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(54) **Low-, medium-, or high-voltage vacuum interrupter with a contact system**

(57) The invention relates to a low-, medium-, or high-voltage vacuum interrupter with a contact system of two opposing contacts with AMF contact system, wherein at least one contact is a moving contact, and the AMF contact profile is bell-shaped.

In order to develop a concept for higher current interruption, which results in effective arc elimination, the invention is, that in the center of each of the AMF-contact profiles a magnetic field weakening element is arranged.

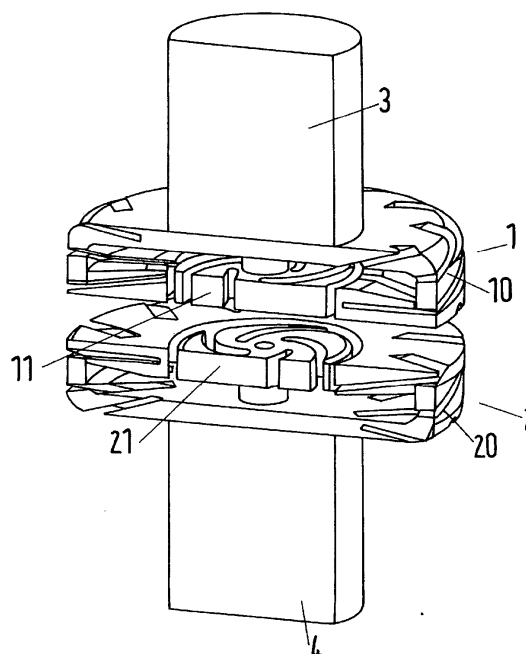


Fig.1

Description

[0001] The invention relates to a low-, medium-, or high-voltage vacuum interrupter with a contact system of two opposing contacts with AMF contact system, wherein at least one contact is a moving contact, and the AMF contact profile is bell-shaped, according to the preamble of claim 1.

[0002] Vacuum interrupters (VIs) are used at Medium Voltage level for high current interruption at occasional fault current and load current switching. The high current interruption above 50kA, as well known, represents a serious challenge for nowadays VIs.

[0003] In order to achieve high current interruption performances, it is necessary to limit the contact-erosion resulting from the local overheating due to the concentrated burning arc. Hence, it's necessary to control the vacuum arc by spreading out the arc thermal energy over as large area as possible on the contact surfaces.

[0004] In case of AMF (axial magnetic field) arc controls the charged particles, which are confined around the magnetic flux lines, in order to stabilise the arc by transforming it into diffuse mode. The quality of this control mode depends on the strength and distribution of the self-created axial B-field (AMF).

[0005] In most designs of the AMF based vacuum interrupters, the AMF strength and distribution is concentrated at the center of interrupter electrodes, especially bell-shaped AMF profiles, leading to high erosion and interruption failure especially at high current. Accordingly there is a need for a contact design to prevent the concentration of the AMF in the center of electrodes at high current level.

[0006] It has been reported in the state of the art, that AMF distribution with higher magnetic flux density at contact periphery than in its center, by the use of a concave shape, should perform better than the uniformly distributed or bell-shaped AMF.

[0007] It has been shown later that the new redistribution of the AMF (concave shape) in the inter-electrode gap in the radial direction does effectively distribute the cathode spots more uniformly across the cathode's surface. And the resulting anode erosion with such AMF is much less pronounced than that obtained with the standard AMF profile.

[0008] It is well known, that introducing ferromagnetic components within the contact can increase significantly the magnetic field and in a certain way can alter the AMF distribution, but in contrast, it can increase also significantly the nominal AC current losses.

[0009] Instead of introducing ferromagnetic components, it has been reported, that the concave AMF distribution can be obtained by innovative contacts coils assembly where a second inner AMF coil is arranged co-axially within the main AMF coil but in the inverse direction. Several embodiments using one-segment coils or two-segment coils assemblies are disclosed in the US Patent 20100230388.

[0010] The main object of this state of the art is, to obtain a better AMF arc control by readjusting the radial distribution of the AMF, but without introducing any ferromagnetic material. However, in this assembly, the contact's impedance, for nominal current conduction, and the contact's mechanical stability while closing remain as an issue.

[0011] Referring to that state of the art, it is the object of the invention, to develop a concept for higher current interruption, which a resulting effective arc elimination.

[0012] This is solved by the invention in that, in the center of each of the AMF-contact profiles is arranged a magnetic field weakening element, arranged in a central opening of the AMF contact piece.

[0013] The contacts concept is a multiple-contact system based only on AMF arc control, in which each electrode is constituted of two co-axial contacts.

[0014] By that the inner magnetic field will be weakened, so that the current density at the periphery of the contact pieces will increase.

[0015] In a further advantageous embodiment, the magnetic field weakening element is an TMF- or radial-magnetfield-contact.

[0016] Furthermore advantageous is, that the magnetic field weakening element is a TMF-spiral-contact piece, and that the direction of the spiral slots of the opposing TMF-spiral-contact pieces are oriented as such, that the spiral slot direction of one TMF-contact-piece is inverted to the spiral slot direction of the other opposing TMF-contact-piece.

[0017] For that it is advantageous, that the TMF contact pieces are constituted with two, three or four spiral slots.

[0018] An embodiment of the invention is shown in figures.

[0019] The new feature lies on using the well-known spiral TMF contacts in inverted way like it is shown in figure 1 and a detail of that in figure 3, in order to generate a strong axial magnetic field component.

[0020] The invention uses the know-how, that in such extended TMF-AMF contacts investigation from B-field simulations that when the TMF contacts are arranged within the outer cup-shape AMF contacts, they generated in addition to the transverse magnetic component (TMF) also a strong axial component at the contacts surface. However the axial field (AMF) at the mid-gap distance is close to zero due to the cancelation of both axial components generated by the upper and lower parts. When the inner spiral contacts are arranged in the opposite direction as in figure 3, the axial components will rather superpose to create a strong AMF along the gap.

[0021] So the spiral directions between the upper and the lower TMF contact pieces are inverted.

The TMF contact pieces with the spiral slots are constructed as a kind of inlays, which are arranged in central openings in the opposing AMF-contact pieces.

[0022] This AMF generated by the inner inverted spiral contacts is actually opposing locally the main AMF generated by the outer cupshaped contacts coils. This com-

bination leads to a weakening of the AMF towards the contacts center and an increase of the AMF at the contacts periphery which is located at the outer contacts. So this results in what is shown in figure 4.

[0023] Further AMF radial distribution at the mid-gap and at the contacts surface are possible for two gap distances, $d=5\text{mm}$ and $d=10\text{ mm}$. This results in that the maximum AMF is located at the outer contact away from the contacts center.

[0024] This present contacts structure with inverted spiral contacts is simpler, thus cost effective and easier to manufacture, and more compact, and much more robust than the geometries suggested in the state of the art, for the same purpose.

[0025] The total contact resistance (bulk and contact's resistance) is also kept very low because of the spiral slots in the contact pieces.

[0026] From the experimental point of view, were investigated the vacuum arc dynamics and confirmed the effect of this structure (with inverted spiral contacts) on the diffuse arc distribution. The fully diffuse vacuum arc was perfectly distributed over the whole contact surface.

[0027] Further geometries of the inner spiral contacts can be constituted of 4-slots, 3-slots or 2-slots standard TMF-contacts.

Numbers:

[0028]

- | | | |
|----|---|----|
| 1 | upper contact piece | 30 |
| 2 | lower contact piece | |
| 3 | stem | |
| 4 | stem | |
| 10 | bell-shaped upper AMF contact piece | 35 |
| 11 | inner (upper) TMF spiral contact piece | |
| 12 | spiral slots in the upper TMF contact piece | |
| 20 | bell-shaped lower AMF contact piece | |
| 21 | inner (lower) TMF spiral contact piece | |
| 22 | spiral slots in the lower TMF contact piece | 40 |

Claims

1. Low-, medium-, or high-voltage vacuum interrupter with a contact system of two opposing contacts with AMF contact system, wherein at least one contact is a moving contact, and the AMF contact profile is bell-shaped,
characterized in that
in the center of each of the AMF-contact profiles (1, 2) is arranged a magnetic field weakening element (11, 21) arranged in a central opening of the AMF contact piece.
2. Low-, medium-, or high-voltage vacuum interrupter according to claim 1,
characterized in that

the magnetic field weakening element (11, 21) is an TMF- or radialmagnetfield-contact.

3. Low-, medium-, or high-voltage vacuum interrupter according to claim 1 or 2,
characterized in that
the magnetic field weakening element is a TMF-spiral-contact piece, and that the direction of the spiral slots of the opposing TMF-spiral-contact pieces are oriented as such, that the spiral slot direction of one TMF-contact-piece is inverted to the spiral slot direction of the other opposing TMF-contact- piece.
4. Low-, medium-, or high-voltage vacuum interrupter according to claim 3,
characterized in that
the TMF contact pieces are constituted with two or three spiral slots.

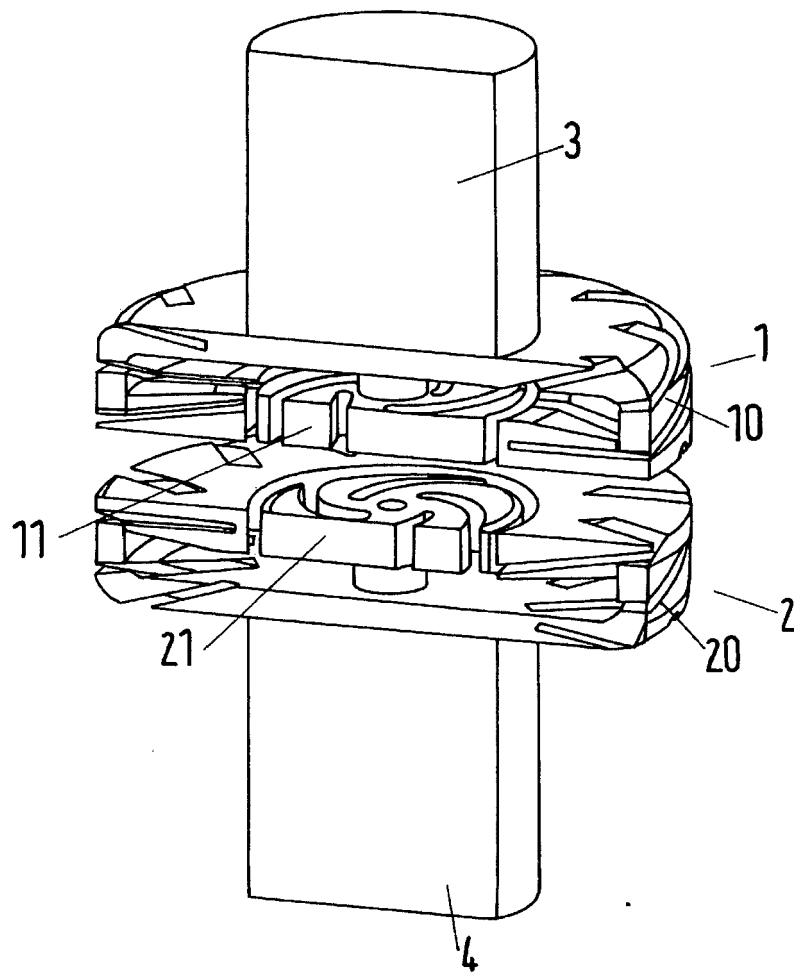


Fig.1

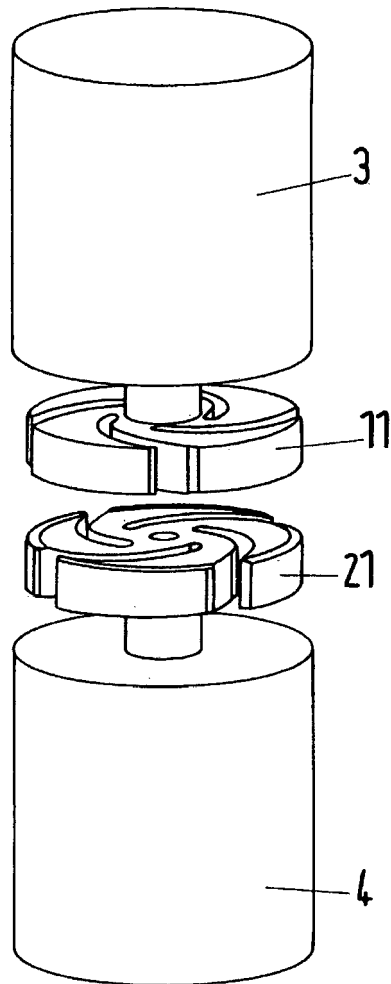


Fig.2

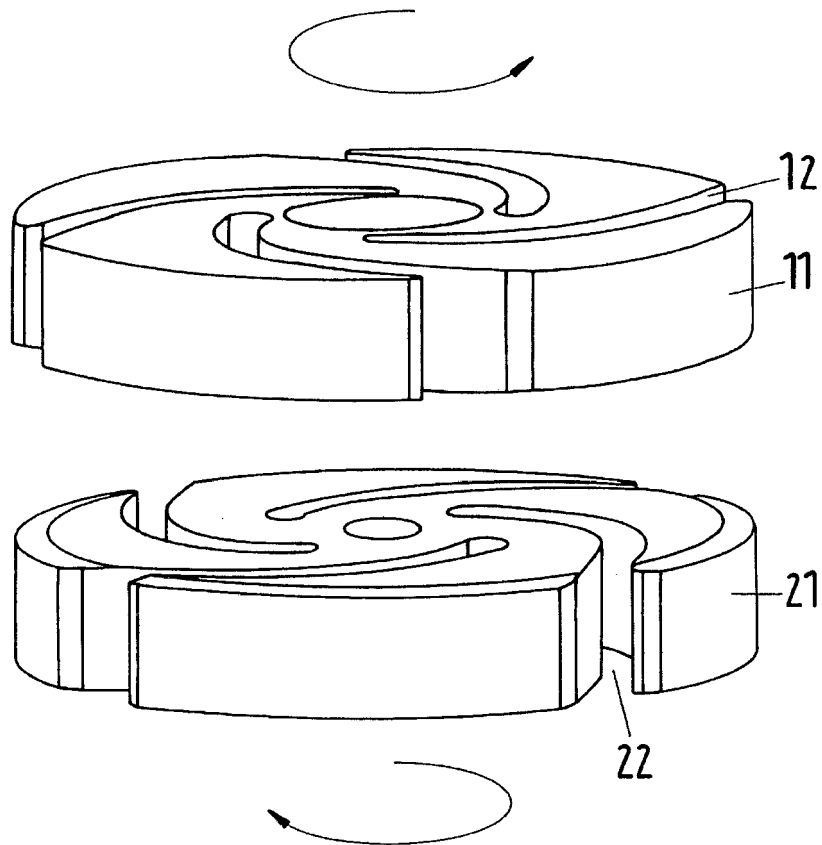


Fig.3

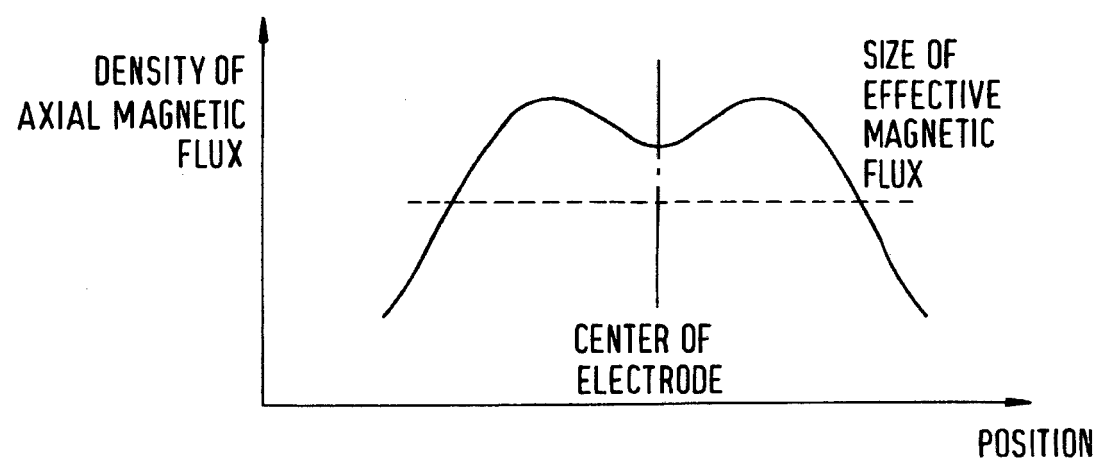


Fig.4



EUROPEAN SEARCH REPORT

Application Number
EP 13 00 5639

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DOCUMENTS CONSIDERED TO BE RELEVANT			
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X	LAMARA TAREK ET AL: "Theoretical and Experimental Investigation of New Innovative TMF-AMF Contacts for High-Current Vacuum Arc Interrup", IEEE TRANSACTIONS ON PLASMA SCIENCE, IEEE SERVICE CENTER, PISCATAWAY, NJ, US, vol. 41, no. 8, 1 August 2013 (2013-08-01), pages 2043-2050, XP011523369, ISSN: 0093-3813, DOI: 10.1109/TPS.2013.2273178 [retrieved on 2013-08-07]	1,2	INV. H01H33/12 H01H33/664
Y	* abstract; figures 3, 7, 10 * * page 2043, paragraph 5 - page 2044, paragraph 4 * * page 2045, paragraph 3 *	3,4	
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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 14 April 2014	Examiner Bräckelmann, Gregor
<p>CATEGORY OF CITED DOCUMENTS</p> <p>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</p> <p>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</p>			

EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 13 00 5639

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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14-04-2014

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