(19) DANMARK

(10) **DK/EP 3710106 T3**

Patent- og
Varemærkestyrelsen

(12) Oversættelse af
europæisk patentskrift

(51) Int.Cl.: ***A 61 N 1/40 (2006.01)***

(45) Oversættelsen bekendtgjort den: **2022-05-23**

(80) Dato for Den Europæiske Patentmyndigheds
bekendtgørelse om meddelelse af patentet: **2022-03-09**

(86) Europæisk ansøgning nr.: **18829903.6**

(86) Europæisk indleveringsdag: **2018-11-16**

(87) Den europæiske ansøgnings publiceringsdag: **2020-09-23**

(86) International ansøgning nr.: **GB2018053335**

(87) Internationalt publikationsnr.: **WO2019097254**

(30) Prioritet: **2017-11-17 GB 201719104**

(84) Designerede stater: **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**

(73) Patenthaver: **Hofmeir Magnetics Limited, The Old Chapel , Union Way, Witney, Oxfordshire OX28 6HD, Storbritannien**

(72) Opfinder: **BEDDARD, Paul, c/o Hofmeir Magnetics Limited, The Old Chapel, Union Way, Witney, Oxfordshire CX28 6HD, Storbritannien**

(74) Fuldmægtig i Danmark: **Plougmann Vingtoft A/S, Strandvejen 70, 2900 Hellerup, Danmark**

(54) Benævnelse: **PULSERET ELEKTROMAGNETISK FELTTERAPIINDRETNING**

(56) Fremdragne publikationer:
EP-A1- 2 874 297
EP-A1- 3 101 779
EP-A2- 0 305 791
EP-B1- 0 305 791
CN-U- 205 598 428
GB-A- 1 495 391
US-A1- 2003 026 113
US-A1- 2015 333 801

DESCRIPTION

Field of the Invention

[0001] The present invention relates to a pulsed electromagnetic field therapy device.

Background of the Invention

[0002] Pulsed electromagnetic fields may be used to provide a physiological effects. For example, pulsed electromagnetic fields may be used for nerve or brain stimulation, or for providing therapeutic benefits (such as treating ailments like joint and muscle pain, and assisting with the healing of broken bones and fractures).

[0003] A number of pulsed electromagnetic field therapy devices are available which produce pulsed electromagnetic fields to provide a physiological effect. They typically include a resonant circuit formed from a capacitor connected to a coil looped inductor through a switch (such as a semiconductor or spark gap switch). With the switch open, the capacitor can be pre-charged before closing the switch to discharge the capacitor into the inductor to initiate oscillation of the resonant circuit. The resonant circuit then oscillates until losses dissipate the energy stored in the resonant circuit. As the resonant circuit oscillates, it generates a sequence of electromagnetic oscillations in the coil looped inductor which is placed adjacent to, or around, a part of the body where the physiological effect of the pulsed electromagnetic field is desired.

[0004] Existing pulsed electromagnetic field therapy devices operate at extremely high voltages (typically thousands of Volts). As a result of these high voltages, expensive high voltage capacitors and switches are required, which makes existing pulsed electromagnetic field therapy devices very expensive to manufacture. Additionally, the high voltages represent a safety risk to the operator and patient, particularly as the design of many existing pulsed electromagnetic field therapy devices are susceptible to lethal single point failures, for example, in a case where the insulation of the coil looped inductor becomes damaged. Therefore, it would be desirable to find a way to generate a pulsed electromagnetic field to provide a physiological effect in a way which eliminates the risks associated with these extremely high voltages.

[0005] Oscillations are damped by resistance losses in the components of the resonant circuit, particularly the semiconductor switch. As a result, existing pulsed electromagnetic field therapy devices are limited to a fairly short decay time, and it would be desirable to increase the decay time so that a physiological effect can be provided over a longer period.

[0006] It is common for existing pulsed electromagnetic field therapy devices to have a very high initial discharge current (typically many kAs). Voltage reflections from components in the resonant circuit, for example from a semiconductor switch which is nearly impossible to impedance match with the resonant circuit, result in high power and broad spectrum radio-frequency transmissions for the first few microseconds of the electromagnetic oscillations. Such radio-frequency interference causes existing pulsed electromagnetic field therapy devices to interfere with other electronic devices or wireless communications networks in the vicinity, and may mean that existing pulsed electromagnetic field therapy devices do not meet regulatory requirements, such as regulations regarding electromagnetic interference.

[0007] Document EP 3 101 779 A1 discloses a magnetic field generator for use in magnetic induction heating or hyperthermia treatment with a drive capacitor with a second terminal which is in electrical communication with first terminal of the tank circuit. However, it is not directed to a pulsed electromagnetic field therapy device.

[0008] It would, therefore, be desirable to develop a pulsed electromagnetic field therapy device which overcomes, or at least mitigates, some or all of these problems.

Summary of the Invention

[0009] The invention is defined in claim 1. Further aspects and preferred embodiments are defined in the appended claims. Aspects, embodiments and examples of the present disclosure which do not fall under the scope of the appended claims do not form part of the invention and are merely provided for illustrative purposes. Furthermore, the methods presented in the present description are provided for illustrative purposes only and do not form part of the present invention.

[0010] According to the invention, there is provided a pulsed electromagnetic field therapy device. The parallel resonant circuit comprises a capacitor connected in parallel with an inductor without a switch between the capacitor and the inductor. That is, there is no switch forming a component of the parallel resonant circuit. The parallel resonant circuit may be formed from a capacitor connected directly to the inductor, or the capacitor may be coupled to the inductor via intervening components other than a switch. The parallel resonant circuit is configured to generate a pulsed electromagnetic field in the inductor while electrical energy is stored in the parallel resonant circuit. The inductor is configured to be placed relative to a part of a body to provide the pulsed electromagnetic field to the part of the body. The pulsed electromagnetic field therapy device further comprises a power source and a switch, where the switch is external to the parallel resonant circuit. That is, the switch is not located between the capacitor and the inductor in the parallel resonant circuit. Rather, the switch selectively connects the power source parallel to the parallel resonant circuit. The switch is configured to selectively connect the parallel resonant circuit to the power source for a current ramping period. During the current ramping period, a current in the inductor is increased to reach a desired current.

[0011] Unlike prior art pulsed electromagnetic field therapy devices, the pulsed electromagnetic field therapy device of the present invention has a parallel resonant circuit which does not require a switch (such as a semiconductor or spark gap switch) to be an integral component of the parallel resonant circuit to selectively power the parallel resonant circuit. By having a switch external to the parallel resonant circuit instead, when current flows around the parallel resonant circuit, it does not pass through a switch on each pass which would unnecessarily dissipate energy stored in the parallel resonant circuit through resistance losses in the switch. Moreover, suitable high voltage switches which can be used as a component of the parallel resonant circuit of a pulsed electromagnetic field therapy device are expensive. Therefore, by having a switch external to the parallel resonant circuit rather than as a component of the parallel resonant circuit, manufacturing costs are significantly reduced and resistance losses from the switch are eliminated. Without these resistance losses from the switch, the decay time of the pulsed electromagnetic field generated by the parallel resonant circuit is greatly increased, thereby increasing the time period over which a physiological effect in generated. Also, the desired current required to obtain a desired time period over which a physiological effect is achieved is much less.

[0012] Moreover, by having a switch external to the parallel resonant circuit rather than as a component of the parallel resonant circuit, it is possible to ramp the current over a period of time (the current ramping period). In contrast, prior art pulsed electromagnetic field therapy devices with a switch as a component of the parallel resonant circuit cause charge from the pre-charged capacitor to be dumped nearly instantaneously into the resonant circuit when the switch in the parallel resonant circuit is closed. The high voltages in the prior art, which are necessary to achieve the high currents needed to overcome resistance losses in the high voltage switch, cause a surge of current in the resonant circuit as soon as the switch is closed. This sudden surge in current in the resonant circuit can result in reflections from the high voltage switch (which intrinsically lacks impedance matching with the resonant circuit) resulting in significant voltage and current spikes and electromagnetic interference which can be harmful to nearby electrical devices. In contrast, increasing the current over the current ramping period, which is made possible by the switchless parallel resonant circuit of the present invention, reduces noise and interference caused by the pulsed electromagnetic field therapy device, which helps the pulsed electromagnetic field therapy device meet regulatory requirements, such as regulations regarding electromagnetic interference.

[0013] Pulsed electromagnetic fields may be used to provide a physiological effect. For example, a pulsed electromagnetic field may be used for nerve or brain stimulation, or for providing therapeutic benefits (such as treating ailments like joint and muscle pain, and assisting with the healing of broken bones and fractures). The inductor may be placed adjacent to, or around, a part of the body (such as a joint or limb) where the physiological effect of the pulsed electromagnetic field is required. The inductor may be a coil looped inductor. The coil looped inductor may be placed adjacent to, or around, a part of the body (such as a joint or limb) where the physiological effect of the pulsed electromagnetic field is required.

[0014] The switch external to the parallel resonant circuit is closed during the current ramping period. The switch external to the parallel resonant circuit is open outside the current ramping period. Therefore, during oscillation of the parallel resonant circuit, the switch is disconnected from the parallel resonant circuit and does not dissipate the energy stored in the parallel resonant circuit through resistance losses nor does the switch lead to reflections.

[0015] A charge stored in the capacitor before the switch external to the parallel resonant circuit is closed may be zero.

[0016] A current in the inductor may be increased over the current ramping period. The rate of change of the current in the inductor may be a function of the power source voltage. The length of the current ramping period may be based on the power source voltage and the desired current at the end of the current ramping period.

[0017] The current ramping period may be one of: greater than 1 µs; greater than 10 µs; between 1 µs and 50 µs; between 10 µs and 50 µs; and between 10 µs and 100 µs, preferably between 1 µs and 100 µs;

[0018] The desired current at the end of the current ramping period may be in the range of one of: 10A and 2000 A; 100 A and 2000 A; 200 A and 2000 A; 200 A and 1600 A; and 500 A and 1600 A; preferably 500 A and 2000 A.

[0019] The pulsed electromagnetic field may be an oscillation, such as a sinusoidal oscillation, caused by oscillation of the parallel resonance circuit.

[0020] The pulsed electromagnetic field may have a frequency of one of: less than 1 MHz; less than 200 KHz; and less than 100 KHz; preferably less than 250 KHz. Prior art pulsed electromagnetic field therapy devices are intended to operate at around 250 KHz but with a spread spectrum of up to 300 MHz as a result of interference. Operating at these high frequencies, and producing even higher frequencies through interference, means that prior art pulsed electromagnetic field therapy devices are prone to interfering with other electronic devices and radio communications networks. However restrictions on the availability of electronic components, the physical size of electronic components, and the presence of the semiconductor switch in the parallel resonant circuit makes it difficult for prior art pulsed electromagnetic field therapy devices to operate at lower frequencies. However, without the limitation of having a high voltage switch in the parallel resonant circuit and instead having the switch external to the parallel resonant circuit, the pulsed electromagnetic field therapy device of the present invention can operate at lower frequencies, which prevents the pulsed electromagnetic field therapy device from interfering with other electronic devices and radio communications networks.

[0021] The switch external to the parallel resonant circuit may be open while the parallel resonant circuit is generating at least a portion of the pulsed electromagnetic field. Because the switch in the prior art forms an integral part of the parallel resonant circuit, acting to form at least a part of the electrical connection between the inductor and capacitor of the parallel resonant circuit, the switch necessarily has to be closed for the resonant circuit of the prior art to generate a pulsed electromagnetic field, which leads to resistance losses in the switch. In contrast, in the present invention, the switch is external to the parallel resonant circuit and does not form a necessary link between the inductor and capacitor of the parallel resonant circuit. Therefore, the switch can be open while the parallel resonant circuit generates the pulsed electromagnetic field (oscillates) avoiding resistance losses in the switch.

[0022] The parallel resonant circuit may be galvanically isolated from the power source. The inductor and other components of the parallel resonant circuit are floating, and therefore safe to touch even if insulation surrounding the inductor or other components were damaged. The galvanic isolation may comprise a transformer.

[0023] The pulsed electromagnetic field therapy device may comprise a further switch external to the parallel resonant circuit and a rectifier to selectively couple the parallel resonant circuit back to a capacitor of the power supply. Closing the further switch may recharge the capacitor of the power supply from the parallel resonant circuit. This substantially reduces oscillation of the parallel resonant circuit and allows at least a portion of the electrical energy remaining in the parallel resonant circuit to be recycled back into the power supply capacitor.

[0024] The power supply may be a single high value capacitor, or a capacitor bank comprising a plurality of capacitors.

[0025] The further switch may couple the parallel resonant circuit to the power supply when the current in the parallel resonant circuit is below a current threshold. The current threshold may be selected based on a current below which little or no significant physiological effect is observed, or below which insufficient physiological effect is observed to meet the needs of a particular physiological or therapeutic application. The physiological current threshold may be 200 A. Once the current in the parallel resonant circuit has dropped below the current threshold, the further switch and rectifier may couple the parallel resonant circuit back to the power supply, thereby recycling at least some of the electrical energy stored in the parallel resonant circuit back into the power supply, which saves considerable electrical energy that might otherwise be wasted generating a pulsed electromagnetic field which provides little or no physiological benefit.

[0026] The switch external to the parallel resonant circuit and/or further switch may receive switching signals over an optical link, for example, a fibre optic cable. Providing switching signals over an optical link reduces high voltage interference which might cause incorrect switching and helps to maintain the galvanic isolation of the parallel resonant circuit.

[0027] The device may be configured to generate a pulsed electromagnetic field discontinuously. The current in the inductor may be ramped and the charge in the parallel resonant circuit may be allowed to decay (or may be quenched, for example, using the further switch). The current may be ramped again immediately or a period of time (such as 100 ms) may be allowed to elapse before the current is ramped again. Having a period when the device is not generating a pulsed electromagnetic field may be desirable to avoid overexposure of a patient to the pulsed electromagnetic field. The duty cycle may be less than 5% (that is, the device may generate a pulsed electromagnetic field for 5% of the time while the device is not generating a pulsed electromagnetic field for 95% of the time). Alternatively, the duty cycle may be less than 1%.

Brief Description of the Drawings

[0028] The invention shall now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 is a simplified circuit diagram of a prior art pulsed electromagnetic field therapy device;

Figure 2a is an example of an oscilloscope trace showing voltage as a function of time in a resonant circuit of the prior art pulsed electromagnetic field therapy device of Figure 1;

Figure 2b is a close-up of the oscilloscope trace in Figure 2a, illustrating interference observed at the start of the electromagnetic oscillations in the prior art pulsed electromagnetic field therapy device of Figure 1;

Figure 3 illustrates a pulsed electromagnetic therapy device according to an embodiment of the present invention;

Figure 4 is an example of an oscilloscope trace showing the current in the resonant circuit of Figure 3 as a function of time; and

Figure 5 is an example of a pulsed electromagnetic field therapy device according to an alternative embodiment of the present invention.

Detailed Description

[0029] Figure 1 is a simplified circuit diagram of a prior art pulsed electromagnetic field therapy device 10. The pulsed electromagnetic field therapy device 10 has a resonant circuit 11 with a capacitor 12 connected to a semiconductor switch 14 and a coil looped inductor 16.

[0030] When the semiconductor switch 14 is open, the capacitor 12 is charged from a high voltage circuit (not shown). Closing the semiconductor switch 14 discharges the capacitor 12 into the coil looped inductor 16, initiating oscillation of the resonant circuit 11.

[0031] Figures 2a and 2b show different views of the same oscilloscope trace of the voltage in the resonant circuit 11 as a function of time. The resonant circuit 11 generates a damped oscillation 18 in the coil looped inductor 16. Figure 2a shows the entire sequence of oscillations until the oscillations completely decay, while Figure 2b shows a close-up view of the start of the oscillations.

[0032] The coil looped inductor 16 is placed adjacent to, or around, a part of the body (such as a limb or joint) where the physiological effect of the pulsed electromagnetic field is desired. With the semiconductor switch 14 closed, the resonant circuit 11 oscillates until losses in the resonant circuit 11 dissipate all of the energy stored in the resonant circuit 11. Resistance losses in the resonant circuit 11 are high. The semiconductor switch 14 being an integral part of the electrical connection between the coil looped inductor 16 and the capacitor 12 in the resonant circuit 11 incurs resistance losses which quickly cause the energy stored in the resonant circuit 11 to decay. Rapid decay limits the time period over which a pulsed electromagnetic field provides a physiological effect. In an attempt to maximise the decay time, the capacitor 12 is charged to a high voltage (typically 10 kV - 25 kV) to achieve a high discharge current (of the order of 2 kA - 3 kA).

[0033] The need to operate at such a high voltage and current cause a whole host of issues with the design and operation of the pulsed electromagnetic field therapy device 10. An expensive high voltage capacitor 12 and semiconductor switch 14 is required, which makes it expensive to manufacture the pulsed electromagnetic field therapy device 10. Additionally, the high voltages represent a safety risk to the operator and patient, particularly as the design of many existing pulsed electromagnetic field therapy devices, like the pulsed electromagnetic field therapy device 10, do not take steps to prevent lethal single point failures, for example, in a case where the insulation of the coil looped inductor 16 becomes damaged.

[0034] The high voltage to which the capacitor 12 is initially charged causes a high initial current discharge from the capacitor 12 which leads to voltage reflections from components within the resonant circuit 11, particularly the semiconductor switch 14. Given the complicated electrical characteristics of semiconductor switch 14 which are needed to handle the high voltages and currents present in the resonant circuit 11, it is virtually impossible to impedance match the semiconductor switch 14 with the rest of the resonant circuit 11. As a result of the impedance mismatch, the semiconductor switch 14 causes voltage reflections which lead to high power broad spectrum radio-frequency interference 19 being observed for the first few microseconds of the electromagnetic oscillations (as shown in Figure 2b). Such radio-frequency interference causes the pulsed electromagnetic field therapy device 10 to interfere with other electronic devices or wireless communications networks in the vicinity, and may mean that the pulsed electromagnetic field therapy device 10 does not meet regulatory requirements, such as regulations regarding electromagnetic interference.

[0035] Figure 3 illustrates a pulsed electromagnetic field therapy device 20 according to an embodiment of the present invention. The pulsed electromagnetic field therapy device 20 has been designed to overcome the above-mentioned shortcomings with existing pulsed electromagnetic field therapy devices, such as pulsed electromagnetic field therapy device 10 described in relation to Figures 1 and 2.

[0036] The pulsed electromagnetic field therapy device 20 has a parallel resonant circuit 21 with a capacitor 22 in parallel with a coil looped inductor 26. A current ramping circuit 25 is external to the parallel resonant circuit 21 and connected in parallel to the parallel resonant circuit 21. The current ramping circuit 25 includes a high current capability capacitor 23 which provides a voltage of around 50 V - 350 V (typically 150 V) and a current of around 100 A - 2000 A. A semiconductor switch 24 selectively connects the high current capability capacitor 23 to the parallel resonant circuit 21 to ramp-up the current in the coil looped inductor 26.

[0037] The oscilloscope trace in Figure 4 shows the current in the parallel resonant circuit 21 as a function of time. The semiconductor switch 24 is closed at t_0 for a current ramping period (indicated by reference numeral 30 in Figure 4) of about 50 µs to ramp-up the current in the coil looped inductor 26. At the end of the current ramping period at t_1, the semiconductor switch 24 is opened, disconnecting the current ramping circuit 25 from the parallel resonant circuit 21 and preventing further increase in the current in the coil looped inductor 26. At the end of the current ramping period, the current in the coil looped inductor 26 has reached a desired current of 1500 A, which is sufficient to provide a physiological effect.

[0038] At the end of the current ramping period at t_1, and with the semiconductor switch 24 open, the current in the coil looped inductor 26 initiates oscillation of the parallel resonant circuit 21. As illustrated by the oscilloscope trace in Figure 4, the parallel resonant circuit 21 generates a sequence of damped sinusoidal oscillations 28 in the coil looped inductor 26. The coil looped inductor 26 is placed adjacent to, or around, a part of the body (such as a limb or joint) where the physiological effect of the pulsed electromagnetic field is desired.

[0039] The parallel resonant circuit 21 oscillates until losses in the parallel resonant circuit 21 dissipate all of the energy stored in the parallel resonant circuit 21.

[0040] An important difference over the pulsed electromagnetic field therapy device 10 is that the semiconductor switch 24 does not need to be a component of the parallel resonant circuit 21 in order to control current within the coil looped inductor 26. Instead, current ramping of the parallel resonant circuit 21 is controlled by current ramping circuit 25 which is external to and connected in parallel to the parallel resonant circuit 21. Not having a semiconductor switch 14 as a component of the parallel resonant circuit 21 provides a number of benefits. Resistance losses in the parallel resonant circuit 21 are low because the semiconductor switch 24 is external to the parallel resonant circuit 21, so resistance losses from the semiconductor switch 24 are not incurred during oscillation of the parallel resonant circuit 21. As a result, the decay time of the damped oscillations is much longer which increases the time period over which the pulsed electromagnetic field provides a physiological effect for a given initial current in the coil looped inductor 26. For example, a physiological effect may be present when the current in the parallel resonant circuit 21 is greater than around 200A, and the pulsed electromagnetic field therapy device 20 enjoys a period of around 1100 µs in which the current in the parallel resonant circuit 21 is providing a physiological effect, as compared with only 60 µs with the pulsed electromagnetic field therapy device 10. As a result, the pulsed electromagnetic field therapy device 20 provides a more sustained physiological effect. Moreover, the coil looped inductor 26 need only be ramped to a lower initial current (only 200 A - 1500 A in the pulsed electromagnetic field therapy device 20 as compared with 2000 A - 3000 A in the pulsed electromagnetic field therapy device 10), leading to lower voltages in the pulsed electromagnetic field therapy device 20 which do not require capacitor 22 or semiconductor switch 24 to be expensive high voltage components, reducing manufacturing costs. Additionally, operating at lower voltages allows capacitor 22 to have a larger capacitance value than a higher voltage capacitor of equivalent physical size, and the selection of a larger capacitance value for capacitor 22 leads to parallel resonant circuit 21 having a lower resonant frequency which allows the pulsed electromagnetic field therapy device 20 to meet regulatory requirements regarding electromagnetic interference.

[0041] In the pulsed electromagnetic field therapy device 10, the charge from the capacitor 12 is dumped into the resonant circuit 11 nearly instantaneously (at point 13 on Figures 2a and 2b) when the semiconductor switch 14 in the resonant circuit 11 is closed. As discussed above, this rapid charge discharged into the resonant circuit 11 leads to current reflections which result in significant interference 19. By not having semiconductor switch 24 as a component of the parallel resonant circuit 21, the current in the parallel resonant circuit 21 is increased more gradually over the course of the current ramping period 30. This, combined with the fact that the semiconductor switch 24 is external to and disconnected from the parallel resonant circuit 24 after the current ramping period 30 so that the impedance mismatched semiconductor switch 24 does not lead to reflections, results in a current profile (Figure 4) in the parallel resonant circuit 21 which is sinusoidal with low distortion, and which does not show the large amount of interference 19 (Figures 2a and 2b) seen in the pulsed electromagnetic field therapy device 10.

[0042] Figure 5 illustrates a pulsed electromagnetic field therapy device 50 according to an alternative embodiment of the present invention. The pulsed electromagnetic field therapy device 50 is generally the same as the pulsed electromagnetic field therapy device 20, with some improvements to electrical safety, charging and control.

[0043] The pulsed electromagnetic field may show no significant physiological effect once the current in the parallel resonant circuit 21 has dropped below a certain current (for example, once the current in the parallel resonant circuit 21 has dropped below 200 A). Therefore, a current threshold may be selected based on a current below which little or no significant physiological effect is observed, or below which insufficient physiological effect is observed to meet the needs of a particular physiological or therapeutic application.

[0044] Once the current in the parallel resonant circuit 21 has dropped below the current threshold (at time t_2), a further switch 64 is closed which connects the parallel resonant circuit 21 to the capacitor bank 53. This substantially reduces oscillation of the parallel resonant circuit 21 and allows at least part of the energy remaining in the parallel resonant circuit 21 to be recycled to at least partially recharge the capacitor bank 53. This saves considerable energy that might otherwise be wasted generating a pulsed electromagnetic field which provides no physiological effect.

[0045] Instead of a single high current capability capacitor 23, the pulsed electromagnetic field therapy device 50 has a capacitor bank 53 which is made up of capacitors 53a and 53b connected in parallel which together offer a high current capability source. The use of capacitor bank 53 may provide redundancy in case a capacitor 53a or 53b fails, and may be cheaper than using a single high current capability capacitor 23. The capacitor bank 53 could provide a high current capability source using more than two capacitors. In fact, it may be beneficial for the capacitor bank 53 to combine a large number of cheap, lower value capacitors which are smaller and therefore easier to pack into spare space in a housing.

[0046] The capacitor bank 53 is charged from power source 54 which is in turn fed from a mains electricity supply. To improve electrical safety, and reduce the risk of a patient or operator receiving an electrical shock from the high voltages and currents present in the current ramping circuit 25 and the parallel resonant circuit 21, the current ramping circuit 25 and the parallel resonant circuit 21 are galvanically isolated from the power source 54 by transformer 55 and diodes 56. Therefore, the inductor 26 and other components of the parallel resonant circuit 21 are floating, and therefore safe to touch even if insulation surrounding the inductor 26, cable 57 or other components is damaged.

[0047] To complete the isolation, the semiconductor switch 24 receives switching signals over a fibre optic cable 55 and the optional further switch 64 receives switching signals over a fibre optic cable 65. This helps to reduce induced interference which might occur on an electrical link.

[0048] Although the invention has been described in relation to particular embodiments. The skilled person will appreciate that various modifications could be made based on other aspects of the disclosure without departing from the scope of the claims.

REFERENCES CITED IN THE DESCRIPTION

Cited references

Patent documents cited in the description

- EP3101779A1 **[0007]**

Patentkrav

1. Pulseret elektromagnetisk feltterapiindretning omfattende:

et parallelresonanskredsløb (21) omfattende en kondensator (22) parallelforbundet med en induktor (26) uden en omskifter mellem kondensatoren og induktoren i parallelresonanskredsløbet, hvor parallel-resonanskredsløbet er konfigureret til at generere et pulseret elektromagnetisk felt omfattende en sekvens af dæmpede elektromagnetiske sinussvingninger i induktoren, mens elektrisk energi er lagret i parallelresonanskredsløbet, og hvor induktoren er konfigureret til at blive placeret i forhold til en del af en krop for at tilvejebringe det pulserede elektromagnetiske felt til delen af kroppen;

hvilken indretning yderligere omfatter:

en strømkilde (23); og

en omskifter (24), uden for parallelresonanskredsløbet, hvilken er konfigureret til: selektivt at forbinde parallelresonanskredsløbet til strømkilden i en strømopbygningsperiode (30), i løbet af hvilken en strøm (I(L1)) i induktoren forøges for at nå en ønsket strøm, og ved enden af strømopbygningsperioden at afbryde parallelresonanskredsløbet fra strømkilden ved at åbne omskifteren, hvor parallelresonanskredsløbet genererer sekvensen af dæmpede elektromagnetiske sinussvingninger (28) i induktoren, mens omskifteren er åben.

2. Indretningen ifølge krav 1, hvor en ladning lagret i kondensatoren, inden omskifteren uden for parallelresonanskredsløbet lukkes, er nul.

3. Indretningen ifølge et hvilket som helst foregående krav, hvor strømopbygningsperioden er en af: større end 1 µs; større end 10 µs; mellem 1 µs og 50 µs; mellem 10 µs og 50 µs; mellem 1 µs og 100 µs; og mellem 10 µs og 100 µs.

4. Indretningen ifølge et hvilket som helst foregående krav, hvor den ønskede strøm er i området af et af: 10 A og 2000 A; 100 A og 2000A; 200 A og 2000 A; 200 A og 1600 A; 500 A og 1600 A; og 500 A og 2000 A.

5. Indretningen ifølge et hvilket som helst foregående krav, hvor det pulserede elektromagnetiske felt har en frekvens af en af: mindre end 1 MHz; mindre end 250 KHz; mindre end 200 KHz og mindre end 100 KHz.

6. Indretningen ifølge et hvilket som helst foregående krav, hvor induktoren er en spolesløjfeinduktor.

7. Indretningen ifølge et hvilket som helst foregående krav, hvor parallel-resonanskredsløbet er galvanisk isoleret fra strømkilden.

8. Indretningen ifølge et hvilket som helst foregående krav, hvor omskifteren uden for parallelresonanskredsløbet modtager skiftesignaler via et optisk link (55).

9. Indretningen ifølge et hvilket som helst foregående krav, yderligere omfattende en yderligere omskifter (64) til selektivt at koble parallelresonanskredsløbet tilbage til en kondensator (53a) af strømforsyningen, hvor lukningen af den yderligere omskifter genoplader strømforsyningskondensatoren fra parallelresonanskredsløbet.

10. Indretningen ifølge krav 9, hvor den yderligere omskifter kobler parallel-resonanskredsløbet til strømforsyningen, når strømmen i parallelresonans-kredsløbet er under en strømtærskel.

11. Indretningen ifølge et hvilket som helst foregående krav, hvor driftscyklussen er 5% eller mindre, eller 1% eller mindre.

DRAWINGS

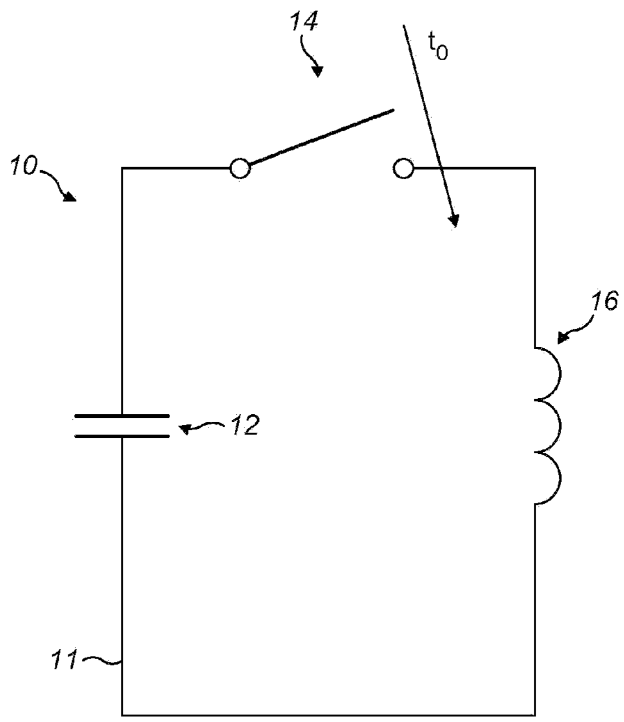

FIG. 1
(Prior Art)

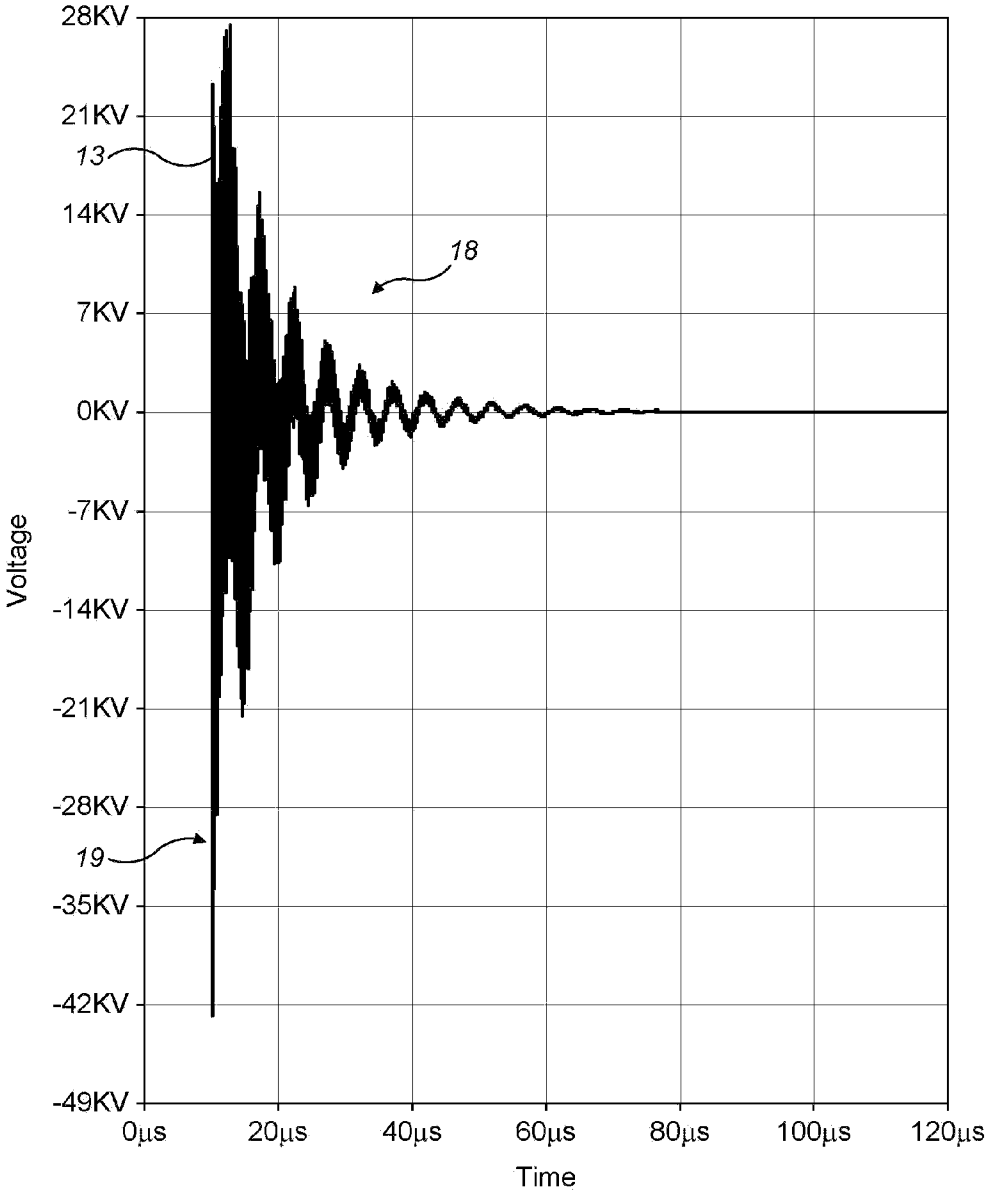

FIG. 2a
(Prior Art)

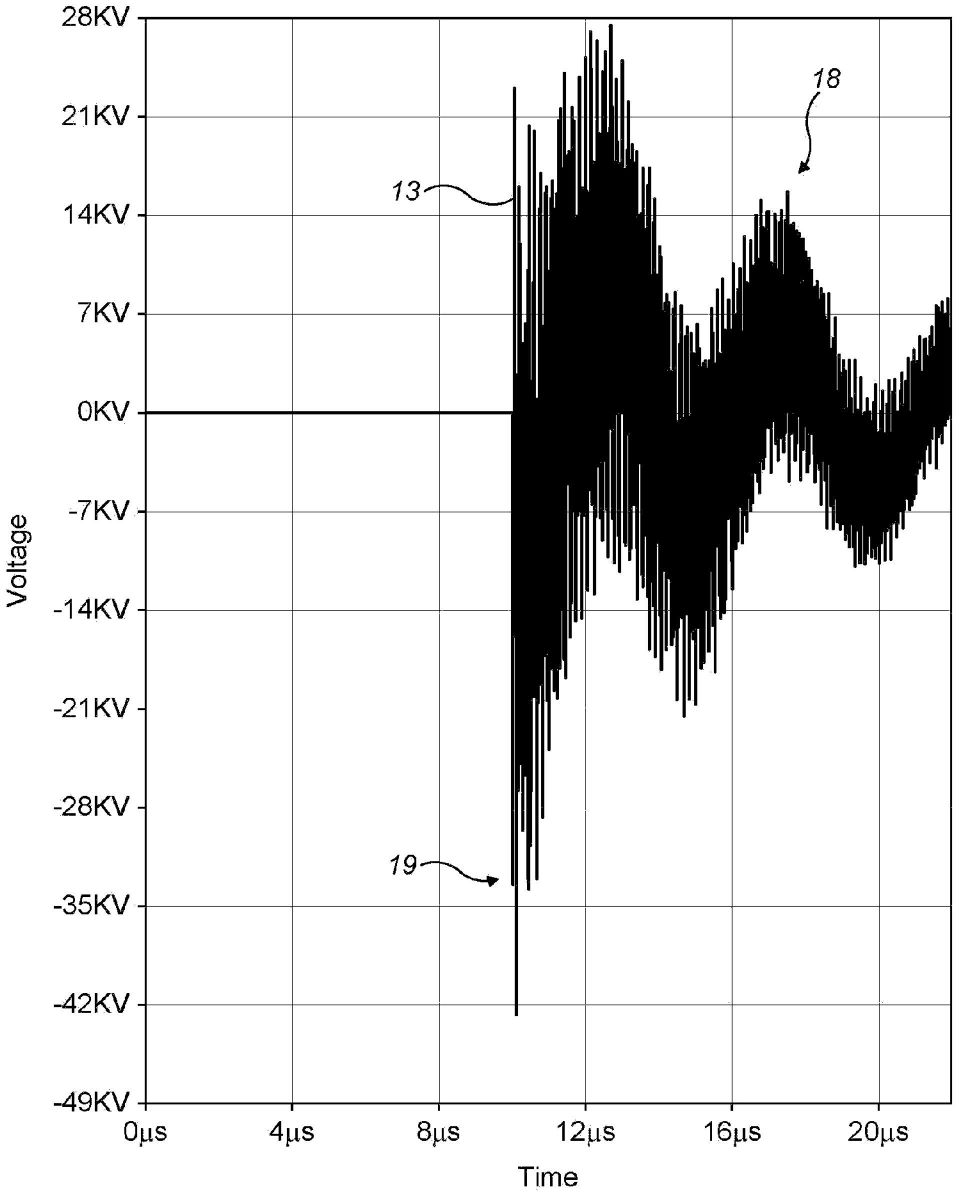

FIG. 2b
(Prior Art)

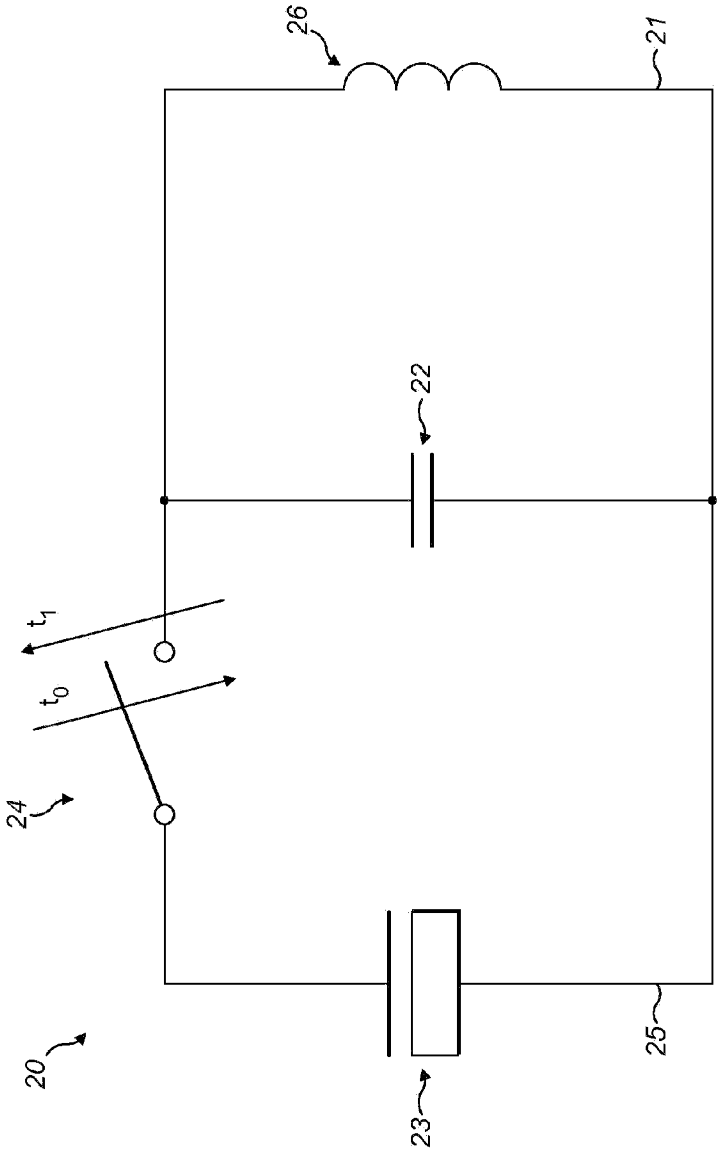

FIG. 3

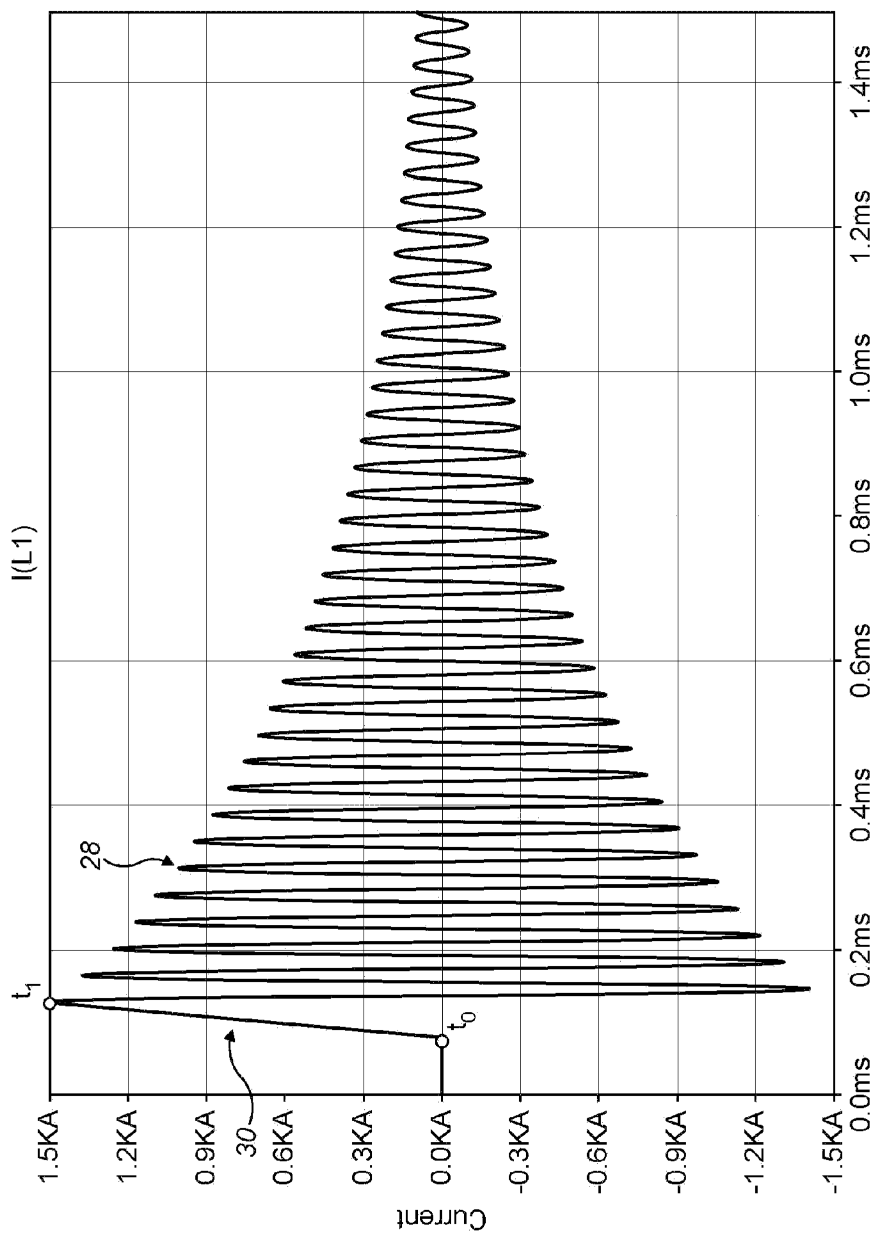
I(L1)
Current
1.5KA
1.2KA
0.9KA
0.6KA
0.3KA
0.0KA
-0.3KA
-0.6KA
-0.9KA
-1.2KA
-1.5KA
0.0ms
0.2ms
0.4ms
0.6ms
0.8ms
1.0ms
1.2ms
1.4ms
Time
t_0
t_1
28
30

FIG. 4

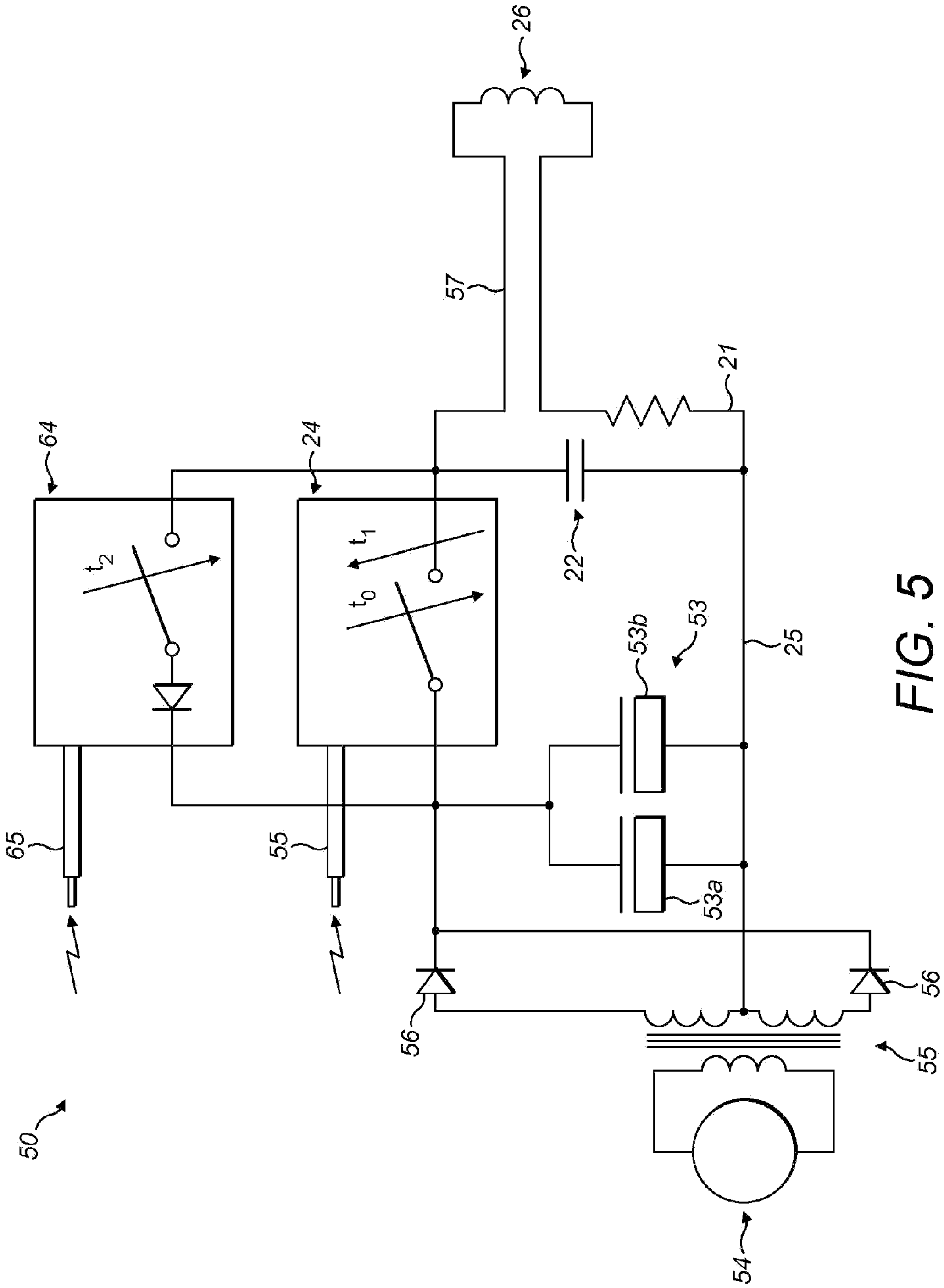

FIG. 5