NO.

LO 1327
LU 93028

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

09-12-2016

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2016008518 A1	21-01-2016	WO 2016008518 A1 WO 2016008598 A1	21-01-2016 21-01-2016
US 2002070428 A1	13-06-2002	NONE	
WO 2015132128 A1	11-09-2015	NONE	

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

LE GOUVERNEMENT
DU GRAND-DUCHÉ DE LUXEMBOURG
Ministère de l'Économie
et du Commerce extérieur

WRITTEN OPINION

File No.	Filing date *(day/month/year)*	Priority date *(day/month/year)*	Application No.
LO1327	14.04.2016		LU93028

International Patent Classification (IPC)
INV. H05K7/14 H01L25/11

Applicant
ABB TECHNOLOGY AG

This report contains indications relating to the following items:

- ☒ Box No. I Basis of the opinion
- ☐ Box No. II Priority
- ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☐ Box No. IV Lack of unity of invention
- ☒ Box No. V Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI Certain documents cited
- ☒ Box No. VII Certain defects in the application
- ☒ Box No. VIII Certain observations on the application

	Examiner
Form LU237A (Cover Sheet) (January 2007)	Pantelakis, P

Application No.
LU93028

WRITTEN OPINION

Box No. I Basis of the opinion

1. This opinion has been established on the basis of the latest set of claims filed before the start of the search.

2. With regard to any **nucleotide and/or amino acid sequence** disclosed in the application and necessary to the claimed invention, this opinion has been established on the basis of:

   a. type of material:

   ☐ a sequence listing

   ☐ table(s) related to the sequence listing

   b. format of material:

   ☐ on paper

   ☐ in electronic form

   c. time of filing/furnishing:

   ☐ contained in the application as filed.

   ☐ filed together with the application in electronic form.

   ☐ furnished subsequently.

3. ☐ In addition, in the case that more than one version or copy of a sequence listing and/or table relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

4. Additional comments:

Box No. V Reasoned statement with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty	Yes:	Claims	1-16
	No:	Claims	
Inventive step	Yes:	Claims	
	No:	Claims	1-16
Industrial applicability	Yes:	Claims	1-16
	No:	Claims	

2. Citations and explanations

see separate sheet

Application No.
LU93028

WRITTEN OPINION

Box No. VII   Certain defects in the application

The following defects in the form or contents of the application have been noted:

see separate sheet

Box No. VIII   Certain observations on the application

see separate sheet

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1 Reference is made to the following documents:

D1 WO 2016/008518 A1 (ABB TECHNOLOGY LTD [CH]) 21 January 2016 (2016-01-21)

D2 US 2002/070428 A1 (BERNHOFF HANS [SE] ET AL) 13 June 2002 (2002-06-13)

D3 WO 2015/132128 A1 (ABB TECHNOLOGY AG [CH]) 11 September 2015 (2015-09-11)

2 The present application does not meet the criteria of patentability, because the subject-matter of **claims 1-16 does not involve an inventive step**.

3 Claim 1:

D1 is regarded as being the prior art closest to the subject-matter of claim 1, and discloses:

High voltage DC system (D1, page 12, lines 11-12, Figure 2, 200) comprising:

a high voltage DC device (D1, page 12, lines 14-18, Figure 2, 120) exhibiting a change of electric potential in longitudinal direction during operation (D1, page 1, lines 17-19) from a first end portion of the high voltage DC device (D1, Figure 2, 122') to a second end portion of the high voltage DC device (D1, Figure 2, 122);

an enclosure (D1, page 12, lines 14-16, Figure 2, 230) comprising:

a tubular insulating body having at least one an electrically insulating enclosure wall (D1, page 8, lines 16-19, page 12, lines 29-31, Figure 2, 230);

at least one ~~resistive field grading~~ layer on at least a part of a surface of the insulating enclosure wall (D1, page 12, line 26-page 13, line 2, Figure 2, 244, 246, 248);

~~wherein the field grading layer has a non linear resistive behavior,~~

wherein a first part of the ~~field grading~~ layer is connected to the first end portion of the high voltage DC device (D1, page 13, lines 17-20, Figure 2, 246),

wherein the field grading layer extends essentially continuously from the first end portion to the second end portion (D1, page 13, lines 17-30, Figure 2, 246, 248).

The subject-matter of claim 1 therefore **differs** from this known high voltage DC system in that the at least one layer on at least a part of a surface of the insulating enclosure wall is not an electrically conducting layer but a resistive field grading layer having a non-linear resistive behavior and is therefore new. The **problem to be solved** by the present invention may be regarded as how to improve the electrical field distribution in the vicinity of the high voltage DC device.

However, these features have already been employed for the same purpose in a similar high voltage DC system (see D2, paragraphs [0013]-[0015], [0034]-[0036], Figure 3). It would be obvious to the person skilled in the art, namely when the same result is to be achieved, to apply these features with corresponding effect to a high voltage DC system according to D1, thereby arriving at a high voltage DC system according to this claim. Therefore, the subject-matter of this claim **does not involve an inventive step.**

4 Claim 16:

The reasoning of paragraph 3 applies, mutatis mutandis, to the subject-matter of this corresponding use claim, whose subject-matter **does not therefore involve an inventive step.**

5 Claims 2-15:

The features of these dependent claims are either disclosed in D1 and/or D2 or are common measures.

Claim 2: D1, page 13, lines 17-30, Figure 2, 248,

Claims 3, 4: D2, paragraphs [0045]-[0046], Figure 7,

Claim 5: D1, page 1, lines 17-19, page 12, lines 13-15, Figure 2, 120,

Claim 6: voltage dividers are commonly used in high voltage DC systems,

Claim 7: D1, page 13, lines 4-15, Figure 2, 242,

Claim 8: D2, paragraphs [0045]-[0046], Figure 7,

Claims 9-10: D2, paragraphs [0034]-[0037], Figures 3, 4,

Claim 11: such materials are commonly used in field grading layers see, D3, paragraph [0039],

Claim 12: D1, page 16, lines 17-24,

Claim 13: D1, page 13, lines 22-30, Figure 2, 246, 248,

Claim 14: D2, paragraph [0037], Figure 4,

Claim 15: D1, page 9, lines 14-20.

The subject-matter of these claims **does not therefore involve an inventive step**.

Re Item VII

Certain defects in the international application

1 The relevant background art disclosed in documents D1-D3 is not mentioned in the description, nor are these documents identified therein.

2 Independent claims 1, 16 are not in the two-part form.

Re Item VIII

Certain observations on the international application

1 Claims 1, 5, 14 are not clear.

2 In claim 1 the term "essentially", is vague and unclear and leaves the reader in doubt as to the meaning of the technical feature to which it refers, thereby rendering the definition of the subject-matter of said claim unclear.

3 In claims 5, 14 the expressions "optionally" and "preferably" respectively have no limiting effect in the scope of the claims and the features following them are to be regarded as entirely optional. The intended limitations are therefore not clear from this claims.