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Inventor(s)	KIMURA; Masaru

POWER SUPPLY DEVICE

Abstract

A battery unit includes: a connecting portion electrically connectable to an electrical apparatus in which the battery unit is mounted; a cell that allows supply of electric power to the electrical apparatus; a relay that switches between a conductive state in which a power supply line between the connecting portion and the cell is electrically connected and an interrupt state in which the power supply line is electrically interrupted; a first notification device that operates, when being supplied with electric power, to allow an operating state to be recognized from outside; and a first supply source that supplies electric power to the first notification device when the first supply source is connected to the first notification device and the relay is in the conductive state.

Inventors: **KIMURA; Masaru (Toyota-shi, JP)**

Applicant: **TOYOTA JIDOSHA KABUSHIKI KAISHA** (Toyota-shi, JP)

Family ID: **1000008421341**

Assignee: **TOYOTA JIDOSHA KABUSHIKI KAISHA (Toyota-shi, JP)**

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This nonprovisional application is based on Japanese Patent Application No. 2024-024541 filed on Feb. 21, 2024 with the Japan Patent Office, the entire contents of which are hereby incorporated by reference.

BACKGROUND

Field

[0002] The present disclosure relates to a power supply device detachable from an electrical apparatus.

Description of the Background Art

[0003] An electrically powered vehicle is well known in which a power supply device including a changeable battery or the like is mounted. For example, Japanese Patent Laying-Open No. 2022-034842 discloses a changeable power supply device including a relay provided in each of the positive and negative power supply lines between the battery and a portion connected with the vehicle.

SUMMARY

[0004] The power supply device as described above requires the determination of the presence or absence of welding while a plurality of relays are being disconnected. When the determination of the presence or absence of welding is performed on the apparatus side (e.g., on the electrically powered vehicle side) in which the power supply device is mounted, however, if the power supply device is removed from the apparatus, a determination result is not associated with the removed power supply device, and accordingly, the determination as to whether or not welding has occurred at a destination may be required. As a result, the number of relay operations may increase.

[0005] An object of the present disclosure is to provide a power supply device that can determine the presence or absence of welding of a relay even when the power supply device is removed from an apparatus in which the power supply device is mounted.

[0006] A power supply device according to an aspect of the present disclosure includes: a connecting portion electrically connectable to an electrical apparatus in which the power supply device is mounted; a power storage device that allows supply of electric power to the electrical apparatus; a relay that switches between a conductive state in which a power supply line between the connecting portion and the power storage device is electrically connected and an interrupt state in which the power supply line is electrically interrupted; a notification device that operates, when being supplied with electric power, to allow the conductive state to be recognized from outside; and a supply source that supplies electric power to the notification device when the supply source is connected to the notification device and the relay is in the conductive state.

[0007] Thus, when the power supply device is removed from the electrical apparatus in which the power supply device is mounted and when the relay is controlled to enter the interrupt state, it can be determined that the relay has been welded if the notification device is operating to allow the operating state to be recognized from outside using electric power of the supply source. Thus, whether welding of the relay has occurred can be determined with high accuracy even when the power supply device is removed from the apparatus in which the power supply device is mounted.

[0008] In an embodiment, the notification device and the supply source are connected in parallel with the relay with respect to the power supply line. When the relay is in the conductive state, the notification device, the supply source, and the relay form a closed circuit, and the supply source supplies electric power to the notification device.

[0009] Thus, when the power supply device is removed from the electrical apparatus in which the power supply device is mounted and when the relay is controlled to enter the interrupt state, it can

be determined that the relay has been welded if the notification device is operating to allow the operating state to be recognized from outside using electric power of the supply source.
[0010] In another embodiment, the notification device includes a light emitting device that emits light in the conductive state.
[0011] Thus, when the light emitting device is emitting light with the power supply device removed from the apparatus in which the power supply device is mounted, it can be determined with high accuracy that the relay has been welded.
[0012] In still another embodiment, the notification device includes a sound generating device that generates a sound in the conductive state.
[0013] Thus, when a sound has been generated by the sound generating device with the power supply device removed from the apparatus in which the power supply device is mounted, it can be determined with high accuracy that the relay has been welded.
[0014] The foregoing and other objects, features, aspects and advantages of the present disclosure will become more apparent from the following detailed description of the present disclosure when taken in conjunction with the accompanying drawings.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0015] FIG. **1** shows an example configuration of a battery change system.
[0016] FIG. **2** shows an example configuration of a battery unit.
[0017] FIG. **3** is a diagram for illustrating the connection relationship between a vehicle and the battery unit.
[0018] FIG. **4** is a diagram for illustrating an example configuration of a power system of the vehicle.
[0019] FIG. **5** is a timing chart showing an example method of determining welding of each relay.
[0020] FIG. **6** is a timing chart showing another example method of determining welding of each relay.
[0021] FIG. **7** shows an example configuration of the battery unit, which is a power supply device according to the present embodiment.
[0022] FIG. **8** shows an example configuration of a battery unit, which is a power supply device according to a modification.
DESCRIPTION OF THE PREFERRED EMBODIMENTS
[0023] Embodiments of the present disclosure will be described below in detail with reference to the drawings. The same or corresponding portions in the drawings are denoted by the same reference characters, and description thereof will not be repeated.
[0024] An example battery change system including a power supply device according to the present embodiment will be described below. FIG. **1** shows an example configuration of the battery change system. As shown in FIG. **1**, battery change system **1** includes a vehicle **100**, a charging rack **120**, and a charging stand **130**.
[0025] Vehicle **100** is configured to allow a plurality of battery units of rectangular parallelepiped shape, including a battery unit **200**, to be detachable in a housing space **101**. FIG. **1** shows, as an example, a case in which vehicle **100** is configured so as to mount therein three battery units and one battery unit **200** is mounted in vehicle **100**, but the upper limit number of mounted battery units is not particularly limited to three. Vehicle **100** includes, for example, an electrically powered vehicle such as a battery electric vehicle or a hybrid electric vehicle.
[0026] Charging rack **120** is configured to so as to mount therein a plurality of battery units. FIG. **1** shows, as an example, a case in which the charging rack is configured so as to mount therein nine battery units and seven battery units including battery unit **200** are mounted in the charging rack.

[0027] Charging rack **120** charges at least any of the housed battery units using electric power supplied from charging stand **130**. Charging rack **120** may charge a plurality of housed battery units one by one in a prescribed order, charge the plurality of housed battery units or some of the housed battery units in parallel, or charge a battery unit specified by charging stand **130**. Charging rack **120** may charge the housed battery units when the battery units are housed, or charge the housed battery units upon receipt of a request from charging stand **130** to start charging.
[0028] Charging stand **130** is configured to provide electric power to charging rack **120**. For example, charging stand **130** may transmit, to charging rack **120**, information specifying a battery unit to be charged among the plurality of battery units housed in charging rack **120**.
[0029] FIG. **2** shows an example configuration of battery unit **200**. As shown in FIG. **2**, battery unit **200** includes a relay circuit **202**, a positive connector **204**, a negative connector **206**, a plurality of cells **208**, a first notification device **212**, and a second notification device **222**.
[0030] Relay circuit **202** includes a relay CR**1-1** connected to a positive power supply line and a relay CR**1-2** connected to a negative power supply line.
[0031] Cells **208** are configured by series connection of a prescribed number of (22 in FIG. **2**) cells **208**. It suffices that cell **208** is, for example, a rechargeable energy storage device, which may be, for example, a nickel-metal hydride battery or include a secondary battery such as lithium ion battery with a liquid or solid electrolyte. Cell **208** may be a capacitor.
[0032] Positive connector **204** and negative connector **206** are configured to be connectable to a connector provided in housing space **101** for battery unit **200** in vehicle **100**. Positive connector **204** and negative connector **206** correspond to a connecting portion electrically connected to vehicle **100** that is an electrical apparatus in which battery unit **200** is mounted. The detailed configurations of first notification device **212** and second notification device **222** will be described later.
[0033] The housing of battery unit **200** shown in FIG. **2** is configured so as to be housed in housing space **101** of battery unit **200** provided in vehicle **100**.
[0034] FIG. **3** is a diagram for illustrating the connection relationship between vehicle **100** and battery unit **200**. As shown in FIG. **3**, housing portions **106**, **108**, **110** are set in housing space **101** of vehicle **100**. Three battery units **200**, **300**, **400** are housed in housing portions **106**, **108**, **110**, respectively. Each of housing portions **106**, **108**, **110** is set such that the longitudinal direction is aligned with the right-left direction of vehicle **100**. Housing portions **106**, **108**, **110** are arranged along the front-rear direction of vehicle **100**. At one end of housing portion **106** in the longitudinal direction, two connection connectors (not shown) are provided that are respectively connectable to positive connector **204** and negative connector **206** of battery unit **200**. The other end of housing portion **106** in the longitudinal direction is provided with an opening configured to allow insertion of battery unit **200**. Battery unit **200** is inserted into the opening of housing portion **106** with the side on which positive connector **204** and negative connector **206** are provided, for example, as the leading edge, and when the position is fixed by, for example, providing a lid on the opening, positive connector **204** and negative connector **206** are connected to the two connection connectors provided in housing portion **106**. When positive connector **204** and negative connector **206** are connected to the two connection connectors, the contacts inside the connectors are brought into contact with each other to be electrically conductive.
[0035] Housing portions **108**, **110** have the same structure as that of housing portion **106**, and detailed description thereof will not be repeated. When battery units **300**, **400** are inserted into housing portions **108**, **110**, respectively, and their positions are fixed as described above, the connector on the vehicle **100** side and the connector on the battery unit side are connected to be electrically conductive.
[0036] When three battery units **200**, **300**, **400** are housed in housing portions **106**, **108**, **110**, respectively, the positive connector of battery unit **200** is electrically connected to the positive power supply line of the power supply system of vehicle **100**, and the negative connector of battery

unit **200** is electrically connected to the positive connector of battery unit **300**. Furthermore, the negative connector of battery unit **300** is electrically connected to the positive connector of battery unit **400**, and the negative connector of battery unit **400** is electrically connected to the negative power supply line of the power supply system of vehicle **100**. As a result, three battery units, which are connected in series, are connected to the power supply system of vehicle **100**.

[0037] The power supply system of vehicle **100** includes a capacitor **102** included in a power control unit (PCU) (not shown), a system main relay (SMR) **104**, and voltage sensors **150**, **152**, **154**, **156**.

[0038] SMR **104** is formed of a relay provided in each of the positive power supply line and the negative power supply line. The negative power supply line is further connected in parallel with a pre-charging relay including a resistive element (not shown) connected in series with the above-mentioned relay.

[0039] Voltage sensor **150** detects a voltage V**0** between the ends of capacitor **102**. Voltage sensor **152** detects a voltage V**1** between the terminals of battery unit **200**. Voltage sensor **154** detects a voltage V**2** between the terminals of battery unit **300**. Voltage sensor **156** detects a voltage V**3** between the terminals of battery unit **400**.

[0040] FIG. **4** is a diagram for illustrating an example configuration of the power supply system of vehicle **100**. As shown in FIG. **4**, the power supply system further includes an electronic control unit (ECU) **140**. ECU **140** uses the PCU to convert a direct-current (DC) power supply composed of the three battery units into alternate-current (AC) power and supply it to a load (e.g., a motor generator) that operates on AC power. Furthermore, ECU **140** outputs a control signal to SMR **104** to control an operation of SMR **104**.

[0041] Furthermore, when battery units **200**, **300**, **400** are housed in housing portions **106**, **108**, **110**, respectively, the various relays included in battery units **200**, **300**, **400** are connected to ECU **140** via communication lines.

[0042] Thus, ECU **140** outputs a control signal to each of relay CR**1-1** and relay CR**1-2** of battery unit **200** housed in housing portion **106** to control operations of relay CR**1-1** and relay CR**1-2**. Furthermore, ECU **140** outputs a control signal to each of a relay CR**2-1** connected to the positive power supply line of battery unit **300** housed in housing portion **108** and a relay CR**2-2** connected to the negative power supply line of battery unit **300** to control operations of relay CR**2-1** and relay CR**2-2**. Furthermore, ECU **140** outputs a control signal to each of a relay CR**3-1** connected to the positive power supply line of battery unit **400** housed in housing portion **110** and a relay CR**3-2** connected to the negative power supply line of battery unit **400** to control operations of relay CR**3-1** and relay CR**3-2**.

[0043] Furthermore, ECU **140** is connected with voltage sensors **150**, **152**, **154**, **156**. Thus, ECU **140** obtains voltage V**0** detected by voltage sensor **150**, voltage V**1** detected by voltage sensor **152**, voltage V**2** detected by voltage sensor **154**, and voltage V**3** detected by voltage sensor **156**.

[0044] When receiving a request for system startup, for example, as a startup switch is operated during stop of the system of vehicle **100**, ECU **140** controls the operation of each relay such that SMR **104** and the relays of battery units **200**, **300**, **400** are brought to the conductive state, thereby starting up the system.

[0045] Furthermore, when receiving a request to stop the system, for example, as the startup switch is operated during system startup of vehicle **100**, ECU **140** controls the operation of each relay such that the relays of SMR **104** and battery units **200**, **300**, **400** are brought to the interrupt state, thereby stopping the system.

[0046] ECU **140** also controls each relay such that the relay is brought to the conductive state when, for example, three mounted battery units **200**, **300**, **400** are charged using an external power supply (e.g., when a connector is connected to an inlet (not shown) of vehicle **100**). Furthermore, ECU **140** controls each relay such that the relay is brought to the interrupt state when, for example, charging of the three mounted battery units **200**, **300**, **400** is completed.

[0047] Particularly if the contact of any of the plurality of relays included in three battery units **200**, **300**, **400** is welded, vehicle **100** configured as described above may fail to switch from the conductive state to the interrupt state. Thus, ECU **140** can, for example, perform a determination process of determining whether or not welding has occurred for each relay before bringing the respective relays of the three battery units **200**, **300**, **400** to the interrupt state when shifting the system to the stop state or when external charging is completed.
[0048] Specifically, ECU **140** can change the combination of the conductive state and the interrupt state of the respective relays of battery units **200**, **300**, **400**, and determine whether or not welding has occurred in each relay depending on whether or not the detection results of voltage sensors **152**, **154**, **156** correspond to the changed combination, or determine whether or not welding has occurred in each relay depending on whether or not the detection result of voltage sensor **150** is the detection result corresponding to the changed combination.
[0049] FIG. **5** is a timing chart showing an example method of determining welding of each relay. LN**1**, LN**3**, LN**5** in FIG. **5** indicate changes in the respective states (control history) of relays CR**1-1**, CR**2-1**, CR**3-1** provided in the positive power supply lines of battery units **200**, **300**, **400**. LN**2**, LN**4**, LN**6** in FIG. **5** indicate changes in the respective states (control history) of relays CR**1-2**, CR**2-2**, CR**3-2** provided in the negative power supply lines of battery units **200**, **300**, **400**.
[0050] For example, it is assumed that battery units **200**, **300**, **400** are housed in housing portions **106**, **108**, **110**, and the respective relays of battery units **200**, **300**, **400** are in the conductive state (on state) and the system of vehicle **100** is in the startup state (vehicle **100** is ready for operation or battery units **200**, **300**, **400** are ready for external charging).
[0051] At a time T(**0**), for example, when a request is received to bring each relay to the interrupt state, for example, upon completion of external charging or upon receipt of a request to shift the system to the stop state, ECU **140** performs a welding determination process.
[0052] When the welding determination process is started, ECU **140** bring all relays CR**1-1**, CR**2-1**, CR**3-1** of the respective battery units **200**, **300**, **400** to the interrupt state as indicated by LN**1**, LN**3**, LN**5** in FIG. **5**, and maintains relays CR**1-2**, CR**2-2**, CR**3-2** of the respective battery units **200**, **300**, **400** in the conductive state as indicated by LN**2**, LN**4**, LN**6** in FIG. **5**.
[0053] ECU **140** then obtains voltages V**1**, V**2**, V**3** detected by voltage sensors **152**, **154**, **156**. When any of the voltages detected by voltage sensors **152**, **154**, **156** becomes not less than a threshold (e.g., a value lower than the lower limit of the voltage of the battery unit), ECU **140** determines that welding has occurred in the relay on the positive side of the battery unit, whose voltage not less than the threshold has been detected and which is to be subjected to detection by the voltage sensor.
[0054] In contrast, when all the voltages detected by voltage sensors **152**, **154**, **156** are less than the threshold, ECU **140** determines that no welding has occurred in the relays on the positive side of battery units **200**, **300**, **400**.
[0055] When determining at a time T(**1**) that no welding has occurred in any of relays CR**1-1**, CR**2-1**, CR**3-1** on the positive side, ECU **140** performs control to bring all relays CR**1-1**, CR**2-1**, CR**3-1** of battery units **200**, **300**, **400** to the conductive state and performs control to bring all relays CR**1-2**, CR**2-2**, CR**3-2** to the interrupt state.
[0056] ECU **140** then obtains voltages V**1**, V**2**, V**3** detected by voltage sensors **152**, **154**, **156**, respectively. For example, when any of the voltages detected by voltage sensors **152**, **154**, **156** becomes not less than the threshold, ECU **140** determines that welding has occurred in the relay on the negative side of the battery unit, whose voltage not less than the threshold has been detected and which is to be detected by the voltage sensor.
[0057] In contrast, when all the voltages detected by voltage sensors **152**, **154**, **156** are less than the threshold, ECU **140** determines that no welding has occurred in the relays on the negative side of battery units **200**, **300**, **400**.
[0058] When determining at a time T(**2**) that no welding has occurred in all relays CR**1-2**, CR**2-2**,

CR**3-2** on the negative side, ECU **140** performs control to bring all relays CR**1-1**, CR**2-1**, CR**3-1** to the interrupt state and maintains relays CR**1-2**, CR**2-2**, CR**3-2** in the interrupt state. This brings the system of vehicle **100** to the stop state.

[0059] The welding determination method is not limited to the method described with reference to FIG. **5**. ECU **140** can, for example, determine whether or not each relay has been welded using the detection result of voltage sensor **150**.

[0060] FIG. **6** is a timing chart showing another example of the welding determination method. LN**7**, LN**9**, LN**11** in FIG. **6** indicate changes in the respective states of relays CR**1-1**, CR**2-1**, CR**3-1** of battery units **200**, **300**, **400**. LN**8**, LN**10**, LN**12** in FIG. **6** indicate the changes in the respective states of relays CR**1-2**, CR**2-2**, CR**3-2** of battery units **200**, **300**, **400**.

[0061] For example, it is assumed that battery units **200**, **300**, **400** are housed in housing portions **106**, **108**, **110**, respectively, and that the respective relays of battery units **200**, **300**, **400** are in the conductive state (on state) and the system of vehicle **100** is in the startup state.

[0062] At a time T(**3**), for example, when receiving a request to bring each relay to the interrupt state, ECU **140** performs the welding determination process.

[0063] When the welding determination process is performed, ECU **140** brings only relay CR**1-1** to the interrupt state, as indicated by LN**7** in FIG. **6**, and maintains the other relays in the conductive state, as indicated by LN**8** to LN**12** in FIG. **6**.

[0064] ECU **140** then obtains voltage V**0** detected by voltage sensor **150**. ECU **140** determines that welding has occurred in relay CR**1-1** when voltage V**0** detected by voltage sensor **150** becomes not less than the threshold. In contrast, when voltage V**0** is less than the threshold, ECU **140** determines that no welding has occurred in relay CR**1-1**.

[0065] When determining at a time T(**4**) that no welding has occurred in relay CR**1-1**, ECU **140** brings relay CR**1-1** to the conductive state, brings relay CR**1-2** to the interrupt state, and maintains the other relays in the conductive state.

[0066] When the obtained voltage V**0** becomes not less than the threshold, ECU **140** determines that welding has occurred in relay CR**1-2**. In contrast, when voltage V**0** is less than the threshold, ECU **140** determines that no welding has occurred in relay CR**1-2**.

[0067] When determining at a time T(**5**) that no welding has occurred in relay CR**1-2**, ECU **140** brings relay CR**1-2** to the conductive state, brings relay CR**2-1** to the interrupt state, and maintains the other relays in the conductive state.

[0068] When the obtained voltage V**0** becomes not less than the threshold, ECU **140** determines that welding has occurred in relay CR**2-1**. In contrast, when voltage V**0** is less than the threshold, ECU **140** determines that no welding has occurred in relay CR**2-1**.

[0069] When determining at a time T(**6**) that no welding has occurred in relay CR**2-1**, ECU **140** brings relay CR**2-1** to the conductive state, brings relay CR**2-2** to the interrupt state, and maintains the other relays in the conductive state.

[0070] When the obtained voltage V**0** becomes not less than the threshold, ECU **140** determines that welding has occurred in relay CR**2-2**. In contrast, when voltage V**0** is less than the threshold, ECU **140** determines that no welding has occurred in relay CR**2-2**.

[0071] When determining at a time T(**7**) that no welding has occurred in relay CR**2-2**, ECU **140** brings relay CR**2-2** to the conductive state, brings relay CR**3-1** to the interrupt state, and maintains the other relays in the conductive state.

[0072] When the obtained voltage V**0** becomes not less than the threshold, ECU **140** determines that welding has occurred in relay CR**3-1**. In contrast, when voltage V**0** is less than the threshold, ECU **140** determines that no welding has occurred in relay CR**3-1**.

[0073] When determining at a time T(**8**) that no welding has occurred in relay CR**3-1**, ECU **140** brings relay CR**3-1** to the conductive state, brings relay CR**3-2** to the interrupt state, and maintains the other relays in the conductive state.

[0074] When the obtained voltage V**0** becomes not less than the threshold, ECU **140** determines

that welding has occurred in relay CR**3-2**. In contrast, when voltage V**0** is less than the threshold, ECU **140** determines that no welding has occurred in relay CR**3-2**.
[0075] When determining at a time T(**9**) that no welding has occurred in relay CR**3-2**, ECU **140** maintains relay CR**3-2** in the interrupt state and brings the other relays to the interrupt state.
[0076] Description has been given by taking, as an example, the case where the welding determination process described with reference to FIGS. **5** and **6** is performed in ECU **140** with battery units **200**, **300**, **400** mounted in vehicle **100**. Alternatively, the welding determination process may be performed using a central processing unit (CPU) of charging rack **120** or charging stand **130**, which is capable of controlling each relay of the battery unit and of obtaining the voltage of each battery unit, with battery units **200**, **300**, **400** housed in charging rack **120**.
[0077] However, in these welding determination processes, since the relays that are controlled to enter the interrupt state once for determination as to whether or not welding has occurred and then enter the conductive state again, the determination result regarding whether or not the most recent welding has occurred may not be obtained. Furthermore, when the battery unit is removed from vehicle **100**, the result of the determination as to whether or not welding has occurred is not associated with the removed battery unit, so the determination as to whether or not welding has occurred may be required again at the destination. This may increase the number of relay operations.
[0078] In the present embodiment, thus, battery unit **200** further includes a first notification device **212** that operates, when being supplied with electric power, to allow an operating state to be recognized from outside, and a first supply source **214** that is connected to first notification device **212** and supplies electric power to first notification device **212** when relay CR**1-1** is in the conductive state.
[0079] FIG. **7** shows an example configuration of battery unit **200**, which is the power supply device according to the present embodiment. As shown in FIG. **7**, first notification device **212** is connected in parallel with relay CR**1-1** with respect to power supply line PL**1** connecting positive connector **204** to cell **208**. First supply source **214** is connected in series with first notification device **212**.
[0080] More specifically, first notification device **212** includes a light emitting device including a light emitting diode (LED) as a light emitting element. The positive terminal of first supply source **214** is connected to a node **218** between positive connector **204** and relay CR**1-1** in power supply line PL**1**. The first supply source is a DC power source composed of, for example, various batteries or capacitors. The negative terminal of first supply source **214** is connected to one end of first notification device **212**. The other end of first notification device **212** is connected to a node **219** between relay CR**1-1** and cell **208** in power supply line PL**1**.
[0081] Thus, when relay CR**1-1** is in the conductive state, a closed circuit is formed by relay CR**1-1**, first notification device **212**, and first supply source **214**, and accordingly, electric power is supplied from first supply source **214** to first notification device **212**. When electric power is supplied to first notification device **212**, the light-emitting element is turned on and the operating state is recognizable from outside. In contrast, when relay CR**1-1** is in the interrupt state, the above closed circuit is not formed, and accordingly, electric power is not supplied to first notification device **212**, so lighting of the light-emitting element is stopped.
[0082] Although first notification device **212** is described as a light emitting device including a light emitting diode as a light emitting element by way of example, the present disclosure is not particularly limited to using the light emitting diode.
[0083] Battery unit **200** further includes a second notification device **222** and a second supply source **224**. Second notification device **222** and second supply source **224** have the same configurations as those of first notification device **212** and first supply source **214** except that second notification device **222** and second supply source **224** are connected in parallel with relay CR**1-2** via nodes **228**, **229** with respect to power supply line PL**2** connecting negative connector

206 to cell **208**. Thus, detailed description thereof will not be repeated.

[0084] When battery unit **200** having such a configuration is removed from vehicle **100**, for example, with relay CR**1-1** and relay CR**1-2** controlled to enter the interrupt state, if relay CR**1-1** has been welded, a closed circuit is formed by first notification device **212**, first supply source **214**, and relay CR**1-1**. Thus, electric power is supplied from first supply source **214** to first notification device **212**, and the light emitting element included in first notification device **212** is turned on. This makes it possible to recognize, from outside battery unit **200**, that relay CR**1-1** has been welded.

[0085] In contrast, when relay CR**1-2** has been welded, a closed circuit is formed by second notification device **222**, second supply source **224**, and relay CR**1-2**. Thus, electric power is supplied from second supply source **224** to second notification device **222**, and the light emitting element included in second notification device **222** is turned on. This makes it possible to recognize, from outside battery unit **200**, that relay CR**1-2** has been welded.

[0086] As described above, when battery unit **200**, which is the power supply device according to the present embodiment, is removed from vehicle **100**, which is an electrical apparatus in which battery unit **200** is mounted, and when relay CR**1-1** and CR**1-2** are controlled to enter the interrupt state, battery unit **200** can determine that relay CR**1-1** has been welded when first notification device **212** is turned on using electric power of first supply source **214** to operate to allow the operating state to be recognized from outside. Alternatively, battery unit **200** can determine that relay CR**1-1** has been welded when second notification device **222** is turned on using electric power of second supply source **224** to operate to allow the operating state to be recognized from outside. Thus, the presence or absence of welding can be determined with high accuracy even when battery unit **200** is removed from the apparatus in which battery unit **200** is mounted. Furthermore, it can be determined in which of relays CR**1-1**, CR**1-2**, CR**2-1**, CR**2-2**, CR**3-1**, CR**3-2** of battery units **200**, **300**, **400** welding has occurred without performing the welding determination process with reference to FIG. **5** or **6**, thus suppressing an increase in the number of relay operations. Thus, a power supply device can be provided that can determine the presence or absence of welding of a relay even when the power supply device is removed from the apparatus in which the power supply device is mounted.

[0087] Modifications will be described below.

[0088] Although the above embodiment has described that first notification device **212** is turned on when welding has occurred in relay CR**1-1**, it suffices that first notification device **212** operates to allow relay CR**1-1** being in the conductive state to be recognized from outside, and the present disclosure is not particularly limited to the state in which first notification device **212** is turned on. For example, the light emitting element of first notification device **212** may blink when welding has occurred in relay CR**1-1**, or may be turned on in such a manner that the color of the emitted light changes over time.

[0089] Although the above embodiment has described that first notification device **212** and second notification device **222** have the same configuration, for example, first notification device **212** and second notification device **222** may report the occurrence of welding in different ways. For example, first notification device **212** may be turned on in a different color from that of second notification device **222**, or first notification device **212** may include a light emitting device and second notification device **222** may include a sound generating device. Thus, the welded relay can be reliably identified.

[0090] Although the above embodiment has described, by way of example, the case in which both first notification device **212** and second notification device **222** include a light emitting device including a light emitting diode as a light emitting element, the present disclosure is not particularly limited to including a light emitting device. For example, a notification device may include a sound-generating device such as a buzzer.

[0091] FIG. **8** shows an example configuration of battery unit **200**, which is a power supply device according to a modification. Battery unit **200** shown in FIG. **8** differs from battery unit **200** shown in FIG. **7** in that it includes a third notification device **312** instead of first notification device **212** and a fourth notification device **322** instead of second notification device **222**. The other components are the same as those of battery unit **200** shown in FIG. **7**.

[0092] Third notification device **312** includes a sound generating device including a buzzer or the like. It suffices that the sound generating device is any device that generates a sound when DC power is supplied, and is not limited to generating a buzzing sound, for example. The sound generating device may be, for example, a device that generates voice or the like. One end of third notification device **312** is connected to the negative terminal of first supply source **214**. The other end of third notification device **312** is connected to node **219** between relay CR**1-1** and cell **208** in power supply line PL**1**.

[0093] Thus, when relay CR**1-1** is in the conductive state, a closed circuit is formed by relay CR**1-1**, third notification device **312**, and first supply source **214**, and accordingly, electric power is supplied from first supply source **214** to third notification device **312**. When electric power is supplied to third notification device **312**, a sound will be generated from the buzzer device, allowing the operating state to be recognized from outside. In contrast, when relay CR**1-1** is in the interrupt state, the above closed circuit is not formed, and accordingly, electric power is not supplied to third notification device **312**. Thus, a sound will not be generated from the buzzer device.

[0094] Fourth notification device **322** in the present modification has the same configuration as that of third notification device **312**, except that it is connected in parallel with relay CR**1-2** via nodes **228**, **229** with respect to power supply line PL**2** together with second supply source **224**. Thus, detailed description thereof will not be repeated.

[0095] When battery unit **200** having such a configuration is removed from vehicle **100**, for example, with relay CR**1-1** and relay CR**1-2** controlled to enter the interrupt state, a closed circuit is formed by third notification device **312**, first supply source **214**, and relay CR**1-1** when relay CR**1-1** has been welded. Thus, electric power is supplied from first supply source **214** to third notification device **312**, and a sound will be generated from the sound generating device included in third notification device **312**. As a result, it can be recognized from outside battery unit **200** that relay CR**1-1** has been welded.

[0096] In contrast, when relay CR**1-2** has been welded, a closed circuit is formed by fourth notification device **322**, second supply source **224**, and relay CR**1-2**. Thus, electric power is supplied from second supply source **224** to fourth notification device **322**, and a sound will be generated from the sound generating device included in fourth notification device **322**. As a result, it can be recognized from outside battery unit **200** that relay CR**1-2** has been welded.

[0097] Although the present modification has described that a sound is generated from third notification device **312** when welding has occurred in relay CR**1-1**, it suffices that third notification device **312** operates to allow relay CR**1-1** being in the conductive state to be recognized from outside, and how to generate a sound is not particularly limited. For example, third notification device **312** may intermittently generate a sound when welding has occurred in relay CR**1-1**, or a sound may be generated in a manner in which the tone and volume change over time.

[0098] Although the present modification has described that third notification device **312** and fourth notification device **322** have the same configuration, third notification device **312** and fourth notification device **322** may report the occurrence of welding in different ways. For example, third notification device **312** may have a different volume, tone, sound generation interval, or voice content from that of fourth notification device **322**. Consequently, the welded relay can be reliably identified.

[0099] The modifications described above may be implemented as appropriate in whole or in part in any combination.

[0100] Although the embodiments of the present disclosure have been described, it should be understood that the embodiments disclosed herein are illustrative and non-restrictive in every respect. The scope of the present disclosure is defined by the terms of the claims and is intended to include any modifications within the scope and meaning equivalent to the terms of the claims.

Claims

1. A power supply device comprising: a connecting portion electrically connectable to an electrical apparatus in which the power supply device is mounted; a power storage device that allows supply of electric power to the electrical apparatus; a relay that switches between a conductive state in which a power supply line between the connecting portion and the power storage device is electrically connected, and an interrupt state in which the power supply line is electrically interrupted; a notification device that operates, when being supplied with electric power, to allow the conductive state to be recognized from outside; and a supply source that allows supply of electric power to the notification device when the supply source is connected to the notification device and the relay is in the conductive state.
2. The power supply device according to claim 1, wherein the notification device and the supply source are connected in parallel with the relay with respect to the power supply line, and when the relay is in the conductive state, the notification device, the supply source, and the relay form a closed circuit, and the supply source supplies electric power to the notification device.
3. The power supply device according to claim 1, wherein the notification device includes a light emitting device that emits light in the conductive state.
4. The power supply device according to claim 1, wherein the notification device includes a sound generating device that generates a sound in the conductive state.