(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 2 669 908 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
04.12.2013 Bulletin 2013/49

(51) Int Cl.:
H01F 27/33 *(2006.01)*

(21) Application number: **12004122.3**

(22) Date of filing: **29.05.2012**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

(71) Applicant: **ABB Technology Ltd.**
8050 Zürich (CH)

(72) Inventors:
- **Kozupa, Michal**
  30-348 Krakow (PL)
- **Platek, Robert**
  30-085 Krakow (PL)
- **Grzegorz, Kmita**
  32-085 Giebultow (PL)
- **Weber, Benjamin**
  59955 Winterberg (DE)
- **Cornelius, Frank**
  59939 Olsberg (DE)

(74) Representative: **Partner, Lothar**
ABB AG
GF IP
Wallstadter Straße 59
68526 Ladenburg (DE)

(54) **Transformer**

(57) The invention is related to a high-voltage transformer (10, 30, 50, 70, 80), comprising a transformer core (38) with at least two limbs (18, 20, 22) and at least one coil (12, 14, 16, 32, 34, 36, 52, 54, 56, 72, 74) arranged around each of the at least two limbs (18, 20, 22), wherein as the coils (12, 14, 16, 32, 34, 36, 52, 54, 56, 72, 74) are constructed in an at least similar way. Interconnection-means (24, 26, 40, 42, 44, 45, 46, 47, 58, 60, 62, 64, 76, 78, 82) are foreseen to mechanically couple the coils (12, 14, 16, 32, 34, 36, 52, 54, 56, 72, 74) at their radially outer sides.

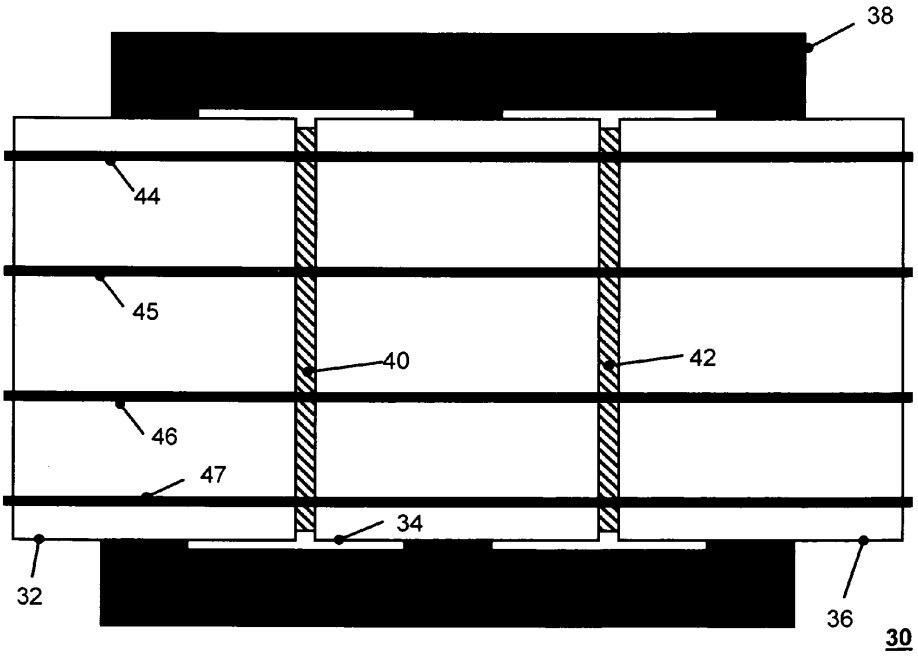

Fig. 2

EP 2 669 908 A1

Description

[0001] The invention relates to a high-voltage transformer, comprising a transformer core with at least two limbs and at least one coil arranged around each of the at least two limbs, whereas the coils are constructed in an at least similar way.

[0002] It is known, that high-voltage transformers, for example within a voltage range from 6kV to 110kV and higher, are used within energy distribution networks as connection elements inbetween different voltage levels. For transmission of electrical energy over long distances a higher voltage level such as 110kV or 380kV is required for decreasing transmission losses, whereas typical electrical loads require for example 6kV level or even lower. Typical rated powers for such high-voltage respectively distribution transformers are for example within a range from 1 MVA to 1 OMVA.

[0003] Energy distribution networks are typically built in a three phase manner, so in principal three different but symmetrical transmission circuits with a common return conductor are foreseen. In the ideal symmetrical loaded case, the currents through all transmission circuits are equal according to amount but with a phase shift inbetween of 120° each. In this symmetrical case the current through the return common conductor is summarized to zero.

[0004] Such transformers comprise a transformer core made from a typically sheeted magnetic material whereas limbs and legs are formed and whereas coils arranged around the limbs. The coils typically comprise a primary and a secondary winding, whereas for a three phase transformer three of such coils are foreseen on the limbs. The reason for making a transformer core from a sheeted magnetic material is to reduce core losses, so that eddy currents induced within the magnetic core material are as low as possible.

[0005] Disadvantageously within this state of the art is that the typically sheeted transformer core and also the coils are subject to some vibrations during operation, even during no-load operation. Those vibrations are basically stimulated by the network frequency, 50Hz or 60Hz. Vibrations of the core - also including vibrations of the different sheets - respectively its legs will also have effect on the coils mounted thereon. Thus a transformer typically produces a non desired noise emission during operation.

[0006] Based on this state of the art it is the objective of the invention to provide a transformer with reduced noise emission.

[0007] This problem is solved by a system of the aforementioned kind. This is characterized in that interconnection-means are foreseen to mechanically couple the coils at their radially outer sides.

[0008] During operation the transformer core respectively its legs are stimulated by the electrically each to each other phase shifted operated coils to vibrations. Thus the basic idea of the invention is based on the assumption, that the vibrations of the legs of the core respectively the coils are not in line, but also phase shifted each to each other. The frequency spectrum of the noise respectively vibrations will cover a wider range of frequencies but especially the 100/120Hz and multiples of it have the highest share. The radially outer sides of the coils are subject to the highest vibrations since they are an open end of such a swinging mechanical system. Thus the radially outer sides of the coils are also a main source for noise emission.

[0009] By mechanically coupling the coils at their outer sides they will no longer be the end of a swinging system. Moreover by using the effect of the phase shift of the vibration of the non-coupled coils, vibrations counteract each to each other when the coils are mechanically coupled. Thus the vibrations of the coils are reduced in an advantageous way and the noise emission therewith. Due to reasons of symmetry, the noise damping effect according to the invention is higher, when the coils are constructed in the same way respectively nearly identical. In this case the possible resonance frequencies within such a mechanical swinging system are not as numerously and a compensation of them is more effective. The interconnection means have preferably to be chosen in that way, that the connected coils can be mechanically seen as one part and vibrations are transmittable from one coil to another. Pressure means and distance elements inbetween the pressed coils are suitable for example to gain such a connection. Of course aspects of electrical insulation of each coil against each other have to be observed, so the interconnection means should preferably be electrically insulating.

[0010] According to a preferred embodiment of the invention the high-voltage transformer is a three-phase transformer. The phase shift inbetween voltage respectively current of the three phase amounts 120° in the symmetrical case, whereas the current through the common return conductor is zero in this case. Thus vibrations, which rise during the operation of such a three phase transformer, will be reduced therewith in a preferred way. But also other transformer types are suitable for a noise reduction according to the invention. For example a single-phase transformer with a divided winding distributed on two coils on two limbs, whereas the coils are arranged in that way, that a 180° phase shift inbetween them is present and whereas the coils are mechanically coupled at their outer surfaces.

[0011] According to a further embodiment of the invention the transformer core has a triangular layout with three parallel limbs, preferably with the same distance inbetween the limbs, so that a belonging 60° angle is build. In this case the transformer core itself is also symmetrical, so that the symmetry respectively belonging phase shift from the electrical side will be transferred on the mechanical side in a preferred manner. Thus the effect of noise damping according to the invention will be once more increased for a triangular transformer.

[0012] According to a further embodiment of the inven-

tion the interconnection-means have no substantial contribution to the mechanical stability of the transformer. Thus the interconnection means are preferably a kind of add-on-kit to reduce the noise emission of an existing transformer respectively transformer type.

[0013] According to a further embodiment of the invention the interconnection-means comprise a wound band-like material. This could be for example an electrically insulating tension belt for applying a pressure force on two or more neighbored coils. But it could also be a kind of insulation foil which is wound several times around the coils to interconnect them mechanically. According to another embodiment of the invention the wound band-like material comprises fibre. This increases the tension stability of the band-like material in an advantageous way, so that a higher pressure force can applied on neighbored coils. According to another embodiment of the invention the wound band-like material is impregnated, for example with an epoxy resin. After hardening such a material it becomes more stiff, so that the mechanical interconnection inbetween the coils is improved once more and vibrations are transmissible in an easy way from one coil to another.

[0014] According to a further embodiment of the invention the interconnection means comprise at least one distance element. The distance element is preferably foreseen to be placed inbetween two adjacent coils so that a high pressure force can applied on the coils, for example by using a wound band-like material. This increases the stiffness of the mechanical connection of the coils. The distance element is preferably made from an insulating material, for example a plastic or even pressboard.

[0015] According to another embodiment of the invention the interconnection means comprise at least one adapter piece, which is integrated within the surface of a belonging transformer coil. An adapter piece might contain for example an L-shaped part, which is fixed by a wound material of an impregnated surface of the transformer coil. Thus a stiff connection of the adapter piece with the coil surface is gained.

[0016] According to another embodiment of the invention adjacent adapter pieces from neighbored coils are form-locking connected each to each other. This might be done either directly or by using an additional interface piece. The connection of the adapter pieces has to become preferably constructed in that way, that as well a pressure as a tension force is transmissible therewith.

[0017] Further advantageous embodiments of the invention are mentioned in the dependent claims.

[0018] The invention will now be further explained by means of an exemplary embodiment and with reference to the accompanying drawings, in which:

Figure 1 shows an exemplary first transformer,
Figure 2 shows an exemplary second transformer,
Figure 3 shows an exemplary third transformer,
Figure 4 shows an exemplary fourth transformer and
Figure 5 shows an exemplary fifth transformer.

[0019] Figure 1 shows an exemplary first transformer 10 from a cross sectional birds view. Three hollow-cylindrical coils 12, 14, 16 with a primary and secondary winding each are arranged around belonging limbs 18, 20, 22 of a transformer core. Inbetween neighbored parts of the radial outer surfaces of the coils 12, 14, 16 distance elements 24, 26 are foreseen to mechanically connect the coils in that way, that vibrations are transmittable from one coil to another. Those distance elements 24, 26 might be made from milled plastic for example and glued on the surface of the coils.

[0020] Figure 2 shows an exemplary second transformer 30 from a side view. Three hollow-cylindrical coils 32, 34, 36 are arranged around the limbs of a transformer core 38. Inbetween neighbored coils 32, 34, 36 distance elements 40, 42 are mounted. Four wound bands 44, 45, 46, 47 are arranged around all three coils so that they are pressed together. The combination of the pressure of the bands 44, 45, 46, 47 and the distance elements 40, 42 connects them in that way, that they can be seen mechanically as one part.

[0021] Figure 3 shows an exemplary third transformer 50 from a cross sectional birds view. Three hollow-cylindrical coils 52, 54, 56 with a primary and secondary winding each are arranged around belonging limbs of a transformer core with triangular layout. Inbetween neighbored parts of the radial outer surfaces of the coils 52, 54, 56 distance elements 58, 60, 62 are foreseen to mechanically connect the coils 52, 54, 56 in that way, that vibrations are transmittable from one coil to another. A band like material, which is wound all three coils applies a pressure force on them and on the distance elements 58, 60, 62 therewith. Due to the symmetrical layout of the transformer core and the coils, a very stiff connection between the coils is gained.

[0022] Figure 4 shows an exemplary fourth transformer 70 from a cross sectional birds view. Two hollow-cylindrical coils 72, 74 with a primary and secondary winding each which are electrically connected in row are arranged around belonging limbs of a transformer core. At the neighbored radial outer surfaces of the coils adapter pieces 76, 78 are foreseen, which are integrated into the surface themselves. By sliding a not shown double cross-like connection element into the adjacent notches of the adapter pieces 76, 78 a stiff connection of both coils 72, 74 is gained.

[0023] Figure 5 shows an exemplary fifth transformer 80 from a cross sectional birds view. Three hollow-cylindrical coils with a primary and secondary winding each are arranged around belonging limbs of a transformer core. A band 82 is arranged loop-like around the three coils for applying a pressure force thereon. Not shown distance elements inbetween the three coils are foreseen so that the coils are connected in a stiff manner.

List of reference signs

[0024]

10 exemplary first transformer

12 first coil of first transformer

14 second coil of first transformer

16 third coil of first transformer

18 first limb of transformer core

20 second limb of transformer core

22 third limb of transformer core

24 first distance element of first transformer

26 second distance element of first transformer

30 exemplary second transformer

32 first coil of second transformer

34 second coil of second transformer

36 third coil of second transformer

38 transformer core

40 first distance element of second transformer

42 second distance element of second transformer

44 first wound band-like material

45 second wound band-like material

46 third wound band-like material

47 fourth wound band-like material

50 exemplary third transformer with triangular layout

52 first coil of third transformer

54 second coil of third transformer

56 third coil of third transformer

58 first distance element of third transformer

60 second distance element of third transformer

62 third distance element of third transformer

64 fifth band-like material

70 exemplary fourth transformer

72 first coil of fourth transformer

74 second coil of fourth transformer

76 first adapter piece

78 second adapter piece

80 exemplary fifth transformer

82 sixth band-like material

Claims

1. High-voltage transformer (10, 30, 50, 70, 80), comprising a transformer core (38) with at least two limbs (18, 20, 22) and at least one coil (12, 14, 16, 32, 34, 36, 52, 54, 56, 72, 74) arranged around each of the at least two limbs (18, 20, 22), whereas the coils (12, 14, 16, 32, 34, 36, 52, 54, 56, 72, 74) are constructed in an at least similar way,
characterized in that
interconnection-means (24, 26, 40, 42, 44, 45, 46, 47, 58, 60, 62, 64, 76, 78, 82) are foreseen to mechanically couple the coils (12, 14, 16, 32, 34, 36, 52, 54, 56, 72, 74) at their radially outer sides.

2. High-voltage transformer according to claim 1, **characterized in that** the transformer is a three-phase transformer.

3. High-voltage transformer according to claim 1 or 2, **characterized in that** the transformer core has a triangular layout (50).

4. High-voltage transformer according to any of the previous claims, **characterized in that** the interconnection-means (24, 26, 40, 42, 44, 45, 46, 47, 58, 60, 62, 64, 76, 78, 82) have no substantial contribution to the mechanical stability of the transformer.

5. High-voltage transformer according to any of the previous claims, **characterized in that** the interconnection-means (24, 26, 40, 42, 44, 45, 46, 47, 58, 60, 62, 64, 76, 78, 82) comprise a wound band-like material (44, 45, 46, 47, 64, 82).

6. High-voltage transformer according to claim 5, **characterized in that** the wound band-like material (44, 45, 46, 47, 64, 82) comprises fibre.

7. High-voltage transformer according claim 5 or 6, **characterized in that** the wound band-like material (44, 45, 46, 47, 64, 82) is impregnated.

8. High-voltage transformer according to any of the previous claims, **characterized in that** the interconnec-

tion means (24, 26, 40, 42, 44, 45, 46, 47, 58, 60, 62, 64, 76, 78, 82) comprise at least one distance element (24, 26, 40, 42, 58, 60, 62).

9. High-voltage transformer according to any of the previous claims, **characterized in that** the interconnection means (24, 26, 40, 42, 44, 45, 46, 47, 58, 60, 62, 64, 76, 78, 82) comprise at least one adapter piece (76, 78), which is integrated within the surface of a belonging transformer coil (72, 74).

10. High-voltage transformer according to claim 9, **characterized in that** adjacent adapter pieces (72, 74) are form-locking connected each to each other.

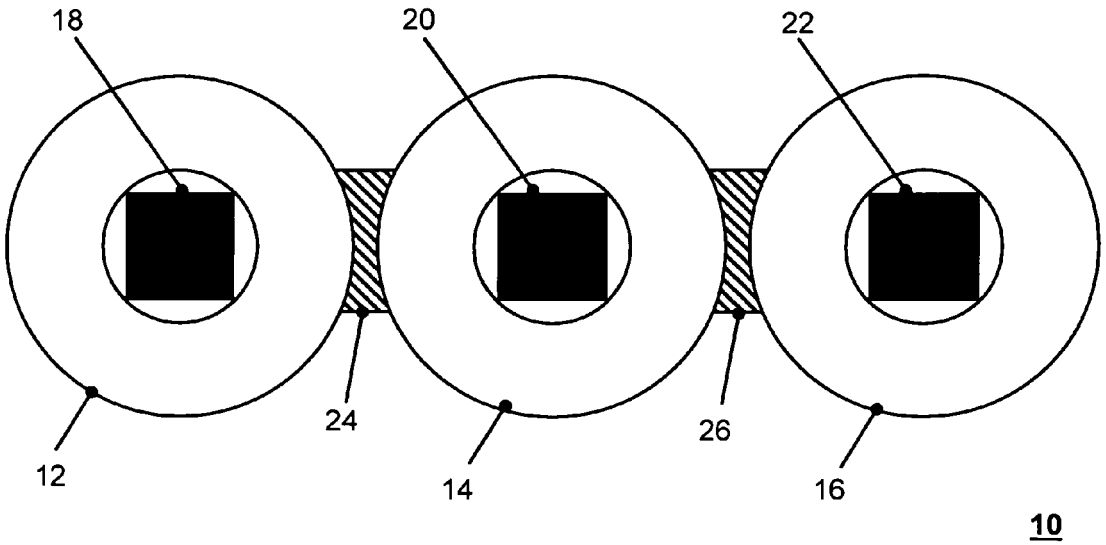

Fig. 1

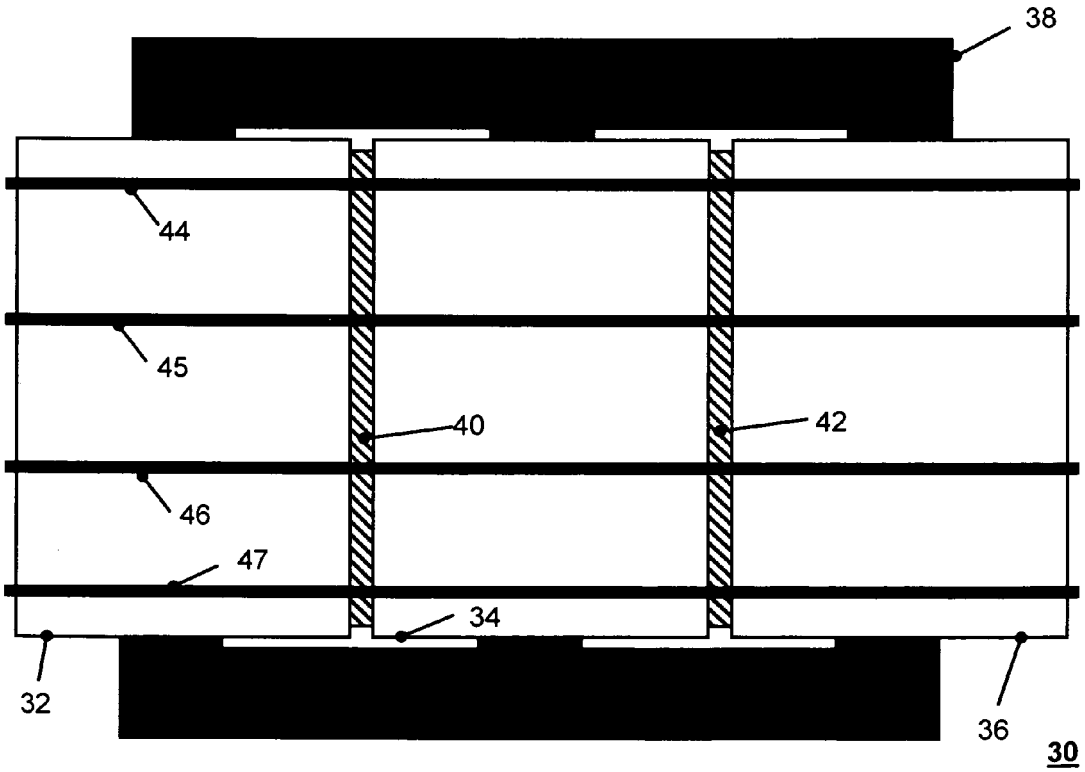

Fig. 2

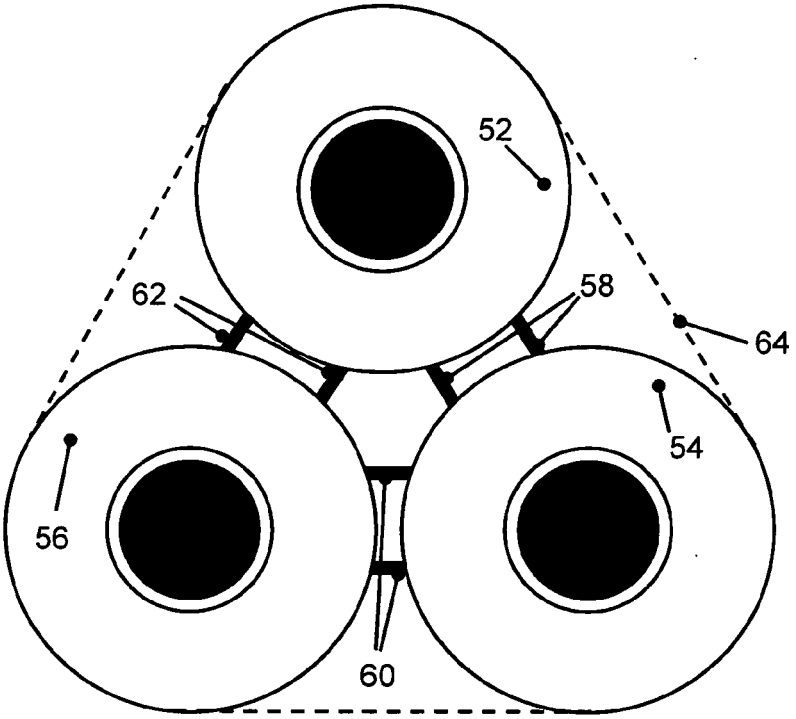

Fig. 3

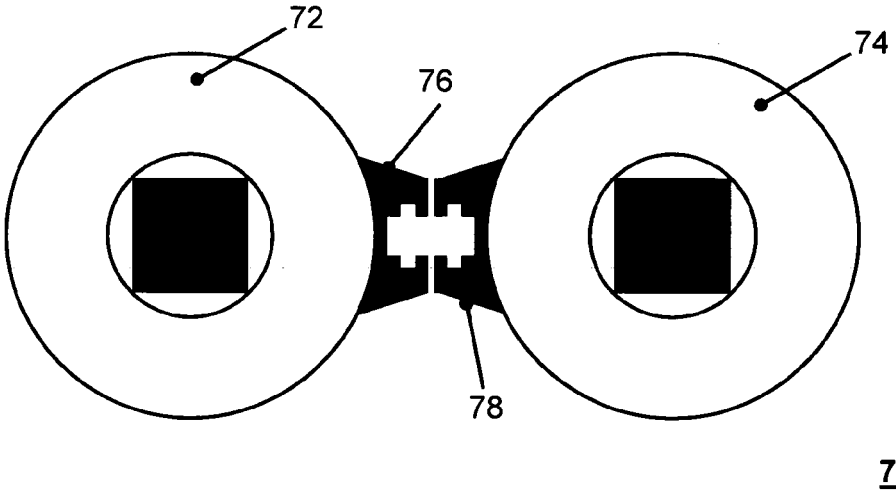

Fig. 4

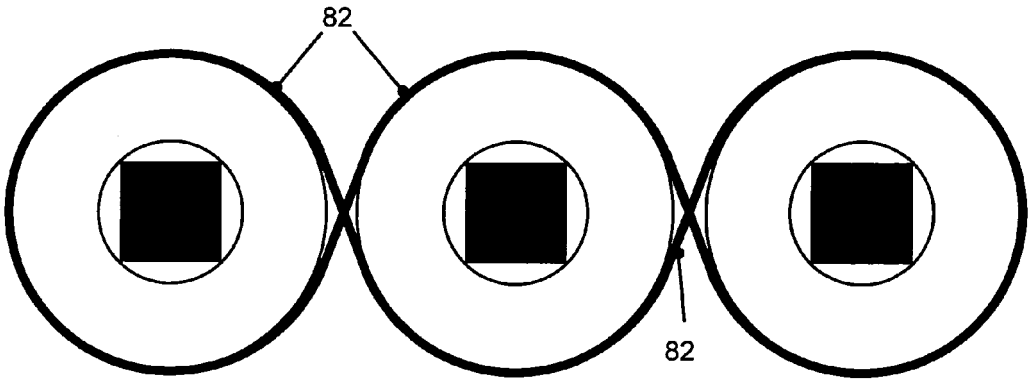

Fig. 5

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 12 00 4122

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 Y	US 4 725 804 A (YARPEZESHKAN HASSAN [US]) 16 February 1988 (1988-02-16) * column 2, line 61 - line 65; figures 1,2 * * column 3, line 23 - column 4, line 9 *	1,2,4,5, 8 3	INV. H01F27/33
X	WO 00/77801 A1 (SQUARE D CO [US]) 21 December 2000 (2000-12-21) * figures 1,4 *	1,2,4,5	
X	US 2 835 875 A (RAYMOND BISTANY) 20 May 1958 (1958-05-20) * column 3, line 27 - line 45; figure 1 *	1,2,4,5	
X	US 3 135 939 A (FORTIER ARTHUR H) 2 June 1964 (1964-06-02) * column 3, line 62 - line 72; figures 1,2,4 *	1,2,4-8	
X	US 3 436 707 A (DERBYSHIRE CHARLES E ET AL) 1 April 1969 (1969-04-01) * abstract; figure 1 *	1,2,4,5, 8	TECHNICAL FIELDS SEARCHED (IPC) H01F
X	FR 1 018 703 A (THOMSON HOUSTON COMP FRANCAISE) 12 January 1953 (1953-01-12) * abstract; figure 1 *	1	
X A	US 3 579 164 A (ROTRUCK JAMES L) 18 May 1971 (1971-05-18) * column 1, line 23 - line 33; figure 1 *	1-3,9,10 6	
X	US 3 374 453 A (BROVERMAN ALVIN Y ET AL) 19 March 1968 (1968-03-19) * abstract; figure 4 *	1,2	
Y A	US 3 684 991 A (TRUMP JOHN GEORGE ET AL) 15 August 1972 (1972-08-15) * abstract; figures 2,7 *	3 1	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	8 August 2012	Rouzier, Brice

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 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 12 00 4122

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.

08-08-2012

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4725804 A	16-02-1988	NONE	
WO 0077801 A1	21-12-2000	CA 2340125 A1	21-12-2000
		EP 1105892 A1	13-06-2001
		US 6326877 B1	04-12-2001
		WO 0077801 A1	21-12-2000
US 2835875 A	20-05-1958	NONE	
US 3135939 A	02-06-1964	NONE	
US 3436707 A	01-04-1969	NONE	
FR 1018703 A	12-01-1953	NONE	
US 3579164 A	18-05-1971	NONE	
US 3374453 A	19-03-1968	GB 1188177 A	15-04-1970
		SE 344133 B	27-03-1972
		US 3374453 A	19-03-1968
US 3684991 A	15-08-1972	AT 329672 B	25-05-1976
		AU 4365572 A	03-01-1974
		BE 785906 A1	08-01-1973
		CA 965165 A1	25-03-1975
		CH 583962 A5	14-01-1977
		DE 2233537 A1	15-02-1973
		FR 2145530 A1	23-02-1973
		GB 1388065 A	19-03-1975
		IT 964453 B	21-01-1974
		JP 53035246 B	26-09-1978
		SE 389222 B	25-10-1976
		US 3684991 A	15-08-1972

EPO FORM P0459

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