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(54) High voltage bushing, high voltage device comprising such bushing and method for cooling

(57) The invention defines a high voltage bushing comprising a hollow insulator housing (12), a high voltage conductor (10) provided inside the housing, a first connection arrangement (30) where the conductor can be connected to a first electric device and a second connection arrangement (32) where the conductor can be connected to a second electric device. Further is defined that at least one of said first connection arrangement and said second connection arrangement is designed as an external connection arrangement in which the conductor (10) has an extended end part (38), the bushing comprises an exit opening (34) through which the extended end part (38) of the conductor exits from the bushing, in order for the extended end part of the conductor to be connectable to an electric device, and the bushing further comprises a cooling arrangement (40; 50; 60) for cooling of the bushing.

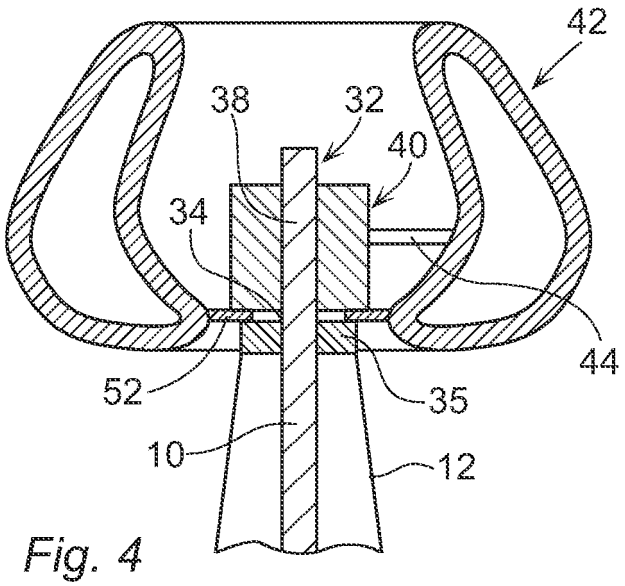

Fig. 4

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Description

Technical field of the invention

[0001] The present invention relates to the field of high voltage power systems, and in particular to high voltage bushings used in high voltage devices forming parts of such systems.

Background of the invention

[0002] It is known that high voltage equipment and devices, e.g. high voltage transformers, reactors, switchgear etc., are usually equipped with bushings that are adapted for carrying current at high potential through a grounded barrier, e.g. a wall or an enclosure of the electric device such as a transformer tank.

[0003] Conventional high voltage bushings comprise an insulator made of ceramic or composite material, which is normally provided with sheds and which is generally hollow. On the inside of the bushing, voltage grading is performed by a condenser core or some other type of voltage grading device, through which an electrical conductor passes. The electrical conductor connects one side of the bushing, where a high voltage electric device is connected, with the other side of the bushing where another electric device is connected. For example, when the first electric device is a transformer, the bushing is fitted on the transformer enclosure and the conductor of the bushing connects the inside of the transformer with the outside, where another electric device can be connected, e.g. a bus, surge arrester or DC-valve.

[0004] An example of a prior art bushing adapted for use with a high voltage transformer will now be described with reference to Fig. 1, showing a schematic cross sectional view of a bushing 1 mounted in a wall 18, such as the tank wall in the case of a transformer. A high voltage conductor 10 runs through the center of a hollow bushing insulator 12 that forms a housing around the high voltage conductor. A condenser core 14 is provided inside the insulator housing for voltage grading of voltage stress that is built up around the high voltage conductor 10. A flange 16 is provided on the outside of the housing 12, by means of which the housing of the bushing is connected to ground, via the transformer tank wall 18.

[0005] In Fig. 1 is also shown how the bottom end portion of the high voltage conductor 10 forms a bottom contact 20 that is arranged to be connected to the internal components of the transformer. For this purpose, a mating internal contact 22 is provided inside the transformer. An upper outer terminal 24 for the conductor 10 is provided at the upper end of the bushing, opposite the bottom contact 20 end. The outer terminal 24 is electrically connected to the conductor 10 through an interface, also forming a top cover of the bushing, in order to electrically connect the conductor and thus the transformer to an external source or device.

[0006] The term high voltage is conventionally used for voltages above approximately 50 kV. Today, the upper limit in commercial high voltage devices is generally 1100 kV, but higher voltages, such as 1200 kV or even more, are envisaged in the near future. Also, current levels are increasing and may be up to 4000-5000 A or even higher.

[0007] For high voltages in the region of 800 kV and more, and current ratings of 2000 A and above, the demands on the bushings are naturally increased, e.g. when it comes to heat dissipation and cooling, electric fields, electric insulation of the bushing etc. In this context, it becomes essential to have a low loss and efficient cooling, in particular to be able to reach the target current. The losses in today's bushings mainly occur due to losses in the conductor and in each contact or joint in the current path between different parts of the bushing. The losses in the conductor itself can be optimized by selecting the material, the shape and the size of the conductor. When it comes to the losses in the outer terminal 24 of the prior art bushing illustrated in Fig. 1, the current is forced to flow from the conductor 10 to the top cover of the bushing via a contact area through the top cover itself, and then via another contact on the outside of the top cover to the outer terminal 24 and external connection. It is recognized that fewer joints would reduce losses which is advantageous in high voltage and high current applications.

Summary of the invention

[0008] It is an object of the present invention to provide a high voltage bushing that improves prior art bushings, and which makes it possible to reach the high voltage levels and high current ratings described above.

[0009] It is also an object of the present invention to provide a high voltage device comprising such a high voltage bushing, and additionally to provide a method for cooling of a high voltage bushing.

[0010] These objects, among others, are achieved by a high voltage bushing and a high voltage device as defined in the independent claims.

[0011] According to the present invention, a high voltage bushing is defined comprising a hollow insulator housing, a high voltage conductor provided inside the housing, a first connection arrangement where the conductor can be connected to a first electric device and a second connection arrangement where the conductor can be connected to a second electric device, **characterized in that** at least one of said first connection arrangement and said second connection arrangement is designed as an external connection arrangement in which the conductor has an extended end part,and the bushing comprises an exit opening through which the extended end part of the conductor exits from the bushing, in order for the extended end part of the conductor to be connectable to an electric device, and the bushing further comprises a cooling arrangement for cooling of the bushing.

[0012] An advantage of this invention is that the losses

are reduced since the contact surfaces and joints are reduced. With the present invention, at least one of the contact areas of the prior art external terminal is made redundant since the current does not have to flow through the top cover, but can flow directly from the conductor to a contact mounted on the conductor, outside the housing. Reduced losses will reduce the need for cooling of the bushing.

[0013] Another advantage is that the cooling of the conductor is improved by direct heat transfer to the surrounding air, which is made possible when the conductor extends outside the bushing. Improved cooling will make it possible to transfer higher power through the bushing, i.e., increase voltage and/or current.

[0014] A further advantage is increased robustness for high currents since fewer parts need to have a current contact function.

[0015] In addition, the feature of a special cooling arrangement for cooling of the bushing, will further improve cooling and contribute to the possibility of increasing the voltages.

[0016] According to one embodiment of the invention, the cooling arrangement may comprise a heat sink thermally connected to the extended end part of the conductor, by means of which heat sink heat is conducted away from the bushing and thereby achieving cooling. The heat from losses inside the bushing is transferred to the conductor and then to the heat sink and thus can be conducted away.

[0017] According to one alternative, the heat sink may be in direct thermal contact with the extended end part.

[0018] According to another alternative, the heat sink may be thermally connected to a device holding the conductor at the exit opening.

[0019] According to a further alternative, the heat sink may be thermally connected to the housing of the bushing.

[0020] According to one aspect of the invention, the heat sink comprises a body made of a material with high thermal conductivity.

[0021] The heat sink may be provided with cooling fins.

[0022] According to another embodiment, the heat sink is thermally connected to a corona shield body arranged on the bushing. In order to additionally improve cooling, the cooling arrangement may comprise a heat-pipe connecting the heat sink with the corona shield body.

[0023] According to yet another embodiment, the heat sink comprises a corona shield body arranged radially outside the extended end part of the conductor. If there is already a corona shield body on the bushing, it is very practical to use this as a heat sink.

[0024] According to another aspect of the invention, the heat sink comprises a hollow body made of a lightweight material. The shape and size of such a body will be adapted to the conditions in every particular case.

[0025] The heat in the heat sink may be transferred to ambient air by natural convection.

[0026] Alternatively, the heat in the heat sink is transferred to ambient air by forced convection. For this purpose, the cooling arrangement may comprise a fan arranged to provide forced convection.

[0027] According to another alternative, the heat in the heat sink is removed by a cooling fluid.

[0028] The heat sink may comprise at least one channel in which a cooling fluid is circulated and the channel may be provided with a connecting device for connecting the channel to an external cooling system.

[0029] When the heat sink is a corona shield body, the corona shield body can be a ring-shaped pipe inside which a cooling fluid is circulated.

[0030] According to a further aspect of the invention, the bushing includes a cover forming part of the housing, that the exit opening for the conductor is designed as a hole in the cover through which hole the extended end part of the conductor exits from the bushing. By letting the conductor go through the cover, the number of joints is reduced compared to prior art, and the thermal losses are reduced. The cover may be designed as a separate part, or as an integrated part of the housing.

[0031] The inventive high voltage bushing finds its applicability primarily as a DC bushing. However, it may also be an AC bushing.

[0032] The inventive high voltage bushing may be a gas insulated bushing.

[0033] The external connection arrangement of the inventive bushing may be an external air contact, i.e. the inventive details of the bushing are applied to a contact of the bushing, which contact is located at an end of the bushing that is in contact with the surrounding air, for example corresponding to the outer terminal of prior art in Fig. 1.

[0034] The bushing may also be a bushing where the housing is a sealed housing whereby the interior of the bushing is sealed off from the surroundings of the bushing. This is required when there is an insulation medium inside the bushing that must not leak out into the surroundings.

[0035] According to the present invention is further defined a high voltage device comprising a bushing in accordance with any one of the claims defining a bushing, and said high voltage device being either one of the first electric device or the second electric device to which the conductor can be connected.

[0036] Finally, according to the present invention is defined a method for cooling of a high voltage bushing, characterized in extending a bushing conductor to the outside of the bushing.

[0037] Further features, advantages and objects will become apparent from the following detailed description of the invention.

Brief description of the drawings

[0038] The present invention will now be described with reference to the enclosed drawings, illustrating embodiments of the invention, by way of example only, and

in which:

Fig. 1 illustrates schematically, in cross section, a high voltage bushing according to prior art,
Fig. 2a illustrates schematically, in cross section, an embodiment of a high voltage bushing according to the present invention,
Fig. 2b illustrates schematically, in cross section, a variant of the embodiment illustrated in Fig. 2a,
Fig. 3 is a schematic, enlarged view of the upper part of a bushing according to the present invention, in cross section, provided with a first embodiment of a cooling arrangement,
Fig. 4 is a schematic, enlarged view of the upper part of a bushing according to the present invention, in cross section, provided with a second embodiment of a cooling arrangement,
Fig. 5 is a schematic, enlarged view of the upper part of a bushing according to the present invention, in cross section, provided with a third embodiment of a cooling arrangement, and
Fig. 6 is a schematic, enlarged view of the upper part of a bushing according to the present invention, in cross section, provided with a fourth embodiment of a cooling arrangement.

Detailed description of the invention

[0039] In this description, the term "high voltage" (HV) will be used for voltages of 50 kV and higher. The present upper limit for commercial high voltage is 1100 kV, but it is foreseen that the invention can be used also for higher voltages, up to 1200 kV or even more. Generally, the present invention will find its applicability from about 200 kV and upwards.

[0040] An embodiment of a bushing according to the present invention is schematically illustrated in Fig. 2a. In principle, the bushing of this embodiment has the same main parts as the prior art bushing in Fig. 1, with the exception of the upper part with the outer terminal 24, and the fact that the present invention is not limited to a bushing with a condenser 14. In the following description, the same reference numerals are used for the same or corresponding parts in the different figures, whenever applicable.

[0041] The inventive bushing in Fig. 2a comprises a hollow bushing insulator that forms a housing 12. A high voltage conductor 10 runs through the center of the housing. There is a flange 16 provided around the housing in order to connect the housing of the bushing to ground potential through contact with the wall 18. The wall 18 may be a wall of any type of high voltage electric device where high voltage bushings are used. For example, when the electric device is a transformer, the wall 18 would be the transformer tank wall. Inside the bushing, surrounding the conductor 10, there is also arranged some type of voltage grading device 14.

[0042] At the bottom end of the bushing there is a first connection arrangement 30 in the form of a contact for connecting the conductor with a corresponding contact 22 of an electric device located on this side of the bushing. The electric device on this first side of the bushing will be referred to as a first electric device. In the case of the first electric device being a transformer, the first connection arrangement 30 in the form of the contact would be inside the transformer and the transformer would have a mating internal contact 22. At the upper end of the bushing, on the other side of the wall 18, there is provided a second connection arrangement 32, in the form of an external connection arrangement comprising an exit opening 34 in the housing 12, through which the conductor 10 exits from the bushing. The exit opening is provided with a top cover 35 which has a hole 36 through which the conductor 10 runs to the outside of the bushing. This will in the following be referred to as the second side of the bushing. The conductor 10 may be described as being extended outside the housing of the bushing by means of the conductor having an extended end part 38 forming an extended free end of the conductor. The conductor end part 38 extending outside the bushing is adapted for contact with a second electric device. In the case of the bushing being fitted to a transformer, the second side of the bushing could for instance be connected to an external device, bus or cable.

[0043] In Fig. 2b is illustrated a variant of the embodiment in Fig. 2a and the same reference numerals are used. The variant in Fig. 2b differs from the embodiment in Fig. 2a in that the wall of the housing 12 stretches beyond the extended free end part 38 of the conductor 10. Another way of describing the variant in Fig. 2b is that the cover 35 with the protruding extended end part 38 of the conductor is arranged as being recessed in the upper end of the housing 12 of the bushing.

[0044] In Fig. 3 is illustrated the upper part of a bushing according to the present invention, which bushing comprises a first embodiment of a cooling arrangement. In principle the bushing itself is based on the bushing illustrated in Fig. 2a. The same reference numerals have been used for features having correspondence in the embodiment of Figs. 2a and 2b, and these features will not be repeated here. The same applies to the figures illustrating other embodiments. The conductor 10 of the bushing has an extended end part 38 that extends outside the bushing. Around the extended end part is arranged a heat sink 40. The heat sink is thermally connected to the end part 38 of the conductor, for example by being directly connected to the end part, or by being connected to some kind of holding or clamping device that holds the conductor in the correct position at the exit opening 34. Alternatively, the heat sink may be in thermal contact with the housing 12, in most cases via the cover 35 if there is a separate cover. Combinations of the described alternatives for achieving thermal contact between the conductor and the heat sink are of course also possible.

[0045] The heat sink 40 is made of a material displaying high thermal conductivity, such as a suitable metal,

e.g. copper, aluminum. The heat sink may be solid, or provided with cooling channels as will be described further down. The heat sink may have any shape that is found suitable under the practical circumstances, and its size/mass may be adjusted to the specific needs from case to case. In order to further increase the cooling effect, the surface of the heat sink may be provided with cooling fins (not shown). The heat from losses inside the bushing is transferred to the heat sink 40 via the conductor 10 and can be conducted away from the heat sink either by natural convection to surrounding air or gas, or by forced cooling through convection, which may be achieved by the cooling arrangement comprising a fan arranged to blow air or gas onto the heat sink. Other alternatives may include surrounding the heat sink with some other kind of cooling medium.

[0046] In the embodiment illustrated in Fig. 4, the bushing comprises a second embodiment of an arrangement for cooling. In this embodiment, the heat sink of Fig. 3 is combined with a corona shield body 42 arranged radially outside the extended end part 38 of the conductor 10. The corona shield may be a hollow or solid body, e.g. ring-shaped, of metal or some other electrically conductive material. The corona shield is thermally connected to the housing 12 of the bushing 1 and thereby to the conductor 10. In most cases, the corona shield body would be connected to the cover 35 of the housing by a support device 52 comprising plates, bars or similar. A corona shield body is often quite voluminous and therefore offers a substantial surface for heat transfer to the surroundings. Also for this embodiment natural convection, forced convection etc. may be used. As an option, there may be provided additional equipment for promoting heat transfer between the heat sink and the corona shield body, for example such as heatpipes 44 arranged between the heat sink 40 and the corona shield body 42.

[0047] In the schematic illustration in Fig. 5, the bushing comprises a third embodiment of an arrangement for cooling. This arrangement for cooling comprises a corona shield body 50 by itself and it is arranged radially outside the extended end part 38 of the conductor 10. As mentioned above, the corona shield may be a hollow or solid ring of metal or some other electrically conductive material. Here it is illustrated as a hollow pipe, for example of a light material such as aluminium. The corona shield is thermally connected to the housing 12 of the bushing 1 via a support device 52 connected to the cover 35 and thereby to the conductor 10. When the corona shield is a pipe, the interior of the pipe may be used for circulating a cooling medium, such as a gas, air, or a liquid, such as water or oil. For this purpose it may be connected to an external cooling system. A similar solution is of course also conceivable for the embodiment in Fig. 4. As an alternative, there may be used a lightweight body of a thermally conductive material, which does not have the function of a corona shield, but merely has the function of enhancing cooling. Such a body may have any conceivable shape that is suitable under the circumstances and it may well be hollow in order to offer the possibility of circulating a cooling fluid, e.g. air.

[0048] In Fig. 6 is shown a fourth embodiment of a cooling arrangement, in which a heat sink 60 similar to Fig. 3, is illustrated. In this heat sink 60 is provided a channel 62 in which a cooling fluid may be circulated. For this purpose, the channel is connected to an external cooling system (not illustrated) via connecting means. This channel may also be divided into several channels, in order to achieve good circulation of the cooling fluid from the cooling system. The cooling fluid may be liquid or gas, for example air, water or oil.

[0049] It should be understood that combinations of the described embodiments are of course possible. It should also be mentioned that, even though the given examples are primarily based on the bushing type illustrated in Fig. 2a, also the variant illustrated in Fig. 2b could modified to include a cooling arrangement, e.g. the arrangement according to the embodiment in Fig. 5, and vice versa.

[0050] In the embodiments of Figs. 2a, 2b, 3, 4, 5 and 6, the housing 12 is shown as comprising a separate cover 35 at its upper end. This cover is provided with an exit opening 34, through which the end part 38 of the conductor 10 exits from the bushing. Alternatively, the cover can be integrated in the housing and be made in one piece with the housing.

[0051] Since the conductor extends through the cover, or corresponding integrated part of the housing, heat can be transferred from the conductor to the cover, to the housing, to the corona shield and to the surrounding air. Also electrical contact is ensured between the conductor, the cover, the housing and the corona shield.

[0052] In the illustrated embodiments, the bushing is only provided with one external connection arrangement in accordance with the present invention, namely the second connection arrangement 32 at the upper end. The first connection arrangement 30 is illustrated as a regular contact used in prior art. However, it should be perfectly clear that also the first connection arrangement 30 may be designed in the same way as the illustrated second connection arrangement 32, whenever suitable. This may for example be the case when the bushing is a wall bushing between valve halls.

[0053] The described bushing may be used both for DC and AC applications.

[0054] In the description, it has been indicated that a transformer may be a high voltage device on which the inventive high voltage bushing is used. However, it is emphasized that the inventive high voltage bushing may also be used with other types of high voltage devices, such as reactors, breakers, generators, switchgear or any other suitable device finding an application in high voltage systems. Further, the terms electric device and high voltage device should also be interpreted as including cables, buses, surge arresters, DC valves and the like, within the context of the present invention.

[0055] When the inventive bushing is used in a trans-

former, oil is used as insulating medium inside the transformer and on the other side of the bushing the medium is air, for example in a HVDC valve hall. This type of bushing is generally referred to as an air-oil bushing. However, as indicated above, the bushing according to the invention is suitable for use in many electric devices, irrespective of the media on the respective sides of the bushing, such as air-air (wall bushing), air-gas (gas switchgear), etc. It should also be mentioned that the present invention bears no restriction as to the choice of insulation medium inside the bushing. It may for example be gas, oil, gel, or combinations thereof.

[0056] The present invention is not limited to the described embodiment, given as example only, but may be varied and modified in many ways within the scope of the appended claims, as will be realized by a person skilled in the art.

Claims

1. A high voltage bushing comprising
a hollow insulator housing (12),
a high voltage conductor (10) provided inside the housing,
a first connection arrangement (30) where the conductor can be connected to a first electric device and a second connection arrangement (32) where the conductor can be connected to a second electric device,
characterized in that at least one of said first connection arrangement and said second connection arrangement is designed as an external connection arrangement in which
the conductor (10) has an extended end part (38),
the bushing comprises an exit opening (34) through which the extended end part (38) of the conductor exits from the bushing, in order for the extended end part of the conductor to be connectable to an electric device, and
the bushing further comprises a cooling arrangement (40; 50; 60) for cooling of the bushing.

2. A high voltage bushing according to claim 1, **characterized in that** the cooling arrangement comprises a heat sink (40; 50; 60) thermally connected to the extended end part (38) of the conductor (10), by means of which heat sink heat is conducted away from the bushing and thereby achieving cooling.

3. A high voltage bushing according to claim 2, **characterized in that** the heat sink (40; 50; 60) is in direct thermal contact with the extended end part (38).

4. A high voltage bushing according to claim 2, **characterized in that** heat sink (40; 50; 60) is thermally connected to a device holding the conductor at the exit opening (34).

5. A high voltage bushing according to claim 2, **characterized in that** the heat sink (40; 50; 60) is thermally connected to the housing of the bushing.

6. A high voltage bushing according to any one of claims 2-5, **characterized in that** the heat sink (40; 50; 60) comprises a body made of a material with high thermal conductivity.

7. A high voltage bushing according to claim 6, **characterized in that** said heat sink (40) is thermally connected to a corona shield body (42) arranged on the bushing.

8. A high voltage bushing according to claim 7, **characterized in that** the cooling arrangement comprises a heatpipe (44) connecting the heat sink (40) with the corona shield body (42).

9. A high voltage bushing according to any one of claims 2-5, **characterized in that** the heat sink comprises a corona shield body (50) arranged radially outside the extended end part (38) of the conductor (10).

10. A high voltage bushing according to any one of claims 2-5, **characterized in that** the heat sink comprises a hollow body made of a lightweight material.

11. A high voltage bushing according to any one of claims 2-10, **characterized in that** the heat in the heat sink (40; 50; 60) is transferred to ambient air by natural convection.

12. A high voltage bushing according to any one of claims 2-10, **characterized in that** the heat in the heat sink (40; 50; 60) is transferred to ambient air by forced convection.

13. A high voltage bushing according to any one of claims 2-10, **characterized in that** the heat in the heat sink (40; 50; 60) is removed by a cooling fluid.

14. A high voltage bushing according to claim 13, **characterized in that** the heat sink (50; 60) comprises at least one channel in which a cooling fluid is circulated and that the channel is provided with a connecting device for connecting the channel to an external cooling system.

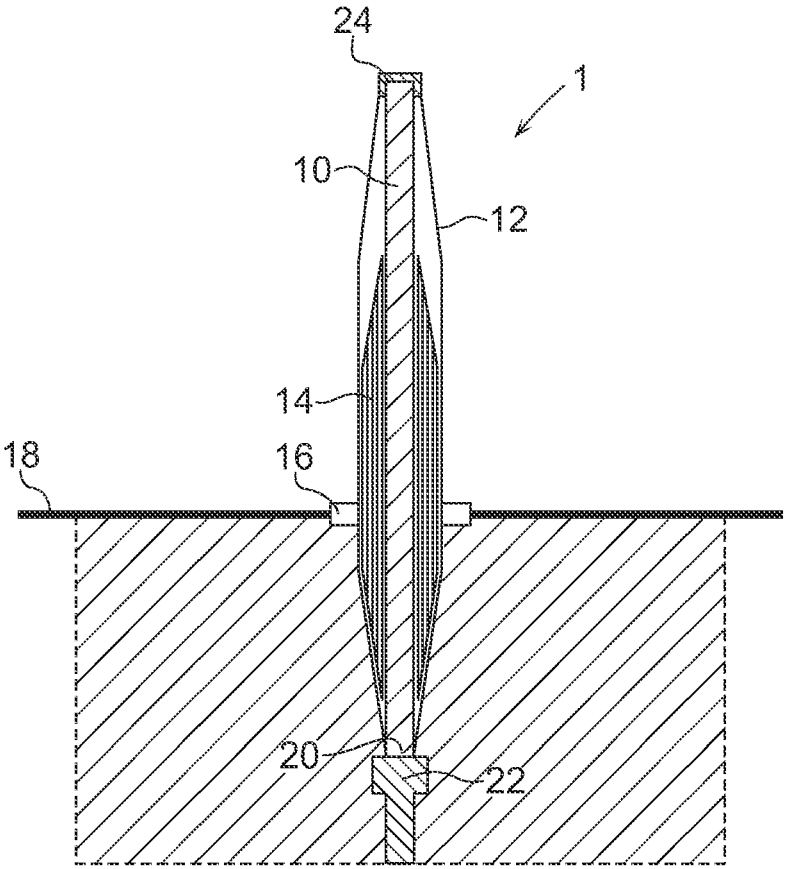
15. A high voltage bushing according to claim 9, **characterized in that** the corona shield body (50) is a ring-shaped pipe inside which a cooling fluid is circulated.

16. A high voltage bushing according to any one of claims 1-15, **characterized in that** the bushing includes a cover (35) forming part of the housing (12),

that the exit opening (34) for the conductor (10) is designed as a hole (36) in the cover through which hole the extended end part (38) of the conductor (10) exits from the bushing.

17. A high voltage device comprising a bushing in accordance with any one of claims 1-16, and said high voltage device being either one of the first electric device or the second electric device to which the conductor can be connected.

18. A method for cooling of a high voltage bushing, **characterized in** extending a bushing conductor to the outside of the bushing.



Prior art

Fig. 1

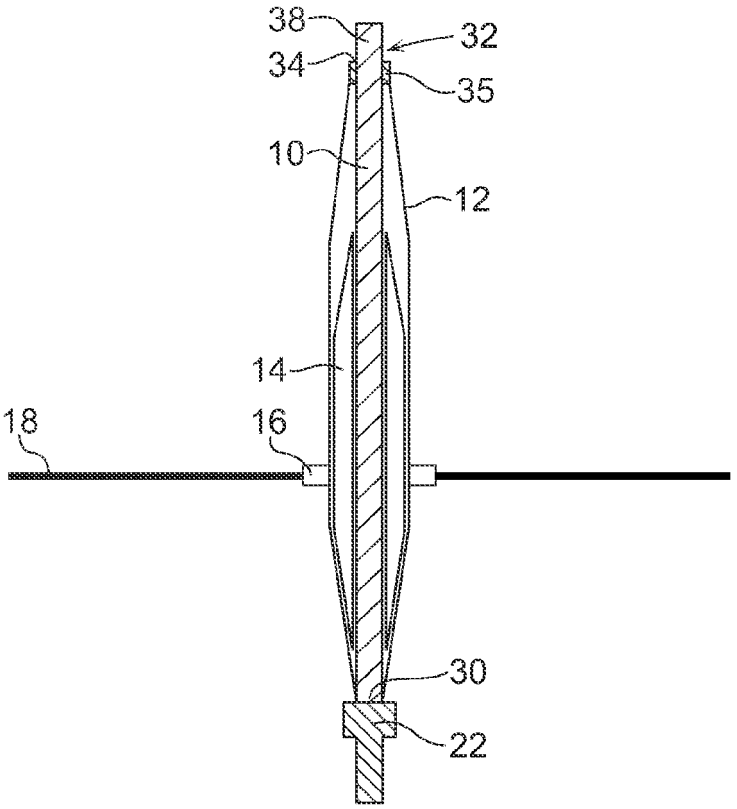


Fig. 2a

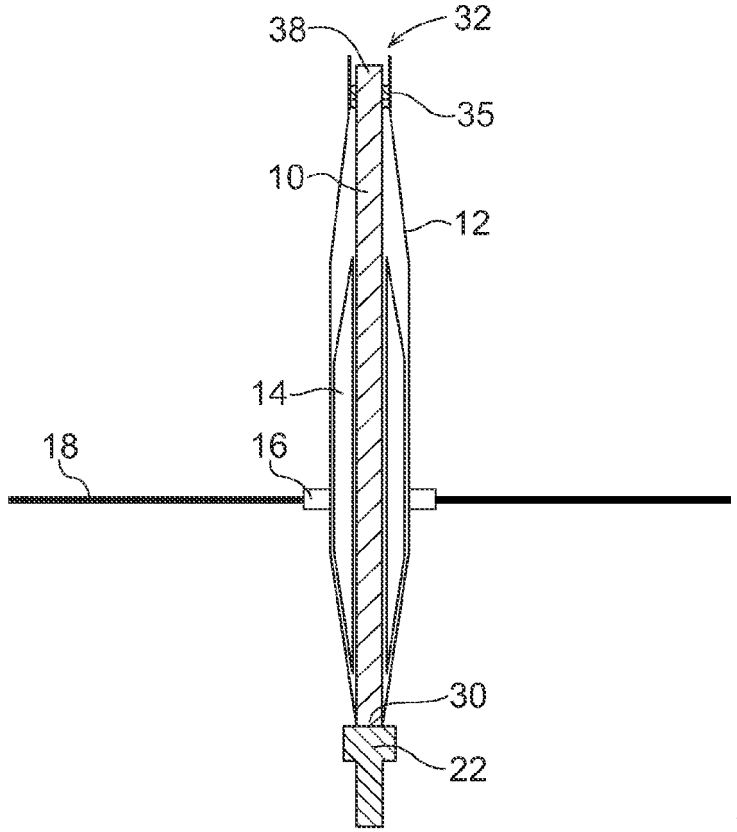


Fig. 2b

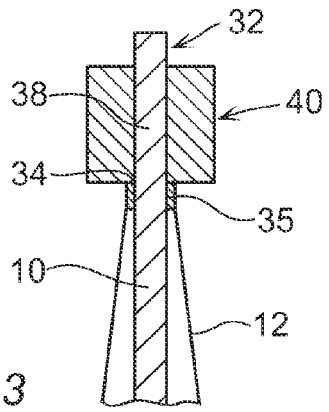


Fig. 3

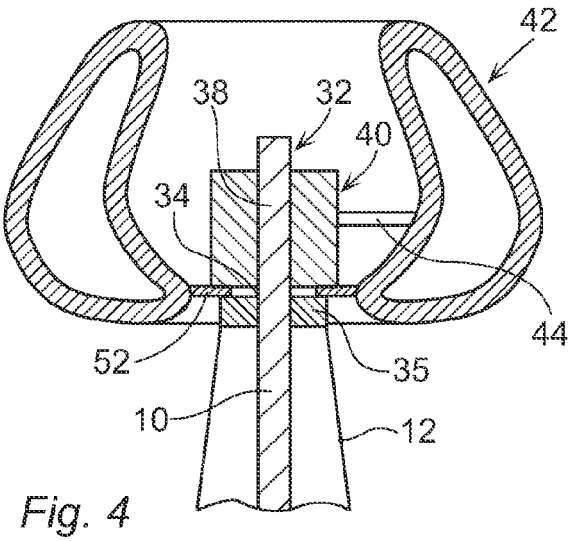


Fig. 4

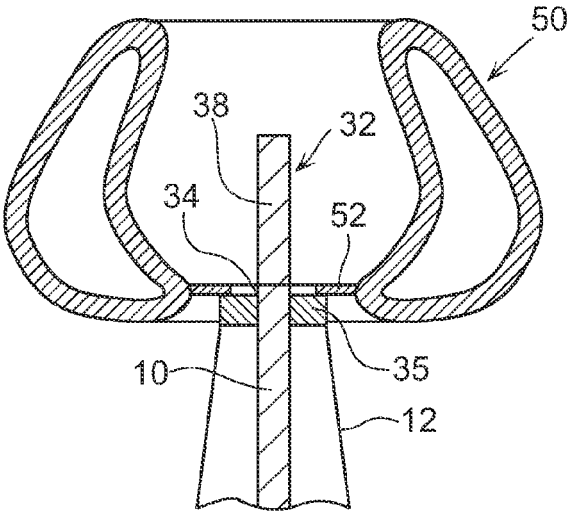


Fig. 5

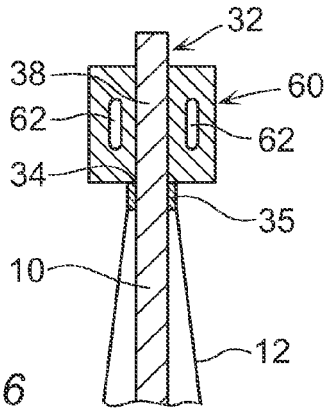


Fig. 6

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 08 15 7484

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	DE 27 57 571 A1 (FELTEN & GUILLEAUME CARLSWERK) 5 July 1979 (1979-07-05) * page 5, column 2, line 7 - line 9; figures 1,2 * * page 5, line 33 - line 36 * * page 6, line 25 - line 34 * -----	1-18	INV. H01B17/54 ADD. H01B17/26
X	US 4 358 631 A (MATSUDA SETSUYUKI) 9 November 1982 (1982-11-09) * column 2, line 4 - line 19; figure 1 * -----	1-5,11, 17,18	
A	US 3 767 835 A (ENGELHARDT J) 23 October 1973 (1973-10-23) * column 5, line 31 - line 33; figure 1 * -----	7	
A	US 3 760 089 A (HILDENBRAND J ET AL) 18 September 1973 (1973-09-18) * column 3, line 1 - line 4; figure 1 * -----	16	

TECHNICAL FIELDS SEARCHED (IPC)

H01B
H01T

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	22 October 2008	Hillmayr, Heinrich

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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