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(54) **INTEGRATED REACTANCE MODULE**

INTEGRIERTES REAKTANZMODUL

MODULE DE RÉACTANCE INTÉGRÉ

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- **SAKAMOTO H ET AL: "A MAGNETIC COUPLED CHARGER WITH NO-LOAD PROTECTION", IEEE TRANSACTIONS ON MAGNETICS, IEEE SERVICE CENTER, NEW YORK, NY, US, vol. 34, no. 4, PART 01, 1 July 1998 (1998-07-01), pages 2057-2059, XP000833270, ISSN: 0018-9464, DOI: DOI:10.1109/20.706793**

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Description

TECHNICAL FIELD

[0001] The present invention relates to an integrated reactance module intended for use in DC/DC resonant converters and particularly to contactless energy transfer circuits enabling safe and sparkless connection of electrical devices.

BACKGROUND ART

[0002] Inductive contactless energy transfer systems are particularly suitable for environments where gas or dust ignition hazard occurs, such as mines, fuel stations and chemical laboratories, as well as those environments where the use of direct connections is impracticable, such as implants or rotating components.

[0003] Contemporary DC/DC resonant converters comprise a number of inductive elements which, depending on the applied resonant circuit, can additionally be magnetically coupled or magnetically non-coupled. The cylindrical shape of inductive elements is not suited for optimal utilization of mounting surface area. Where a plurality of inductive elements is used, the distances between inductive elements should be increased in order to avoid undesired couplings. In such case integrated inductive elements may advantageously be used.

[0004] A prior art inductive module known from the US Patent No. 7,598,839 comprises N inductors and N+1 core elements. Each magnetic element has a cavity to situate a winding. These magnetic elements are stacked in such a manner that the back of a preceding magnetic element closes the magnetic circuit of a subsequent magnetic element.

[0005] A structure described in the US Patent No. 7,525,406 comprises a plurality of coupling and non-coupling inductive elements and at least one closed magnetic circuit composed of adjacent magnetic elements, which have penetrated grooves for electric current conductors along an X-axis and a Y-axis orthogonal to the X-axis. The current conductors situated along the same axis provide mutual inductance whereas there is no coupling between mutually orthogonal current conductors.

[0006] From the US Patent No. 7,242,275 there is known a variable inductive element immune to high voltage between a control circuit and the controlled inductance. This variable inductor includes two cores of a permeable magnetic material formed in the shape of the letter "E" having three legs, including a centre leg and two outer legs. The main winding is wound around the centre leg of the first core, whereas the control winding is wound around the outer legs of the second core. Both cores are separated by means of a dielectric insulating spacer. The use of an additional magnetic flux conductor is optional. The described variable inductive element is intended for use in voltage converter resonant circuits.

[0007] The aforementioned examples illustrate embodiments of integrated reactance elements and an embodiment of a controlled reactance element. These components can be used in typical DC/DC resonant converters implementations. However, the aforementioned integrated reactance elements are not entirely suitable for use in resonant converters that provide contactless energy transfer to a separate receiver. For example, a contactless energy transfer circuit is known from the Polish patent application No. P-381975. This circuit comprises a plurality of reactance elements in its transmitter part and an inductive element including a magnetic element in a portable receiver part. For the purpose of said disconnectable and contactless energy converter it is advisable to develop a specific integrated reactance module, which would include all essential inductive power elements. This module should also ensure reliable operation with open magnetic circuit, optimal energy transfer to a receiver with closed, or partially closed, magnetic circuit, and allow for correction of the resonant frequency changes caused by proximity of an inductive receiving element.

[0008] The US patent US4675638 and the German patent application DE3802062A1 present integrated reactance modules, comprising a magnetic element and a plurality of coaxial windings of reactance power elements separated from each other with magnetic flux conductors constituting an integral part of the magnetic element, wherein all the windings of reactance power elements are situated inside the magnetic element

[0009] In an article "A magnetic coupled charger with no-load protection" by Sakamoto H et al. (IEEE Transactions on Magnetics vol. 34 no. 4, part 01, 1 July 1998), pages 2057-2059, ISSN: 0018-9464) there is presented an integrated reactance module (Fig. 6), comprising a winding of reactance power elements (N_{M1}) situated inside a magnetic element and a winding of a control circuit (NF_2) situated outside the magnetic element. The winding of a control circuit is not used directly for transmitting power but only for control of the power transmission, therefore it is not a winding of reactance power element.

DISCLOSURE OF THE INVENTION

[0010] The integrated reactance module according to the invention has windings of integrated reactance elements situated in a common magnetic element and magnetically isolated and separated from each other by means of magnetic flux conductors being an integral part of the magnetic element. The magnetic element is specifically designed for concentration of magnetic field lines produced by the said reactance elements.

BRIEF DESCRIPTION OF DRAWINGS

[0011] The object of the invention is shown in exemplary embodiments in drawings, where:

Fig. 1 shows the view of the integrated reactance module and the reactance receiving element,

Fig. 2 shows an example of application circuit which utilizes reactance elements of the integrated module shown in Fig. 1,

Fig. 3 shows a simplified version of the integrated reactance module, and

Fig. 4 shows the proposed application circuit of the simplified reactance module according to Fig. 3.

MODES FOR CARRYING OUT THE INVENTION

Exemplary embodiment I

[0012] The integrated reactance module ZMR shown in Fig. 1 comprises reactance elements L1, L2, L3 situated on a magnetic element EM and separated from each other by magnetic flux conductors SM. Such module is applicable to a device for contactless charging of batteries of portable mining equipment. The device for contactless charging of portable mining equipment, shown in Fig. 2, comprises an arrangement of current switches K1, K2, connected with the reactance elements L1, L2, L3 of the integrated reactance module and auxiliary reactance elements C1, C2, C3, C4, C5. The reactance element L1 in connection with the reactance element C1 constitutes the main resonant circuit, wherein the main portion of the energy of the whole circuit is stored. The magnetic element EM provides concentration of magnetic field lines. The magnetic field energy from the neighbourhood of this element can be received by means of the reactance receiving element L4 provided with the magnetic receiving element EMO. Both magnetic elements EM and EMO are separated by means of an insulating spacer I. When the reactance receiving element L4 is brought close, an alternating voltage is induced across its terminals, which after rectification is applied to the battery of portable mining equipment. The reactance elements L2, L3 ensure optimum commutation conditions for the switches K1, K2. The diodes D1, D2 limit the maximum values of voltage and current in the main resonant circuit, thereby ensuring reliable operation in transient states when rapid changes in operating conditions occur. The reactance elements L2 and L3 integrated with the reactance element L1 enable correction of self-resonant frequency of the main resonant circuit.

[0013] The integrated reactance module ZMR according to the invention allows energy transfer to the reactance element L4 incorporated within the energy receiver. Owing to the fact that all three reactance power elements L1, L2, L3 are incorporated in a single magnetic element EM, the structure comprising the resonant circuits is compact and the connections between the reactance elements are contained within the module. The integral structure of the integrated reactance elements allows for "parametric" correction of the resonant frequency correction depending on the distance from reactance receiving element. Such correction is particularly advantageous if the commutation circuit operates at a set frequency. Then, in case of connecting the load by bringing close the reactance receiving element L4, the self-resonant frequency of the main resonant circuit will be tuned towards higher frequencies. Since the reactance receiving element L4 is provided with the magnetic element EMO, its approaching to the integrated reactance module ZMR changes the reluctances of the other reactance elements L2, L3 and, consequently, their reactances will increase. Since both reactance elements L2, L3 are connected with the main resonant circuit, a partial correction of self-resonant frequency of the main resonant circuit is possible. This property allows for construction of simple and highly reliable converters without the need for complex systems of output parameters control.

Exemplary embodiment II

[0014] A simplified version of the integrated reactance module ZMR, shown in Fig. 3, is applicable to a device for contactless charging of batteries of miner's lamps. The module comprises reactance elements L1, L2 situated on the magnetic element EM and separated from each other by means of the magnetic flux conductor SM. The device for contactless charging of batteries of miner's lamps, as shown in Fig. 4, includes an arrangement of current switches K1, K2, connected with reactance elements L1, L2, of the integrated reactance module and auxiliary reactance elements C1, C2, C3, C4, C5. The reactance element L1, in connection with the reactance element C1 constitutes the main resonant circuit wherein the main portion of the energy of the whole circuit is stored. The magnetic element EM provides concentration of magnetic flux. The magnetic field energy from the neighbourhood of this element can be received by means of the reactance receiving element L4 provided with the magnetic receiving element EMO. Both magnetic elements EM and EMO are separated by means of an insulating spacer I. As a result of nearing the reactance receiving element L4, an alternating voltage is induced across its terminals, which after rectification is applied to the battery of the miner's lamp.

Claims

1. A contactless energy transfer circuit, comprising a magnetic receiving element (EMO) comprising a reactance receiving element (L4) configured to receive magnetic field energy from an integrated reactance module comprising a magnetic element (EM) and a plurality of coaxial windings of reactance power elements (L1), (L2) ... (LN), separated from each other by means of magnetic flux conductors (SM) constituting an integral part of the magnetic element (EM), which is configured to concentrate magnetic field lines generated by the reactance power elements (L1), (L2) ... (LN), **characterized in that** the outermost winding of reactance power elements (L2) is

situated outside the magnetic element (EM) and the other windings of reactance power elements (L1), (L3) ... (LN) are situated inside the magnetic element (EM), wherein the magnetic receiving element (EMO) is separated from the magnetic element (EM) by an insulating spacer (I).

2. The contactless energy transfer circuit according to claim 1, wherein the outermost winding of reactance power elements (L2) is connected in series with a capacitive reactance power element (C2, C3) and at least one other winding of reactance power elements (L1), said other winding of reactance power elements being connected in parallel with another capacitive reactance power element (C1) for constituting a main resonant circuit, in which the main portion of the energy of the whole circuit is stored, thereby forming a series-parallel LCLC-type tank circuit.

Patentansprüche

1. Kontaktloser Energieübertragungsschaltkreis, aufweisend ein magnetisches Empfangselement (EMO), aufweisen ein Reaktanz empfangendes Element (L4), das konfiguriert ist für einen Empfang von magnetischer Feldenergie von einem integrierten Reaktanzmodul, aufweisend ein magnetisches Element (EM) und mehrere Koaxialwicklungen von Reaktanzstromelementen (L1), (L2) ... (LN), die durch Magnetflussleiter (SM) voneinander getrennt sind, die einen integrierten Teil des magnetischen Elements (EM) bilden, das konfiguriert ist für ein Konzentrieren der vom Reaktanzstromelement (L1), (L2) ... (LN) erzeugten Magnetfeldlinien, **dadurch gekennzeichnet, dass** die äußerste Wicklung von Reaktanzstromelementen (L2) außenseitig des Magnetelements (EM) und die anderen Wicklungen von Reaktanzstromelementen (L1), (L3) ... (LN) innenseitig des Magnetelements (EM) angeordnet sind, wobei das magnetische Empfangselement (EMO) durch einen isolierenden Abstandhalter (I) vom magnetischen Element (EM) getrennt ist.

2. Kontaktloser Energieübertragungsschaltkreis nach Anspruch 1, wobei die Wicklung von Reaktanzstromelementen (L2) in Reihe mit einem kapazitiven Reaktanzstromelement (C2, C3) geschaltet ist und wenigsten eine andere Wicklung von Reaktanzstromelementen (L1) aufweist, wobei die andere Wicklung von Reaktanzstromelementen parallel mit einem anderen kapazitiven Reaktanzstromelement (C1) geschaltet ist, um einen Hauptresonanzkreis zu bilden, in dem der Hauptteil der Energie des gesamten Schaltkreises gespeichert ist, wodurch ein seriell-paralleler Tankschaltkreis vom LCLC-Typ gebildet wird.

Revendications

1. Circuit de transfert d'énergie sans contact, comprenant un élément de réception magnétique (EMO) comprenant un élément de réception de réactance (L4) configuré pour recevoir une énergie de champ magnétique à partir d'un module de réactance intégré comprenant un élément magnétique (EM) et une pluralité d'enroulements coaxiaux d'éléments de puissance de réactance (L1), (L2) ... (LN), séparés l'un de l'autre au moyen de conducteurs de flux magnétique (SM) faisant partie intégrante de l'élément magnétique (EM), qui est configuré pour concentrer des lignes de champ magnétique générées par les éléments de puissance de réactance (L1), (L2) ... (LN), **caractérisé en ce que** l'enroulement le plus extérieur des éléments de puissance de réactance (L2) est situé à l'extérieur de l'élément magnétique (EM) et les autres enroulements des éléments de puissance de réactance (L1), (L3) ... (LN) sont situés à l'intérieur de l'élément magnétique (EM), dans lequel l'élément de réception magnétique (EMO) est séparé de l'élément magnétique (EM) par une entretoise isolante (I).

2. Circuit de transfert d'énergie sans contact selon la revendication 1, dans lequel l'enroulement le plus extérieur des éléments de puissance de réactance (L2) est relié en série à un élément de puissance de réactance capacitif (C2, C3) et à au moins un autre enroulement des éléments de puissance de réactance (L1), ledit autre enroulement des éléments de puissance de réactance étant relié en parallèle à un autre élément de puissance de réactance capacitif (C1) pour constituer un circuit résonnant principal, dans lequel la portion principale de l'énergie du circuit complet est stockée, en constituant de ce fait un circuit de réservoir de type LCLC série-parallèle.

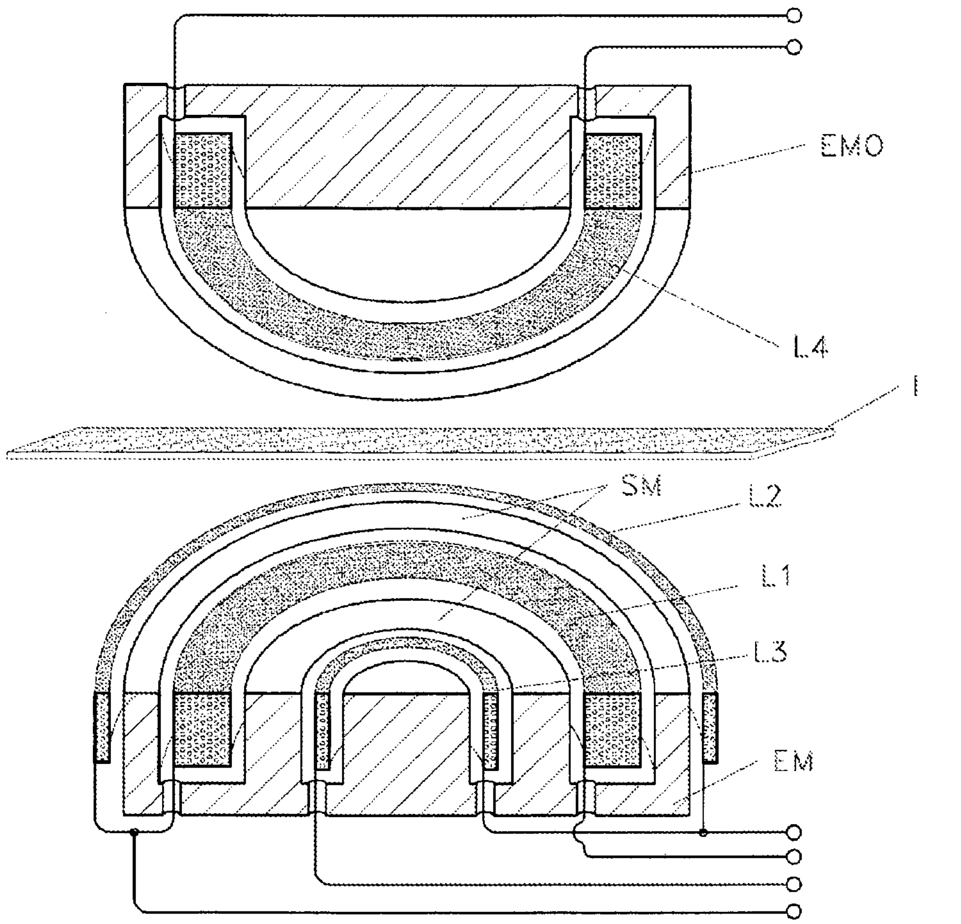

Fig. 1

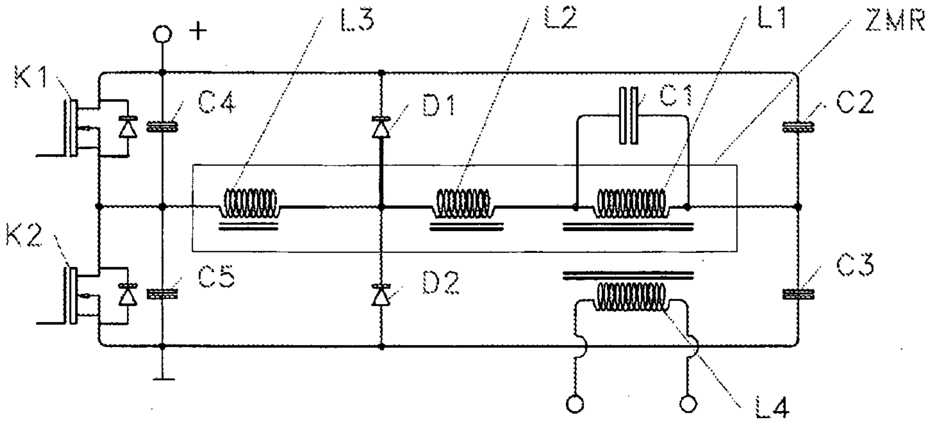

Fig. 2

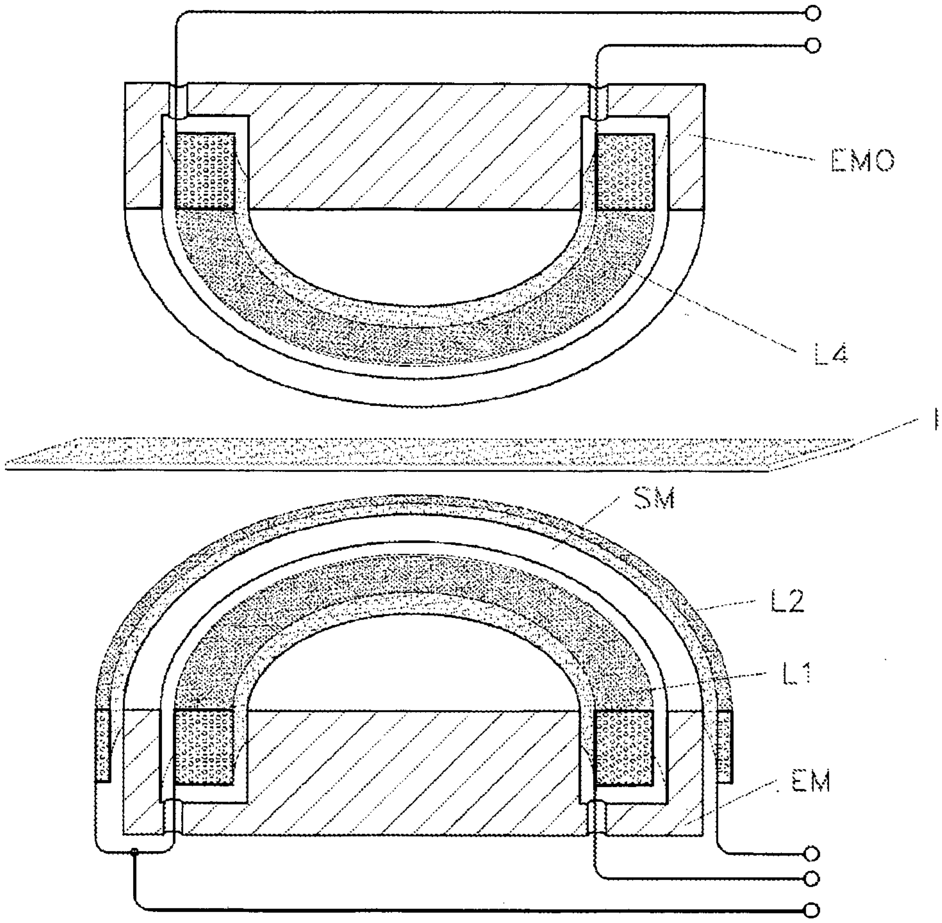

Fig. 3

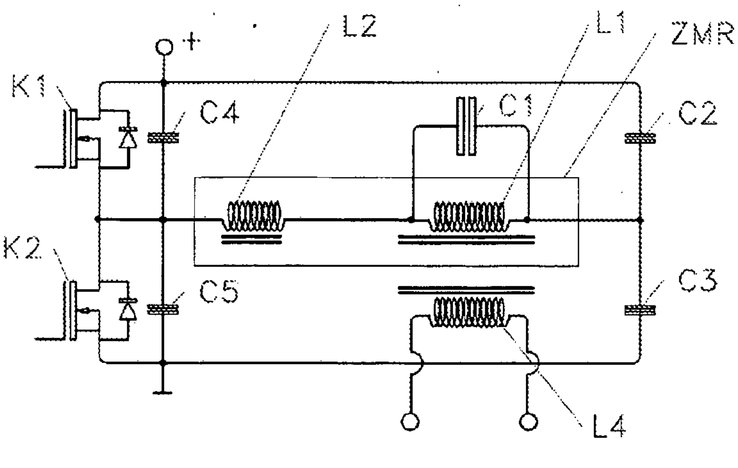

Fig. 4

REFERENCES CITED IN THE DESCRIPTION

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