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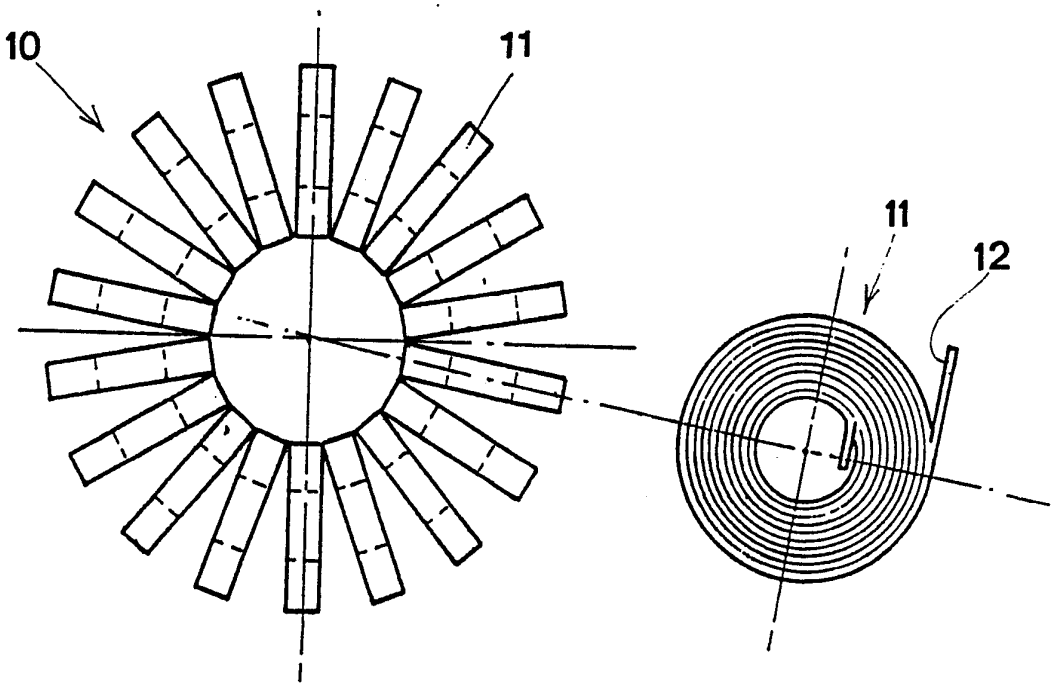
(54) Title: REACTOR HAVING A TOROIDAL MAGNETIC CIRCUIT CONSISTING OF COILS FORMED OF A FLAT CONDUCTOR WOUND SPIRALLY



(57) Abstract

Reactor having a toroidal magnetic circuit (10) exposed to air, consisting of a group of coils (11), obtained from a spirally wound flat conductor (12), mounted radially so that the centres of the spirals are arranged on a circle.

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REACTOR HAVING A TOROIDAL MAGNETIC CIRCUIT CONSISTING OF COILS FORMED OF A FLAT CONDUCTOR WOUND SPIRALLY

In modern power electronics frequent use is made of protection reactors having a magnetic circuit exposed to air, low inductance values but high current values, and harmonic components of relatively high frequency. For reasons of electromagnetic compatibility the magnetic flow of these reactors must remain within them. The toroidal shaped reactor is therefore a preferred configuration since the whole magnetic flow is confined within the inner ring.

To obtain maximum efficiency additional losses must obviously be reduced and inductance remain constant as frequency varies.

Purpose of this present invention is a reactor having a toroidal magnetic circuit giving a high level of efficiency.

To achieve this purpose the reactor is formed of a group of coils, each consisting of a spirally wound flat conductor, said coils being mounted radially so that the

centre of each one coincides with a geometric circle to form a toroid.

In each coil the flat conductor's cross section is rectangular, being so wound that the broad sides of said section lie parallel to the axis of the coil with the beginning and end of the spiral in the centre of each coil and external to it.

This means that the larger dimension, namely the width, of each single flat conductor is parallel to the lines of magnetic flow, and that the smaller dimension, namely the thickness, is crosswise to said lines of flow.

It is possible to have numerous coils in parallel, with thin conductors of this kind that will minimize parassitic effects, caused by the variable magnetic flow through said conductors, and which lead to an uneven distribution of current and consequent additional losses.

The toroidal reactor realized using this constructional technique will therefore have low losses due to high frequency current while inductance value will remain constant as the frequency varies.

The spiral formed by each single coil may be circular or may be a long oval in shape.

The beginning and end of the spiral are in the centre of the coil and external to it.

The toroidal winding is formed of said coils mounted symmetrically.

The beginning and end of the elementary coils are connected in series or in parallel, or in both, so as to create a number of ways in parallel.

Connections are made so that circulating currents together

form the internal magnetic flow.

If z is the total number of coils and k the chosen number of ways in parallel, z/k is the number of coils that will therefore be connected in series.

The empty space between component coils and around the toroid serves for cooling purposes.

There may be numerous coils in parallel, with thin conductors, so as to reduce to the minimum parassitic effects due to the variable magnetic flow that passes through said flat conductors and brings about an uneven distribution of current resulting in additional losses.

Where this constructional technique is adopted to make a toroidal reactor, losses due to high frequency current will be low and inductance value will be maintained constant during variation of frequency.

Total current is in fact evenly split up among the groups in parallel for reasons of symmetry without any need for transpositions. No "circulating" current can exist and losses due to high frequency are greatly reduced.

One variation may be obtained by mounting internally a toroidal-shaped core of magnetic material and this can be divided into several parts or be a single whole; in the latter case the coils must be wound directly onto the core.

One advantage of the core solution is that of obtaining a greater magnetic flow with respect to an equal number of Ampere-turns in the winding.

The structure here described, with or without internal core, can be used not only to obtain an inductor but also to realize a transformer.

In this case part of the elementary coils are primary

and part are secondary; primary and secondary coils may have different numbers of turns, a different cross section of the elementary conductor and also a different configuration.

The flat conductor described may be solid but may also be stranded and flattened.

This latter form is suitable for strong current at high frequency; the advantage consists in the presence of numerous stranded conductors in parallel, all with a small cross section, more easily wound, giving reduced losses and with all ends on the outside.

If I is the total current, n the number of turns in each coil, z the total number of coils and k the number of ways in parallel, the total magnetomotive force acting on the toroid is $I \cdot n \cdot z/k$, while the current that passes through each flat conductor is I/k.

In the event of several elementary coils having to be connected in series, an even number of elementary coils are wound alternatively in one direction and in the other in such a way that both ends are outside the spirals.

By so doing a continuous series of coils can be obtained without any intermediate connections or joins.

A winding is thus formed in which the conductor fills up practically 100% of the space available for it.

Two or more flat conductors of different widths can be used for each spiral.

The narrower conductor is placed internally in the spiral and thus also inside the toroid.

This of course implies one or more joins in each elementary coil.

Characteristics and purposes of the invention will be made

still clearer by the following example of its execution illustrated by diagrammatic drawings.

Example of execution

Fig. 1 Front view of a component coil.

Fig. 2 The same coil seen from the side.

Fig. 3 Side view of the reactor.

Fig. 4 Illustration of how two coils are connected.

The toroid winding 10 comprises component coils 11 each formed of a flat conductor 12 wound spirally.

Said coils are mounted symmetrically so that their centres lie in a circle and form a toroid.

If n = the number of turns in the component coils,

N = the number of turns in series in the toroid,

z = the number of component coils, and

K = the number of ways in parallel

we then have:

$$N = \frac{n\ z}{K}$$

for K = 1: component coils all in series,

for K = z: component coils all in parallel.

The flat conductors in the various coils may be connected in pairs by joining up the internal ends.

Fig. 4 shows how two radial coils 14 and 17 are joined up, drawn on a single geometrical plane.

As will be seen, the inner end 15 of the coil 14 is connected, by means of the length 20 common to both, to the inner end 18 of the coil 17.

The outer ends of coils 14 and 17, respectively 16 and 19, are connected to the other radial coils, in parallel or in series.

CLAIMS

1. Reactor with a toroidal magnetic circuit (10) characterized in that it consists of a group of coils (11) (14) (17),each formed of a spirally wound flat conductor (12), said coils being mounted radially so that their centre coincides with a geometric circle giving rise to a toroid.

2. Reactor as in claim 1, characterized in that each flat conductor (12) of each coil (11) has a rectangular cross section and is wound so that the broad sides of said section lie parallel to the axis of the coil (11) and so that the beginning and end of the spiral are in the centre and outside each coil (11).

3. Reactor as in claim 1, characterized in that the flat conductor (12) is solid.

4. Reactor as in claim 1, characterized in that the flat conductor (12) is made of pressed strands.

5. Reactor as in claim 1, characterized in that the various coils (11) (14) (17) are associated two by two in pairs, connections being made between the inner ends (15) (18) of two adjacent coils (14) (17) which are therefore connected in series as all or part of the various pairs are connected one to another by the external ends (18) (19) of the coils (14 (17) in parallel.

6. Reactor as in claim 1, characterized in that the various coils (11) (14) (17) are associated two by two in pairs by connection between the internal ends (15) (18) of two adjacent coils (14)(17) which are therefore continuously connected in series since all or part of the various pairs are connected one to another by the external ends (16) (19) of the coils (14)(17) in series.

7. Reactor as in claim 1, characterized in that the coils (11) (14) (17) are circular in shape.

8. Reactor as in claim 1, characterized in that the coils (11) (14) (17) are oval in shape.

9. Reactor as in claims 5 and 6, characterized in that the coils (14) (17) of the pair are wound in opposite directions.

10. Reactor as in claim 1, characterized in that the coils (11) (14) (17) are made from two or more flat conductors (12) of different widths, the narrower conductor being placed inside the spiral and thus inside the toroid.

11. Reactor as in claim 1, characterized in that inside the reactor there is a toroidal shaped core of magnetic material, the coils being wound directly onto said core.

12. Reactor as in claim 1, characterized in that the numbers of turns in the coils are different.

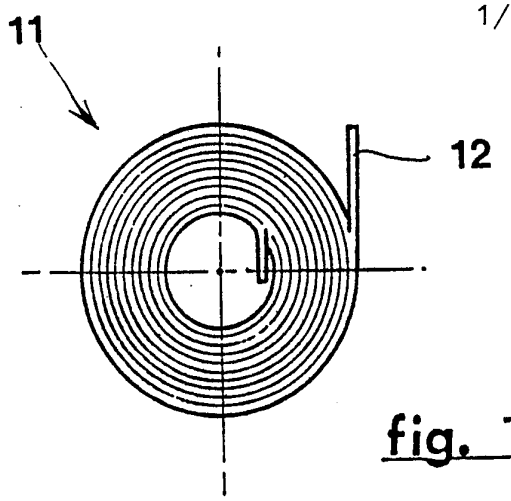

fig. 1

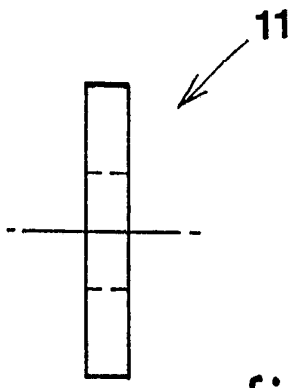

fig. 2

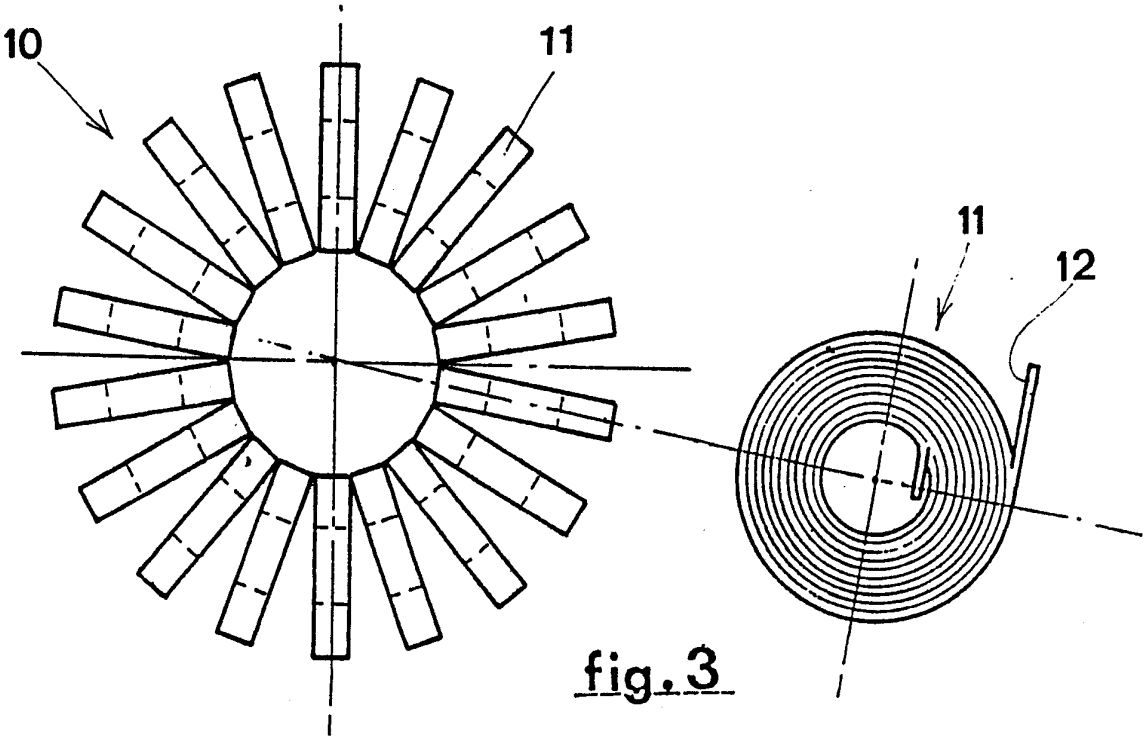

fig. 3

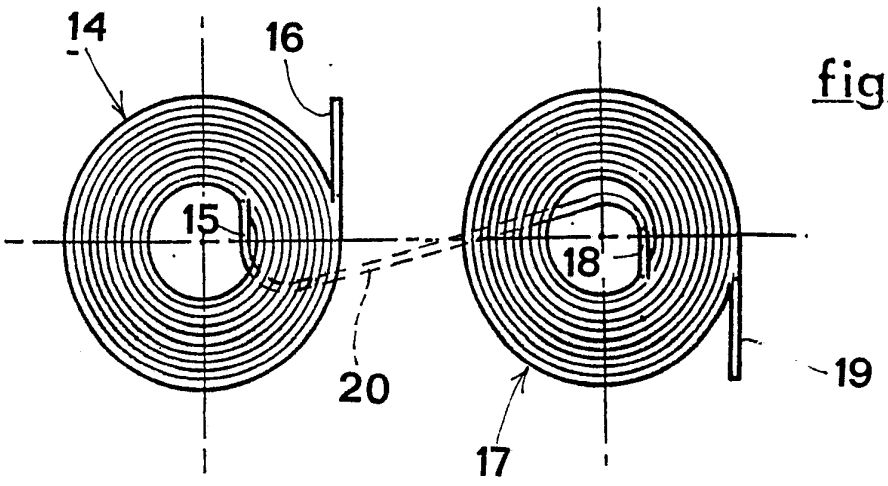

fig. 4

INTERNATIONAL SEARCH REPORT

International Application No PCT/IT 92/00009

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl. 5 H01F27/28

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
Int.Cl. 5	H01F

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched[8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category °	Citation of Document,[11] with indication, where appropriate, of the relevant passages[12]	Relevant to Claim No.[13]
X	US,A,4 631 509 (ARII ET AL) 23 December 1986 see column 1, line 6 - line 13 see column 2, line 29 - line 60; figures	1,3
A		2,11

X	US,A,4 639 707 (TANAKA ET AL) 27 January 1987 see column 1, line 64 - column 2, line 25 see column 3, line 12 - line 68; figures	1,3
A		2,11

A	US,A,2 521 513 (GRAY) 5 September 1950 see column 3, line 34 - line 62; figure 1	1-3,7

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
25 MAY 1992	01 JUN 1992
International Searching Authority	**Signature of Authorized Officer**
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ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO. IT 9200009 SA 56719

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 25/05/92
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US-A-4631509	23-12-86	None	
US-A-4639707	27-01-87	None	
US-A-2521513		None	