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(54) GAS INSULATED ELECTRIC APPARATUS WITH MEANS TO PREVENT GAS LEAKAGE

(57) The present invention relates to a gas insulated electric apparatus (1) comprising an enclosure (7) and an electric high voltage appliance (9) located inside the enclosure. The enclosure (7) contains an insulation gas (8) comprising at least 70 % by volume of CO_2. The insulation gas has an elevated and pre-determined operating gas pressure level. The enclosure (7) comprises a CO_2-barrier arrangement (15) adapted to reduce the permeability of CO_2 through the enclosure wall.

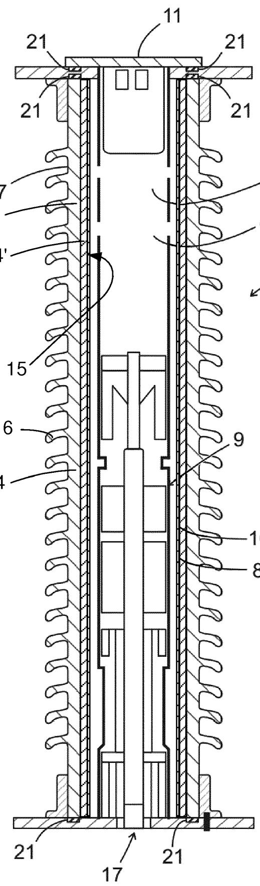

Fig. 2

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Description

TECHNICAL FIELD

[0001] The present disclosure relates to a gas insulated electric apparatus with means to prevent gas leakage.

BACKGROUND ART

[0002] In gas insulated electric apparatuses such as medium and high voltage switchgears or control gears an electrical active part is arranged in a gas-tight enclosure or housing. The enclosure or housing defines an insulating space that is arranged to contain an insulation gas at an elevated pressure, which can be several bars. The insulating space separates the enclosure from the electrical active part without letting electrical current pass through. The insulation gas serves as an electric insulation medium and prevents electric discharge between the enclosure and the electrical components inside the enclosure. Further, the insulation gas serves as a cooling medium for suppressing temperature rise due to electric current. In a switchgear which typically comprises a circuit breaker and/or a disconnector, the insulation gas also serves as an arc-extinguishing medium for extinguishing arcs that may occur at the switching operation. Conventionally, sulphur hexafluoride gas (SF_6 or SF6 gas) has been widely used as insulation gas. However, in view of the known environmental drawbacks of SF6, the use of other insulation gases has been proposed, such as carbon dioxide (CO_2) gas.

[0003] Generally, the enclosure of the gas insulated electrical apparatuses is filled with the insulation gas up to a pre-determined operational rated gas pressure level before it is taken into operation. The pre-determined pressure level can be chosen depending on the insulation gas, switched current/voltage and/or the switching capacity of the electric apparatus. The pressure level is measured during the operation continuously or at predetermined intervals. If the gas pressure level is below a pre-defined lowest acceptable pressure level, also called alarm level, an alarm is generated to the operator. If the alarm is generated, the enclosure should be filled with insulation gas to the pre-determined operational gas pressure level. If the enclosure is not replenished, there is a risk that the insulation gas pressure will continue to decrease and consequently operational disturbances are caused. Normally, the electrical apparatus has a pre-defined blocking pressure level (also named lock-out gas pressure level) and when the blocking pressure level is reached, the function of the gas insulated electric apparatus will be blocked and cease. When the gas insulated electrical apparatus is a switchgear, it is usually configured to react in one of two ways: either the function of the gas insulated electric apparatus will be blocked such that it will not be possible to open or close the electric contact of the switchgear, or the electric contact will be forced open and stay open. The refilling operation and monitoring of the alarms in the electrical apparatuses are time and labour consuming tasks. Therefore, there is a need to reduce service occasions while operational disturbances of gas insulated electrical apparatuses are effectively avoided.

SUMMARY OF THE INVENTION

[0004] The inventors of the present invention have noted that refilling due to reduced gas pressure level occur more frequently in gas insulated electric apparatuses having CO_2-based gas as an insulation gas compared to electric apparatuses comprising SF6 as an insulation gas. It has been discovered that there can be a problem with leakage of CO_2-based gas resulting in pressure drop in the insulators, which occurs faster than in prior art gas insulated apparatuses. It was discovered that the leakage occurs through the insulation material of the enclosure and through sealings of the enclosure. It was not expected that the permeation would be so much higher than before, especially in view that the insulation material used in the enclosures of the electrical apparatuses today resists gas leakage of SF6 very well. It was discovered that one reason for the leakage can be a higher operating pressure of CO_2 gas which can be about 12 bar, which is about twice the pressure required for SF6 gas (normally 5-7 bar).

[0005] The leakage leads to a need to refill the insulation gas more often than previously when SF6 has been used. For example, there may be a need to refill CO_2 after already two to four years which would mean a considerable increase in service efforts compared to apparatus having SF6 as insulation gas. Therefore, a new problem of reducing service occasions in connection with CO_2 insulated electrical apparatuses was realized.

[0006] The insulation material of the enclosure is normally manufactured from an epoxy-based composite material, which has excellent insulating, e.g. electrical and thermal, properties and mechanical properties and are suitable for the demanding conditions e.g. of circuit breakers.

[0007] Therefore, there is a desire to maintain the properties of the insulation material as close to the previous epoxy composite insulator material properties as possible. In addition CO_2 leakage needs to be avoided or at least substantially reduced.

[0008] In view of the discovered problems stated above, it is an objective of the present invention to provide a gas insulated electric apparatus comprising an enclosure and an electric high voltage appliance inside the enclosure which has decreased need for service occasions and thus has improved operational robustness. Further, it is an objective to provide an enclosure with insulation material with excellent insulating properties while CO_2 leakage is avoided or at least substantially reduced.

[0009] The objectives above are attained by a gas insulated electric apparatus comprising an enclosure and an electric high voltage appliance inside the enclosure, wherein the enclosure contains an insulation gas comprising at least 70 % by volume of CO_2. The insulation gas has an elevated and pre-determined operating gas pressure level. The enclosure comprises a CO_2-barrier arrangement. The CO_2-barrier arrangement is adapted to reduce the permeability of CO_2 through an enclosure wall of the enclosure. The gas may contain different amounts of CO_2 for example from 75 to 100 % by volume of CO_2, and the remainder up to 100% by volume may contain other gases, such as oxygen.

[0010] The CO_2-barrier arrangement can be provided in different ways. Suitably, the enclosure comprises an enclosure wall which comprises or is connected to the CO_2-barrier arrangement. In this way a space saving and robust barrier can be provided.

[0011] The enclosure wall has an inner surface of insulation material which may comprise or be arranged in contact with the CO_2-barrier arrangement. Thus, flexibility e.g. with regard of different materials is improved. The whole enclosure wall may comprise or consist of the insulation material. Also, the barrier arrangement can be a component of the insulation material, which can be a composite material. The barrier properties may be obtained or increased by using fillers, such as clay, in the insulation material.

[0012] According to a variant, the CO_2-barrier arrangement is a coating on the inner surface of the enclosure wall. In this way it is possible to arrange the barrier arrangement in contact with the insulation gas in the enclosure. Alternatively, the CO_2-barrier arrangement can be comprised as a component in the insulation material of the enclosure wall. In this case the barrier may be provided as fillers in the insulation material of the enclosure wall. Thus, a compact barrier construction can be obtained.

[0013] According to another embodiment the inner surface of the enclosure wall comprises a separate layer of insulation material, and wherein the CO_2-barrier arrangement is a coating on an inner surface and/or the outer surface of the separate insulation material layer. Thus, the CO_2-barrier arrangement can be arranged in many different ways, e.g. to an insulator body in a post-treatment process. Alternatively, the inner surface of the enclosure wall comprises a separate layer of insulation material, and wherein the CO_2-barrier arrangement is a component in the separate layer of insulation material. Also in this case the barrier may be provided as fillers in the separate layer of insulation material and a compact barrier construction can be obtained.

[0014] The coating can be a layer comprising SiO_x compound. Such compounds are electrically inert, stable and tolerate e.g. temperature variations well. According to one variant, the coating is a glass film layer. Such films can be applied directly to the enclosure wall when the enclosure is produced or in a post-treatment process. Thus, manufacture of such barriers is flexible.

[0015] Alternatively or additionally, the coating is a layer obtained by means of chemical vapor deposition, preferably plasma impulse chemical vapor deposition. For example, a SiO_x-containing layer can be obtained in such a way. Such treatment can be suitably performed during the manufacture of the insulator body.

[0016] The enclosure can be sealed with one or more sealings comprising a CO_2-barrier arrangement adapted to reduce the permeability of CO_2 through the sealings. In this way the barrier properties are further improved. The sealings can be made of a polymeric material of various types, for example NBR or EPDM rubber, but is not limited to these materials.

[0017] The electric high voltage appliance can be a high voltage interrupter. Alternatively, the electric apparatus can be a gas insulated live tank circuit breaker, or a gas insulated dead tank circuit breaker, or a gas insulated switchgear. It may alternatively be a control gear such as a gas insulated instrument transformer. In either one of these apparatuses it will be of great value to have an apparatus that will have a reliable functionality for many years without requiring refilling of insulation gas.

[0018] The gas insulated electric apparatus may be an outdoor gas insulated electric apparatus. It is an advantage that the apparatus according to the invention is suitable for outdoor use.

[0019] Suitably, the operating gas pressure level is from 1.0 MPa up to 1.2 MPa. The barrier arrangement of the present disclosure is especially suitable for uses in electrical apparatus having high operating pressures.

[0020] Further features and advantages are described below in the detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] The invention will now be described in more detail with reference to the enclosed schematic drawings given only as examples in which:

Fig. 1 shows a schematic perspective view of a gas insulated electric apparatus; and

Fig. 2 shows a partial cross section view of the gas insulated electric apparatus of Fig. 1 with an enclosure wall comprising a CO_2-barrier arrangement.

Fig. 3 shows a partial cross section view of the gas insulated electric apparatus of Fig. 1 with an enclosure wall comprising another example of a CO_2-barrier arrangement.

DETAILED DESCRIPTION

[0022] The gas insulated electric apparatus of the present disclosure can be a gas insulated circuit breaker. It can find its application as a gas insulated live tank circuit breaker or a gas insulated dead tank circuit breaker. Alternatively, the gas insulated electric apparatus may e.g. be a gas insulated switchgear, or a control gear such as a gas insulated instrument transformer. The gas insulated apparatus can be suitable for use outdoors.

[0023] The gas insulated electric apparatus comprises generally an electrically insulating enclosure having a wall made of a polymeric material and/or a composite material capable to resist the pressure inside the enclosure and can be for example an epoxy-based material. The inner surface of the enclosure wall, i.e. the surface facing an insulation space in which the insulation gas is contained, comprises or consists of insulation material. The insulation material can be provided in the form of a separate layer connected to the enclosure wall or it may be the inner surface of the enclosure wall, which is made of the insulating material. The separate layer of insulating material may be the same or different material as the material the enclosure is made of. For example, the layer may comprise glass fibres which may also re-inforce the enclosure wall structure. The outer surface of the enclosure, i.e. the surface facing the surroundings of the enclosure, can comprise a plurality of sheds. The sheds may extend along the whole or partial length of the enclosure.

[0024] According to the invention, the enclosure comprises or is connected to a CO_2-barrier arrangement. Usually, the inner surface of the enclosure which is covered with an insulation material layer, comprises or is in contact with the CO_2-barrier arrangement.

[0025] The insulation material of the enclosure comprises or consists of an inert material having insulating properties so that the electrical apparatus can function as desired. By insulating properties is meant in this application at least electrically insulating properties, i.e. that the material does not conduct electricity. The insulation material may comprise or consist of a polymeric material. Preferably, the insulation material is a composite material comprising a polymeric material and a reinforcing insulation material to increase the mechanical and electrical stability of the material. Suitable polymeric materials include but are not limited to materials based on epoxy resins and synthetic rubbers. The reinforcing insulation material can be for example glass fibres or fibres or filaments of other inert materials having good mechanical and thermal stability. According to one embodiment, the insulation material of the enclosure is epoxy reinforced with glass fibres, which provide excellent insulating properties, and mechanical and thermal stability. Alternatively or additionally, a separate insulation material layer may be provided in any suitable manner on the inner surface of the enclosure wall. For example, the separate insulation material layer may be provided as a tube which may be fitted to be in close-fitting contact with the inner surface of the enclosure wall.

[0026] According to the present invention, the enclosure comprises a CO_2-barrier arrangement. The CO_2-barrier arrangement may be provided in different ways. The enclosure wall may comprise or be arranged to be connected to a CO_2-barrier arrangement. Alternatively or additionally, the enclosure may comprise a separate insulation material layer arranged to be in contact with the enclosure wall, which separate insulation material layer may comprise or be in contact with a CO_2-barrier arrangement. For example, the CO_2-barrier arrangement may be provided as a coating on the inner surface of the enclosure wall or on the inner and/or the outer surface of the separate insulation material layer. For example, the CO_2-barrier arrangement may be in the form of a porcelain tube. Thus, when a composite insulator or insulation layer or the enclosure is manufactured, the porcelain tube can be placed on a mandrel of a filament winding machine, and the filaments used for the enclosure are wound directly on the porcelain tube. The porcelain tube thus constitutes the CO_2-barrier arrangement and the filaments are comprised in the insulator for the electric apparatus. Alternatively, the enclosure wall or the separate insulation layer may be coated and the coating may be a layer comprising SiO_x compound and/or the coating may be a glass film layer. Alternatively or additionally, the coating can be a SiO_x-containing layer obtained by means of chemical vapor deposition, preferably plasma impulse chemical vapor deposition.

[0027] According to a further alternative, the CO_2-barrier arrangement can be provided as a component in, i.e. integrated with, the insulation material of the enclosure wall or the separate insulation layer. Thus it can constitute a component in the composite insulation material. The barrier can be provided for example in the form of filler particles and/or a chemical filling material, which are included in the insulation material.

[0028] In Fig. 1 is schematically illustrated a gas insulated electric apparatus 1 according to the invention. The electric apparatus in the example is a circuit breaker, e.g. a circuit breaker for one pole in a three pole circuit breaker assembly. The circuit breaker 1 comprises a hollow upper high voltage (HV) unit insulator 3 and a hollow lower support insulator 5. The upper insulator and the lower insulator are connected to each other so that a lower end of the upper insulator 3 is connected to an upper end of the lower insulator 5 by means of attachment means. Together, the hollow upper insulator 3 and the hollow lower insulator 5 form an enclosure 7 that delimits an insulation space 10. The enclosure 7 is filled with an insulation gas 8, as shown in Fig. 2.

[0029] Fig. 2 further illustrates the upper insulator 3 more in detail. As shown in the drawing, the gas insulated electric apparatus further includes an electric high voltage appliance 9 located inside the enclosure 7 in the insulation space 10. In the illustrated example showing a circuit breaker, the high voltage appliance 9 is a high voltage interrupter that is located inside the upper insulator 3. The interrupter may e.g. be a puffer type interrupter as shown in Fig. 2. The upper end of the upper insulator 3 comprises a top cover 11, which closes off the enclosure 7.

[0030] In the examples of Fig. 2 and 3 the enclosure 7 comprises an enclosure wall 12 of e.g. epoxy composite material, which is insulating, and defines and surrounds the insulation space 10. The inner surface of the enclosure wall 12 forms suitably a cylindrical, preferably circular cylindrical, shape. The outer surface of the wall 12 comprises a plurality of sheds 16 that extend along the length of the enclosure wall 12. Thus, the wall 12 radially surrounds the insulation space 10 and suitably comprises or is consisted of insulation material 14, e.g. the epoxy composite material.

[0031] In Fig. 2, the wall 12 comprises on its inner surface a further separate insulation material layer 14', which has an inner surface facing the insulation space 10 and an outer surface facing the enclosure wall 12. The separate insulation material layer 14' may be of the same or different material as the enclosure wall 12 material. In the example shown in Fig. 2, the inner surface of the separate insulation material layer 14' comprises glass fibres and comprises a coating layer 15 of e.g. glass film, which constitutes the CO_2-barrier arrangement. However, the CO_2-barrier arrangement could be of other type and provided in any suitable way as described above. The coating layer 15 could be alternatively or additionally sandwiched between the enclosure wall 12 and the separate insulation material layer 14'.

[0032] In the example of Fig. 3, the enclosure 7 is structurally similar to the example of Fig. 2, except that there is no separate insulation material layer 14' on the inner surface of the enclosure wall 12. Instead, the CO_2-barrier arrangement 15 is arranged as a coating layer directly on the inner surface of the enclosure wall 12, which comprises or consists of insulation material. Alternatively, the CO_2-barrier arrangement could be arranged as a filler material in the insulation material 14 of the enclosure wall 12.

[0033] The enclosure 7 in both Fig. 2 and 3 comprises a number of sealings 21 suitably placed at all connection areas. The sealings may be sealings located in contact areas between metal parts, between metal and polymer or rubber materials, or between parts made of rubber or polymer materials. The sealings are located in different contact areas of the parts of the apparatus, both for sealing of the enclosure towards the exterior as well as sealings applied to parts and components inside the enclosure. Examples of sealing areas where sealings are used are the contact area between the upper insulator 3 and the lower insulator 5, the contact area between the upper insulator 3 and the top cover 11, sealings between the lower insulator 5 and the mechanism housing 13 and parts of the mechanism housing, sealings associated with the HV interrupter or other HV electric appliance of the electric apparatus. The material suitable for the sealings can be e.g. polymeric materials, such as NBR or EPDM rubber, but is not limited to these materials. Preferably, also the sealings comprise or are connected to a CO_2-barrier arrangement. The CO_2-barrier arrangement may be provided to the sealings in a similar manner as described above in connection with the enclosure wall 12.

[0034] Reference is now made back to Fig. 1. At the lower end of the lower insulator 5 is arranged a mechanism housing 13. Inside the mechanism housing 13 is located a link mechanism adapted to connect a lower end of a support insulator pull rod 17 to an operating shaft 19. The pull rod is adapted to extend all the way up through the lower insulator 5 into the upper insulator 3 where it is connected to the high voltage appliance 9, i.e. the interrupter. Thus the interrupter of the circuit breaker can be operated by means of the operating shaft 19. In a three pole circuit breaker assembly, the operating shaft 19 will be connected to the circuit breakers of all three poles and they can consequently be operated simultaneously. The mechanism housing 13 also includes connections (not shown) to a gas pipe (not shown) for filling the enclosure with gas and e.g. a connection (not shown) to a gas density monitor device (not shown). The gas pipe connection comprises a non-return valve.

[0035] The insulation gas 8 used in the electric comprises at least 70 % by volume of CO_2. The remainder up to 100 % by volume in the insulation gas may also comprise e.g. oxygen O_2 or another gas to an extent of less than 30 % by volume.

[0036] The enclosure 7 is suitably filled with insulation gas to a pre-determined operational gas pressure, which is determined based on the insulation gas, switched current/voltage and/or the switching capacity of the electric apparatus. The pressure level preferably exceeds a pre-determined and tested blocking gas pressure level of the electric apparatus. For example, the filling pressure of the gas including CO_2 can be from 1.0 MPa up to 1.2 MPa (12 bar), i.e. the absolute pressure of the total gas measured at 20°C. By absolute pressure is meant zero-referenced pressure against a perfect vacuum, the pressure being thus equal to gauge pressure plus atmospheric pressure. For example, in case a gas insulated electric apparatus having CO_2 as insulation gas and NBR rubber (nitrile butadiene rubber) sealings, the enclosure is filled with gas to a pre-determined operational pressure of from about 1.1 MPa to 1.2 MPa in order to fulfil the circuit breaking function. This pressure is also referred to as an elevated and pre-determined operating gas pressure level. An alarm pressure can then be pre-determined and set to a value of for example 1.01 MPa. Thus, when the pressure is decreased and reaches the value of 1.01 MPa, an alarm is generated. The alarm is suitably generated automatically. To ensure the functionality of the electric apparatus, a blocking pressure is set to a pre-determined value, which can be e.g. 1.0 MPa. If the pressure is decreased and the blocking pressure level is reached, the function of the gas insulated electric apparatus will be blocked and cease. In this way also an indication of CO_2-leakage is obtained.

[0037] Usually, the enclosure is filled with insulation gas to a pre-determined rated gas pressure level at the production plant and tested. The rated gas pressure level is the working gas pressure at which the apparatus is intended to work. The gas pressure is then lowered again for storage and transport. At the installation site, the enclosure is again filled up with gas to the rated gas pressure level, before it is taken into operation.

[0038] The invention shall not be considered limited to the illustrated embodiments, but can be modified and altered in many ways, as realised by a person skilled in the art, without departing from the scope defined in the appended claims.

Claims

1. A gas insulated electric apparatus (1) comprising an enclosure (7) and an electric high voltage appliance (9) located inside the enclosure, the enclosure (7) containing an insulation gas (8) comprising at least 70 % by volume of CO_2, wherein the insulation gas has an elevated and pre-determined operating gas pressure level, **characterized in that** the enclosure (7) comprises a CO_2-barrier arrangement (15).

2. The gas insulated electric apparatus according to claim 1, wherein the enclosure (7) comprises an enclosure wall (12) which comprises or is connected to the CO_2-barrier arrangement (15).

3. The gas insulated electric apparatus (1) according to claim 2, wherein the enclosure wall (12) has an inner surface of insulation material (14) comprising or being arranged in contact with the CO_2-barrier arrangement (15).

4. The gas insulated electric apparatus (1) according to claim 3, wherein the CO_2-barrier arrangement (15) is a coating on the inner surface of the enclosure wall (12).

5. The gas insulated electric apparatus (1) according to claim 3 or 4, wherein the CO_2-barrier arrangement (15) is comprised as a component in the insulation material (14) of the enclosure wall (12).

6. The gas insulated electric apparatus (1) according to claim 3, wherein the inner surface of the enclosure wall (12) comprises a separate layer of insulation material (14'), and wherein the CO_2-barrier arrangement (15) is a coating on an inner surface and/or the outer surface of the separate insulation material layer (14').

7. The gas insulated electric apparatus (1) according to claim 3 or 6, wherein the inner surface of the enclosure wall (12) comprises a separate layer of insulation material (14'), and wherein the CO_2-barrier arrangement (15) is a component in the separate layer of insulation material (14').

8. The gas insulated electric apparatus (1) according to claim 4 or 6, wherein the coating is a layer comprising SiO_x compound.

9. The gas insulated electric apparatus (1) according to claim 4, 6 or 8, wherein the coating is a glass film layer.

10. The gas insulated electric apparatus (1) according to claim 4, 6, 8 or 9, wherein the coating is a layer obtained by means of chemical vapor deposition, preferably plasma impulse chemical vapor deposition.

11. The gas insulated electric apparatus (1) according to any one of the preceding claims, wherein the enclosure (7) is sealed with one or more sealings (21) comprising a CO_2-barrier arrangement adapted to reduce the permeability of CO_2 through the sealings (21).

12. The gas insulated electric apparatus (1) according to any one of the preceding claims, wherein the electric high voltage appliance (9) is a high voltage interrupter.

13. The gas insulated electric apparatus (1) according to any one of the preceding claims, wherein the electric apparatus is a gas insulated live tank circuit breaker, or a gas insulated dead tank circuit breaker, or a gas insulated switchgear.

14. The gas insulated electric apparatus (1) according to any one of the preceding claims, wherein the electric apparatus is an outdoor gas insulated electric apparatus.

15. The gas insulated electric apparatus (1) according to any one of the preceding claims, wherein the operating gas pressure level is from 1.0 MPa up to 1.2 MPa.

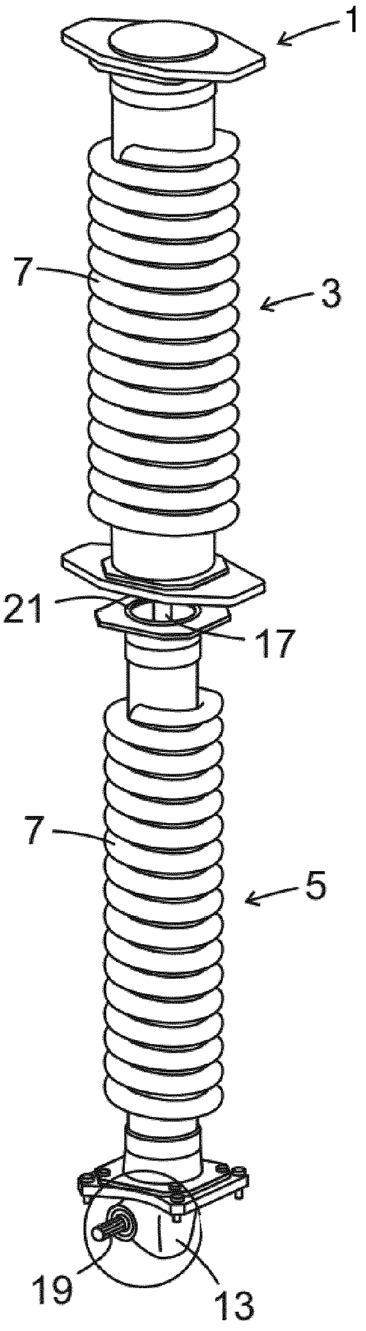

Fig. 1

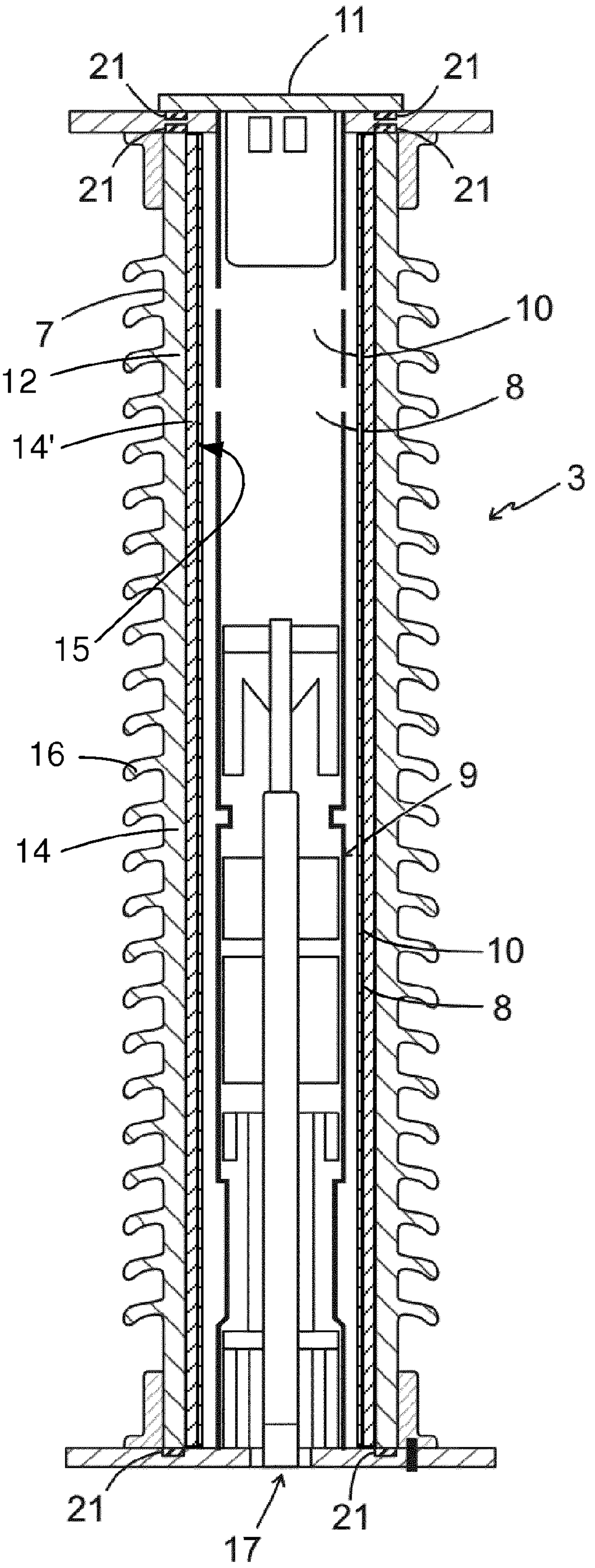

Fig. 2

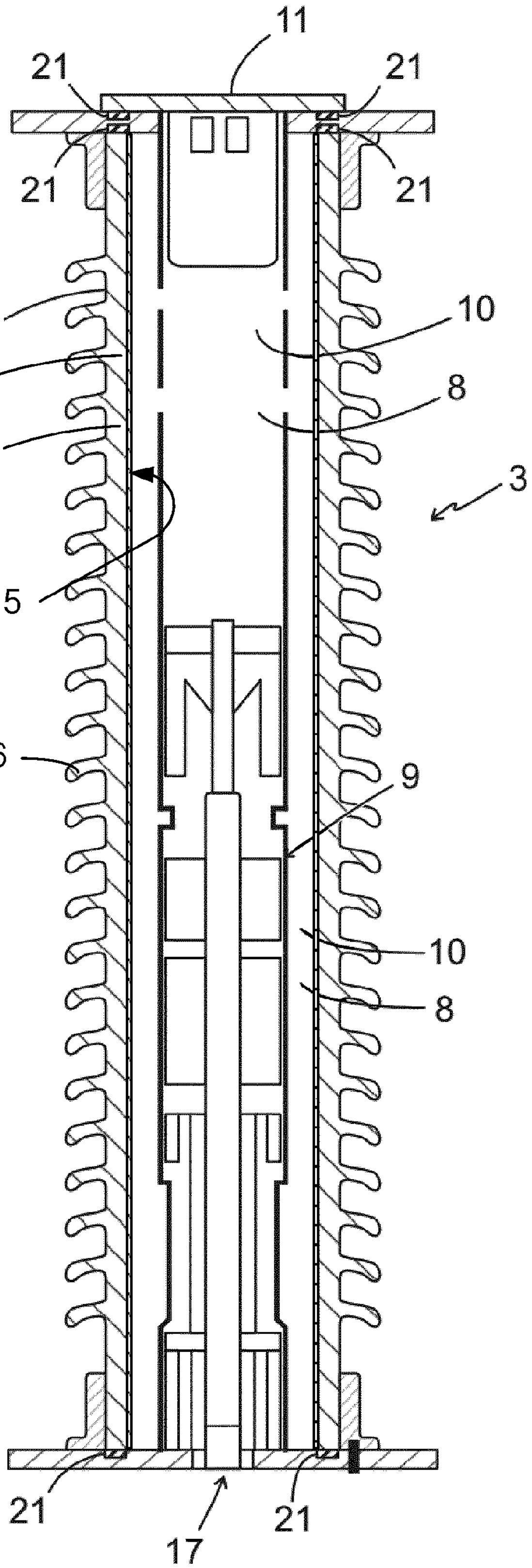

Fig. 3

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EUROPEAN SEARCH REPORT

Application Number
EP 17 17 5797

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	EP 3 171 382 A1 (ABB SCHWEIZ AG [CH]) 24 May 2017 (2017-05-24) * paragraphs [0009], [0028] - [0040]; figures 1,2 *	1-15	INV. H01H33/56 H01H33/02
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TECHNICAL FIELDS SEARCHED (IPC)

H01H
H02B
H01B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	30 November 2017	Arenz, Rainer

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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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
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30-11-2017

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