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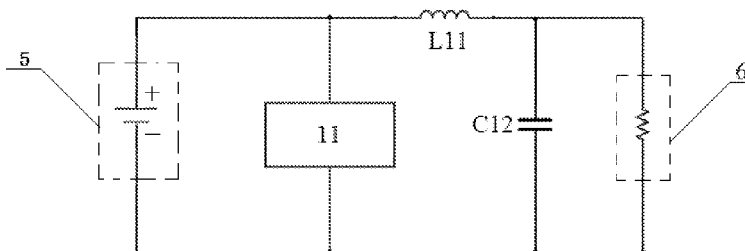


Fig. 3

(57) Abstract: An electric vehicle running control system is provided. The electric vehicle running control system comprises: a heating circuit (11) connected with an in-vehicle battery (5) to form a heating loop for heating the in-vehicle battery (5); a load capacitor (C12); and a first current storage element (L11) connected with the load capacitor (C12) and the heating circuit (11) respectively for reducing an interference between the heating circuit (11) and the load capacitor (C12).

ELECTRIC VEHICLE RUNNING CONTROL SYSTEM

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority to and benefits of Chinese Patent Application Serial No. 201210015386.4, filed with the State Intellectual Property Office of P. R. China on January 18, 2012, the entire contents of which are incorporated herein by reference.

FIELD

The present disclosure relates to a power electronics field, and more particularly to an electric vehicle running control system.

BACKGROUND

As electric vehicles need to run under complicated road conditions and environment conditions, an in-vehicle battery as a power of the electric vehicles needs to adapt to these conditions. Especially when the electric vehicles are in a low temperature environment, the in-vehicle battery needs to have excellent performances of discharging and charging in the low temperature environment and high input/output power. In general, a resistance and a polarization of the in-vehicle battery may be increased in the low temperature, which may reduce a capacity of the in-vehicle battery. Therefore, in order to keep the capacity of the in-vehicle battery in the low temperature, the electric vehicles are provided with a heating circuit of the in-vehicle battery.

Fig. 1 is a schematic diagram of the electric vehicle running control system according to the prior art. As shown in Fig.1, the heating circuit F is connected with the in-vehicle battery E to form a heating loop. By controlling an energy to flow between the in-vehicle battery E and the heating circuit F so as to heat a damping element in the heating circuit F, the in-vehicle battery E is heated, which increases the charging and discharging performance of the in-vehicle battery E.

However, if the in-vehicle circuit needs to be heated as the electric vehicle is running in the low temperature, as a load capacitor C also needs to supply power for a vehicle load R continuously, the heating circuit F and the load capacitor C will work simultaneously. Then, the working of the heating circuit F may cause the voltage of the in-vehicle battery E to fluctuate violently (even to become a negative value), and meanwhile the heating circuit may not work normally due to the influence of the loading circuit, as shown in Fig. 2. Fig. 2 shows schematic

waveform charts of the heating circuit F and the load capacitor C in Fig. 1, in which V_F is a voltage of the heating circuit F, V_C is an output voltage of the load capacitor C.

SUMMARY

5 The present disclosure is aimed to solve at least one of the problems, particularly defects that a heating circuit can not work normally due to an interference between a heating circuit and a load capacitor caused by heating during the running.

10 According to embodiments of the present disclosure, an electric vehicle running control system is provided. The system comprises: a heating circuit connected with an in-vehicle battery to form a heating loop for heating the in-vehicle battery; a load capacitor; and a first current storage element connected with the load capacitor and the heating circuit respectively for reducing an interference between the heating circuit and the load capacitor.

15 In one embodiment, the heating circuit comprises a damping element, a bidirectional switchgear, a second current storage element and a first charge storage element, the damping element and the second current storage element are connected in series to form a first part, the bidirectional switchgear and the first charge storage element are connected in series to form a second part, one end of the first part is connected with a positive electrode of the in-vehicle battery, the other end of the first part is connected with one end of the second part and one end of the first current storage element respectively, and the other end of the second part is connected with the
20 load capacitor and a negative electrode of the in-vehicle battery.

 In one embodiment, the system further comprises a heating circuit control module configured for controlling the heating circuit to connect with or disconnect from the in-vehicle battery by controlling the bidirectional switchgear to switch on or off.

25 In one embodiment, the damping element is an internal parasitic resistor of the in-vehicle battery, and the second current storage element is an internal parasitic inductor of the in-vehicle battery. In another embodiment, the damping element is a resistor, the first current storage element and the second current storage element are inductors, and the first charge storage element is a capacitor.

30 In one embodiment, the heating circuit further comprises an energy summing unit for summing an energy in the heating circuit and an energy in the in-vehicle battery after the bidirectional switchgear is switched off from a switched-on state, and the energy summing unit

comprises a polarity reversing unit for reversing a voltage polarity of the first charge storage element after the bidirectional switchgear is switched off from the switched-on state.

In another embodiment, the heating circuit further comprises an energy transferring unit for transferring an energy in the heating circuit to an energy storage element after the bidirectional switchgear is switched off from a switched-on state, and the energy transferring unit comprises an electric power recharging unit for transferring the energy in the heating circuit to the energy storage element after the bidirectional switchgear is switched off from the switched-on state.

In yet another embodiment, the heating circuit further comprises an energy summing and transferring unit for transferring a part of an energy in the heating circuit to an energy storage element after the bidirectional switchgear is switched off from a switched-on state, and then summing a remaining energy in the heating circuit and an energy in the in-vehicle battery.

In one embodiment, the energy summing and transferring unit comprises an energy summing unit and an energy transferring unit, the energy transferring unit is configured for transferring the part of the energy in the heating circuit to the energy storage element after the bidirectional switchgear is switched off from the switched-on state, the energy summing unit is configured for summing the remaining energy in the heating circuit and the energy in the in-vehicle battery after the part of the energy is transferred by the energy transferring unit, the energy transferring unit comprises the electric power recharging unit for transferring the part of the energy in the heating circuit to the energy storage element after the bidirectional switchgear is switched off from the switched-on state, and the energy summing unit comprises the polarity reversing unit for reversing the voltage polarity of the first charge storage element after the part of the energy is transferred by the electric power recharging unit.

In one embodiment, the polarity reversing unit comprises: a first single-pole double-throw switch located at both ends of the first charge storage element and a second single-pole double-throw switch located at both ends of the first charge storage element, a lead-in wire of the first single-pole double-throw switch is connected in the heating circuit, a first lead-out wire of the first single-pole double-throw switch is connected with a first pole plate of the first charge storage element, a second lead-out wire of the first single-pole double-throw switch is connected with a second pole plate of the first charge storage element, a lead-in wire of the second single-pole double-throw switch is connected in the heating circuit, a first lead-out wire of the second single-pole double-throw switch is connected with the second pole plate of the first charge storage

element, a second lead-out wire of the second single-pole double-throw switch is connected with the first pole plate of the first charge storage element, and the heating circuit control module is connected with the first single-pole double-throw switch and the second single-pole double-throw switch respectively, for reversing the voltage polarity of the first charge storage element by changing respective connection relations between the lead-in wire and the lead-out wires of the first single-pole double-throw switch and the second single-pole double-throw switch.

In another embodiment, the polarity reversing unit comprises: a third current storage element; a first switch, in which the first charge storage element, the third current storage element and the first switch are connected in series sequentially to form a loop, and the heating circuit control module is connected with the first switch, for reversing the voltage polarity of the first charge storage element by controlling the first switch to switch on; and a first unidirectional semiconductor element, in which the first unidirectional semiconductor element is connected in series between the first charge storage element and the third current storage element or between the third current storage element and the first switch.

In yet another embodiment, the polarity reversing unit comprises: a second charge storage element; and a first DC-DC module, in which the heating circuit control module is connected with the first DC-DC module for transferring an energy in the first charge storage element to the second charge storage element, and then reversely transferring an energy in the second charge storage element back to the first charge storage element, by controlling the first DC-DC module, so as to reverse the voltage polarity of the first charge storage element.

In one embodiment, the electric power recharging unit comprises a second DC-DC module, and the heating circuit control module is connected with the second DC-DC module for transferring an energy in the first charge storage element to the in-vehicle battery, by controlling the second DC-DC module.

In one embodiment, the energy summing and transferring unit comprises a third DC-DC module, and the heating circuit control module is connected with the third DC-DC module for transferring a part of an energy in the first charge storage element to the energy storage element, and then summing a remaining energy in the first charge storage element and the energy in the in-vehicle battery, by controlling the third DC-DC module.

In one embodiment, the system further comprises an energy limiting circuit for limiting a current flowing from the heating circuit to the in-vehicle battery.

In one embodiment, the bidirectional switchgear comprises: a first unidirectional branch for realizing a flowing of an energy from the in-vehicle battery to the heating circuit; and a second unidirectional branch for realizing a flowing of an energy from the heating circuit to the in-vehicle battery. The heating circuit control module is connected with the first unidirectional branch and/or the second unidirectional branch for controlling the first unidirectional branch and/or the second unidirectional branch connected to be on or off.

In one embodiment, the energy limiting circuit comprises a fourth current storage element connected in series in the second unidirectional branch.

In one embodiment, the bidirectional switchgear comprises a second switch, a second unidirectional semiconductor element and a third unidirectional semiconductor element, the second switch and the second unidirectional semiconductor element are connected in series to form the first unidirectional branch, the third unidirectional semiconductor element forms the second unidirectional branch, the heating circuit control module is connected with the second switch for controlling the first unidirectional branch to be on or off by controlling the second switch to switch on or off, and the fourth current storage element is connected with the third unidirectional semiconductor element in series.

In one embodiment, the bidirectional switchgear further comprises a third switch in the second unidirectional branch, the third switch is connected with the third unidirectional semiconductor element in series, the heating circuit control module is connected with the third switch for controlling the second unidirectional branch to be on or off by controlling the third switch to switch on or off, and the fourth current storage element is connected in series between the third unidirectional semiconductor element and the third switch.

In one embodiment, the heating circuit further comprises a fourth unidirectional semiconductor element, a fifth unidirectional semiconductor element, a fourth switch, and a fifth switch, a cathode of the fifth unidirectional semiconductor element is connected between the third switch and the fourth current storage element, an anode of the fifth unidirectional semiconductor element is connected to one end of the fifth switch, and the other end of the fifth switch is connected to a negative electrode of the in-vehicle battery; an anode of the fourth unidirectional semiconductor element is connected between the third unidirectional semiconductor element and the fourth current storage element, a cathode of the fourth unidirectional semiconductor element is connected to one end of the fourth switch, and the other end of the fourth switch is connected to

the negative electrode of the in-vehicle battery; and the heating circuit control module is connected with the fourth switch and the fifth switch respectively for controlling the fourth switch and the fifth switch to switch on or off.

In one embodiment, the heating circuit control module is configured for: controlling the
5 second switch and the third switch to switch on to enable an energy to flow from the in-vehicle battery to the first charge storage element and to flow from the first charge storage element to the in-vehicle battery; switching off the third switch and switching on the fifth switch when a voltage applied to the first charge storage element is greater than a first predetermined voltage of the in-vehicle battery; and switching off the fifth switch and switching on the third switch and the
10 fourth switch when a current flowing through the fourth current storage element is zero, to enable the voltage polarity of the first charge storage element to reverse.

In another embodiment, the heating circuit control module is configured for: controlling the second switch and the third switch to switch on to enable an energy to flow from the in-vehicle battery to the first charge storage element and to flow from the first charge storage element to the
15 in-vehicle battery; switching off the third switch and switching on the fifth switch when a voltage applied to the first charge storage element is less than or equal to a second predetermined voltage of the in-vehicle battery; switching off the fifth switch and switching on the third switch and the fourth switch when a current flowing through the fourth current storage element reaches a second predetermined current; switching off the fourth switch when the current flowing through the fourth
20 current storage element reaches a first predetermined current, to enable an energy in the fourth current storage element to flow to the in-vehicle battery; and switching on the third switch and the fourth switch when the current flowing through the fourth current storage element is zero, to enable the voltage polarity of the first charge storage element to reverse.

According to the electric vehicle running control system of the present disclosure, the first
25 current storage element is connected with the load capacitor to form a filter circuit. When the in-vehicle battery is heated as the electric vehicle is running, the filter circuit can filter a violent voltage fluctuation generated by the heating circuit and reduce an output voltage ripple of the load capacitor, which makes the output voltage of the load capacitor tend to be stable and avoids an influence on the heating circuit caused by the load capacitor. Thus, the heating circuit and the load
30 capacitor may work simultaneously without interference with each other.

Additional aspects and advantages of the embodiments of the present disclosure will be given

in part in the following descriptions, become apparent in part from the following descriptions, or be learned from the practice of the embodiments of the present disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

5 These and other aspects and advantages of the disclosure will become apparent and more readily appreciated from the following descriptions taken in conjunction with the drawings in which:

Fig. 1 is a schematic diagram of an electric vehicle running control system according to the prior art;

10 Fig. 2 shows schematic waveform charts of a heating circuit and a load capacitor in Fig. 1;

Fig. 3 is a schematic diagram of an electric vehicle running control system according to an embodiment of the present disclosure;

Fig. 4 is a schematic diagram of a heating circuit in the electric vehicle running control system according to an embodiment of the present disclosure;

15 Fig. 5 shows schematic waveform charts of the heating circuit and a load capacitor in Fig. 4;

Fig. 6 is a schematic diagram of the electric vehicle running control system according to a preferred embodiment of the present disclosure;

Fig. 7 is a schematic diagram of an embodiment of an energy summing unit in Fig.6;

Fig. 8 is a schematic diagram of an embodiment of a polarity reversing unit in Fig.7;

20 Fig. 9 is a schematic diagram of an embodiment of the polarity reversing unit in Fig.7;

Fig. 10 is a schematic diagram of an embodiment of the polarity reversing unit in Fig.7;

Fig. 11 is a schematic diagram of an embodiment of a first DC-DC module in Fig. 10;

Fig. 12 is a schematic diagram of the electric vehicle running control system according to a preferred embodiment of the present disclosure;

25 Fig. 13 is a schematic diagram of the electric vehicle running control system according to a preferred embodiment of the present disclosure;

Fig. 14 is a schematic diagram of an embodiment of an electric power recharging unit in Fig.13;

Fig. 15 is a schematic diagram of an embodiment of a second DC-DC module in Fig. 14;

30 Fig. 16 is a schematic diagram of the electric vehicle running control system according to a preferred embodiment of the present disclosure;

Fig. 17 is a schematic diagram of a preferred embodiment of an energy summing and transferring unit in Fig. 16;

Fig. 18 is a schematic diagram of an embodiment of the heating circuit in the electric vehicle running control system according to the present disclosure;

5 Fig. 19 is a schematic diagram of a preferred embodiment of the heating circuit in the electric vehicle running control system according to the present disclosure;

Fig. 20 is a schematic diagram of a preferred embodiment of the heating circuit in the electric vehicle running control system according to the present disclosure;

10 Fig. 21 is a schematic diagram of the electric vehicle running control system according to a preferred embodiment of the present disclosure; and

Fig. 22 shows schematic waveform charts of the heating circuit and the load capacitor in Fig. 21.

DETAILED DESCRIPTION

15 Embodiments of the present disclosure will be described in detail in the following descriptions, examples of which are shown in the accompanying drawings, in which the same or similar elements and elements having same or similar functions are denoted by like reference numerals throughout the descriptions. The embodiments described herein with reference to the accompanying drawings are explanatory and illustrative, which are used to generally understand
20 the present disclosure. The embodiments shall not be construed to limit the present disclosure.

It should be noted that, unless otherwise specified, in the following description, the term “heating circuit controlling module” refers to any controller which can output control instructions (such as a pulse waveform) according to predetermined conditions or at predetermined times to control a heating circuit connected to switch on or off correspondingly, such as a PLC
25 (Programming Logic Controller); the term “bidirectional switch” refers to any bidirectional switch that can realize on-off controlling according to electric signals or self-characteristics, such as a MOSFET (Metal Oxide Semiconductor Field Effect Transistor) or an IGBT (Insulated Gate Bipolar Transistor) with a reverse freewheeling diode; the term “charge storage element” refers to any device which can storage charges, such as a capacitor; the term “current storage element”
30 refers to any device that can storage a current, such as an inductor; the term “forward direction” refers to a direction that an energy flows from the in-vehicle battery to the heating circuit, the term

“reverse direction” refers to a direction that the energy flows from the heating circuit to the in-vehicle battery; the term “in-vehicle battery” comprises a primary battery (such as a dry battery or an alkaline battery) and a secondary battery (such as a lithium ion battery, a nickel cadmium battery, a nickel-metal hydride battery or a lead-acid battery); the term “damping element” refers to any device that consumes the energy by blocking the current flowing, such as a resistor; the term “heating loop” refers to a loop formed by the in-vehicle battery and the heating circuit.

In the following, the electric vehicle running control system according to the present disclosure will be described in detail with reference to the accompanied drawings.

Fig. 3 is a schematic diagram of an electric vehicle running control system according to an embodiment of the present disclosure. As shown in Fig.3, the system comprises a heating circuit 11 and a load capacitor C12. The heating circuit 11 is configured to connect with the in-vehicle battery 5 to form a heating loop. The load capacitor C12 is configured to supply energy to a vehicle load 6. The system further comprises a current storage element L11. The current storage element L11 is connected with the load capacitor C12 and the heating circuit 11 respectively.

In order to prolong a life time of the in-vehicle battery 5, the heating circuit 11 is connected with the in-vehicle battery 5 in a low temperature so that the in-vehicle battery 5 can be heated by the heating circuit 11. When a heating condition is reached, the in-vehicle battery 5 is heated, and when a stopping heating condition is reached, the heating circuit 11 is disconnected from the in-vehicle battery 5.

The current storage element L11 and the load capacitor C12 are connected in series to form an LC filter circuit. When the in-vehicle battery 5 is heated as the electric vehicle is running, the LC filter circuit can filter a violent voltage fluctuation generated by the heating circuit 11 and reduce an output voltage ripple of the load capacitor C12, which makes the output voltage of the load capacitor C12 tend to be stable and avoids an influence on the heating circuit 11 caused by the load capacitor C12. Thus, the heating circuit 11 and the load capacitor C12 may work simultaneously without interference with each other.

Fig. 4 is a schematic diagram of the heating circuit 11 in the electric vehicle running control system according to an embodiment of the present disclosure. As shown in Fig. 4, the heating circuit 11 comprises a damping element R1, a bidirectional switchgear 1, a current storage element L1 and a charge storage element C1. The damping element R1 and the current storage element L1 are connected in series to form a first part. The bidirectional switchgear 1 and the charge storage

element C1 are connected in series to form a second part. One end of the first part is connected with a positive electrode of the in-vehicle battery 5, the other end of the first part is connected with one end of the second part and one end of the current storage element L11 respectively, and the other end of the second part is connected with the load capacitor C12 and a negative electrode of the in-vehicle battery 5 respectively. Specifically, one end of the damping element R1 is connected with the positive electrode of the in-vehicle battery 5, the other end of the damping element R1 is connected with one end of the current storage element L1, the other end of the current storage element L1 is connected with one end of the bidirectional switchgear 1 and one end of the current storage element L11 respectively, the other end of the current storage element L11 is connected with one end of the load capacitor C12, the other end of the load capacitor C12 is connected with one end of the charge storage element C1 and the negative electrode of the in-vehicle battery 5 respectively. Further, it should be understood that the example in Fig. 4 is only illustrative and not intended to limit the present disclosure. In other embodiments, the damping element R1 and the current storage element L1 may be exchanged, and/or the bidirectional switchgear 1 and the charge storage element C1 may be exchanged.

Furthermore, it should be noted that, considering different characters of different types of in-vehicle batteries, in the present disclosure, the “in-vehicle battery” may refer to an ideal battery which does not comprise an internal parasitic resistor or an internal parasitic inductor, or to an ideal battery in which both the internal parasitic resistor and the internal parasitic inductor are very small. The “in-vehicle battery” may also refer to a battery pack which comprises the internal parasitic resistor and the internal parasitic inductor. Therefore, it should be understood by the person skilled in the art that, when the “in-vehicle battery” refers to the ideal battery which does not comprise the internal parasitic resistor or the internal parasitic inductor, or to the ideal battery in which both the internal parasitic resistor and the internal parasitic inductor are very small, the damping element R1 is an external damping element of the in-vehicle battery, the current storage element L1 is an external current storage element of the in-vehicle battery; when the “in-vehicle battery” refers to the battery pack which comprises the internal parasitic resistor and the internal parasitic inductor, the damping element R1 may be the external damping element of the battery pack or the internal parasitic resistor of the battery pack, and similarly, the current storage element L1 may be the external current storage element of the battery pack or the internal parasitic inductor of the battery pack.

A working process of the electric vehicle running control system according to the present disclosure will be described as follows with reference to Figs. 4 and 5.

As shown in Fig. 4, the system may further comprise a heating circuit control module 100. The heating circuit control module 100 is connected with the bidirectional switchgear 1, and is configured to control the heating circuit 11 to connect with or disconnect from the in-vehicle battery 5 by controlling the bidirectional switchgear 1 to switch on or off.

Thus, when the heating condition is reached, the heating circuit control module 100 controls the bidirectional switchgear 1 to switch on, and the in-vehicle battery 5 is connected with the heating circuit 11 to form the loop. The in-vehicle battery 5 discharges through the loop, that is, the charge storage element C1 is charged by the in-vehicle battery 5. When the current in the loop comes back to zero from a forward peak current, the charge storage element C1 starts to discharge through the loop, that is, the in-vehicle battery 5 is charged by the charge storage element C1. During the charging and discharging of the in-vehicle battery 5, both the forward current and the reverse current in the loop can flow through the damping element R1, and thus the in-vehicle battery 5 is heated by the heating of the damping element R1. When the stopping heating condition is reached, the heating circuit control module 100 controls the bidirectional switchgear 1 to switch off to make the heating circuit 11 stop working.

Fig. 5 shows schematic waveform charts of the heating circuit 11 and the load capacitor C12 in Fig. 4. In Fig. 5, T is a single working period of the electric running control system, V_{C1} is a voltage of the charge storage element C1 in the heating circuit 11, V_{C12} is a voltage of the load capacitor C12, I_{L11} is a current flowing into the current storage element L11, I_1 is a current flowing from the load capacitor C12 to the vehicle load 6. It should be noted that, the raising and falling of the voltage V_{C12} depend on whether the current I_{L11} (i.e., the current flowing into the load capacitor C12) is greater than the current I_1 . If the current I_{L11} is greater than the current I_1 , the voltage V_{C12} raises; if the current I_{L11} is less than the current I_1 , the voltage V_{C12} falls; and if the current I_{L11} is equal to the current I_1 , the voltage V_{C12} keeps constant. The working process of the electric vehicle running control system in Fig.4 during the single period T is as follows.

a) During the running of the electric vehicle, if the in-vehicle battery 5 needs to be heated, the heating circuit control module 100 controls the bidirectional switchgear 1 to switch on, and the heating circuit 11 is connected with the in-vehicle battery 5 to form a heating loop. The in-vehicle battery 5 discharges through the heating circuit 11, that is, the in-vehicle battery 5 the first charge

storage element C1 in the heating circuit 11, and the voltage V_{C1} of the charge storage element C1 raises. Meanwhile, the in-vehicle battery 5 also charges the load capacitor C12 through the current storage element L11, and the vehicle load 6 works with the energy provided by the load capacitor C12. At this time, as the current I_{L11} flowing into the current storage element L11 is less than the current I_1 flowing from the load capacitor C12 to the vehicle load 6, the output voltage V_{C12} of the load capacitor C12 falls, as a time period $t1$ shown in Fig. 5.

b) When the current in the heating loop comes back to zero from the forward peak current, the charge storage element C1 in the heating circuit 11 starts to charge the in-vehicle battery 5 through the heating loop, and the voltage V_{C1} of the charge storage element C1 falls. Meanwhile, the charge storage element C1 in the heating circuit 11 also charges the load capacitor C12 through the current storage element L11, and the vehicle load 6 works with the energy provided by the load capacitor C12. At this time, as the current I_{L11} flowing into the current storage element L11 is greater than the current I_1 flowing from the load capacitor C12 to the vehicle load 6, the output voltage V_{C12} of the load capacitor C12 raises, as a time period $t2$ shown in Fig. 5.

c) When the charge storage element C1 in the heating circuit 11 discharges to a lowest voltage, the heating circuit control module 11 controls the bidirectional switchgear 1 to switch off so as to disconnect the heating circuit 11 from the in-vehicle battery 5, and the voltage value V_{C1} of the charge storage element C1 keeps constant. At this time, the vehicle load 6 works with the energy provided by the load capacitor C12. As the current I_{L11} flowing into the current storage element L11 is equal to the current I_1 flowing from the load capacitor C12 to the vehicle load 6, the output voltage value V_{C12} of the load capacitor C12 keeps constant, as a time period $t3$ shown in Fig. 5.

As shown in Fig. 5, voltage waveforms tend to be stable, which is because the current storage element L11 is connected with the load capacitor C12 to form an LC filter circuit, which can filter a violent voltage fluctuation generated by the heating circuit 11 and reduce an output voltage ripple of the load capacitor C12.

With the electric vehicle running control system according to one embodiment of the present disclosure, by using the current storage element L11 and the load capacitor C12 to form the LC filter circuit, when the in-vehicle battery is heated as the vehicle is running, the LC filter circuit can filter a negative voltage generated by the heating circuit 11 and improve the output voltage fluctuation of the load capacitor C12, which makes the output voltage of the load capacitor C12 tend to be stable and avoid an influence on the heating circuit 11 caused by the load capacitor C12.

Thus, the heating circuit 11 and the load capacitor C12 can work simultaneously without interference with each other.

During the above heating, when the current flows back to the in-vehicle battery 5 from the heating circuit 11, the energy in the charge storage element C1 will not totally flow back to the in-vehicle battery 5, and a part of the energy remains in the charge storage element C1, which finally makes the voltage of the charge storage element C1 approach or equal to that of the in-vehicle battery 5, and thus resulting in that the energy can not flow from the in-vehicle battery 5 to the charge storage element C1, which is disadvantageous for a cycle operation of the heating circuit 11.

Thus, in preferred embodiments of the present disclosure, the system is further provided with additional units that sum the energy in the charge storage element C1 and the energy in the in-vehicle battery 5 and transfer the energy in the charge storage element C1 to other energy storage elements. At a certain time, the bidirectional switchgear 1 is switched off, and the energy in the charge storage element C1 is summed and/or transferred.

Fig. 6 is a schematic diagram of the electric vehicle running control system according to a preferred embodiment of the present disclosure. As shown in Fig. 6, the heating circuit 11 further comprises an energy summing unit 300. The energy summing unit 300 is connected with a path formed with the current storage element L1 and the charge storage element C1, and is configured to sum the energy in the heating circuit 11 and the energy in the in-vehicle battery 5 after the bidirectional switchgear 1 is switched off from a switched-on state. This makes the in-vehicle battery 5 able to charge the energy summed into the charge storage element C1 after the bidirectional switchgear 1 is switched on again, which increases a working efficiency of the heating circuit 11.

Fig. 7 is a schematic diagram of an embodiment of the energy summing unit 300. As shown in Fig. 7, the energy summing unit 300 comprises a polarity reversing unit 102. The polarity reversing unit 102 is connected with the path formed with the current storage element L1 and the charge storage element C1, and is configured to reverse a voltage polarity of the charge storage element C1 after the bidirectional switchgear 1 is switched off from the switched-on state. As the voltage polarity of the charge storage element C1 after polarity reversing and the voltage polarity of the in-vehicle battery 5 are serially summed up, when the bidirectional switchgear 1 is switched on again, the energy in the charge storage element C1 can be summed with the energy in the

in-vehicle battery 5.

Fig. 8 is a schematic diagram of an embodiment of the polarity reversing unit 102. As shown in Fig. 8, the polarity reversing unit 102 comprises a single-pole double-throw switch J1 and a single-pole double-throw switch J2. The single-pole double-throw switch J1 is located at both ends of the charge storage element C1. A lead-in wire of the single-pole double-throw switch J1 is connected in the heating circuit 11, a first lead-out wire of the single-pole double-throw switch J1 is connected with a first pole plate of the charge storage element C1, and a second lead-out wire of the single-pole double-throw switch J1 is connected with a second pole plate of the charge storage element C1. The single-pole double-throw switch J2 is located at both ends of the charge storage element C1. A lead-in wire of the single-pole double-throw switch J2 is connected in the heating circuit 11, a first lead-out wire of the single-pole double-throw switch J2 is connected with the second pole plate of the charge storage element C1, and a second lead-out wire of the single-pole double-throw switch J2 is connected with the first pole plate of the charge storage element C1. The heating circuit control module 100 is connected with the single-pole double-throw switch J1 and the single-pole double-throw switch J2 respectively, for reversing the voltage polarity of the charge storage element C1 by changing respective connection relations between the lead-in wire and the lead-out wires of the single-pole double-throw switch J1 and the single-pole double-throw switch J2.

According to the above embodiment, the respective connection relation between the lead-in wire and the lead-out wires of the single-pole double-throw switch J1 and the single-pole double-throw switch J2 can be preset in such a way: when the bidirectional switchgear 1 is switched on, the lead-in wire of the single-pole double-throw switch J1 is connected with the first lead-out wire of the single-pole double-throw switch J1, and the lead-in wire of the single-pole double-throw switch J2 is connected with the first lead-out wire of the single-pole double-throw switch J2; and when the bidirectional switchgear 1 is switched off, with the control of the heating circuit control module 100, the lead-in wire of the single-pole double-throw switch J1 is switched to connect with the second lead-out wire of the single-pole double-throw switch J1 and the lead-in wire of the single-pole double-throw switch J2 is switched to connect with the second lead-out wire of the single-pole double-throw switch J2. Thus, the voltage polarity reversing of the charge storage element C1 is achieved.

Fig. 9 is a schematic diagram of another embodiment of the polarity reversing unit 102. As

shown in Fig. 9, the polarity reversing unit 102 comprises a unidirectional semiconductor element D3, a current storage element L2 and a switch K9. The charge storage element C1, the current storage element L2 and the switch K9 are connected in series sequentially to form a loop. The unidirectional semiconductor element D3 is connected in series between the charge storage element C1 and the current storage element L2 or between the current storage element L2 and the switch K9. The heating circuit 11 is also connected with the switch K9, for reversing the voltage polarity of the charge storage element C1 by controlling the switch K9 to switch on.

According to the above embodiment, when the bidirectional switchgear 1 is switched off, the switch K9 is controlled to switch on by the heating circuit control module 100. Accordingly, the charge element C1 forms an LC oscillation loop with the unidirectional semiconductor element D3, the current storage element L2 and the switch K9. The charge element C1 discharges through the current storage element L2, and the voltage polarity reversing of the charge storage element C1 is achieved when the current in the oscillation loop comes back to zero after passing through a positive half period.

Fig. 10 is a schematic diagram of yet another embodiment of the polarity reversing unit 102. As shown in Fig. 10, the polarity reversing unit 102 comprises a first DC-DC module 2 and a charge storage element C2. The first DC-DC module 2 is connected with the charge storage element C1 and the charge storage element C2 respectively. The heating circuit control module 100 is also connected with the first DC-DC module 2 for transferring the energy in the charge storage element C1 to the charge storage element C2, and then reversely transferring an energy in the charge storage element back C2 to the charge storage element C1, by controlling the first DC-DC module 2, so as to reverse the voltage polarity of the charge storage element C1.

The first DC-DC module 2 is a commonly used DC-DC (direct current to direct current) converting circuit for reversing the voltage polarity in the art. A circuit structure of the first DC-DC module 2 is not limited in the present disclosure. As long as the voltage polarity reversing of the charge storage element C1 can be achieved, a person skilled in the art can increase, replace or delete elements in the circuit according to actual requirements.

Fig. 11 is a schematic diagram of an embodiment of the first DC-DC module 2. As shown in Fig. 11, the first DC-DC module 2 comprises a bidirectional switch Q1, a bidirectional switch Q2, a bidirectional switch Q3, a bidirectional switch Q4, a first transformer T1, a unidirectional semiconductor element D4, a unidirectional semiconductor element D5, a current storage element

L3, a bidirectional switch Q5, a bidirectional switch Q6, a second transformer T2, a unidirectional semiconductor element D6, a unidirectional semiconductor element D7 and a unidirectional semiconductor element D8.

In the embodiment, all the bidirectional switch Q1, the bidirectional switch Q2, the bidirectional switch Q3 and the bidirectional switch Q4 are MOSFETs, and the bidirectional switch Q5 and the bidirectional switch Q6 are IGBTs. A pin 1, a pin 4 and a pin 5 of the first transformer T1 are dotted terminals, and a pin 2 and a pin 3 of the second transformer T2 are dotted terminals.

An anode of the unidirectional semiconductor element D7 is connected with an end a of the capacitor C1, a cathode of the unidirectional semiconductor element D7 is connected with drains of the bidirectional switch Q1 and the bidirectional switch Q2 respectively, a source of the bidirectional switch Q1 is connected with a drain of the bidirectional switch Q3, a source of the bidirectional switch Q2 is connected with a drain of the bidirectional switch Q4, both the sources of the bidirectional switch Q3 and the bidirectional switch Q4 are connected with an end b of the capacitor C1, and thus a full bridge circuit is formed, in which the voltage polarity of the end a of the capacitor C1 is positive, and the voltage polarity of the end b is negative.

Further, in the full bridge circuit, the bidirectional switch Q1 and the bidirectional switch Q2 are upper bridge arms, the bidirectional switch Q3 and the bidirectional switch Q4 are lower bridge arms. The full bridge circuit is connected with the charge storage element C2 through the first transformer T1. The pin 1 of the first transformer T1 is connected with a first node N1, a pin 2 of the first transformer T1 is connected with a second node N2, a pin 3 and the pin 5 of the first transformer T1 are connected with anodes of the unidirectional semiconductor element D4 and the unidirectional semiconductor element D5 respectively. The cathodes of the unidirectional semiconductor element D4 and the unidirectional semiconductor element D5 are connected with one end of the current storage element L3, the other end of the current storage element L3 is connected with an end d of the charge storage element C2. The pin 4 of the first transformer T1 is connected with an end c of the charge storage element C2, the anode of the unidirectional semiconductor element D8 is connected with the end d of the charge storage element C2, and the cathode of the unidirectional semiconductor element D8 is connected with the end b of the charge storage element C1. At this time, the voltage polarity of the end c of the charge storage element C2 is negative, and the voltage polarity of the end d is positive.

In Fig. 11, the end c of the charge storage element C2 is connected with an emitter of the bidirectional switch Q5, a collector of the bidirectional switch Q5 is connected with the pin 2 of the second transformer T2, the pin 1 of the second transformer T2 is connected with the end a of the charge storage element C1, the pin 4 of the second transformer T2 is connected with the end a of the charge storage element C1, the pin 3 of the second transformer T2 is connected with the anode of the unidirectional semiconductor element D6, the cathode of the unidirectional semiconductor element D6 is connected with a collector of the bidirectional switch Q6, and an emitter of the bidirectional switch Q6 is connected with the end b of the charge storage element C2.

Further, the bidirectional switch Q1, the bidirectional switch Q2, the bidirectional switch Q3, the bidirectional switch Q4, the bidirectional switch Q5 and the bidirectional switch Q6 are controlled respectively by the heating circuit control module 100 to switch on or off.

In the following, a working process of the first DC-DC module 2 will be described.

1. After the bidirectional switchgear 1 is switched off, the heating circuit control module 100 controls the bidirectional switch Q5 and the bidirectional switch Q6 to switch off, controls the bidirectional switch Q1 and the bidirectional switch Q4 to switch on simultaneously so as to form a phase A, and controls the bidirectional switch Q2 and the bidirectional switch Q3 to switch on simultaneously so as to form a phase B. Then, the heating circuit control module 100 controls the phase A and the phase B to switch on alternately, so as to form the full bridge circuit.

2. When the full bridge circuit works, the energy in the charge storage element C1 is transferred to the charge storage element C2 through the first transformer T1, the unidirectional semiconductor element D4, the unidirectional semiconductor element D5 and the current storage element L3. At this time, the voltage polarity of the end c of the charge storage element C2 is negative, and the voltage polarity of the end d is positive.

3. The heating circuit control module 100 controls the bidirectional switch Q5 to switch on, and the charge storage element C1 forms a path with the charge storage element C2 through the second transformer T2 and the unidirectional semiconductor element D8. Thus, the energy in the charge storage element C2 is reversely transferred to the charge storage element C1, in which a part of the energy is stored in the second transformer T2. At this time, the heating circuit control module 100 controls the bidirectional switch Q5 to switch off and controls the bidirectional switch Q6 to switch on. Then, the energy stored in the second transformer T2 is transferred to the charge

storage element C1 through the second transformer T2 and the unidirectional semiconductor element D6, so as to reversely charge the charge storage element C1. At this time, the voltage polarity of the end a of the charge storage element C1 is reversed to be negative, the voltage polarity of the end b of the charge storage element C1 is reversed to be positive. The voltage polarity reversing of the charge storage element C1 is achieved.

It should be understood by the person skilled in the art that, the above embodiments are not intended to limit methods for reversing the voltage polarity of the charge storage element C1. The person skilled in the art can use other structures to achieve the voltage polarity reversing of the charge storage element C1, such as a charge pump.

Fig. 12 is a schematic diagram of the electric vehicle running control system according to a preferred embodiment of the present disclosure. As shown in Fig. 12, the system further comprises an energy transferring unit 400. The energy transferring unit 400 is connected with a path formed with the current storage element L1 and the charge storage element C1. The energy transferring unit 400 is configured to transfer the energy in the heating circuit 11 to an energy storage element 500 after the bidirectional switchgear 1 is switched off from the switched-on state. The energy transferring unit 400 is used to recycle the energy in the heating circuit 11. The energy storage element 500 may be an external capacitor, a low temperature battery, a power grid or any other electric equipment.

Preferably, the energy storage element 500 is the in-vehicle battery 5, and the energy transferring unit 400 comprises an electric power recharging unit 103. The electric power recharging unit 103 is connected with the path formed with the current storage element L1 and the charge storage element C1, for transferring the energy in the heating circuit 11 to the in-vehicle battery 5 after the bidirectional switchgear 1 is switched off from the switched-on state, as shown in Fig. 13.

According to the present disclosure, when the energy in the heating circuit 11 is transferred to the in-vehicle battery 5 by the electric power recharging unit 103 after the bidirectional switchgear 1 is switched off, the energy transferred can be used circularly after the bidirectional switchgear 1 is switched on again, which increases the working efficiency of the heating circuit 11.

Fig. 14 is a schematic diagram of an embodiment of the electric power recharging unit 103. As shown in Fig. 14, the electric power recharging unit 103 comprises a second DC-DC module 3. The second DC-DC module 3 is connected with the charge storage element C1 and the in-vehicle

battery 5 respectively. The heating circuit control module 100 is also connected with the second DC-DC module 3, for transferring the energy in the charge storage element C1 to the in-vehicle battery 5 by controlling the second DC-DC module 3.

The second DC-DC module 3 is a commonly used DC-DC converting circuit for transferring the energy in the art. A circuit structure of the second DC-DC module 3 is not limited in the present disclosure. As long as the energy transferring of the charge storage element C1 can be achieved, a person skilled in the art can increase, replace or delete the elements in the circuit according to actual requirements.

Fig. 15 is a schematic diagram of an embodiment of the second DC-DC module 3. As shown in Fig. 15, the second DC-DC module 3 comprises a bidirectional switch S1, a bidirectional switch S2, a bidirectional switch S3, a bidirectional switch S4, a third transformer T3, a current storage element L4 and four unidirectional semiconductor elements. In the embodiment, all the bidirectional switch S1, the bidirectional switch S2, the bidirectional switch S3 and the bidirectional switch S4 are MOSFETs.

A pin 1 and a pin 3 of the third transformer T3 are dotted terminals. The cathodes of two unidirectional semiconductor elements of the four unidirectional semiconductor elements are connected to form a group, and a connection point thereof is connected with the positive electrode of the in-vehicle battery 5 through the current storage element L4. The anodes of the other two unidirectional semiconductor elements are connected to form another group, and a connection point thereof is connected with the negative electrode of the in-vehicle battery 5. Junction points between the two groups are connected with the pin 3 and the pin 4 of the third transformer T3 respectively. Thus, a bridge rectifier circuit is formed.

Further, a source of the bidirectional switch S1 is connected with a drain of the bidirectional switch S3, a source of the bidirectional switch S2 is connected with a drain of the bidirectional switch S4, the drains of the bidirectional switch S1 and the bidirectional switch S2 are connected with the positive end of the charge storage element C1, and the sources of the bidirectional switch S3 and the bidirectional switch S4 are connected with the negative end of the charge storage element C1. Thus, a full bridge circuit is formed.

In the full bridge circuit, the bidirectional switch S1 and the bidirectional switch S2 are upper bridge arms, the bidirectional switch S3 and the bidirectional switch S4 are lower bridge arms. The pin 1 of the third transformer T3 is connected with a node between the bidirectional switch S1 and

the bidirectional switch S3, a pin 2 of the third transformer T3 is connected with a node between the bidirectional switch S2 and the bidirectional switch S4.

Further, the bidirectional switch S1, the bidirectional switch S2, the bidirectional switch S3 and the bidirectional switch S4 are controlled respectively by the heating circuit control module 100 to switch on or off.

In the following, the working process of the second DC-DC module 3 will be described.

1. After the bidirectional switchgear 1 is switched off, the heating circuit control module 100 controls the bidirectional switch S1 and the bidirectional switch S4 to switch on simultaneously so as to form a phase A, and controls the bidirectional switch S2 and the bidirectional switch S3 to switch on simultaneously so as to form a phase B. Then, the heating circuit control module 100 controls the phase A and the phase B to switch on alternately, so as to form the full bridge circuit to work.

2. When the full bridge circuit works, the energy in the charge storage element C1 is transferred to the in-vehicle battery 5 through the third transformer T3 and the rectifier circuit, in which the rectifier circuit converts an input alternating current into a direct current and then output the direct current to the in-vehicle battery 5, so as to achieve the electric power recharging.

It should be understood by the person skilled in the art that, the above embodiments are not intended to limit methods for transferring the energy in the heating circuit 11 to the element storage elements. The person skilled in the art can use other structures to transfer the energy in the heating circuit 11, such as a charge pump or a transformer.

Fig. 16 is a schematic diagram of the electric vehicle running control system according to a preferred embodiment of the present disclosure. As shown in Fig. 16, the system further comprises an energy summing and transferring unit 600. The energy summing and transferring unit 600 is connected with the path formed with the current storage element L1 and the charge storage element C1, for transferring a part of the energy in the heating circuit 11 to the energy storage element 500 after the bidirectional switchgear 1 is switched off from the switched-on state, and then summing a remaining energy in the heating circuit 11 and the energy in the in-vehicle battery 5. The energy summing and transferring unit 600 may not only increase the working efficiency of the heating circuit 11, but also recycle the energy in the heating circuit 11.

The summing the remaining energy in the heating circuit 11 and the energy in the in-vehicle battery 5 is achieved by reversing the voltage polarity of the charge storage element C1. As the

voltage polarity of the charge storage element C1 after reversing and the voltage polarity of the in-vehicle battery 5 are serially summed up, when the bidirectional switchgear 1 is switched on again, the energy in the in-vehicle battery 5 can be summed with the energy in the charge storage element C1.

Fig. 17 is a schematic diagram of an embodiment of the energy summing and transferring unit 600. As shown in Fig. 17, the energy summing and transferring unit 600 comprises a third DC-DC module 4. The third DC-DC module 4 is connected with the charge storage element C1 and the in-vehicle battery 5 respectively. The heating circuit control module 100 is also connected with the third DC-DC module 4 for transferring a part of the energy in the charge storage element C1 to the energy storage element 500, and then summing a remaining energy in the charge storage element C1 and the energy in the in-vehicle battery 5, by controlling the third DC-DC module 4.

The third DC-DC module 4 is a commonly used DC-DC converting circuit for transferring the energy and reversing the voltage polarity in the art. A circuit structure of the third DC-DC module 4 is not limited in the present disclosure. As long as the energy transferring and voltage polarity reversing of the charge storage element C1 can be achieved, a person skilled in the art can increase, replace or delete the elements in the circuit according to actual requirements.

As shown in Fig. 17, the third DC-DC module 4 comprises a bidirectional switch S1, a bidirectional switch S2, a bidirectional switch S3, a bidirectional switch S4, a bidirectional switch S5, a bidirectional switch S6, a fourth transformer T4, a unidirectional semiconductor element D13, a unidirectional semiconductor element D14, a current storage element L4 and four unidirectional semiconductor elements. In the embodiment, the bidirectional switch S1, the bidirectional switch S2, the bidirectional switch S3 and the bidirectional switch S4 are MOSFETs, and the bidirectional switch S5 and the bidirectional switch S6 are IGBTs.

A pin 1 and a pin 3 of the fourth transformer T4 are dotted terminals. The cathodes of two unidirectional semiconductor elements of the four unidirectional semiconductor elements are connected to form a group, and a connection point thereof is connected with the positive electrode of the in-vehicle battery 5 through the current storage element L4. The anodes of the other two unidirectional semiconductor elements are connected to form another group, and the connection point thereof is connected with the negative electrode of the in-vehicle battery 5. Junction points between the two groups are connected with the pin 3 and the pin 4 of the third transformer T3 respectively through the bidirectional switch S5 and the bidirectional switch S6. Thus, a bridge

rectifier circuit is formed.

Further, a source of the bidirectional switch S1 is connected with a drain of the bidirectional switch S3, a source of the bidirectional switch S2 is connected with a drain of the bidirectional switch S4, the drains of the bidirectional switch S1 and the bidirectional switch S2 are connected
5 with the positive end of the charge storage element C1 through the unidirectional semiconductor element D13, and the sources of the bidirectional switch S3 and the bidirectional switch S4 are connected with the negative end of the charge storage element C1 through the unidirectional semiconductor element D14. Thus, a full bridge circuit is formed.

In the full bridge circuit, the bidirectional switch S1 and the bidirectional switch S2 are upper
10 bridge arms, the bidirectional switch S3 and the bidirectional switch S4 are lower bridge arms. The pin 1 of the fourth transformer T4 is connected with a node between the bidirectional switch S1 and the bidirectional switch S3, a pin 2 of the fourth transformer T4 is connected with a node between the bidirectional switch S2 and the bidirectional switch S4.

Further, the bidirectional switch S1, the bidirectional switch S2, the bidirectional switch S3,
15 the bidirectional switch S4, the bidirectional switch S5 and the bidirectional switch S6 are controlled respectively by the heating circuit control module 100 to switch on or off.

In the following, the working process of the third DC-DC module 4 will be described.

1. After the bidirectional switchgear 1 is switched off, when the electric power recharging to the charge storage element C1 is needed to achieve energy transferring, the heating circuit control
20 module 100 controls the bidirectional switch S5 and the bidirectional switch S6 to switch on, controls the bidirectional switch S1 and the bidirectional switch S4 to switch on simultaneously so as to form a phase A, and controls the bidirectional switch S2 and the bidirectional switch S3 to switch on simultaneously so as to form a phase B. Then, the heating circuit control module 100 controls the phase A and the phase B to switch on alternately, so as to form the full bridge circuit to
25 work.

2. When the full bridge circuit works, the energy in the charge storage element C1 is transferred to the in-vehicle battery 5 through the fourth transformer T4 and the rectifier circuit, in which the rectifier circuit converts the input alternating current into the direct current and then output the direct current to the in-vehicle battery 5 so as to achieve the electric power recharging.

3. When the polarity of the charge storage element C1 needs to be reversed so as to achieve the energy summing, the heating circuit control module 100 controls the bidirectional switch S5

and the bidirectional switch S6 to switch off, and controls the bidirectional switch S1 and the bidirectional switch S4 to switch on (otherwise, controls the bidirectional switch S2 and the bidirectional switch S3 to switch on). At this time, the energy in the charge storage element C1 flows reversely back to the negative end thereof through the positive end thereof, the bidirectional switch S1, a primary side of the fourth transformer T4 and the bidirectional switch S4, or the energy in the charge storage element C1 flows reversely back to the negative end thereof through the positive end thereof, the bidirectional switch S2, the primary side of the fourth transformer T4 and the bidirectional switch S3, in which the voltage polarity of the charge storage element C1 is reversed by a magnetic inductance of the primary side of the fourth transformer T4.

In another embodiment, the energy summing and transferring unit 600 may comprise the energy summing unit and the energy transferring unit. The energy transferring unit is connected with the path formed with the current storage element L1 and the charge storage element C1 for transferring a part of the energy in the heating circuit 11 to the energy storage element after the bidirectional switchgear 1 is switched off from the switched-on state. The energy summing unit is also connected with the path formed with the current storage element L1 and the charge storage element C1 for summing the remaining energy in the heating circuit 11 and the energy in the in-vehicle battery 5 after the energy transferring is conducted by the energy transferring unit.

It should be noted that, any energy summing unit 300 and energy transferring unit 400 described in the above embodiments may be used hereinto transfer and sum the energy in the charge storage element C1.

It should be understood by the person skilled in the art that the above embodiments are not intended to limit methods for transferring and then summing the energy in the heating circuit 11. The person skilled in the art can use other structures to transfer and sum the energy in the heating circuit 11, such as a charge pump.

According to another embodiment of the present disclosure, the system may further comprise an energy limiting circuit for limiting a current flowing from the heating circuit 11 to the in-vehicle battery 5. The bidirectional switchgear 1 may comprise a first unidirectional branch for realizing a flowing of the energy from the in-vehicle battery 5 to the heating circuit 11 and a second unidirectional branch for realizing a flowing of the energy from the heating circuit 11 to the in-vehicle battery 5. The heating circuit control module 100 is connected with the first unidirectional branch and/or the second unidirectional branch for controlling the first

unidirectional branch and/or the second unidirectional branch connected to be on or off. Further, the energy limiting circuit may comprise a current storage element L111. The current storage element L111 is connected in series in the second unidirectional branch for limiting the current flowing to the in-vehicle battery 5.

5 Fig. 18 is a schematic diagram of an embodiment of the bidirectional switchgear 1. As shown in Fig. 18, the bidirectional switchgear 1 comprises a switch K6, a unidirectional semiconductor element D11 and a unidirectional semiconductor element D12. The switch K6 and the unidirectional semiconductor element D11 are connected in series to form the first unidirectional branch, the unidirectional semiconductor element D12 forms the second unidirectional branch. The
10 heating circuit control module 100 is connected with the switch K6 for controlling the first unidirectional branch to be on or off by controlling the switch K6 to switch on or off, and the current storage element L111 is connected with the unidirectional semiconductor element D12 in series. In the bidirectional switchgear shown in Fig. 18, the heating is stated only by switching on the switch K6, and the heating is stopped only by switching off the switch K6.

15 Although the bidirectional switchgear 1 in Fig. 18 realizes the energy flowing forward and reversely along relatively independent branches, it can not realize the switching off the reversely flowing energy. To this end, the present disclosure provides another embodiment of the bidirectional switchgear 1.

Fig. 19 is a schematic diagram of another embodiment of the bidirectional switchgear 1. As
20 shown in Fig. 19, the bidirectional switchgear 1 may further comprise a switch K7 in the second unidirectional branch. The switch K7 is connected with the unidirectional semiconductor element D12 in series. The heating circuit control module 100 is also connected with the switch K7 for controlling the second unidirectional branch to be on or off by controlling the switch K7 to switch on or off. Thus, as there are switches (i.e. the switch K6 and the switch K7) in both of the two
25 unidirectional branches, the bidirectional switchgear 1 in Fig. 19 can switch off both the forward flowing and the reversely flowing of the energy.

In Fig. 19, the current storage element L111 is connected in series between the unidirectional semiconductor element D12 and the switch K7, so as to limit the current flowing to the in-vehicle battery 5.

30 According to embodiments of the present disclosure, when the in-vehicle battery needs to be heated, the heating circuit control module 100 controls the bidirectional switchgear 1 to switch on,

the in-vehicle battery 5 is connected with the heating circuit 11 to form the loop, and the charge storage element C1 is charged by the in-vehicle battery 5. When the current in the loop comes back to zero from the forward peak current, the charge storage element C1 starts to discharge, and the current flows back to the in-vehicle battery 5 from the charge storage element C1. Both the forward current and the reverse current in the loop flow through the damping element R1, and then the in-vehicle battery 5 is heated by the heating of the damping element R1. The above charging and discharging are implemented circularly. When the temperature of the in-vehicle battery 5 reaches the stopping heating condition, the heating circuit control module 100 controls the bidirectional switchgear 1 to switch off so as to make the heating circuit 11 stop working.

In order to save elements and reduce a size of the heating circuit 11, in a preferred embodiment, the current storage element L111 may also be used in the polarity reversing unit 102, so as to limit the current flowing from the heating circuit 11 to the in-vehicle battery 5 when the voltage polarity of the charge storage element C1 is reversed.

Fig. 20 is a schematic diagram of the heating circuit according to a preferred embodiment of the present disclosure. As shown in Fig. 20, the bidirectional switchgear 1 may use the structure of the bidirectional switchgear in Fig. 19, the current storage element L111 is connected in series between the unidirectional semiconductor element D12 and the switch K7 in the second unidirectional branch of the bidirectional switchgear 1. The heating circuit 11 further comprises a unidirectional semiconductor element D15, a unidirectional semiconductor element D16, a switch K10, and a switch K11. A cathode of the unidirectional semiconductor element D16 is connected between the switch K7 and the current storage element L111, an anode of the unidirectional semiconductor element D16 is connected to one end of the switch K11, and the other end of the switch K11 is connected to a negative electrode of the in-vehicle battery 5. An anode of the unidirectional semiconductor element D15 is connected between the unidirectional semiconductor element D12 and the current storage element L111, a cathode of the unidirectional semiconductor element D15 is connected to one end of the switch K10, and the other end of the switch K10 is connected to the negative electrode of the in-vehicle battery 5. The heating circuit control module 100 is also connected with the switch K10 and the switch K11 respectively for controlling the switch K10 and the switch K11 to switch on or off.

In the preferred embodiment, the heating circuit control module 100 may control the switch K6, the switch K7, the switch K10 and the switch K11 by many different on-off strategies, as long

as the on-off strategy can both realize the energy flowing between the in-vehicle battery 5 and the charge storage element C1 and reverse the voltage polarity of the charge storage element C1.

For example, in one embodiment, when the in-vehicle battery 5 needs to be heated, the heating circuit control module 100 controls the switch K6 and the switch K7 to switch on to enable the energy to flow from the in-vehicle battery 5 to the charge storage element C1 and then to flow from the charge storage element C1 to the in-vehicle battery 5 (in which, the switch K6 and the switch K7 may be switched on simultaneously, or the switch K7 may be switched on after the switch K6 is switched off). When a voltage applied to the charge storage element C1 is greater than a first predetermined voltage of the in-vehicle battery 5, the heating circuit controlling module 100 switches off the switch K7, switches on the switch K11, and then switches off the switch K11 until a current flowing through the current storage element L111 is zero. And the heating circuit control module 100 switches on the switch K7 and the switch K10 to enable the voltage polarity of the charge storage element C1 to reverse.

In another example, when the in-vehicle battery 5 needs to be heated, the heating circuit control module 100 controls the switch K6 and the switch K7 to switch on to enable the energy to flow from the in-vehicle battery 5 to the charge storage element C1 and then to flow from the charge storage element C1 to the in-vehicle battery 5. When a voltage applied to the charge storage element C1 is less than or equal to a second predetermined voltage of the in-vehicle battery 5, the heating circuit control module 100 switches off the switch K7 and switches on the switch K11. When a current flowing through the current storage element L111 reaches a second predetermined current, the heating circuit control module 100 switches off the switch K11 and switches on the switch K7 and the switch K10. When the current flowing through the current storage element L111 reaches a first predetermined current, the heating circuit control module 100 switches off the switch K10 to enable an energy in the current storage element L111 to flow to the in-vehicle battery 5. When the current flowing through the current storage element L111 is zero, the heating circuit control module 100 switches on the switch K7 and the switch K10 to enable the voltage polarity of the charge storage element C1 to reverse.

In the following, the working process of the electric vehicle running control system including the energy summing unit 300 will be described with reference to Fig. 21 and Fig. 22.

In the electric vehicle running control system shown in Fig. 21, the heating circuit 11 comprises the damping element R1, the bidirectional switchgear 1, the current storage element L1

and the charge storage element C1 connected in series. The heating circuit 11 is connected with the in-vehicle battery 5 to form a heating loop. The load capacitor C12 is connected with the vehicle load 6 in parallel for providing energy to the vehicle load 6. The current storage element L11 is connected with the load capacitor C12 and the heating circuit 11 respectively. The heating circuit control module 100 is connected with the bidirectional switchgear 1 for controlling the heating circuit 11 to connect with or disconnect from the in-vehicle battery 5 by controlling the bidirectional switchgear 1 to switch on or off. The unidirectional semiconductor element D3, the current storage element L2 and the switch K9 form the polarity reversing unit 102. The heating circuit control module 100 can control the switch K9 to switch on and off.

Fig. 22 shows schematic waveform charts of the heating circuit 11 and the load capacitor C2 in Fig. 21, in which T is a single working period of the electric vehicle running control system, V_{C1} is the voltage of the charge storage element C1 in the heating circuit 11, V_{C12} is the voltage of the load capacitor C12, I_{L11} is the current flowing into the current storage element L11, and I_1 is the current flowing from the load capacitor C12 to the vehicle load 6. It should be noted that the raising and falling of the voltage V_{C12} depend on whether the current I_{L11} (i.e., the current flowing into the load capacitor C12) is greater than the current I_1 . If the current I_{L11} is greater than the current I_1 , the voltage V_{C12} raises; if the current I_{L11} is less than the current I_1 , the voltage V_{C12} falls; and if the current I_{L11} is equal to the current I_1 , the voltage V_{C12} keeps constant. The working process of the electric vehicle running control system in Fig. 21 during the single period T is as follows.

a) During the running of the electric vehicle, if the in-vehicle battery needs to be heated, the heating circuit control module 100 controls the bidirectional switchgear 1 to switch on, and the heating circuit 11 is connected with the in-vehicle battery 5 to form a heating loop. The in-vehicle battery 5 discharges through the heating circuit 11, that is, the in-vehicle battery 5 charges the charge storage element C1 in the heating circuit 11, and the voltage V_{C1} of the charge storage element C1 raises. Meanwhile, the in-vehicle battery 5 also charges the load capacitor C12 through the current storage element L11, and the vehicle load 6 works with the energy provided by the load capacitor C12. At this time, as the current I_{L11} flowing into the current storage element L11 is less than the current I_1 flowing from the load capacitor C12 to the vehicle load 6, the output voltage V_{C12} of the load capacitor C12 falls, as a time period t_1 shown in Fig. 22.

b) When the current in the heating loop comes back to zero from the forward peak current,

the charge storage element C1 in the heating circuit 11 starts to charge the in-vehicle battery 5 through the heating loop, and the voltage V_{C1} of the charge storage element C1 falls. Meanwhile, the charge storage element C1 in the heating circuit 11 also charges the load capacitor C12 through the current storage element L11, and the vehicle load 6 works with the energy provided by the load capacitor C12. At this time, as the current I_{L11} flowing into the current storage element L11 is greater than the current I_1 flowing from the load capacitor C12 to the vehicle load 6, the output voltage V_{C12} of the load capacitor C12 raises, as a time period t2 shown in Fig. 22.

c) When the charge storage element C1 in the heating circuit 11 discharges to a lowest voltage, the heating circuit control module 11 controls the bidirectional switchgear 1 to switch off so as to disconnect the heating circuit 11 from the in-vehicle battery 5. Meanwhile, the heating circuit control module 100 controls the switch K9 to switch on to enable the polarity reversing unit 102 to work, that is, the charge storage element C1 discharges through the loop formed with the unidirectional semiconductor element D3, the current storage element L2 and the switch K9 so as to reverse the voltage polarity. At this time, the voltage V_{C1} of the charge storage element C1 falls to a negative value, and then the heating circuit control module 100 controls the switch K9 to switch off. At this time, as the vehicle load 6 is working with the energy provided by the load capacitor C12, the current I_{L11} flowing into the current storage element L11 is equal to the current I_1 flowing from the load capacitor C12 to the vehicle load 6, and thus the output voltage V_{C12} of the load capacitor C12 keeps constant, as a time period t3 shown in Fig. 22.

It can be seen clearly from Fig. 22 that, the voltage waveforms tend to be stable, this is because the current storage element L11 is connected with the load capacitor C12 to form an LC filter circuit, which can filter the violent voltage fluctuation generated by the heating circuit 11 and reduce an output voltage ripple of the load capacitor C12.

Although explanatory embodiments have been shown and described, it would be appreciated by those skilled in the art that changes, alternatives, and modifications may be made in the embodiments without departing from spirit and principles of the disclosure. Such changes, alternatives, and modifications all fall into the scope of the claims and their equivalents.

Claims

1. An electric vehicle running control system, comprising:

5 a heating circuit connected with an in-vehicle battery to form a heating loop for heating the in-vehicle battery;

a load capacitor; and

a first current storage element connected with the load capacitor and the heating circuit respectively for reducing an interference between the heating circuit and the load capacitor.

10 2. The electric vehicle running control system according to claim 1, wherein the heating circuit comprises a damping element, a bidirectional switchgear, a second current storage element and a first charge storage element, the damping element and the second current storage element are connected in series to form a first part, the bidirectional switchgear and the first charge storage element are connected in series to form a second part, one end of the first part is connected with a positive electrode of the in-vehicle battery, the other end of the first part is connected with one end
15 of the second part and one end of the first current storage element respectively, and the other end of the second part is connected with the load capacitor and a negative electrode of the in-vehicle battery.

3. The electric vehicle running control system according to claim 1 or 2, further comprising:

20 a heating circuit control module configured for controlling the heating circuit to connect with or disconnect from the in-vehicle battery by controlling the bidirectional switchgear to switch on or off.

4. The electric vehicle running control system according to any one of claims 1-3, wherein the damping element is an internal parasitic resistor of the in-vehicle battery, and the second current storage element is an internal parasitic inductor of the in-vehicle battery.

25 5. The electric vehicle running control system according to any one of claims 1-4, wherein the damping element is a resistor, the first current storage element and the second current storage element are inductors, and the first charge storage element is a capacitor.

6. The electric vehicle running control system according to any one of claims 1-5, wherein the heating circuit further comprises an energy summing unit for summing an energy in the heating
30 circuit and an energy in the in-vehicle battery after the bidirectional switchgear is switched off from a switched-on state, and the energy summing unit comprises a polarity reversing unit for

reversing a voltage polarity of the first charge storage element after the bidirectional switchgear is switched off from the switched-on state.

7. The electric vehicle running control system according to any one of claims 1-6, wherein the heating circuit further comprises an energy transferring unit for transferring an energy in the heating circuit to an energy storage element after the bidirectional switchgear is switched off from a switched-on state, and the energy transferring unit comprises an electric power recharging unit for transferring the energy in the heating circuit to the energy storage element after the bidirectional switchgear is switched off from the switched-on state.

8. The electric vehicle running control system according to any one of claims 1-7, wherein the heating circuit further comprises an energy summing and transferring unit for transferring a part of an energy in the heating circuit to an energy storage element after the bidirectional switchgear is switched off from a switched-on state, and then summing a remaining energy in the heating circuit and an energy in the in-vehicle battery.

9. The electric vehicle running control system according to any one of claims 1-8, wherein the energy summing and transferring unit comprises an energy summing unit and an energy transferring unit,

the energy transferring unit is configured for transferring the part of the energy in the heating circuit to the energy storage element after the bidirectional switchgear is switched off from the switched-on state,

the energy summing unit is configured for summing the remaining energy in the heating circuit and the energy in the in-vehicle battery after the part of the energy is transferred by the energy transferring unit,

the energy transferring unit comprises the electric power recharging unit for transferring the part of the energy in the heating circuit to the energy storage element after the bidirectional switchgear is switched off from the switched-on state, and

the energy summing unit comprises the polarity reversing unit for reversing the voltage polarity of the first charge storage element after the part of the energy is transferred by the electric power recharging unit.

10. The electric vehicle running control system according to any one of claims 1-9, wherein the polarity reversing unit comprises a first single-pole double-throw switch located at both ends of the first charge storage element and a second single-pole double-throw switch located at

both ends of the first charge storage element,

a lead-in wire of the first single-pole double-throw switch is connected in the heating circuit, a first lead-out wire of the first single-pole double-throw switch is connected with a first pole plate of the first charge storage element, a second lead-out wire of the first single-pole double-throw
5 switch is connected with a second pole plate of the first charge storage element,

a lead-in wire of the second single-pole double-throw switch is connected in the heating circuit, a first lead-out wire of the second single-pole double-throw switch is connected with the second pole plate of the first charge storage element, a second lead-out wire of the second single-pole double-throw switch is connected with the first pole plate of the first charge storage
10 element, and

the heating circuit control module is connected with the first single-pole double-throw switch and the second single-pole double-throw switch respectively, for reversing the voltage polarity of the first charge storage element by changing respective connection relations between the lead-in wire and the lead-out wires of the first single-pole double-throw switch and the second single-pole
15 double-throw switch.

11. The electric vehicle running control system according to any one of claims 1-10, wherein the polarity reversing unit comprises:

a third current storage element;

a first switch, in which the first charge storage element, the third current storage element and
20 the first switch are connected in series sequentially to form a loop, and the heating circuit control module is connected with the first switch, for reversing the voltage polarity of the first charge storage element by controlling the first switch to switch on; and

a first unidirectional semiconductor element, in which the first unidirectional semiconductor element is connected in series between the first charge storage element and the third current
25 storage element or between the third current storage element and the first switch.

12. The electric vehicle running control system according to any one of claims 1-11, wherein the polarity reversing unit comprises:

a second charge storage element; and

a first DC-DC module, in which the heating circuit control module is connected with the first
30 DC-DC module for transferring an energy in the first charge storage element to the second charge storage element, and then reversely transferring an energy in the second charge storage element

back to the first charge storage element, by controlling the first DC-DC module, so as to reverse the voltage polarity of the first charge storage element.

13. The electric vehicle running control system according to any one of claims 1-12, wherein the electric power recharging unit comprises a second DC-DC module, and the heating circuit
5 control module is connected with the second DC-DC module for transferring an energy in the first charge storage element to the in-vehicle battery, by controlling the second DC-DC module.

14. The electric vehicle running control system according to any one of claims 1-13, wherein the energy summing and transferring unit comprises a third DC-DC module, and the heating
10 circuit control module is connected with the third DC-DC module for transferring a part of an energy in the first charge storage element to the energy storage element, and then summing a remaining energy in the first charge storage element and the energy in the in-vehicle battery, by controlling the third DC-DC module.

15. The electric vehicle running control system according to any one of claims 1-14, further comprising:

15 an energy limiting circuit for limiting a current flowing from the heating circuit to the in-vehicle battery.

16. The electric vehicle running control system according to any one of claims 1-15, wherein the bidirectional switchgear comprises a first unidirectional branch for realizing a flowing of
an energy from the in-vehicle battery to the heating circuit, and a second unidirectional branch for
20 realizing a flowing of an energy from the heating circuit to the in-vehicle battery, and

the heating circuit control module is connected with the first unidirectional branch and/or the second unidirectional branch for controlling the first unidirectional branch and/or the second unidirectional branch connected to be on or off.

17. The electric vehicle running control system according to any one of claims 1-16, wherein
25 the energy limiting circuit comprises a fourth current storage element connected in series in the second unidirectional branch.

18. The electric vehicle running control system according to any one of claims 1-17, wherein the bidirectional switchgear comprises a second switch, a second unidirectional
semiconductor element and a third unidirectional semiconductor element,

30 the second switch and the second unidirectional semiconductor element are connected in series to form the first unidirectional branch, the third unidirectional semiconductor element forms

the second unidirectional branch,

the heating circuit control module is connected with the second switch for controlling the first unidirectional branch to be on or off by controlling the second switch to switch on or off, and

the fourth current storage element is connected with the third unidirectional semiconductor element in series.

19. The electric vehicle running control system according to any one of claims 1-18, wherein the bidirectional switchgear further comprises a third switch in the second unidirectional branch, the third switch is connected with the third unidirectional semiconductor element in series, the heating circuit control module is connected with the third switch for controlling the second unidirectional branch to be on or off by controlling the third switch to switch on or off, and the fourth current storage element is connected in series between the third unidirectional semiconductor element and the third switch.

20. The electric vehicle running control system according to any one of claims 1-19, wherein the heating circuit further comprises a fourth unidirectional semiconductor element, a fifth unidirectional semiconductor element, a fourth switch and a fifth switch,

a cathode of the fifth unidirectional semiconductor element is connected between the third switch and the fourth current storage element, an anode of the fifth unidirectional semiconductor element is connected to one end of the fifth switch, and the other end of the fifth switch is connected to a negative electrode of the in-vehicle battery;

an anode of the fourth unidirectional semiconductor element is connected between the third unidirectional semiconductor element and the fourth current storage element, a cathode of the fourth unidirectional semiconductor element is connected to one end of the fourth switch, and the other end of the fourth switch is connected to the negative electrode of the in-vehicle battery; and

the heating circuit control module is connected with the fourth switch and the fifth switch respectively for controlling the fourth switch and the fifth switch to switch on or off.

21. The electric vehicle running control system according to any one of claims 1-20, wherein the heating circuit control module is configured for:

controlling the second switch and the third switch to switch on to enable an energy to flow from the in-vehicle battery to the first charge storage element and to flow from the first charge storage element to the in-vehicle battery;

switching off the third switch and switching on the fifth switch when a voltage applied to the

first charge storage element is greater than a first predetermined voltage of the in-vehicle battery;
and

switching off the fifth switch and switching on the third switch and the fourth switch when a
current flowing through the fourth current storage element is zero, to enable the voltage polarity of
5 the first charge storage element to reverse.

22. The electric vehicle running control system according to any one of claims 1-21, wherein
the heating circuit control module is configured for:

controlling the second switch and the third switch to switch on to enable an energy to flow
from the in-vehicle battery to the first charge storage element and to flow from the first charge
10 storage element to the in-vehicle battery;

switching off the third switch and switching on the fifth switch when a voltage applied to the
first charge storage element is less than or equal to a second predetermined voltage of the
in-vehicle battery;

switching off the fifth switch and switching on the third switch and the fourth switch when a
15 current flowing through the fourth current storage element reaches a second predetermined
current;

switching off the fourth switch when the current flowing through the fourth current storage
element reaches a first predetermined current, to enable an energy in the fourth current storage
element to flow to the in-vehicle battery; and

20 switching on the third switch and the fourth switch when the current flowing through the
fourth current storage element is zero, to enable the voltage polarity of the first charge storage
element to reverse.

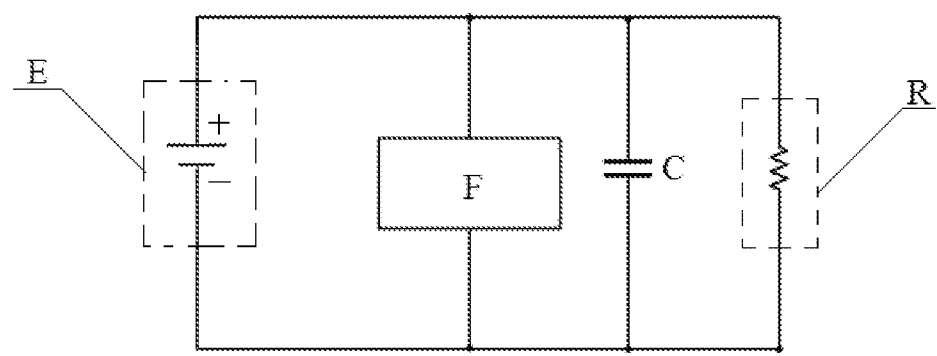


Fig. 1

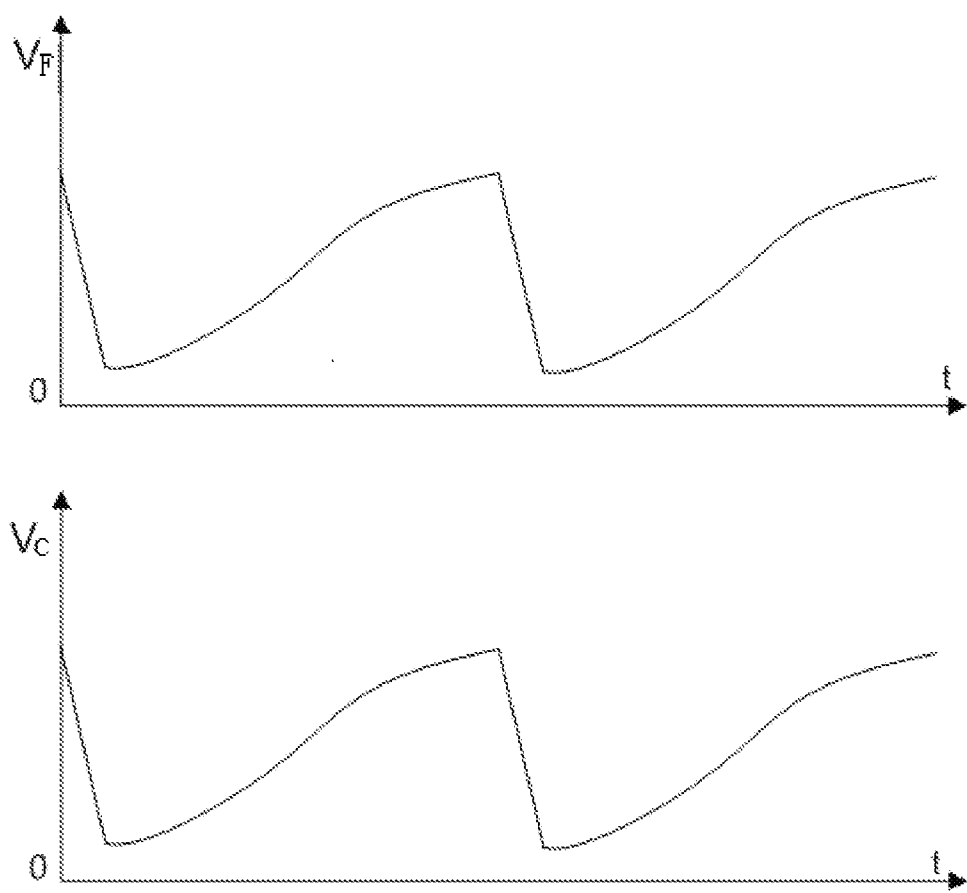


Fig. 2

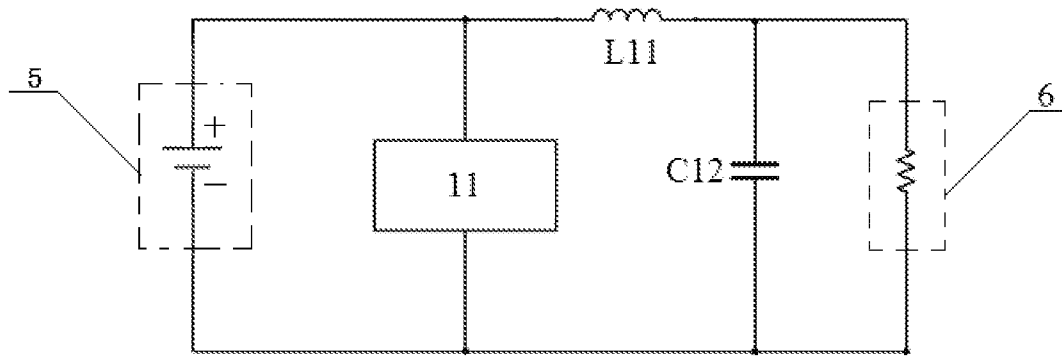


Fig. 3

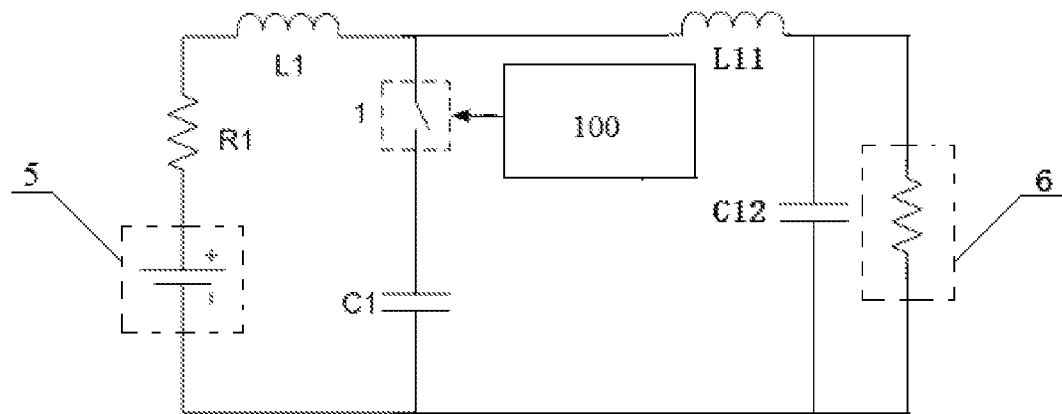


Fig. 4

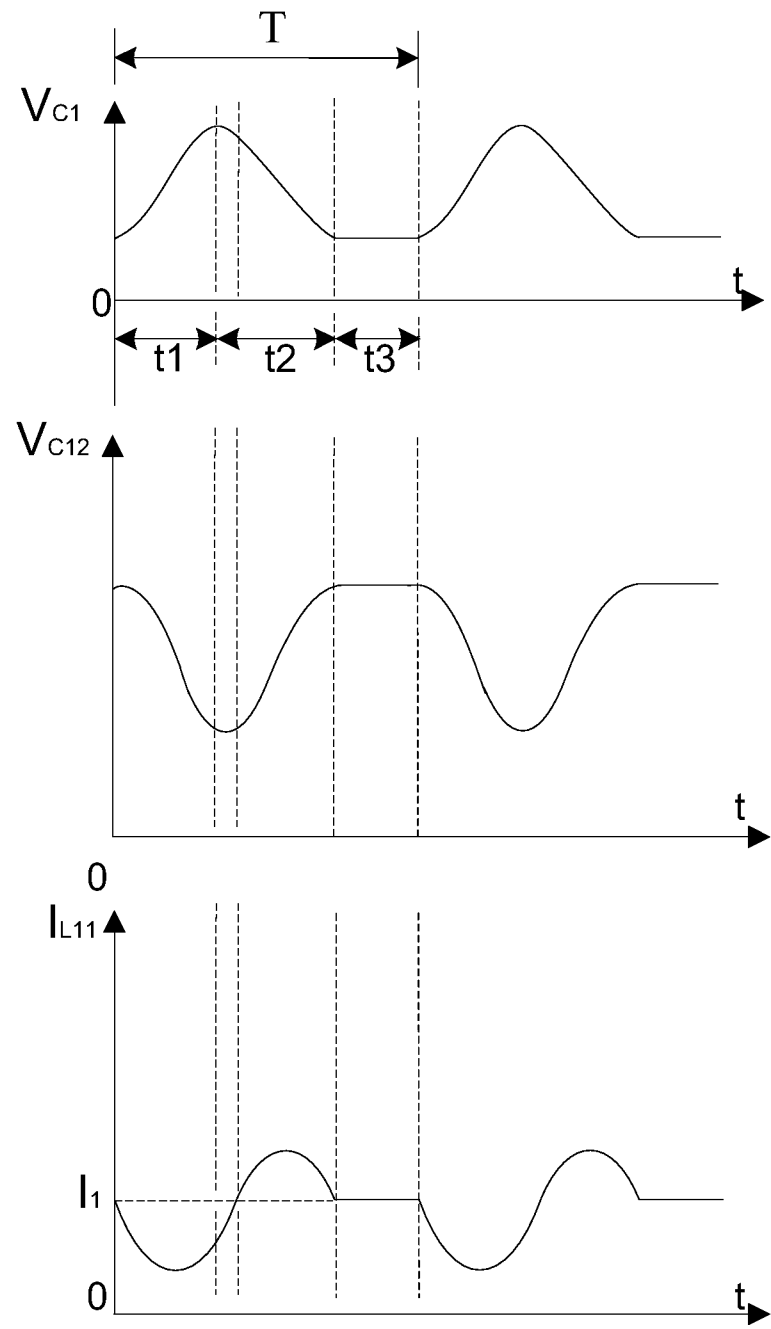


Fig. 5

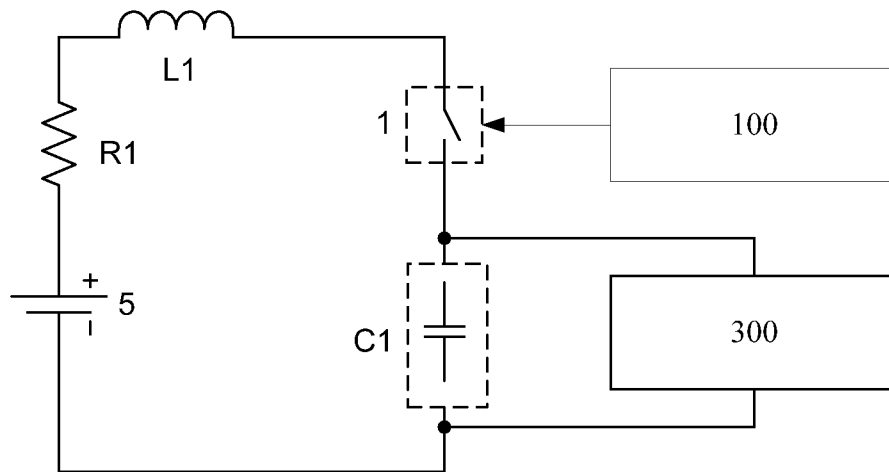


Fig. 6

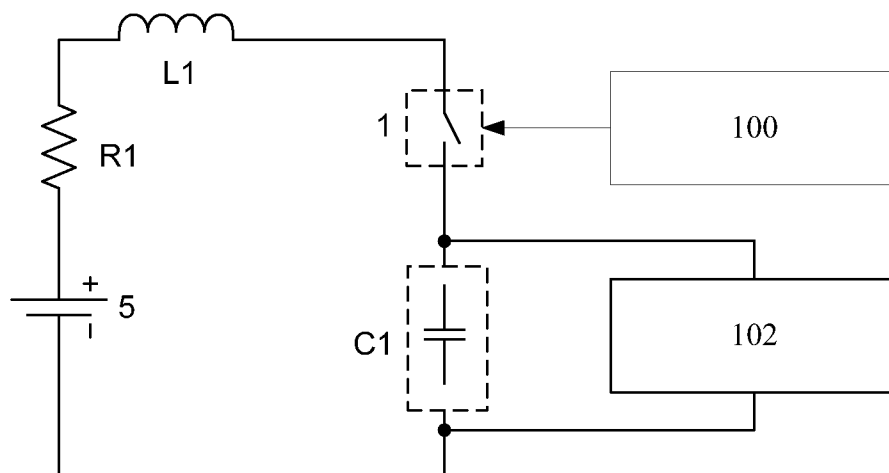


Fig. 7

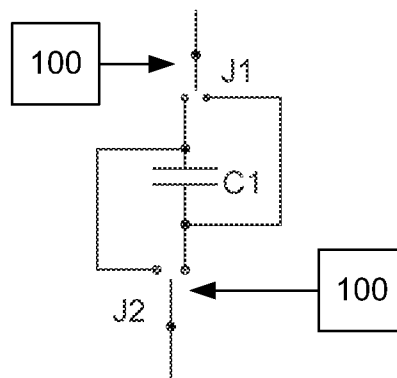


Fig. 8

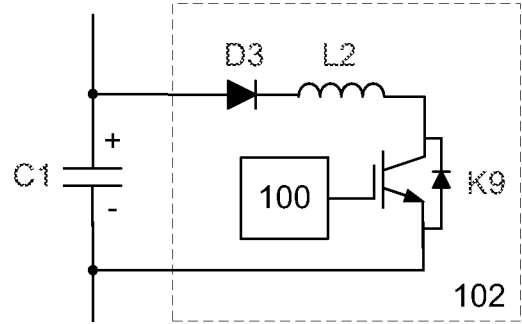


Fig. 9

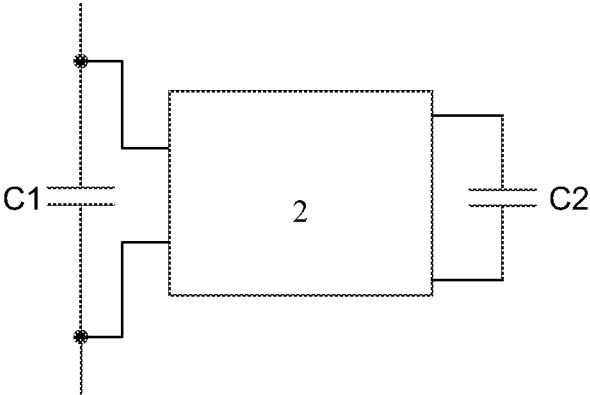


Fig. 10

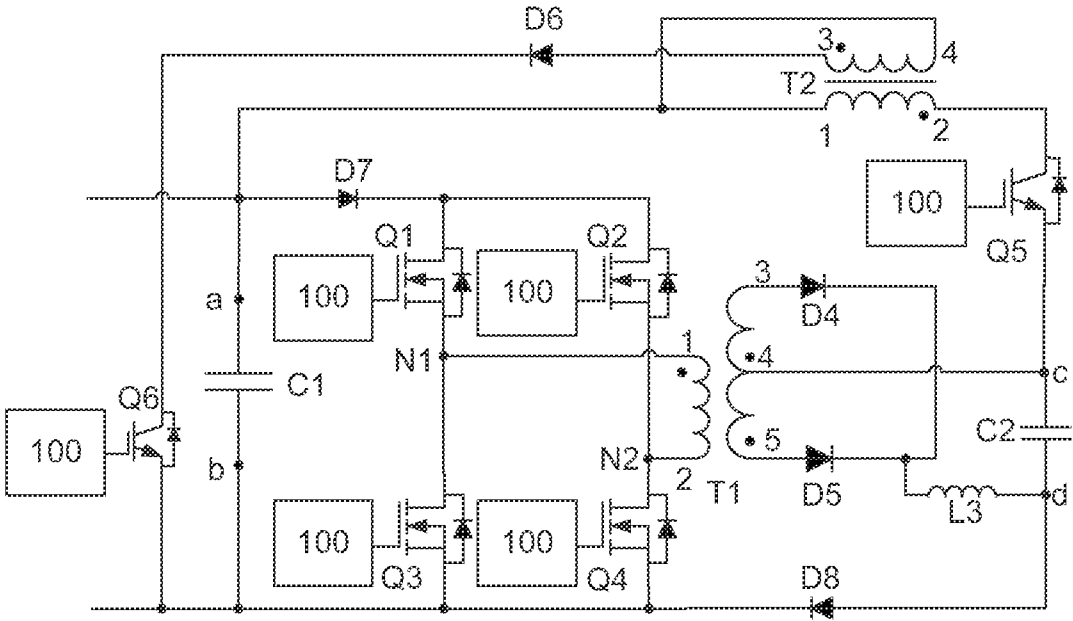


Fig. 11

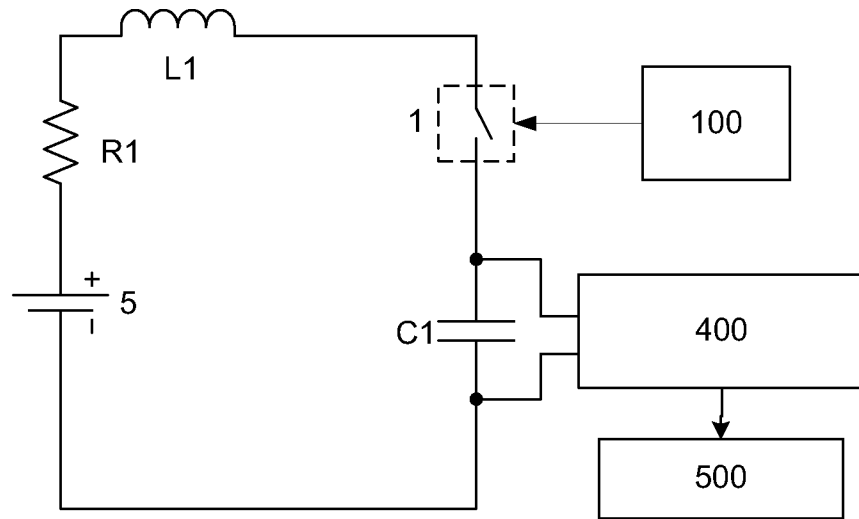


Fig. 12

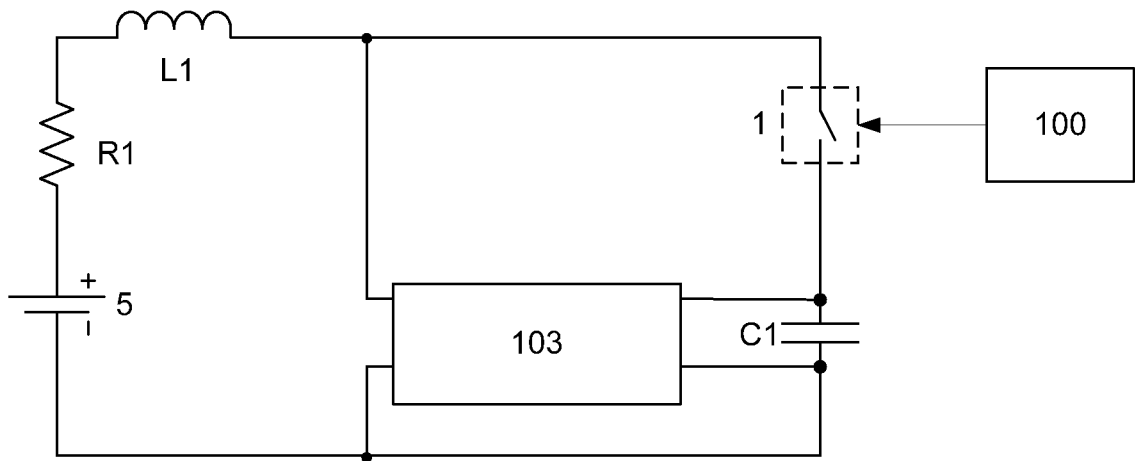


Fig. 13

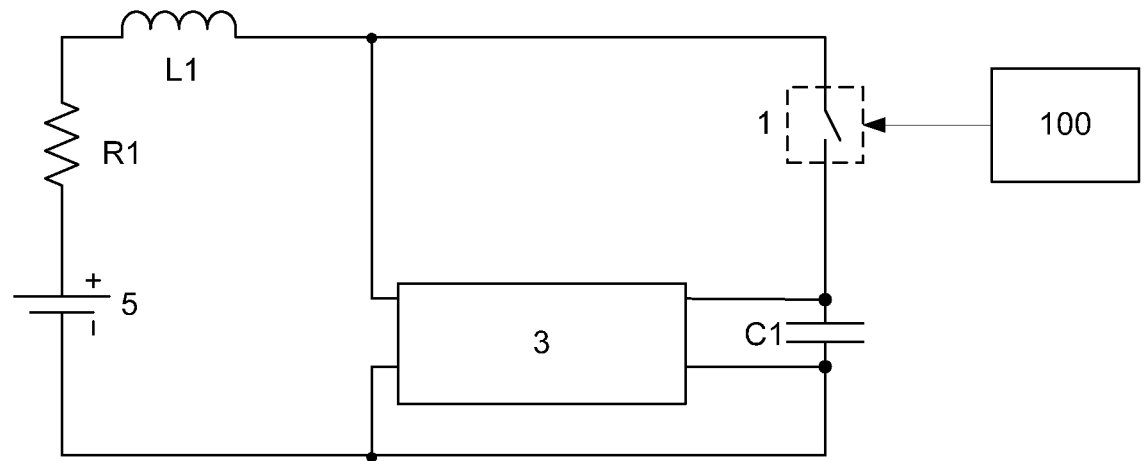


Fig. 14

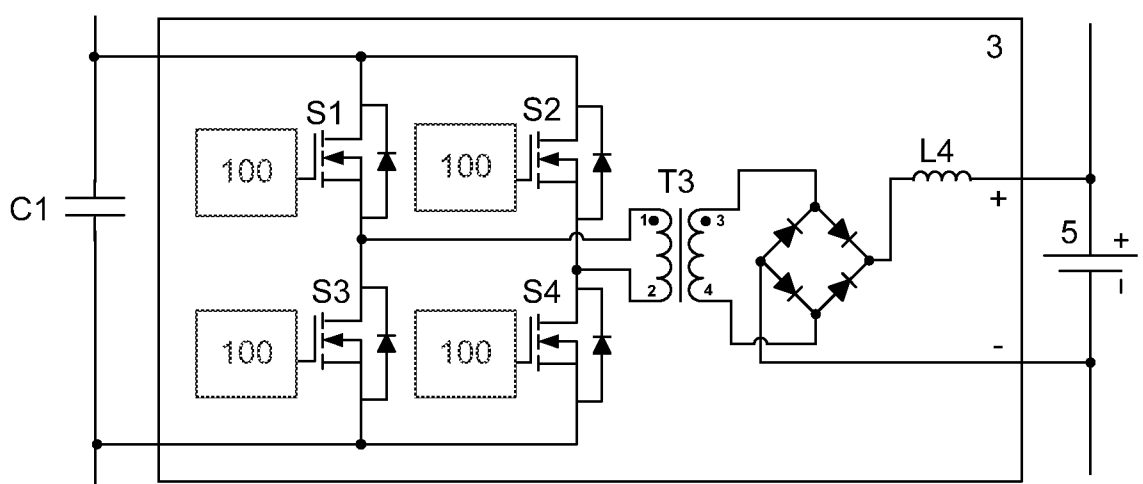


Fig. 15

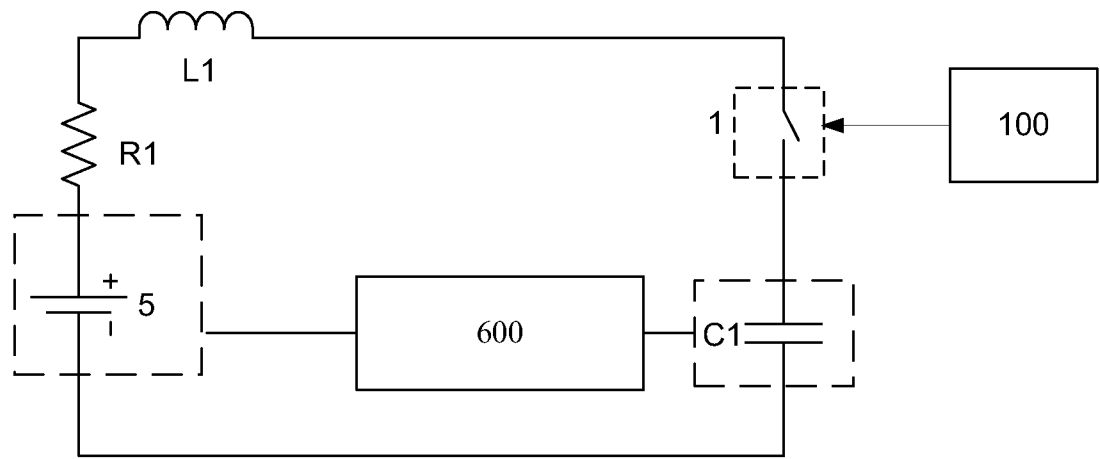


Fig. 16

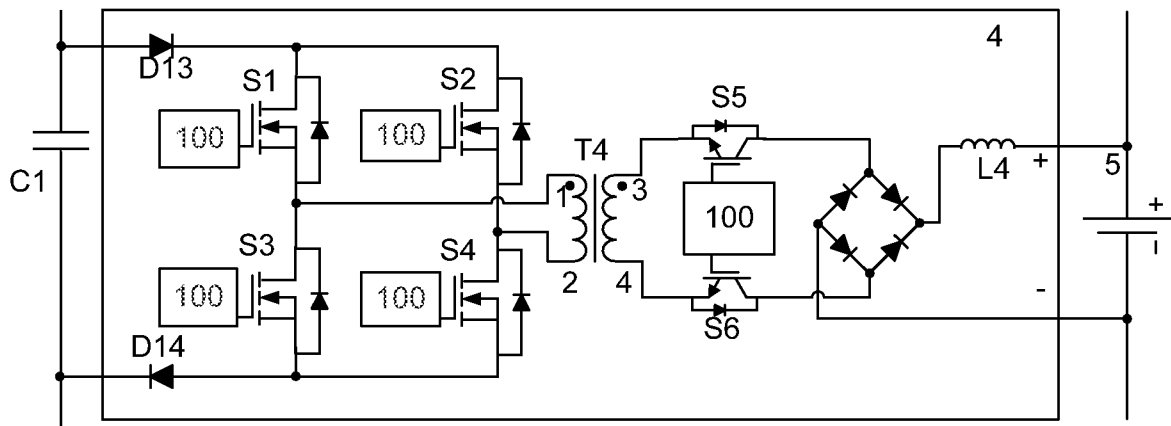


Fig. 17

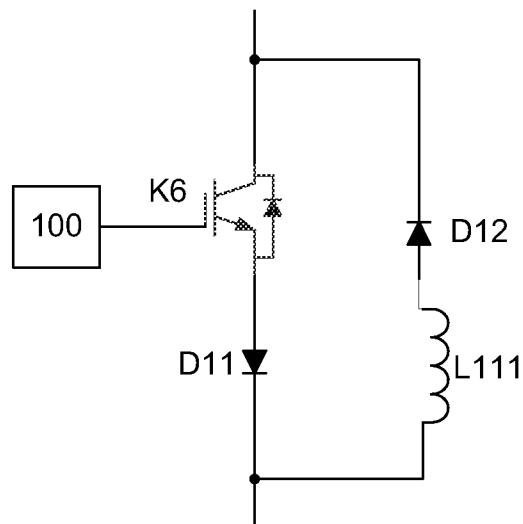


Fig. 18

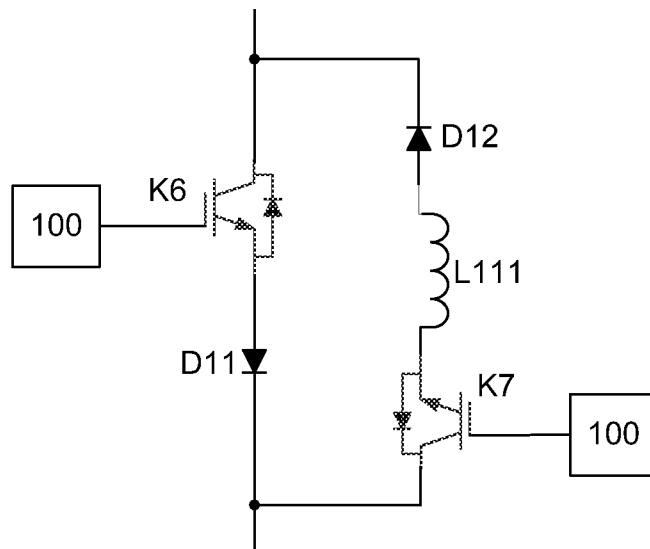


Fig. 19

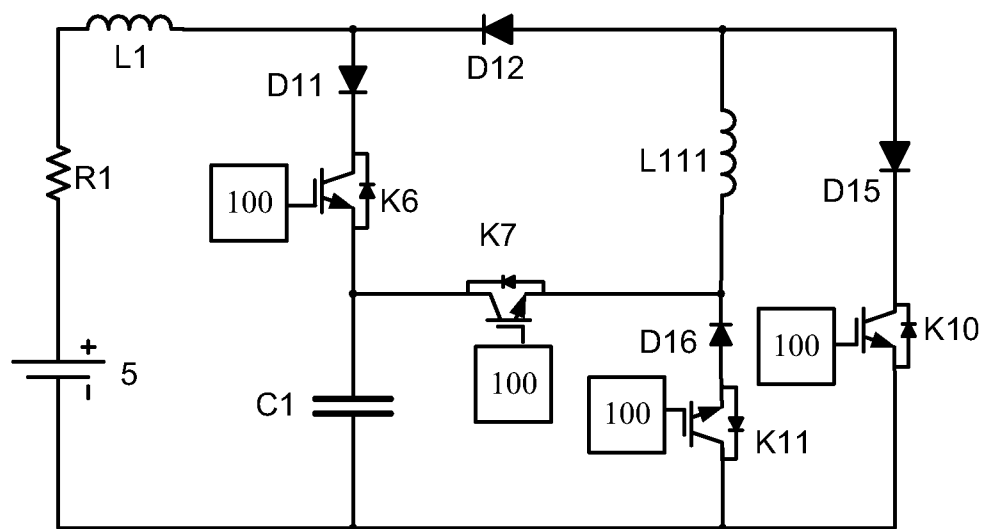


Fig. 20

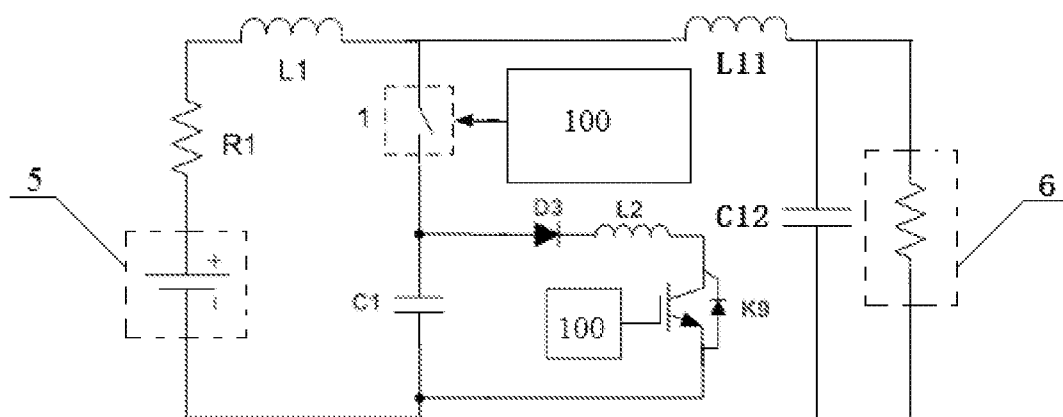


Fig. 21

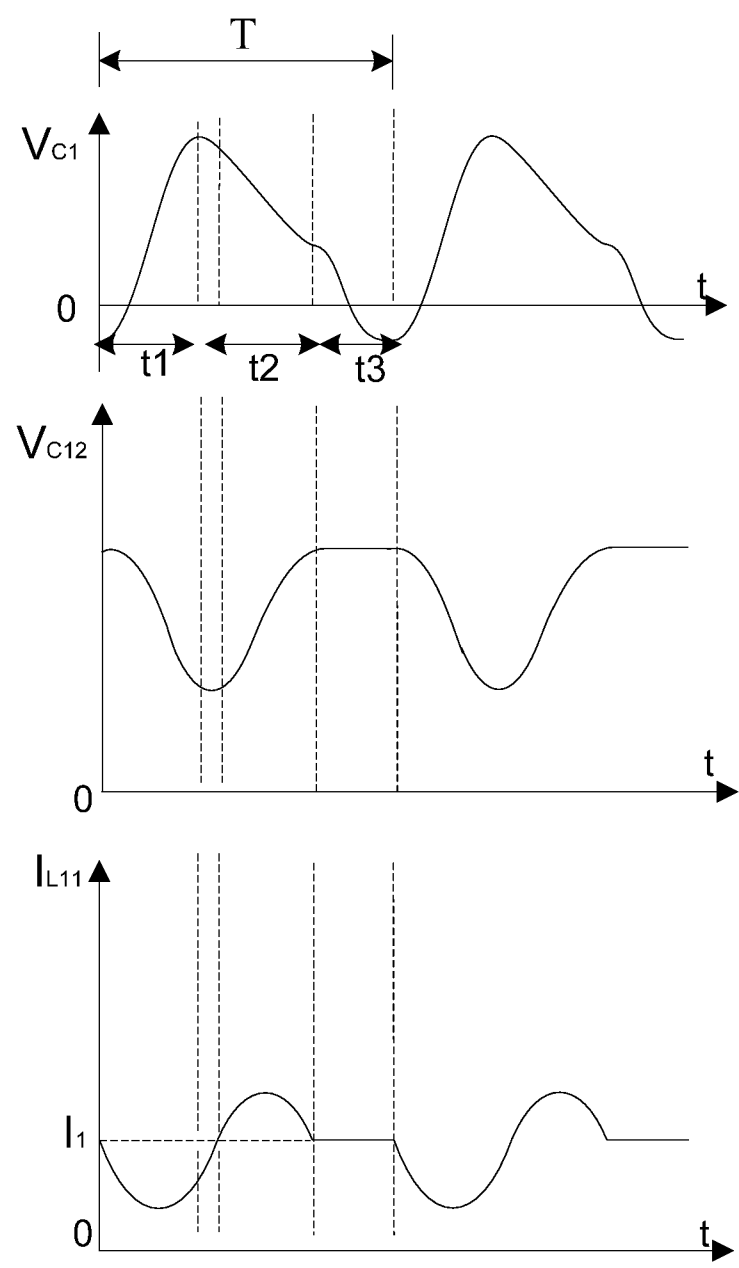


Fig. 22

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2013/070644

A. CLASSIFICATION OF SUBJECT MATTER

See the extra sheet

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: B60L11/-; H01M10/-; H02J7/-; H05B3/-

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI; EPODOC; CNPAT; CNKI: (vehicle? or car? or automobile?), (heat+ or warm+), circuit, (batter+ or cell?), (capacitance? or capacitor?), (inductance? or inductor?), current, (resistance? or resistor? or damping), control+, interfere+

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P, X	CN 202541450 U (BYD CO., LTD.) 21 Nov. 2012 (21.11.2012) See claims 1-22	1-22
A	CN 102082306 A (BYD CO., LTD.) 01 Jun. 2011 (01.06.2011) See paragraph 28 to paragraph 30 in the description, figure 1	1-22
A	CN 201667552 U (BYD CO., LTD.) 08 Dec. 2010 (08.12.2010) See the whole document	1-22
A	CN 102074752 A (BYD CO., LTD.) 25 May 2011 (25.05.2011) See the whole document	1-22

☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:	“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
“A” document defining the general state of the art which is not considered to be of particular relevance	“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
“E” earlier application or patent but published on or after the international filing date	“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
“L” document which may throw doubts on priority claim (S) or which is cited to establish the publication date of another citation or other special reason (as specified)	“&” document member of the same patent family
“O” document referring to an oral disclosure, use, exhibition or other means	
“P” document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search 11 Apr. 2013 (11.04.2013)	Date of mailing of the international search report 25 Apr. 2013 (25.04.2013)
Name and mailing address of the ISA/CN The State Intellectual Property Office, the P.R.China 6 Xitucheng Rd., Jimen Bridge, Haidian District, Beijing, China 100088 Facsimile No. 86-10-62019451	Authorized officer CHEN, Biao Telephone No. (86-10)62085430

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2013/070644

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 102074754 A (BYD CO., LTD.) 25 May 2011 (25.05.2011) See the whole document	1-22
A	CN 202111197 U (NORTH CHINA GRID CO., LTD., <i>et al</i>) 11 Jan. 2012 (11.01.2012) See the whole document	1-22
A	CN 201994390 U (TIANJIN SANQIANG ELECTRIC VEHICLE CO., LTD.) 28 Sep. 2011 (28.09.2011) See the whole document	1-22
A	WO 2009/099342 A2 (RESTECH LIMITED) 13 Aug. 2009 (13.08.2009) See the whole document	1-22
A	US 6340879 B1 (NOKIA MOBILE PHONES LTD.) 22 Jan. 2002 (22.01.2002) See the whole document	1-22

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2013/070644

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
CN 202541450 U	21.11.2012	None	
CN 102082306 A	01.06.2011	EP 2413454 A1	01.02.2012
		EP 2413455 A1	01.02.2012
		EP 2413456 A1	01.02.2012
		EP 2413457 A1	01.02.2012
		EP 2413458 A1	01.02.2012
		EP 2413459 A1	01.02.2012
		EP 2413460 A1	01.02.2012
		EP 2413461 A1	01.02.2012
		EP 2413462 A1	01.02.2012
		EP 2413463 A1	01.02.2012
		EP 2413464 A1	01.02.2012
		EP 2413465 A1	01.02.2012
		EP 2413466 A1	01.02.2012
		EP 2413467 A1	01.02.2012
		EP 2413468 A1	01.02.2012
		EP 2413469 A1	01.02.2012
		EP 2421114 A1	22.02.2012
		US 2012/0024838 A1	02.02.2012
		US 2012/0025754 A1	02.02.2012
		US 2012/0025755 A1	02.02.2012
		US 2012/0025756 A1	02.02.2012
		US 2012/0025772 A1	02.02.2012
		US 2012/0025774 A1	02.02.2012
		US 2012/0025775 A1	02.02.2012
		US 2012/0025776 A1	02.02.2012
		US 2012/0025777 A1	02.02.2012
		US 2012/0025778 A1	02.02.2012
		US 2012/0025779 A1	02.02.2012
		US 2012/0025780 A1	02.02.2012
		US 2012/0025781 A1	02.02.2012

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2013/070644

Continuation of : A. CLASSIFICATION OF SUBJECT MATTER

B60L 11/18 (2006.01) i

H01M 10/50 (2006.01) i

H02J 7/00 (2006.01) i

H05B 3/00 (2006.01) n

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2013/070644

Continuation of : Information on patent family members

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
		US 2012/0025782 A1	02.02.2012
		US 2012/0025783 A1	02.02.2012
		US 2012/0031890 A1	09.02.2012
		US 2012/0032642 A1	09.02.2012
		US 2012/0280659 A1	08.11.2012
		US 2012/0279951 A1	08.11.2012
		US 2012/0280658 A1	08.11.2012
		US 2012/0306432 A1	06.12.2012
		WO 2012/013065 A1	02.02.2012
		WO 2012/013066 A1	02.02.2012
		WO 2012/013067 A1	02.02.2012
		WO 2012/013068 A1	02.02.2012
		WO 2012/013069 A1	02.02.2012
		WO 2012/013070 A1	02.02.2012
		WO 2012/013071 A1	02.02.2012
		WO 2012/013072 A1	02.02.2012
		WO 2012/013073 A1	02.02.2012
		WO 2012/013074 A1	02.02.2012
		WO 2012/013075 A1	02.02.2012
		WO 2012/013076 A1	02.02.2012
		WO 2012/013077 A1	02.02.2012
		WO 2012/013078 A1	02.02.2012
		WO 2012/013079 A1	02.02.2012
		WO 2012/013081 A1	02.02.2012
		WO 2012/013082 A1	02.02.2012
		CA 2805781 A1	02.02.2012
		CA 2805797 A1	02.02.2012
		CA 2806407 A1	02.02.2012
		CA 2806628 A1	02.02.2012
		CA 2807002 A1	02.02.2012

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2013/070644

Continuation of : Information on patent family members

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
		CN 102074753 A	25.05.2011
		CN 102074755 A	25.05.2011
		CN 102074756 A	25.05.2011
		CN 102074758 A	25.05.2011
		CN 102074759 A	25.05.2011
		CN 102074760 A	25.05.2011
		CN 102074761 A	25.05.2011
		CN 102074762 A	25.05.2011
		CN 102088116 A	08.06.2011
		CN 102088117 A	08.06.2011
		CN 102170030 A	31.08.2011
		CN 102170031 A	31.08.2011
		CN 102255108 A	23.11.2011
		CN 102255110 A	23.11.2011
		CN 102255111 A	23.11.2011
		CN 102306849 A	04.01.2012
		CN 201936966 U	17.08.2011
		CN 201936967 U	17.08.2011
		CN 201936969 U	17.08.2011
		CN 201966300 U	07.09.2011
		CN 202009058 U	12.10.2011
		CN 202009060 U	12.10.2011
		CN 202042565 U	16.11.2011
		CN 202042566 U	16.11.2011
		CN 202042567 U	16.11.2011
		CN 202042568 U	16.11.2011
		CN 202042572 U	16.11.2011
		CN 202076379 U	14.12.2011
		CN 202076380 U	14.12.2011
		CN 202076381 U	14.12.2011

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2013/070644

Continuation of : Information on patent family members

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
		CN 202103139 U	04.01.2012
		CN 202121024 U	18.01.2012
		CN 202145485 U	15.02.2012
		HK 1158370 A1	28.12.2012
		HK 1158371 A1	28.12.2012
		HK 1158372 A1	25.01.2013
		HK 1158373 A1	01.02.2013
		HK 1158374 A1	25.01.2013
		HK 1158375 A1	01.02.2013
		HK 1158378 A1	28.12.2012
		HK 1158379 A1	01.02.2013
		HK 1158829 A1	01.02.2013
		TW M439195 U1	11.10.2012
CN 201667552 U	08.12.2010	None	
CN 102074752 A	25.05.2011	EP 2469683 A1	27.06.2012
		US 2012/0161711 A1	28.06.2012
		WO 2012/083635 A1	28.06.2012
		HK 1158376 A1	25.01.2013
		TW M438023 U	21.09.2012
		US 2012/0299551 A1	29.11.2012
CN 102074754 A	25.05.2011	EP 2413454 A1	01.02.2012
		WO 2012/013065 A1	02.02.2012
		US 2012/0025755 A1	02.02.2012
		HK 1158377 A1	28.12.2012
CN 202111197 U	11.01.2012	None	
CN 201994390 U	28.09.2011	None	
WO 2009/099342 A2	13.08.2009	US 2009/0201620 A1	13.08.2009
		CA 2751225 A1	13.08.2009
		TW 200945756 A	01.11.2009
US 6340879 B1	22.01.2002	EP 1026769 A2	09.08.2000

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2013/070644

Continuation of : Information on patent family members

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
		JP 20002-28231 A	15.08.2000
		DE 19904181 A1	10.08.2000