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(54) **INSTALLATION DEVICE WITH AN ARRANGEMENT FOR DRIVING A BI-STABLE RELAY**

(57) The invention is about an installation device (1) with one bi-stable relay (2) and an arrangement for driving the bi-stable relay (2), the relay (2) being provided with one actuating coil (3) and electrical connections to an auxiliary circuit, the arrangement including

- one or more current transformers (4)
- a rectifier circuit (5), connected to the current transformers (4),
- a voltage regulator circuit (6), said voltage regulator circuit (6) being fed with rectified current from the rectifier circuit (5), and said voltage regulator circuit (6) further including two or more outputs,
- a control circuit (7),
- an energy supply circuit (8) for supplying the control circuit (7), said energy supply circuit (8) being fed through the voltage regulation circuit (6),
- a driver circuit (11) for driving the relay (2), said driver circuit (11) being coupled energy-wise to the voltage regulator circuit (6) and the energy supply circuit (8), wherein said energy supply circuit (8) comprising a first blocking diode (9) and a first buffer capacitor (10) for buffering the supply to the control circuit (7), and where said driver circuit (11) being coupled signal-wise to the control circuit (7) to receive a driving signal, and where the driver circuit (11) includes a H-bridge driver circuit, and where the energy supply circuit (8) includes a second buffer capacitor (12) connected to the signal supplying one half or both halves of the H-bridge driver circuit.

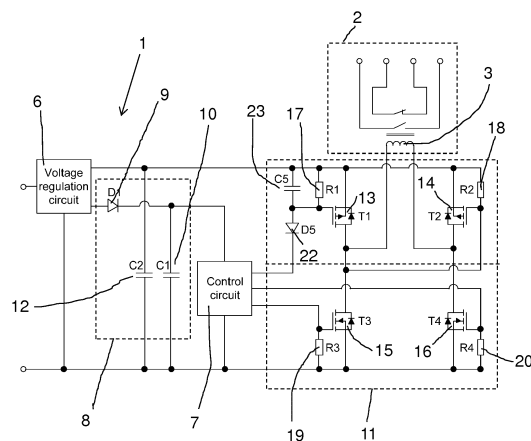


Fig. 2

Description

[0001] The invention is about an installation device with one bi-stable relay and an arrangement for driving the bi-stable relay, the relay being provided with one actuating coil and electrical connections to an auxiliary circuit, the arrangement including one or more current transformers, a rectifier circuit, connected to the current transformers, a voltage regulator circuit, said voltage regulator circuit being fed with rectified current from the rectifier circuit, and said voltage regulator circuit further including two or more outputs, a control circuit, an energy supply circuit for supplying the control circuit, said energy supply circuit being fed through the voltage regulation circuit, a driver circuit for driving the relay, said driver circuit being coupled energy-wise to the voltage regulator circuit and the energy supply circuit, according to the preamble of claim 1.

[0002] The invention deals with installation devices providing means to be coupled to a main circuit and comprising current transducers, electronic circuitry, and a bi-stable electromechanical relay to control an auxiliary circuit. The installation device may be employed for various purposes such as metering, control, monitoring, and protection of electrical equipment or electrical loads. Examples of such installation devices are electronic overload relays, protective relays, motor starters, motor controllers, etc.

[0003] One or more current transducers may be employed for sensing the current flowing through one or more phases of the main circuit. The current transducers could be current transformers however other types of transducers such as Rogowski coils are also possible. Current transformers may be used both for sensing the electrical current flowing through the main circuit and for supplying the installation device with electrical energy in the case of self-supplied devices. In this case, a rectifier circuit would be included as shown in the example from Fig. 1. However, installation devices may also feature other power source types such as a dedicated power supply source.

[0004] The electronic circuitry typically comprises a voltage regulation circuit, a current sense circuit, a control circuit, and a driver circuit able to send suitable switching signals to the bi-stable relay. The control circuit implements data processing and control functionalities of the installation device and may be based on a microcontroller, ASIC or a collection of digital and/or analog components. The current sense circuit converts the signals from the current transducers to signals suitable for the control circuit and may comprise one or more current shunt resistors and one or more amplifiers. An energy buffer circuit may also be provided to temporarily ensure partial or total operation of the installation device in the case of a disturbance or interruption of the power supply.

[0005] The bi-stable relay is used to send control commands and/or signals to the auxiliary circuit, such as trip and reset. Bi-stable relays may feature one or two coils,

those with two coils being possible to control with simpler driver circuits but featuring higher cost, larger size, and/or lower electrical efficiency. Bi-stable relays with one coil are typically more compact, more efficient, and cheaper to produce as well as to mechanically integrate in installation devices. However, they require more complex electronic driver circuits able to send bidirectional current pulses through the coil, for example positive and negative current pulses.

[0006] US5657194 shows a circuit and method for automatically resetting a solid state relay with one relay coil, wherein the circuit includes a trip coil, energized by a trip comparator circuit, and a reset coil, energized by a reset circuit. Thus the circuit shown in US5657194 is quite complicated, consumes a lot of energy, has significant size and cost.

[0007] Modern installation devices should preferably feature very low energy consumption, low operating voltage, compact size, and low cost. In self-supplied installation devices low energy consumption and low operating voltage helps reducing the load on the secondary circuit of the current transformers resulting in better accuracy, lower cost, smaller size, and less material usage of the current transformers. Apart environmental and cost benefits, low energy consumption of installation devices causes less heat dissipation allowing easier and tighter integration into applications. Furthermore, self-supplied installation devices must operate even when the main circuit is not energized, for example in the case of an automatic reset event following a trip action. In such case, electrical energy is typically stored into one or more buffer capacitors in order to allow the installation device performing the required functions. The leakage currents of the electrical circuitry must be extremely small in order to avoid wasting the energy stocked in the buffer capacitor(s). For example, the leakage current through the driver circuit in non-active state (off state) may have to be lower than 100 nA. When a current pulse is delivered by the driver circuit into the coil of the bi-stable relay, the voltage of the buffer capacitor would decay during the generation of the pulse. The driver and the control circuit must be designed such that reliable operation and high energy efficiency is ensured even when the voltage of the buffer capacitor decays.

[0008] Bi-stable relays with two coils are more expensive, larger, and less efficient than their counterparts with only one coil. However, bi-stable relays with one coil require more complex electronic driver circuit which can drive positive or negative current pulses through the coil. The electronic driver circuit must thus feature a differential output satisfying the specific needs of installation devices, such as low cost, extremely small leakage current, high efficiency, and reliable operation with low supply voltage decaying during the generation of the pulse. These are conflicting requirements and suitable solutions are presently not available. Installation devices may present additional particularities such as different voltage supply levels for the electronic control circuit and for the

driver circuit or for part of the driver circuit.

[0009] Thus it is the objective of the present invention to provide an installation device with an arrangement for driving a bi-stable relay with one relay coil with low energy consumption, low operating voltage, compact size, and at low cost.

[0010] The objective is achieved by an installation device with the features of claim 1. So according to the invention, said energy supply circuit comprises a first blocking diode and a first buffer capacitor for buffering the supply to the control circuit, and said driver circuit is coupled signal-wise to the control circuit to receive a driving signal, and the driver circuit includes a H-bridge driver circuit, and the energy supply circuit includes a second buffer capacitor connected to the signal supplying one half or both halves of the H-bridge driver circuit.

[0011] The installation device according to the invention comprises one or more current transformers, one rectifier circuit, one voltage regulation circuit, one control circuit, one bi-stable relay controlling an auxiliary circuit, a differential driver circuit to energize the relay, and at least two buffer capacitors able to store energy for reliable operation of the control circuit and of the differential driver circuit.

[0012] According to a preferred embodiment of the invention, the H-bridge driver circuit includes two high-side transistors and two low-side transistors, configured to drive an electrical current through the coil of the bi-stable relay in two possible alternating directions, and the H-bridge driver circuit further includes a pull-up resistor for each of the high-side transistors and a pull-down resistor for each of the low-side transistors.

[0013] According to a preferred embodiment of the invention, a first current path leads through a first one of the high-side transistors and a first one of the low-side transistors, and a second current path leads through the other high-side transistor and the other low-side transistor, and at least one high-side transistor is controlled by connecting its gate to the drain of the low-side transistor from the same current path, where the connection can be direct or indirect via a connecting diode and/or other component(s) such as a resistor.

[0014] According to a preferred embodiment of the invention, the two high-side transistors are of P-channel MOSFET type, and the gate of at least one high-side transistor is controlled via a control diode, whereby the anode of the control diode is connected to the gate of said high-side transistor.

[0015] According to a preferred embodiment of the invention, at least one capacitor is provided to the gate of the high side transistor being connected in parallel to the pull-up resistor associated with this high side transistor.

[0016] According to a preferred embodiment of the invention, both high-side transistors are provided with capacitors connected to their gates in parallel to the pull-up resistors associated with each of the high-side transistors, and both high-side transistors are controlled via diodes, whereby the anode of the each diode is connect-

ed to the gate of the high-side transistor to which the diode is associated.

[0017] According to a preferred embodiment of the invention, each high-side transistor from the H-bridge driver circuit is controlled by connecting its gate via a diode to the drain of the low-side transistor sharing the same current path.

[0018] According to a preferred embodiment of the invention, at least one high-side transistor is controlled via an inverting circuit sharing the same control signal as the low-side transistor from the same current path as the said high-side transistor.

[0019] According to a preferred embodiment of the invention, the said inverting circuit comprises a transistor of N-channel MOSET type or of NPN bipolar junction type.

[0020] According to a preferred embodiment of the invention, a device restricting the current flow in one direction such as a blocking diode is connected between the voltage regulator and the second buffer capacitor such that current flow from the second buffer capacitor to the voltage regulator is restricted.

[0021] According to a preferred embodiment of the invention, each half of the H-bridge driver circuit is supplied by a dedicated supply signal and where each supply signal is provided with a buffer capacitor and with a blocking diode.

[0022] According to a preferred embodiment of the invention, a further diode and/or a resistor is/are placed between the second buffer capacitor and the first buffer capacitor, allowing current to flow between the second buffer capacitor and the first buffer capacitor.

[0023] According to a preferred embodiment of the invention, the said inverting circuit comprises a transistor of NPN bipolar junction type, with its base connected to a circuit formed by a resistor in parallel with the series connection of another resistor and a capacitor.

[0024] According to a preferred embodiment of the invention, the electronic circuitry of the H-bridge driver circuit is partly or fully integrated in an integrated circuit.

[0025] The invention will be described in greater detail by description of three embodiments with reference to the accompanying drawings, wherein

- 45 Figure 1 shows a schematic representation of a self-supplied installation device featuring a bi-stable relay controlled by a driver circuit,
- Figure 2 shows an arrangement according to a first embodiment of the invention where the gate of the high-side transistor T1 is controlled via a diode D5 and where the gate of the high-side transistor T2 is controlled by connecting it directly to the drain of the low-side transistor T3 sharing the same current path,
- 55 Figure 3 shows an arrangement according to a second embodiment of the invention where each

branch of the H-bridge driver feature isolated power supplies via the blocking diodes D1 and D2 with dedicated buffer capacitors C1 and C2 respectively, and where the high-side transistor T1 is controlled by an inverting transistor T5 sharing the same control signal as the low-side transistor T4,

Figure 4 shows an arrangement according to a third embodiment of the invention where a diode D7 is placed between the buffer capacitor C2 and the buffer capacitor C1 allowing current to flow between C2 and C1 but restricting the current flow from C1 to C2.

[0026] In the figures, identical or equivalent elements and components or elements and components performing an equivalent function have the same reference numerals.

[0027] Figure 1 shows an installation device 1, with one bi-stable relay 2 and an arrangement for driving the bi-stable relay 2, the relay 2 being provided with one actuating coil 3 and electrical connections to an auxiliary circuit. The arrangement includes - one or more current transformers 4, a rectifier circuit 5, connected to the current transformers 4, a current sense circuit 33, a voltage regulator circuit 6, said voltage regulator circuit 6 being fed with rectified current from the rectifier circuit 5, and said voltage regulator circuit 6 further including two or more outputs, a control circuit 7, an energy supply circuit 8 for supplying the control circuit 7, said energy supply circuit 8 being fed through the voltage regulation circuit 6, a driver circuit 11 for driving the relay 2, said driver circuit 11 being coupled energy-wise to the voltage regulator circuit 6 and the energy supply circuit 8.

[0028] So the electronic circuitry typically comprises a voltage regulation circuit 6, a current sense circuit 33, a control circuit 7, and a driver circuit 11 able to send suitable switching signals to the bi-stable relay 2. The control circuit 7 implements data processing and control functionalities of the installation device 1 and may be based on a microcontroller, ASIC or a collection of digital and/or analog components. The current sense circuit 33 converts the signals from the current transducers 4 to signals suitable for the control circuit 7 and may comprise one or more current shunt resistors and one or more amplifiers. An energy buffer circuit may also be provided to temporarily ensure partial or total operation of the installation device 1 in the case of a disturbance or interruption of the power supply.

[0029] The bi-stable relay 2 is used to send control commands and/or signals to an auxiliary circuit 34, such as trip and reset.

[0030] The differential driver circuit 11 is an H-bridge driver featuring at least two low-side transistors and two high-side transistors, the high-side transistors being preferentially P-channel MOSFETs, as shown in Fig. 2. The gate of at least one high-side transistor is connected to

the anode of a control diode to allow maintaining the initial gate voltage for the whole duration of the pulse generated by the H-bridge driver. The control diode prevents the gate voltage of the high-side transistor from dropping together with the supply voltage of the H-bridge. The switching signal is applied to the high-side transistor via the control diode and charges the gate of the high-side transistor.

[0031] The charge is maintained on the gate of the transistor by the control diode even when the supply voltage of the H-bridge drops because of the current pulse drawing energy from the buffer capacitor. That is, the control diode allows increasing rapidly the gate-source voltage of the high-side transistor but prevents the same voltage from decreasing. In this way, a high gate-source voltage is ensured throughout the complete pulse duration ensuring low conduction resistance of the high-side transistor and low losses. The duration of the driver pulse is precisely controlled using the corresponding low-side transistor.

[0032] An additional capacitor may be connected between the gate and the source of the high-side transistor in order to increase the time constant of the gate-source voltage decay. The time constant of the gate-source voltage decay depends on the value of the total equivalent capacitance between the gate and the source of the high-side transistor and on the value of the pull-up resistor. This time constant is normally tuned to be significantly higher than the duration of the driver pulse but shorter than the interval between two pulses. In installation devices, the interval between two pulses is much longer than the duration of the pulse allowing easy optimization of the decay time constant. The energy available in the buffer capacitor of the H-bridge can thus be efficiently utilized till the voltage level reaches zero.

[0033] Using a control diode as explained here allows robust operation at low supply voltages of the control circuit and of the driver circuit. Nominal supply voltages down to 1.5 V and even below could be reached. Excellent energy efficiency is also ensured while the complexity and cost of the circuit are remarkable low. Furthermore, the control diode allows using different supply voltages for the control circuit and for the driver circuit maximizing the design flexibility. For example, the supply voltage of the driver circuit may be slightly higher than the supply voltage of the control circuit. Also, the supply voltage of the driver circuit may be smaller than the supply voltage of the control circuit, at least temporarily. Using a control diode of Schottky type may be desired if very small supply voltages are desired.

[0034] An additional novel feature relies in reducing the number of control signals necessary to control the H-bridge by connecting the gate of one high-side transistor to the drain of the low-side transistor from the same current path, as shown in Fig. 2. When the low-side transistor is switched on it drives the gate of the corresponding high-side transistor to also switch it on. The current pulse is stopped when the low-side transistor is switched off;

the high-side transistor will also switch off helped by the pull-up resistor. This simple and cost effective control mechanism can be advantageously combined with a control diode connected to the gate of the high-side transistor as described in the first inventive step, an example being shown in Fig. 3.

[0035] It is also possible to reduce the number of control signals by driving the high-side transistor via an inverting circuit connected to the control signal addressing the corresponding low-side transistor. The inverting circuit can be an N-channel MOSFET as in the example from Fig. 3, or an NPN BJT as in the example from Fig. 4. The inverting transistors also enable shifting the voltage level between the voltage supply values of the control circuit and of the H-bridge allowing for relatively large voltage differences and bringing additional flexibility to the solution. The NPN BJT can be biased using a resistor with relatively small resistance value in series with a capacitor for fast switching in parallel with a resistor with high resistance value for low power consumptions. Low power consumption and fast switching can thus be combined.

[0036] The power supply of the control circuit from the examples in Fig. 2, Fig. 3, and Fig. 4 comprises a storage capacitor C1 and a blocking diode D1 which allows charging the capacitor C1 but prevents it from discharging when the power supply is interrupted or becomes unstable. In practice, additional capacitors may be connected in parallel to C1 to increase the energy storage capacity or to improve the frequency behavior of the capacitor bank. It is also possible to use a combination of blocking diodes, connected in series or in parallel, for various reasons such as adjusting the resulting voltage drop or the reliability of the solution.

[0037] The H-bridge may feature a single supply like in the example from Fig. 2 or isolated supplies for each branch of the H-bridge like in the examples from Fig. 3 and Fig. 4, where each branch is provided with dedicated blocking diode and buffer capacitor. The voltage and energy applied to produce the current pulse through the coil of the bi-stable relay can be precisely controlled for each polarity. This enables detailed control for generating the current pulse required to switch the relay allowing optimizing the solution such that switching is reliably performed with the minimum amount of energy. Minimizing the switching energy positively impacts the cost and the size of the solution, allowing for example for smaller storage capacitors. It is also ensured that if the power supply is interrupted sufficient energy is available to efficiently switch forth and back the bi-stable relay; switching the relay forth would not reduce the voltage available for switching the relay back as in the example from Fig. 2.

[0038] One or more diodes may additionally be placed between the power supply (or supplies) of the H-bridge and the power supply of the control circuit in order to ensure that the voltage supply of the control circuit does not vanishes before the voltage supply (or supplies) of the H-bridge. In the example from Fig. 3, the diode D7 is

placed between the power supply of one branch of the H-bridge and the power supply of the control circuit.

[0039] The H-bridge is preferably implemented using metal-oxide-semiconductor field-effect transistors (MOSFETs) as they feature lower conduction losses than bipolar junction transistors (BJTs) and don't require using additional freewheeling diodes as their body diodes are typically sufficient. However, additional freewheeling diodes with lower losses could be used if necessary. MOSFETs featuring very low leakage drain currents below 100 nA would be preferred for the H-bridge, such as the DMG1016 series featuring one P-channel and one N-channel MOSFET in the same chip. A working solution could also be reached using low-side transistors based on BJTs.

Bezugszeichenliste

[0040]

1	Installation device
2	bi-stable relay
3	actuating coil
4	current transformer
5	rectifier circuit
6	voltage regulation circuit
7	control circuit
8	energy supply circuit
9	first blocking diode
10	first buffer capacitor
11	driver circuit
12	second buffer capacitor
13	high-side transistor
14	high-side transistor
15	low-side transistor
16	low-side transistor
17	pull-up resistor
18	pull-up resistor
19	pull-down resistor
20	pull-down resistor
21	connecting diode
22	control diode
23	capacitor
24	capacitor
25	inverting circuit with inverting transistor of MOSFET type
25a	inverting circuit with inverting transistor of NPN type
26	blocking diode
27	third buffer capacitor
28	blocking diode
29	further diode
30	resistor
31	resistor
32	capacitor
33	current sense circuit
34	auxiliary circuit

Claims

1. An installation device (1) with one bi-stable relay (2) and an arrangement for driving the bi-stable relay (2), the relay (2) being provided with one actuating coil (3) and electrical connections to an auxiliary circuit, the arrangement including
 - one or more current transformers (4)
 - a rectifier circuit (5), connected to the current transformers (4),
 - a voltage regulator circuit (6), said voltage regulator circuit (6) being fed with rectified current from the rectifier circuit (5), and said voltage regulator circuit (6) further including two or more outputs,
 - a control circuit (7),
 - an energy supply circuit (8) for supplying the control circuit (7), said energy supply circuit (8) being fed through the voltage regulation circuit (6),
 - a driver circuit (11) for driving the relay (2), said driver circuit (11) being coupled energy-wise to the voltage regulator circuit (6) and the energy supply circuit (8),

characterized in that said energy supply circuit (8) comprising a first blocking diode (9) and a first buffer capacitor (10) for buffering the supply to the control circuit (7), that said driver circuit (11) being coupled signal-wise to the control circuit (7) to receive a driving signal, and that the driver circuit (11) includes a H-bridge driver circuit, and that the energy supply circuit (8) includes a second buffer capacitor (12) connected to the signal supplying one half or both halves of the H-bridge driver circuit.
2. An installation device according to claim 1, **characterized in that** the H-bridge driver circuit includes two high-side transistors (13, 14) and two low-side transistors (15, 16), configured to drive an electrical current through the coil of the bi-stable relay in two possible alternating directions, and that the H-bridge driver circuit further includes a pull-up resistor (17, 18) for each of the high-side transistors (13, 14) and a pull-down resistor (19, 20) for each of the low-side transistors (15, 16).
3. An installation device according to claim 2, **characterized in that** a first current path leads through a first one (13) of the high-side transistors and a first one (16) of the low-side transistors, and that a second current path leads through the other high-side transistor (18) and the other low-side transistor (15), and that at least one high-side transistor (14) is controlled by connecting its gate to the drain of the low-side transistor (15) from the same current path, where the connection can be direct or indirect via a connecting diode (21) and/or other component(s) such as a resistor.
4. An installation device according to claim 3, **characterized in that** the two high-side transistors are of P-channel MOSFET type, and that the gate of at least one high-side transistor (13) is controlled via a control diode (22), whereby the anode of the control diode (22) is connected to the gate of said high-side transistor (13).
5. An installation device according to claim 4, **characterized in that** at least one capacitor (23) is provided to the gate of the high side transistor (13) being connected in parallel to the pull-up resistor (17) associated with this high side transistor (13).
6. An installation device according to claim 5, **characterized in that** both high-side transistors (13, 14) are provided with capacitors (23, 24) connected to their gates in parallel to the pull-up resistors (17, 18) associated with each of the high-side transistors (13, 14) and that both high-side transistors (13, 14) are controlled via diodes (22, 21) whereby the anode of the each diode (22, 21) is connected to the gate of the high-side transistor (13, 14) to which the diode (22, 21) is associated.
7. An installation device according to claim 6, **characterized in that** each high-side transistor (13, 14) from the H-bridge driver circuit is controlled by connecting its gate via a diode (22, 21) to the drain of the low-side transistor (16, 15) sharing the same current path.
8. An installation device according to claim 6, **characterized in that** at least one high-side transistor (13) is controlled via an inverting circuit (25, 25a) sharing the same control signal as the low-side transistor (16) from the same current path as the said high-side transistor (13).
9. An installation device according to claim 8, **characterized in that** the said inverting circuit (25) comprises a transistor of N-channel MOSFET type or of NPN bipolar junction type (25a).
10. An installation device according to any of the preceding claims, **characterized in that** a device restricting the current flow in one direction such as a blocking diode (26) is connected between the voltage regulator (6) and the second buffer capacitor (12) such that current flow from the second buffer capacitor (12) to the voltage regulator (6) is restricted.
11. An installation device according to any of the preceding claims, **characterized in that** each half of

the H-bridge driver circuit is supplied by a dedicated supply signal and where each supply signal is provided with a buffer capacitor (12, 27) and with a blocking diode (26, 28).

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12. An installation device according to claim 11, **characterized in that** a further diode (29) and/or a resistor is/are placed between the second buffer capacitor (12) and the first buffer capacitor (10) allowing current to flow between the second buffer capacitor (12) and the first buffer capacitor (10).

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13. An installation device according to claim 8, **characterized in that** the said inverting circuit comprises a transistor of NPN bipolar junction type (25a), with its base connected to a circuit formed by a resistor (30) in parallel with the series connection of another resistor (31) and a capacitor (32).

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14. An installation device according to any of the preceding claims, **characterized in that** the electronic circuitry of the H-bridge driver circuit is partly or fully integrated in an integrated circuit.

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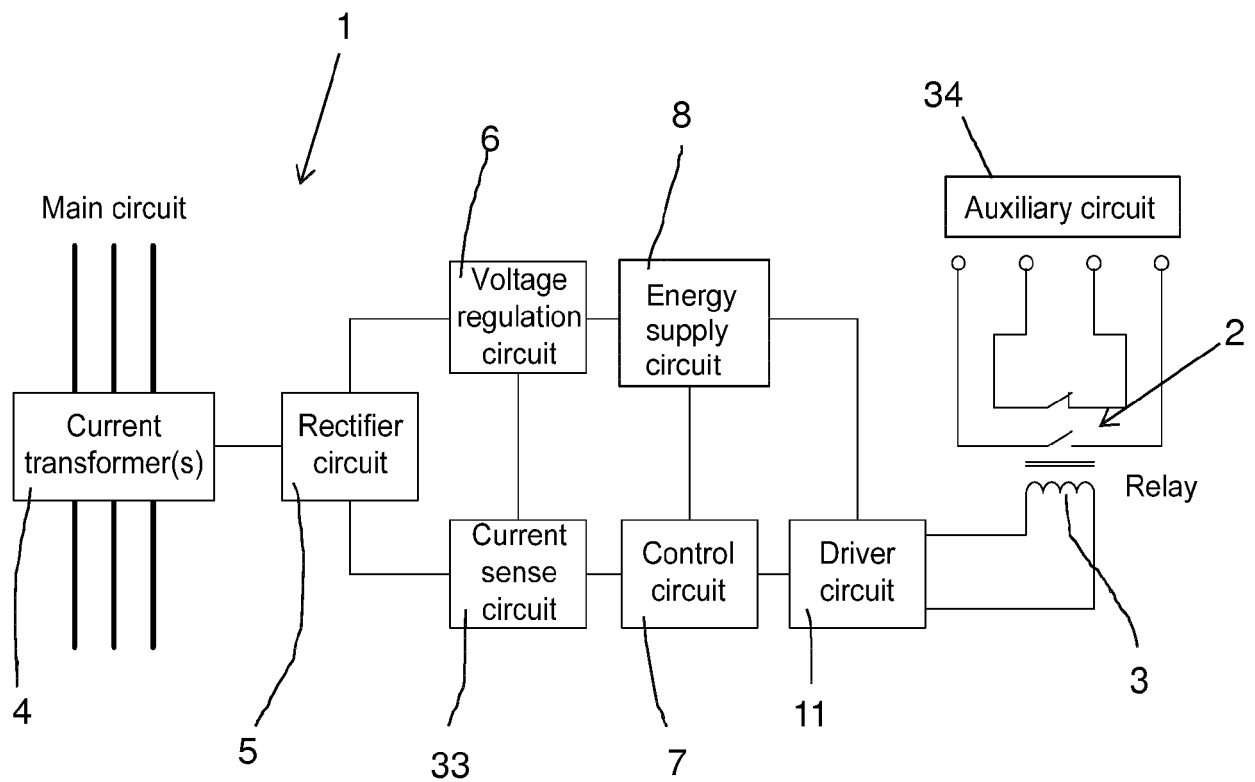


Fig. 1

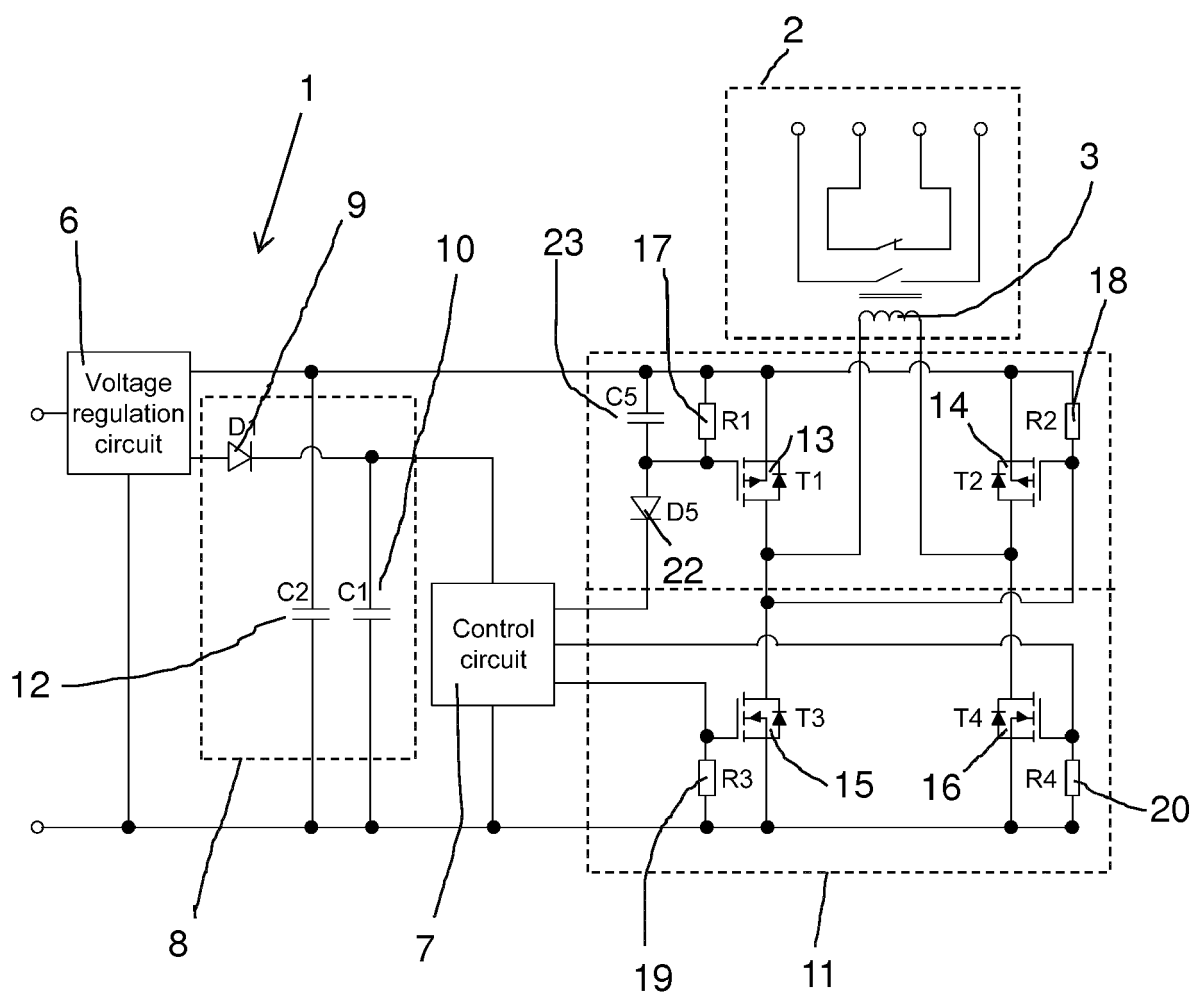


Fig. 2

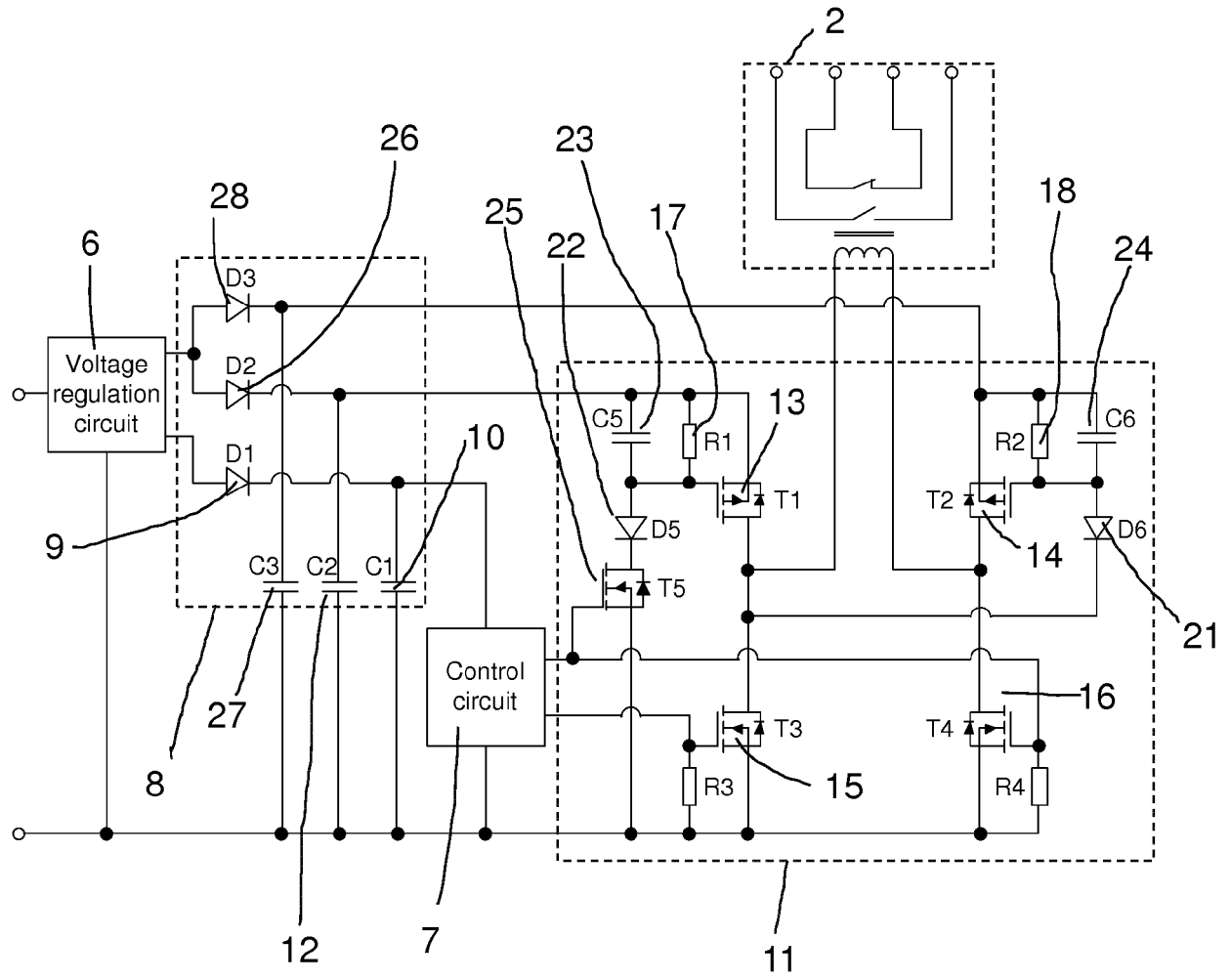


Fig. 3

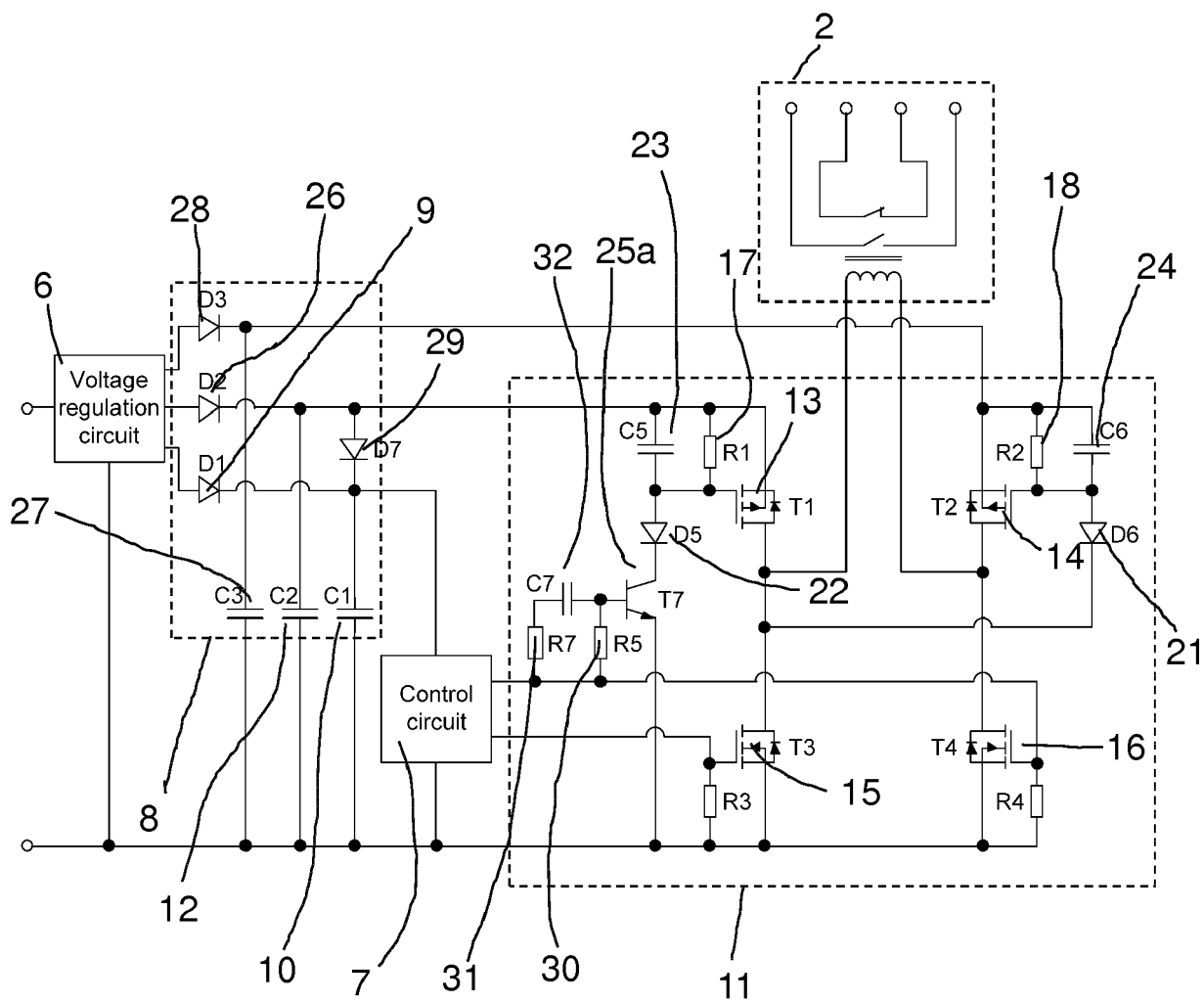


Fig. 4



EUROPEAN SEARCH REPORT

 Application Number
 EP 16 20 4048

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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			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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