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(54) **BATTERY PACK, CHARGING SYSTEM, AND METHOD FOR CONTROLLING CHARGING OF BATTERY PACK**

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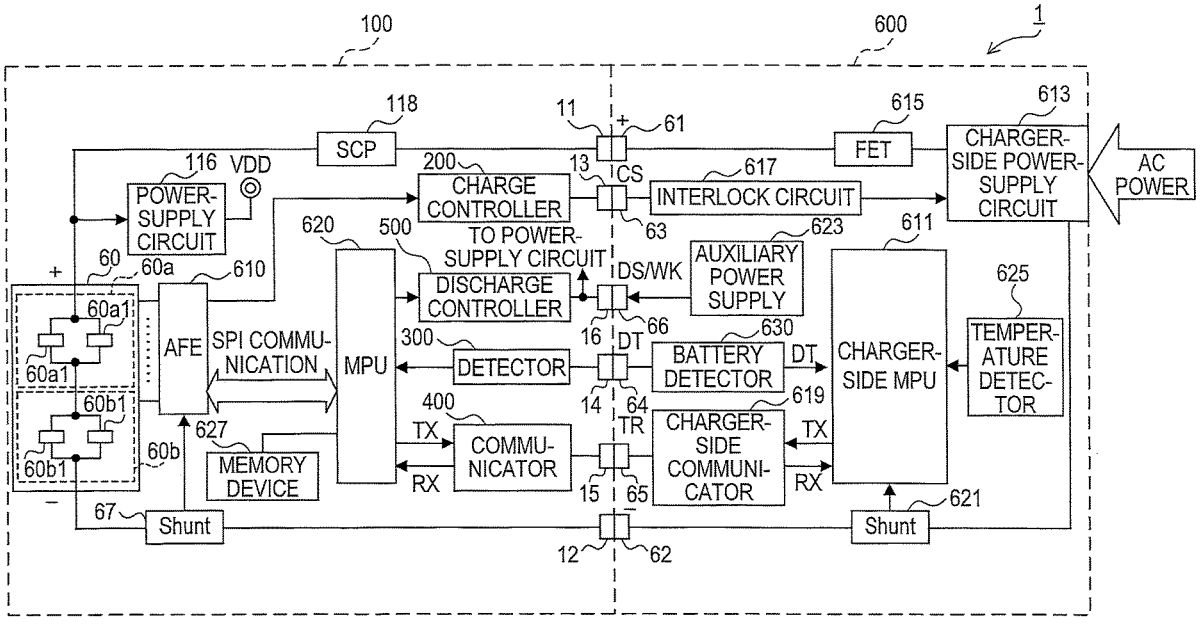
(57) **ABSTRACT**

A battery pack in one aspect of the present disclosure includes a first cell, a memory device, a target current calculator, and an information notifier. The memory device stores a maximum variation of a charging current value. The maximum variation is determined depending on a characteristic of the battery pack. The target current calculator calculates a newest value of a target current value based on (i) a previous value of the target current value and (ii) the maximum variation. The information notifier transmits a charge condition information including the newest value.



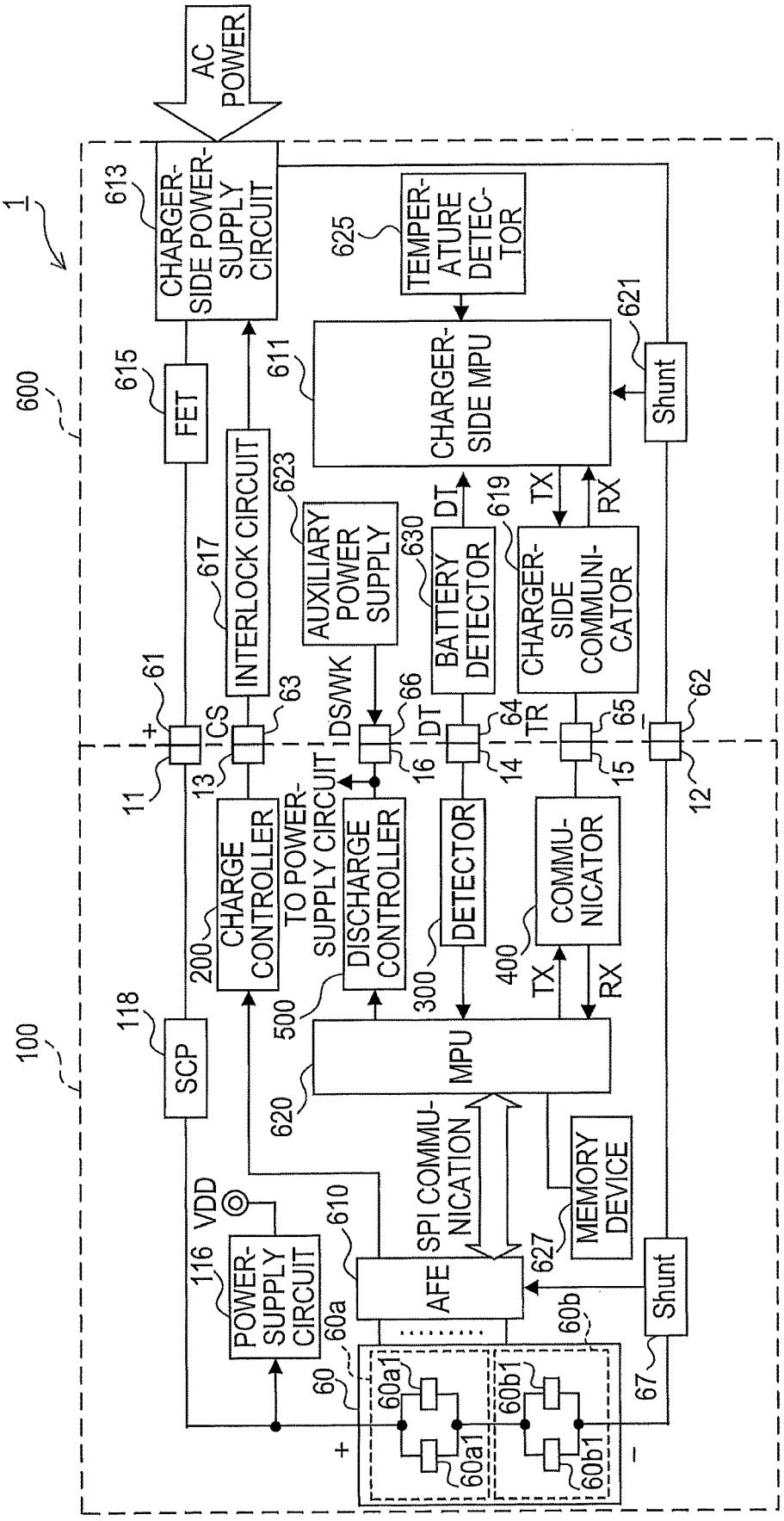

AC POWER
1
600
100
CHARGER-SIDE POWER-SUPPLY CIRCUIT
613
TEMPER-ATURE DETEC-TOR
625
CHARGER-SIDE MPU
611
621
Shunt
FET
615
INTERLOCK CIRCUIT
617
AUXILIARY POWER SUPPLY
623
630
BATTERY DETECTOR
619
CHARGER-SIDE COMMUNI-CATOR
DT
TX
RX
61
63
66
64
65
62
CS
IDS/WK
DT
TR
+
−
11
13
16
14
15
12
CHARGE CONTROLLER
200
TO POWER-SUPPLY CIRCUIT
DISCHARGE CONTROLLER
500
DETECTOR
300
COMMU-NICATOR
400
TX
RX
SCP
118
MPU
620
SPI COMMU-NICATION
MEMORY DEVICE
627
VDD
116
POWER-SUPPLY CIRCUIT
610
AFE
60
60a
60b
60a1
60b1
67
Shunt

FIG. 1

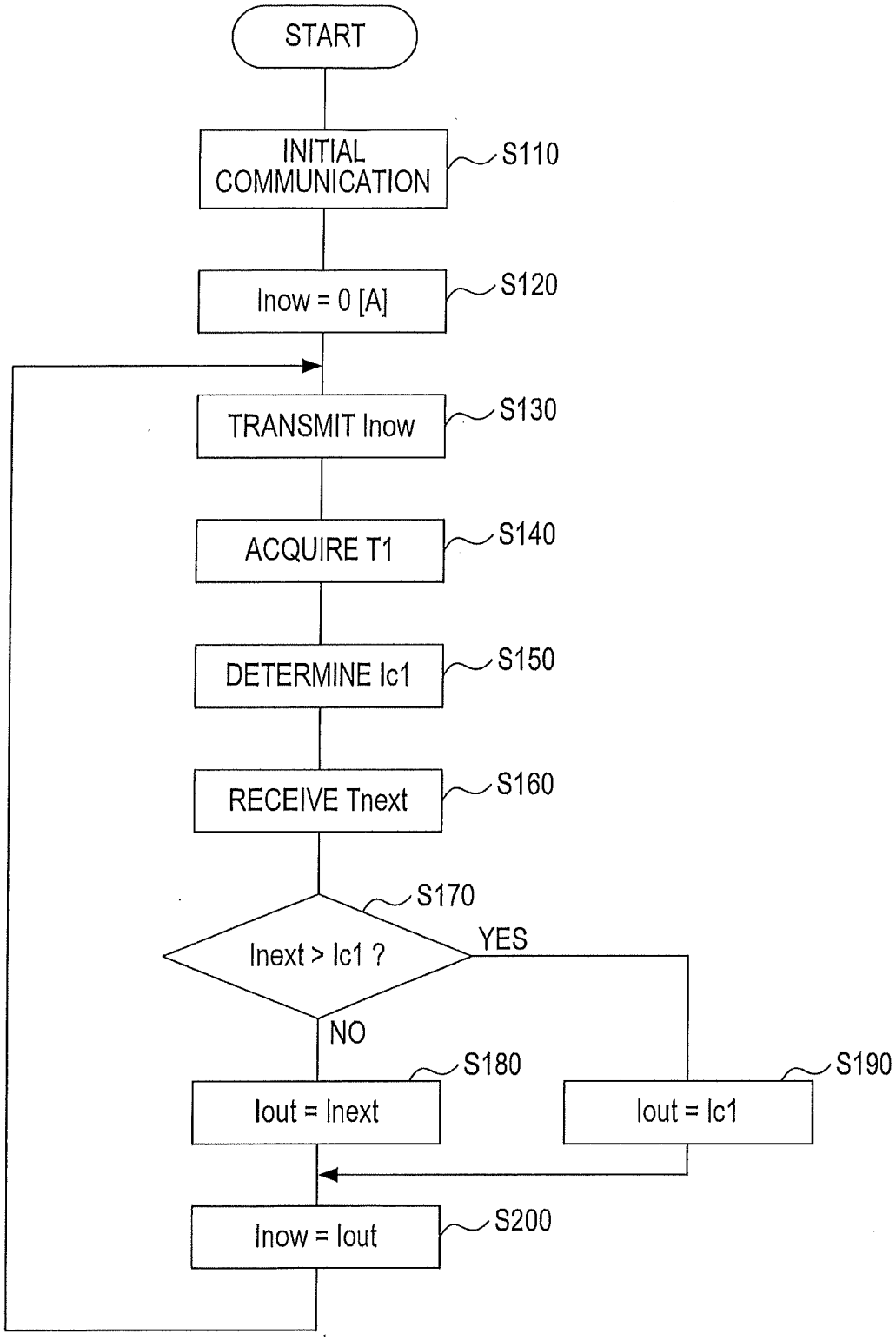

START
INITIAL COMMUNICATION
S110
Inow = 0 [A]
S120
TRANSMIT Inow
S130
ACQUIRE T1
S140
DETERMINE Ic1
S150
RECEIVE Tnext
S160
S170
Inext > Ic1 ?
YES
NO
S180
Iout = Inext
S190
Iout = Ic1
Inow = Iout
S200

FIG. 2

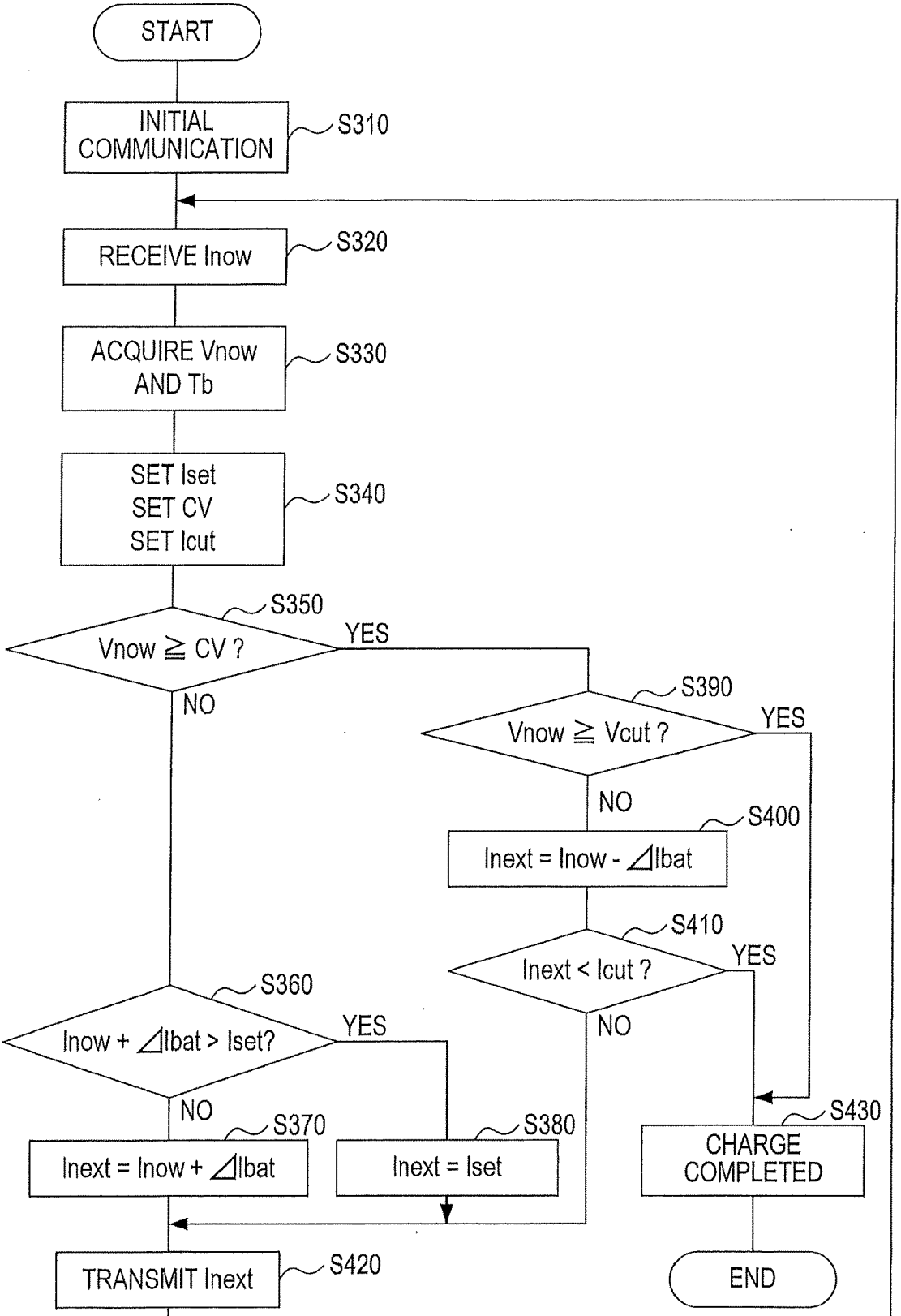

START
INITIAL COMMUNICATION
S310
RECEIVE Inow
S320
ACQUIRE Vnow AND Tb
S330
SET Iset
SET CV
SET Icut
S340
S350
Vnow ≧ CV ?
YES
NO
S390
Vnow ≧ Vcut ?
YES
NO
S400
Inext = Inow - ⊿Ibat
S410
Inext < Icut ?
YES
NO
S360
Inow + ⊿Ibat > Iset?
YES
NO
S370
Inext = Inow + ⊿Ibat
S380
Inext = Iset
S430
CHARGE COMPLETED
TRANSMIT Inext
S420
END

FIG. 3

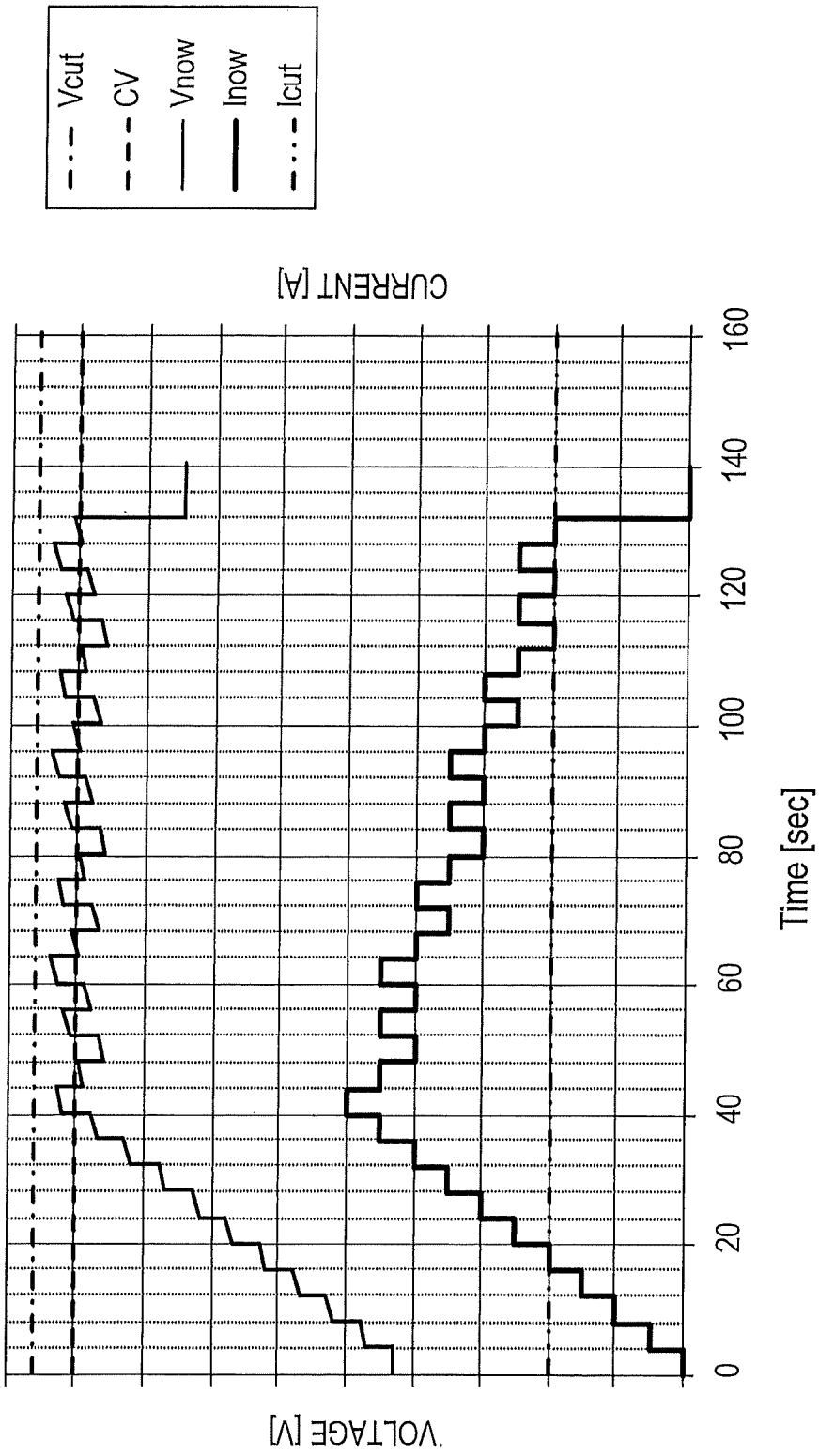

Vcut
CV
Vnow
Inow
Icut
CURRENT [A]
VOLTAGE [V]
0
20
40
60
80
100
120
140
160
Time [sec]

FIG. 4

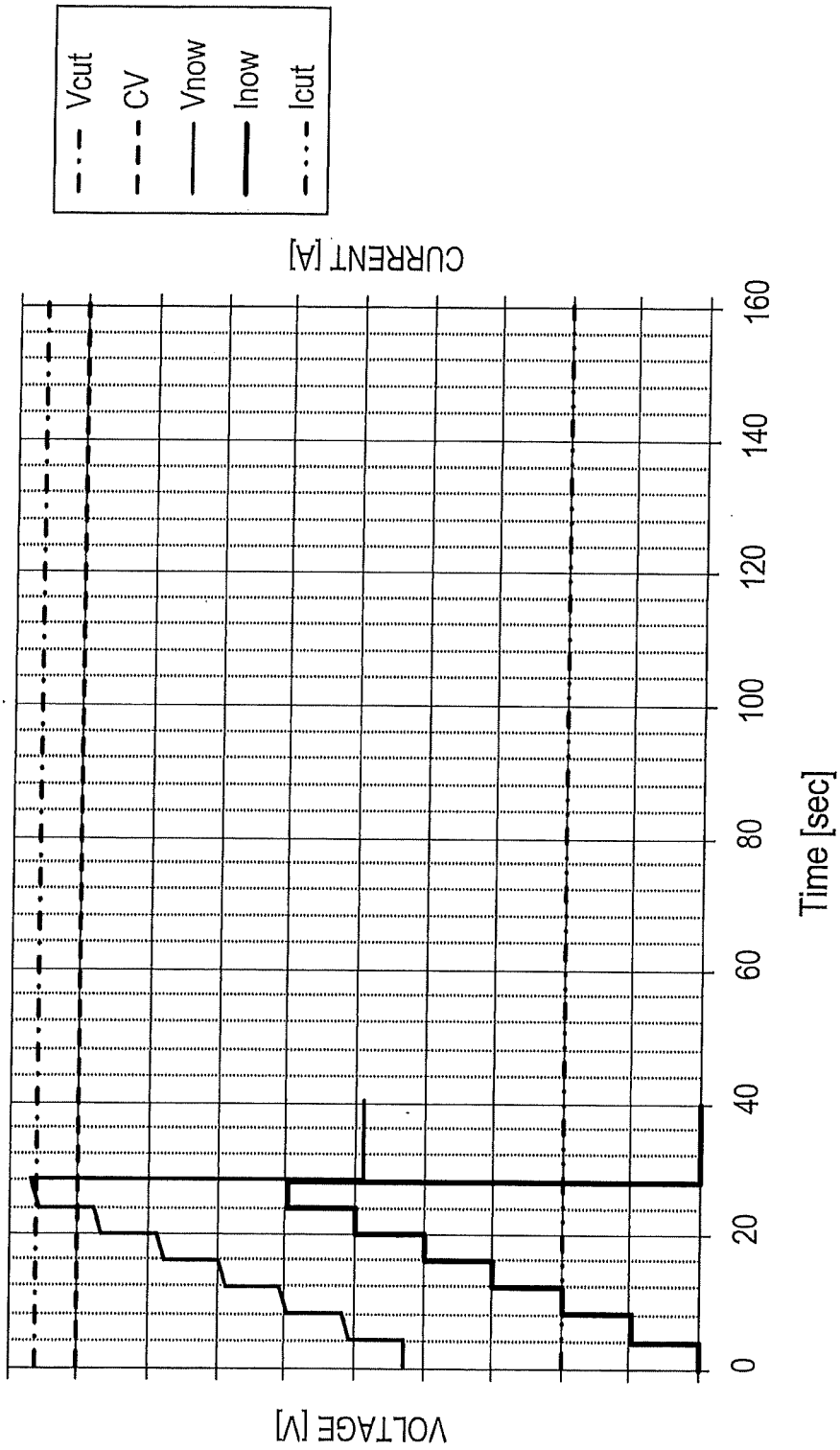

Vcut
CV
Vnow
Inow
Icut
CURRENT [A]
VOLTAGE [V]
0
20
40
60
80
100
120
140
160
Time [sec]

FIG. 5

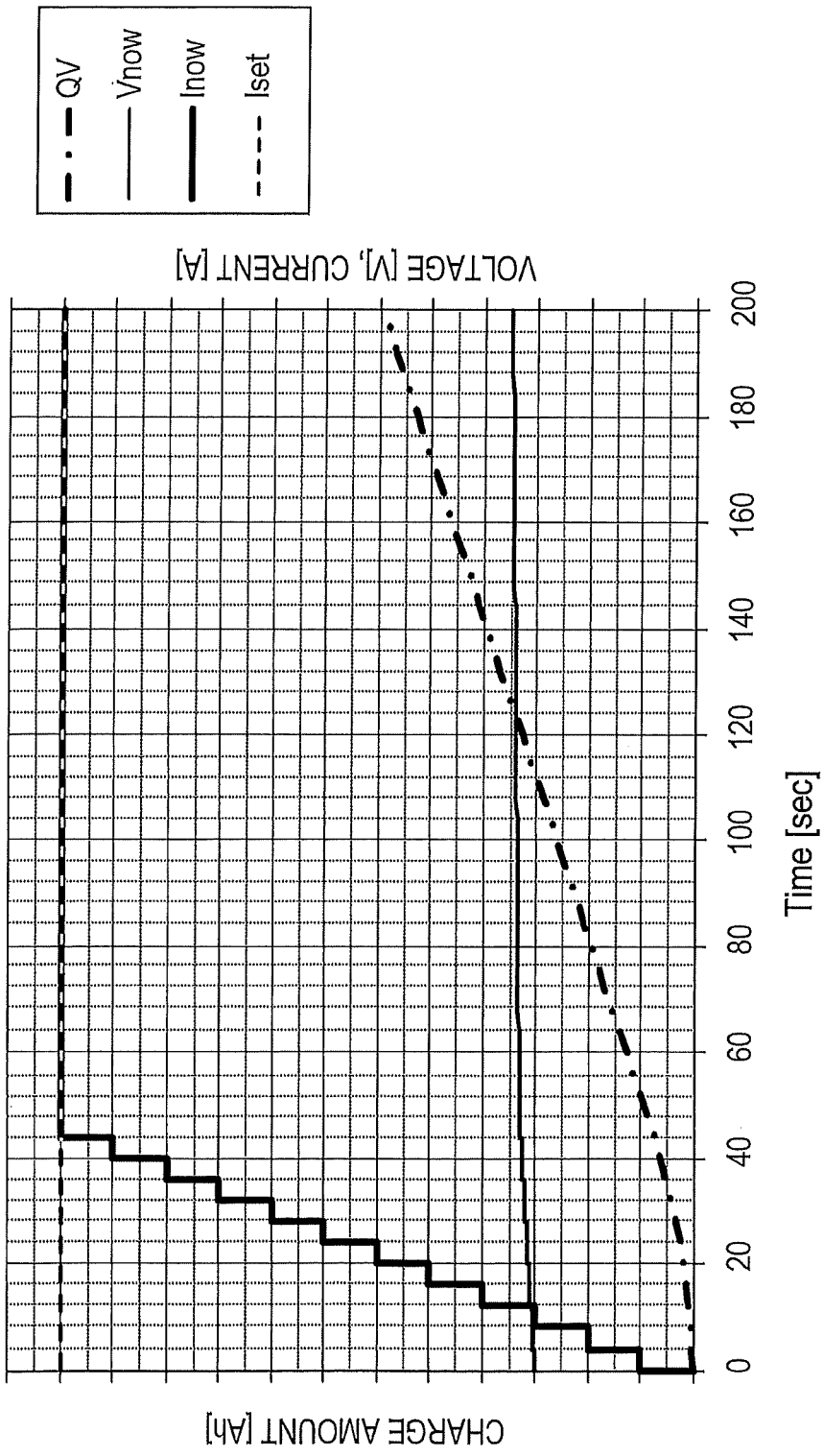

QV
Vnow
Inow
Iset
VOLTAGE [V], CURRENT [A]
CHARGE AMOUNT [Ah]
0
20
40
60
80
100
120
140
160
180
200
Time [sec]

FIG. 6

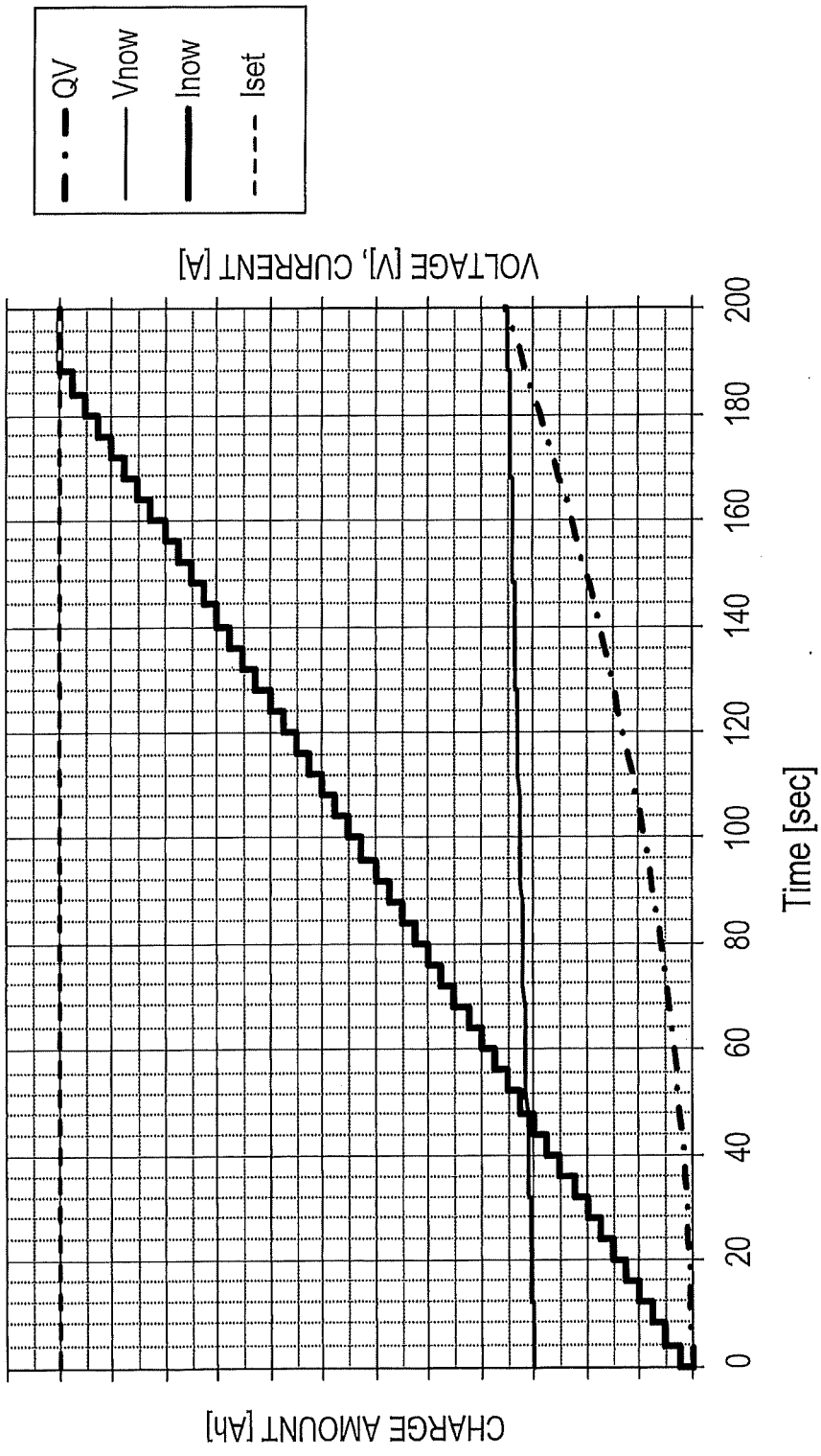

QV
Vnow
Inow
Iset
VOLTAGE [V], CURRENT [A]
CHARGE AMOUNT [Ah]
0
20
40
60
80
100
120
140
160
180
200
Time [sec]

FIG. 7

BATTERY PACK, CHARGING SYSTEM, AND METHOD FOR CONTROLLING CHARGING OF BATTERY PACK

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of Japanese Patent Application No. 2019-163120 filed on Sep. 6, 2019 with the Japan Patent Office, the disclosure of which is incorporated herein by reference.

BACKGROUND

[0002] The present disclosure relates to charging of a battery pack.

[0003] Japanese Patent No. 3972930 discloses a charging system including a battery pack and a charger. The battery pack includes a battery to be charged with a charging current supplied from the charger. The charger performs a control process. In the control process, the charger increases the charging current by a fixed magnitude (e.g., by a predetermined maximum variation) with lapse of a time period, to thereby bring the value of the charging current up to a target current value.

SUMMARY

[0004] Some charging systems may include a charging stop function in order to inhibit damage to a battery pack. The charging stop function stops a charging operation when a voltage of a battery pack (hereinafter also referred to as a battery voltage) exceeds a predetermined permissible upper limit.

[0005] Some chargers may be configured to be connected not only to a single type of battery pack but also to multiple types of battery packs. Such chargers can charge the multiple types of battery packs, and thus can be used in various situations.

[0006] However, the case where the charger is configured to be connected to multiple types of battery packs may cause a situation where rise in the battery voltage caused by increase in a charging current supplied from the charger is too large for the battery pack to which the charger is connected. In such a situation, the battery voltage may exceed the permissible upper limit of the battery pack to thereby activate the charging stop function.

[0007] Battery packs may differ, depending on their types, in characteristics of each battery pack therein (e.g., an internal resistance of a cell, a charge capacity of the cell, and so on). If the internal resistance of the cell is large, rise in the battery voltage with respect to a unit variation of the charging current (e.g., a maximum variation of the charging current) becomes large. Thus, in the battery pack with the cell having a large internal resistance, the charging stop function may be activated before the battery pack is sufficiently charged, whereby charging may be stopped. Such an event is also referred to as, for example, early stop of charging.

[0008] To cope with this, setting a smaller maximum variation may be able to inhibit activation of the charging stop function described above. However, in that case, since an increase rate of the charging current is smaller, it takes longer for the charging current to reach a target value, and thus, a charging time for the battery pack to be sufficiently charged may become longer.

[0009] In one aspect of the present disclosure, it is desirable to be able to inhibit activation of the charging stop function caused by rise in the battery voltage with increase in the charging current, and further to reduce the charging time.

[0010] A battery pack in one aspect of the present disclosure includes a first cell, a memory device, a target current calculator, and/or an information notifier.

[0011] The first cell is charged with a charging current supplied from a charger. The memory device stores a maximum variation of a charging current value. The charging current value corresponds to a magnitude of the charging current. The maximum variation is determined depending on a characteristic of the battery pack.

[0012] The target current calculator calculates a newest value of a target current value based on (i) a previous value of the target current value and (ii) the maximum variation. The target current value corresponds to the magnitude of the charging current required to charge the first cell. In other words, the target current value corresponds to a target value of the charging current value. The information notifier transmits, to the charger, charge condition information including the newest value. The previous value may correspond to any value calculated earlier than the newest value, or may correspond to a value calculated immediately before the newest value.

[0013] As described above, the maximum variation corresponds to the characteristic of the battery pack, and thus, the target current value may be increased or decreased according to the characteristic of the battery pack. The battery pack notifies the charger of such a target current value.

[0014] This makes it possible to inhibit an excessive increase of the charging current. As a result, a variation of a charging voltage caused by the change in the charging current can fall within a range according to the characteristic of the battery pack. The charging voltage is a voltage that the charger applies to the battery pack.

[0015] Accordingly, this battery pack can inhibit an excessive variation of the charging voltage, thus inhibiting early stop of charging and damage to the first cell. The early stop of charging refers to, for example, stop of a charging operation caused by extraordinary increase in the charging voltage before completion of charging of the first cell. The damage to the first cell refers to, for example, damage to the first cell caused by an impermissible charging voltage.

[0016] The characteristic of the battery pack may include at least a magnitude of an impedance of the first cell.

[0017] The variation of the charging voltage caused by the change in the charging current varies according to, for example, the characteristic of the battery pack (e.g., the magnitude of the impedance of the first cell). Thus, use of the maximum variation makes it possible to set the variation of the charging voltage to a value suited to the characteristic of the battery pack. Accordingly, since the variation of the charging voltage is limited according to the characteristic of the battery pack, this battery pack can inhibit the excessive variation of the charging voltage.

[0018] The battery pack may include a second cell. The second cell may be charged with the charging current. The first cell may be connected in series to the second cell, or may be connected in parallel with the second cell. The

characteristic of the battery pack may depend on at least an arrangement (or configuration) of the first cell and the second cell.

[0019] The characteristic of the battery pack may be generally determined according to the configuration of the battery, such as the series-connected configuration of the first cell and the second cell, the parallel-connected configuration of the first cell and the second cell, or the number of branches for the cells. In the case where the battery pack includes the first cell and the second cell connected in parallel with each other, the variation of the charging voltage caused by the change in the charging current may vary according to the total number of the cells, the number of the branches, and/or the number of the cells included in each branch. Such a characteristic of the battery pack makes it possible to set the variation of the charging voltage suited to the battery pack including the first cell and the second cell connected in parallel with each other.

[0020] Next, the above-described battery pack may further include an operation information acquirer. The operation information acquirer may acquire charging operation information from the charger. The charging operation information may relate to an operation required for the charger to charge the first cell. The charging operation information may include the charging current value. The target current calculator may set the charging current value included in the charging operation information as the previous value in order to calculate the newest value.

[0021] Since the charging operation information is acquired from the charger, this battery pack can accurately get the magnitude of the charging current that the charger is outputting to the battery pack. Since the newest value is calculated based on (i) the maximum variation and (ii) the charging current value included in the charging operation information, this battery pack can calculate the newest value properly even when an error is caused between the previous value and the charging current value.

[0022] Accordingly, this battery pack can inhibit calculation of an improper newest value, thus inhibiting the excessive variation of the charging voltage.

[0023] Next, the above-described battery pack may further include a voltage comparator. The voltage comparator may determine whether a cell voltage value is smaller than a target voltage value. The cell voltage value may correspond to a magnitude of a voltage of the first cell. The target voltage value may correspond to the magnitude of the voltage of the first cell required for the charger to charge the first cell. The target current calculator may calculate the newest value by adding the maximum variation to the previous value, in response to the voltage comparator determining that the cell voltage value is smaller than the target voltage value.

[0024] Such a configuration enables this battery pack to calculate the newest value so as to increase the charging current value while maintaining the cell voltage value of the first cell within tolerance. Accordingly, this battery pack can increase the charging current value within tolerance, thus reducing a charging time from initiation to completion of the charging.

[0025] The target current calculator may calculate the newest value by subtracting the maximum variation from the previous value, in response to the voltage comparator determining that the cell voltage value is larger than or equal to the target voltage value.

[0026] Such a configuration enables this battery pack to calculate the newest value while inhibiting the cell voltage value of the first cell beyond tolerance, by reducing the target current value when the cell voltage value is larger than or equal to the target voltage value. Accordingly, this battery pack enables continued proper charging operation while inhibiting occurrence of charging stop caused by an impermissible cell voltage value.

[0027] The above-described battery pack may further include a charging current comparator. The charging current comparator may determine whether a provisional current value is smaller than or equal to a reference current value. The provisional current value may correspond to a sum of the previous value and the maximum variation. The reference current value may correspond to an upper limit of the charging current value permissible in the first cell at charging.

[0028] The target current calculator may calculate the newest value by adding the maximum variation to the previous value, in response to the charging current comparator determining that the provisional current value is smaller than or equal to the reference current value. The target current calculator may set the reference current value as the newest value, in response to the charging current comparator determining that the provisional current value is larger than the reference current value.

[0029] Such a configuration enables this battery pack to calculate the newest value so as to increase the charging current value of the first cell while maintaining the charging current value within tolerance. Accordingly, this battery pack can increase the charging current value within tolerance, thus reducing the charging time from initiation to completion of the charging.

[0030] Furthermore, this battery pack can calculate the newest value while inhibiting the magnitude of the charging current beyond tolerance. Accordingly, this battery pack enables continued proper charging operation while inhibiting occurrence of charging stop caused by an impermissible charging current.

[0031] A charging system in another aspect of the present disclosure may include the above-mentioned battery pack and a charger.

[0032] The charger may include a current outputter, a condition information acquirer, and/or an output current setter. The current outputter may supply the charging current to the battery pack. The condition information acquirer may acquire the charge condition information from the battery pack. The output current setter may set the magnitude of the charging current based on the newest value included in the charge condition information.

[0033] In this charging system, the charger is notified of the charge condition information from the battery pack, and the charger supplies the battery pack with the charging current of the magnitude set based on the newest value included in the charge condition information. Similarly to the above-described battery pack, this charging system can inhibit the excessive variation of the charging voltage, thus inhibiting the early stop of charging and damage to the first cell.

[0034] The charger may further include an output current comparator. The output current comparator may determine whether the newest value is smaller than or equal to an upper limit current value. The upper limit current value may

correspond to an upper limit of the charging current value determined according to a temperature of the charger.

[0035] The output current setter may set the newest value as a value corresponding to the magnitude of the charging current, in response to the output current comparator determining that the newest value is smaller than or equal to the upper limit current value. The output current setter may set the upper limit current value as a value corresponding to the magnitude of the charging current, in response to the output current comparator determining that the newest value is larger than the upper limit current value.

[0036] Such a configuration enables this charging system to inhibit damage to the charger caused by an excessive temperature rise during charging of the battery pack by the charger.

[0037] Another aspect of the present disclosure includes a method for controlling charging of a battery pack, the method including:

[0038] calculating a newest value of a target current value based on (i) a previous value of the target current value and (ii) a maximum variation, the target current value corresponding to a magnitude of a charging current required to charge a cell of the battery pack, the maximum variation being determined depending on a characteristic of the battery pack; and

[0039] notifying a charger of charge condition information including the newest value.

[0040] This method exerts effects similar to those of the above-described battery pack.

BRIEF DESCRIPTION OF THE DRAWINGS

[0041] Example embodiments of the present disclosure will be described below with reference to the accompanying drawings, in which:

[0042] FIG. **1** is a block diagram showing an overview of a battery pack and a charger;

[0043] FIG. **2** is a flowchart showing a flow of a charge control process performed by a charger-side MPU of the charger;

[0044] FIG. **3** is a flowchart showing a flow of a charge condition setting process performed by an MPU of the battery pack;

[0045] FIG. **4** is a time chart showing profiles of a cell voltage value Vnow and an output current value Inow in an embodiment;

[0046] FIG. **5** is a time chart showing profiles of a cell voltage value Vnow and an output current value Inow in Comparative Example 1;

[0047] FIG. **6** is a time chart showing profiles of a cell voltage value Vnow, an output current value Inow, and a charge amount QV in the embodiment; and

[0048] FIG. **7** is a time chart showing profiles of a cell voltage value Vnow, an output current value Inow, and a charge amount QV in Comparative Example 2.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0049] The present disclosure is not limited to example embodiments below, and can take various forms within the technical scope of the present disclosure.

1. First Embodiment

1-1. Overall Configuration

[0050] A configuration of a charging system **1** according to the present embodiment will be described with reference to FIG. **1**.

[0051] As shown in FIG. **1**, the charging system **1** includes a battery pack **100** and a charger **600**.

[0052] The battery pack **100** is configured to be connected to the charger **600**.

[0053] The charger **600** supplies electric power to the battery pack **100**. The battery pack **100** is also configured to be connected to an external device (not shown) to supply electric power to the external device. Examples of the external device may include an electric working machine and a lighting device. The electric working machine and the lighting device operate with the electric power from the battery pack **100**. Examples of the electric working machine may include a power tool, such as a hammer drill, a chainsaw, and a grinder, and a working machine for gardening, such as a grass cutter, a hedge trimmer, and a lawn trimmer.

[0054] The battery pack **100** includes a battery **60**, an Analog Front End (AFE) **610**, a Micro Processing Unit (MPU) **620**, a power-supply circuit **116**, and a Self Control Protector (SCP) **118**.

[0055] The battery pack **100** further includes a positive terminal **11**, a negative terminal **12**, a CS terminal **13**, a DT terminal **14**, a TR terminal **15**, a DS terminal **16**, a charge controller **200**, a detector **300**, a communicator **400**, a discharge controller **500**, and a memory device **627**.

[0056] The battery **60** includes a first cell **60***a* and a second cell **60***b*. The cell **60***a* and the second cell **60***b* in the present embodiment are connected in series to each other. The first cell **60***a* includes electric power storages (or partial cells) **60***a***1** connected in parallel with each other. That is, the first cell **60***a* includes branches each having the corresponding electric power storage **60***a***1**. The electric power storage **60***a***1** is configured to be charged with the charging current. The second cell **60***b* includes electric power storages (or partial cells) **60***b***1**. The electric power storage **60***b***1** is configured to be charged with the charging current. In other embodiments, the first cell **60***a* may include the electric power storages **60***a***1** connected in series to each other, or may include the electric power storages **60***a***1** connected in series to each other and the electric power storages **60***a***1** connected in parallel with each other. The first cell **60***a* and the second cell **60***b* are rechargeable batteries, and each may be, for example, a lithium ion battery or the like. A rated voltage of the battery **60** in the present embodiment is, for example, 18 V. The rated voltage of the battery **60** is not limited to 18 V, and may be 36 V, 72 V, or other voltage. The first cell **60***a* and the second cell **60***b* are charged with a charging current supplied from the charger **600**. A voltage output from the battery **60** is referred to as a battery voltage.

[0057] The MPU **620** includes a microcomputer with a CPU, a ROM, a RAM, and I/Os, and performs various controls including charge/discharge control of the battery **60**. The MPU **620** further includes interrupt ports PT (not shown) that receive various signals input thereto. When (i) the detector **300** detects a connected state, where the battery pack **100** is connected to the charger **600**, and (ii) a specified condition is satisfied, the MPU **620** transitions from a normal operation mode (or a control operation state) to a

sleep mode (or a low-power operation state). In the sleep mode, part of the operation of the MPU **620** is stopped to reduce power consumption. Then, when any one of the interrupt ports PT receives a signal during the sleep mode, the MPU **620** wakes up and transitions to the normal operation mode. For example, the MPU **620** wakes up when (i) the detector **300** detects the connected state and (ii) the interrupt port PT receives a connection detection information Sa**1**. The MPU **620** transitions to the sleep mode when (i) the detector **300** does not detect the connected state (i.e., the charger **600** is detached) and (ii) a specified condition is satisfied.

[0058] In other words, the MPU **620** is configured to switch to any of operation modes (operation states) including the normal operation mode and the sleep mode. The MPU **620** in the control operation state controls charge and discharge of the battery **60**. The MPU **620** in the low-power operation state does not perform control of charge and discharge of the battery **60**. The low-power operation state consumes lower power in comparison to the control operation state.

[0059] The AFE **610** is an analog circuit mounted on a circuit board, and detects the voltage of each of the first cell **60***a* and the second cell **60***b* (hereinafter also referred to as a cell voltage) in accordance with a command from the MPU **620**. The AFE **610** also detects a temperature of the first cell **60***a* (hereinafter also referred to as a cell temperature) via a first thermistor (not shown) included in the battery **60**. The AFE **610** performs a cell balancing process for equalizing remaining energies of the first cell **60***a* and the second cell **60***b*. The AFE **610** detects a board temperature via a second thermistor (not shown) provided on the circuit board. The AFE **610** detects, via a shunt resistor **67**, a charging current flowing into the battery **60** (specifically, the first cell **60***a* and the second cell **60***b*) and a discharge current flowing out of the battery **60** (specifically, the first cell **60***a* and the second cell **60***b*). The AFE **610** converts values of the detected cell voltages, the detected cell temperature, the detected board temperature, the detected charging current, and the detected discharge current into respective digital signals, and outputs the resulting digital signals to the MPU **620**.

[0060] Further, the AFE **610** determines whether to permit or prohibit charging of the first cell **60***a* based on the detected state of the first cell **60***a*, generates a charging permission signal or a charging prohibition signal, and outputs the generated signal to the charge controller **200**.

[0061] The power-supply circuit **116** includes a regulator. When the battery pack **100** (specifically, the MPU **620**) is in a shutdown state (hereinafter also referred to as an inactive state), the regulator receives electric power from an auxiliary power supply **623** in the charger **600** via the DS terminal **16**, and generates a power-supply voltage VDD. The power-supply voltage VDD is used to operate internal circuits of the battery pack **100**. The charger **600** includes a charger-side DS terminal **66** to be connected to the DS terminal **16**. The charger-side DS terminal **66** is connected to the auxiliary power supply **623**.

[0062] The battery pack **100** transitions to the shutdown state when the first cell **60***a* or the second cell **60***b* enters an over-discharge state. Upon being supplied with the power-supply voltage VDD, the MPU **620** returns from the shutdown state to a non-shutdown state (hereinafter also referred to as an active state). If the first cell **60***a* and the second cell **60***b* are in a chargeable state, the MPU **620** outputs a charging permission signal to the charger **600**. When the magnitude of the battery voltage reaches a specified voltage value, the power-supply circuit **116** is supplied with electric power from the battery **60**. The power-supply circuit **116** generates the power-supply voltage VDD by receiving the electric power from the battery **60**.

[0063] The SCP **118** is provided on a positive-side connection line of the battery pack **100**. The positive-side connection line of the battery pack **100** connects a positive electrode of the battery **60** to the positive terminal **11**. The SCP **118** includes a fuse. The SCP **118** includes an internal circuit to blow the fuse in accordance with a command from the MPU **620**. Upon the fuse being blown, the positive-side connection line breaks, and charge and discharge of the battery **60** via the positive terminal **11** cannot be performed. That is, the battery **60** is unable to be reused.

[0064] The MPU **620** commands the SCP **118** to blow the fuse as a last resort in order to ensure safety, in a case where (i) charging is not stopped in spite of a charging prohibition signal being output from the battery pack **100** to the charger **600** or (ii) discharge is not stopped in spite of a discharge prohibition signal being output from the battery pack **100** to the external device. That is, the SCP **118** is a circuit for ensuring double safety against an overcharge state and an over-discharge state of the first cell **60***a* and/or the second cell **60***b*. The SCP **118** may regularly diagnose whether the internal circuit therein operates normally and output the diagnosis result to the MPU **620**. If the SCP **118** has no self-diagnosis function, the MPU **620** may perform an SCP diagnosis process to thereby determine whether the SCP **118** operates properly.

[0065] The MPU **620** determines, based on the various signals input thereto, a state of the first cell **60***a* and/or the second cell **60***b*. Then, the MPU **620** determines whether to permit or prohibit charging of the first cell **60***a* and the second cell **60***b* based on the determined state of the first cell **60***a* and/or the second cell **60***b*, and generates a charging permission signal or a charging prohibition signal. The MPU **620** outputs the charging permission signal or the charging prohibition signal to the charge controller **200** via the AFE **610**. Similarly, the MPU **620** determines whether to permit or prohibit discharge from the first cell **60***a* and/or the second cell **60***b* based on the determined state of the first cell **60***a* and/or the second cell **60***b*, generates a discharge permission signal or a discharge prohibition signal, and outputs the generated signal to the discharge controller **500**. To improve responsiveness to the external device (specifically, the electric working machine), the MPU **620** may generate a discharge permission signal continuously during the sleep mode and output the discharge permission signal to the discharge controller **500**.

[0066] When the battery pack **100** is connected to the external device, the positive terminal **11** and the negative terminal **12** are respectively connected to a device-side positive terminal and a device-side negative terminal of the external device. When the battery pack **100** is connected to the charger **600**, the positive terminal **11** and the negative terminal **12** are respectively connected to a charger-side positive terminal **61** and a charger-side negative terminal **62** of the charger **600**. This enables power supply from the battery pack **100** to the external device and power supply from the charger **600** to the battery pack **100**.

[0067] The CS terminal **13** is connected to the charge controller **200**. When the battery pack **100** is connected to

the charger **600**, the CS terminal **13** outputs a charging permission signal or a charging prohibition signal to the charger **600**. The charge controller **200** outputs the charging permission signal through the CS terminal **13** when the charger controller **200** receives the charging permission signal from the AFE **610**. The charge controller **200** outputs the charging prohibition signal through the CS terminal **13** when the charger controller **200** receives the charging prohibition signal from the AFE **610**.

[0068] The memory device **627** is configured to store a maximum variation ΔIbat used in a target current calculation process to be described later. The memory device **627** includes a storage (e.g., a memory), and the MPU **620** can read out various information (e.g., the maximum variation ΔIbat) stored in the storage. The maximum variation ΔIbat corresponds to a maximum variation of the charging current during the charge control. In other words, the maximum variation ΔIbat is a maximum variation of a charging current value corresponding to the magnitude of the charging current.

[0069] The maximum variation ΔIbat corresponds to a characteristic of the battery pack **100**. In the present embodiment, the maximum variation ΔIbat corresponds to a characteristic of the first cell **60***a*. The characteristic(s) of the battery pack **100** corresponds/correspond to an impedance Z of the first cell **60***a* and/or the arrangement of the first cell **60***a* and the second cell **60***b*. In other words, the characteristic(s) of the battery pack **100** is/are determined according to the total number of the cells, the series-connected configuration of the cells, the parallel-connected configuration of the cells, the number of the branches for the cells connected in parallel, and/or the like. In the battery pack **100**, the maximum variation ΔIbat corresponding to such a characteristic of the battery pack **100** is stored in the memory device **627**. Specifically, the maximum variation ΔIbat is set such that a voltage variation ΔViz calculated by multiplying the maximum variation ΔIbat by the impedance Z is smaller than a difference value ΔVa between a charge completion voltage value Vcut and a target voltage value CV (ΔVa=Vcut−CV).

[0070] The charger **600** includes a charger-side CS terminal **63** to be connected to the CS terminal **13**. The charger **600** includes an interlock circuit **617** connected to the charger-side CS terminal **63**. The charger **600** includes a charger-side power-supply circuit **613** configured to supply a DC power. The interlock circuit **617** permits a power supply operation by the charger-side power-supply circuit **613** during receipt of the charging permission signal from the battery pack **100**. The interlock circuit **617** prohibits the power supply operation by the charger-side power-supply circuit **613** during receipt of the charging prohibition signal from the battery pack **100**. The charger-side power-supply circuit **613** is configured to convert an AC power from a commercial power supply (e.g., AC 100 V) into the DC power with an AC/DC converter or the like to supply the DC power.

[0071] The DT terminal **14** is connected to a charger-side communication terminal **64** of the charger **600** when the battery pack **100** is connected to the charger **600**. The charger-side communication terminal **64** is connected to a battery detector **630**. The DT terminal **14** has an electric potential VDT. The electric potential VDT varies depending on whether the charger **600** is connected to the battery pack **100**. The electric potential VDT also varies depending on whether the battery pack **100** is in the inactive state or in the active state.

[0072] The battery detector **630** determines whether the electric potential VDT indicates the inactive state or the active state of the battery pack **100**. Based on the determination result, the battery detector **630** detects whether the battery pack **100** is in the inactive state. Upon detection that the battery pack **100** is in the active state, the battery detector **630** turns ON a discharge switch **615**. The discharge switch **615** is provided on a positive-side connection line of the charger **600**. The positive-side connection line of the charger **600** is a power line provided between the charger-side positive terminal **61** and the charger-side power-supply circuit **613**. The discharge switch **615** may include, for example, a Field Effect Transistor (FET).

[0073] This allows power supply from the charger **600** to the battery pack **100** to thereby charge the battery **60** (specifically, the fist cell **60***a* and the second cell **60***b*). Upon detection that the battery pack **100** is in the inactive state, the battery detector **630** turns OFF the discharge switch **615**.

[0074] The DT terminal **14** is connected to the detector **300** of the battery pack **100**. The detector **300** detects the electric potential VDT, and determines whether the electric potential VDT indicates that the charger **600** is unconnected to (or disconnected from) the battery pack **100**. The detector **300** detects, based on the electric potential VDT, whether the charger **600** is connected to the battery pack **100**. The detector **300** outputs the detection result to the MPU **620** through the interrupt port(s) PT. The detector **300** may output the detection result to the AFE **610**. Further, the detector **300** may output the detection result to the MPU **620** and the AFE **610**.

[0075] The MPU **620** acquires, based on the detection result input thereto, charger information including unconnection information, OFF information, and ON information. The charger information (i.e., the unconnection information, the OFF information, and the ON information) is transmitted from the charger **600** to the battery pack **100**, and is received by the battery pack **100**.

[0076] The unconnection information indicates that the charger **600** is unconnected to the battery pack **100**. The OFF information indicates that the charger **600** is connected to the battery pack **100** and that the discharge switch **615** is OFF. The ON information indicates that the charger **600** is connected to the battery pack **100** and that the discharge switch **615** is ON.

[0077] The TR terminal **15** is a terminal for serial communication, and is connected to the communicator **400**. The communicator **400** includes a Universal Asynchronous Receiver/Transmitter (UART) circuit configured to perform a half-duplex communication.

[0078] The charger **600** includes a charger-side TR terminal **65** to be connected to the TR terminal **15**, and a charger-side communicator **619** connected to the charger-side TR terminal **65**. The charger-side communicator **619** includes a Universal Asynchronous Receiver/Transmitter (UART) circuit configured to perform a half-duplex communication.

[0079] The charger **600** includes a charger-side MPU **611**. The charger-side MPU **611** includes a microcomputer with a CPU, a ROM, a RAM, and I/Os, and performs various controls including charge control of the charger **600**. The charger-side MPU **611** detects, via a shunt resistor **621**, the

magnitude of a discharge current flowing out of the charger-side power-supply circuit **613**. If the charger-side MPU **611** detects an anormal magnitude of the discharge current, the charger-side MPU **611** stops charging of the battery **60** (specifically, the first cell **60***a* and the second cell **60***b*) with such anormal discharge current by, for example, turning OFF the discharge switch **615**.

[0080] When a specified condition is satisfied after charging of the battery pack **100** is complete, the charger-side MPU **611** transitions from a normal operation mode (or a control operation state) to a sleep mode (or a low-power operation state). In the sleep mode, part of the operation of the charger-side MPU **611** is stopped to reduce power consumption. Before transitioning from the normal operation mode to the sleep mode, the charger-side MPU **611** transmits a sleep transition signal Sa**2** to the MPU **620** via the charger-side communicator **619**. The sleep transition signal Sa**2** is a parameter signal indicating that the charger-side MPU **611** of the charger **600** has transitioned to the sleep mode.

[0081] The MPU **611** includes interrupt ports PT (not shown) that receive various signals input thereto. When any one of the interrupt ports PT receives a signal during the sleep mode, the charger-side MPU **611** wakes up and transitions to the normal operation mode. For example, the charger-side MPU **611** wakes up when (i) the charger-side MPU **611** detects a connected state, where the charger **600** is connected to the battery pack **100**, and (ii) the interrupt port PT receives a connection detection information Sb**1**. The charger-side MPU **611** transitions to the sleep mode when (i) the charger-side MPU **611** does not detect the connected state (i.e., the battery pack **100** is detached) and (ii) a specified condition is satisfied.

[0082] The MPU **620** performs a serial communication with the charger-side MPU **611** via the communicator **400**, the TR terminal **15**, the charger-side TR terminal **65**, and the charger-side communicator **619**. The MPU **620** and the charger-side MPU **611** communicate with each other in a specified communication cycle Tc (e.g., Tc=8 [sec]) as long as communication therebetween is established. The MPU **620**, the communicator **400**, and the TR terminal **15** perform a two-way communication with the charger **600**.

[0083] The DS terminal **16** is connected to the discharge controller **500**. When the battery pack **100** is connected to the external device (specifically, the electric working machine), the DS terminal **16** outputs a discharge permission signal or a discharge prohibition signal to the external device. The discharge controller **500** outputs the discharge permission signal or the discharge prohibition signal through the DS terminal **16** based on the discharge permission signal or the discharge prohibition signal input from the MPU **620**. When the battery pack **100** in the inactive state is connected to the charger **600**, the electric power from the auxiliary power supply **623** is input to the DS terminal **16** via the charger-side DS terminal **66**.

[0084] The charger **600** includes a temperature detector **625** configured to detect a temperature of the charger **600**. The temperature detector **625** transmits the detected temperature (hereinafter also referred to as a detector temperature T**1**) to the charger-side MPU **611**. The charger-side MPU **611** stores the detector temperature T**1** in a storage, such as the RAM in the charger-side MPU **611**. The temperature detector **625** may include a thermistor (not shown) provided adjacent to, for example, any of the charger-side power-supply circuit **613**, the discharge switch **615**, the shunt resistor **621**, and so on.

1-2. Charge Condition Setting Process and Charge Control Process

[0085] An explanation will be given of various processes performed in the charger **600** and the battery pack **100** during charging of the battery pack **100**. Specifically, a charge control process performed by the charger-side MPU **611** of the charger **600** and a charge condition setting process performed by the MPU **620** of the battery pack **100** will be described with reference to flowcharts of FIGS. **2** and **3**, respectively. In the present embodiment, whether the charging is completed is determined based on the first cell **60***a*. In another embodiment, whether the charging is completed may be determined based on the second cell **60***b*. In yet another embodiment, whether the charging is completed may be determined based on both the first cell **60***a* and the second cell **60***b*, and the charging of the battery pack **100** may be completed by completion of the charging of the first cell **60***a* and/or the second cell **60***b*.

[0086] The charger-side MPU **611** wakes up when (i) the charger-side MPU **611** detects the connected state and (ii) the charger-side MPU **611** receives the connection detection information Sb**1** through the interrupt port PT, and then, the charger-side MPU **611** initiates the charge control process. The MPU **620** wakes up when (i) the detector **300** detects the connected state and (ii) the interrupt port PT receives the connection detection information Sa**1**, and then, the MPU **620** initiates an operation in the normal operation mode (i.e., the control operation state), and initiates the charge condition setting process.

[0087] The charge control process by the charger-side MPU **611** and the charge condition setting process by the MPU **620** are initiated simultaneously, and then performed concurrently.

[0088] Upon initiating the charge control process, the charger-side MPU **611** firstly performs an initial communication process in S**110** (S represents a step: the same applies hereinafter). Upon initiating the charge condition setting process, the MPU **620** performs an initial communication process in S**310**. The initial communication processes include confirming that signals can be mutually transmitted and received between the battery pack **100** and the charger **600** (i.e., between the MPU **620** and the charger-side MPU **611**).

[0089] Upon completing the initial communication process properly, the charger-side MPU **611** proceeds to S**120**, and sets an output current value Inow to 0 ampere ([A]). The output current value Inow is one of internal variables used in the charge control process performed by the charger-side MPU **611**. The output current value Inow is an internal variable for storing a current value of the discharge current output by the charger-side power-supply circuit **613**. The discharge current output by the charger-side power-supply circuit **613** also corresponds to a charging current for charging the battery pack **100**.

[0090] In subsequent S**130**, the charger-side MPU **611** transmits the output current value Inow to the MPU **620**. In detail, the charger-side MPU **611** transmits a numerical value set as the output current value Inow to the MPU **620**.

[0091] Upon completing the initial communication process properly, the MPU **620** receives, in S**320**, the output current value Inow from the charger-side MPU **611**. In this

step, the MPU **620** waits until it receives the output current value Inow. In other words, the MPU **620** performing the process in S**320** acquires, from the charger **600**, the output current value Inow included in charging operation information. The charging operation information indicates the charging operation by the charger **600**. The output current value Inow is information of the charging current output to the battery pack **100** by the charger **600**. In detail, the MPU **620** acquires the output current value Inow from the charger-side MPU **611** via the communicator **400** and the charger-side communicator **619**.

[0092] In subsequent S**140**, the charger-side MPU **611** acquires a charger temperature T**1** from the temperature detector **625**. The charger-side MPU **611** stores the detector temperature T**1** as one of the internal variables used in the charge control process, in the storage in the charger-side MPU **611**.

[0093] In subsequent S**150**, the charger-side MPU **611** determines an upper limit current value Ic**1** based on the detector temperature T**1**. The upper limit current value Ic**1** corresponds to a permissible upper limit of the magnitude of the charging current to be output by the charger **600**. The upper limit current value Ic**1** is one of the internal variables used in the charge control process performed by the charger-side MPU **611**. The charger-side MPU **611** calculates the upper limit current value Ic**1** corresponding to the charger temperature T**1** using a calculation formula, mapping information, or the like generated based on a correlation between the charger temperature T**1** and the upper limit current value Ic**1**, and sets the calculation result as the upper limit current value Ic**1**. The higher the charger temperature T**1** of the charger **600** is, the smaller the upper limit current value Ic**1** set by the charger-side MPU **611** is.

[0094] In S**330**, the MPU **620** acquires a cell voltage value Vnow and a battery temperature Tb. The MPU **620** acquires a value of the cell voltage of the first cell **60***a* from the AFE **610** and stores it, as the cell voltage value Vnow, in the storage in the MPU **620**. The MPU **620** acquires the cell temperature of the first cell **60***a* from the AFE **610** and stores it, as the battery temperature Tb, in the storage in the MPU **620**.

[0095] In subsequent S**340**, the MPU **620** sets a reference current value Iset, a target voltage value CV, and a charge completion current value Icut. These are the internal variables used in the charge control process performed by the charger-side MPU **611**.

[0096] The reference current value Iset corresponds to an upper limit of the magnitude of the charging current permissible in the first cell **60***a* during charging by the charger **600**. The MPU **620** calculates the reference current value Iset corresponding to the battery temperature Tb acquired in S**330** using a calculation formula, mapping information, or the like generated based on a correlation of the reference current value Iset with the battery temperature Tb, and sets the calculation result as the reference current value Iset.

[0097] The target voltage value CV is a target value of the cell voltage in the first cell **60***a* during charging by the charger **600**. That is, the target voltage value CV corresponds to the magnitude of the cell voltage required for the charger **600** to charge the first cell **60***a*. The MPU **620** calculates the target voltage value CV corresponding to the battery temperature Tb acquired in S**330** using a calculation formula, mapping information, or the like generated based on a correlation of the target voltage value CV with the battery temperature Tb, and sets the calculation result as the target voltage value CV.

[0098] The charge completion current value Icut is a threshold value for determining completion of charging of the first cell **60***a*. More specifically, the charge completion current value Icut corresponds to the magnitude of the charging current supplied from the charger **600** when the first cell **60***a* is in a charge completion state. The MPU **620** calculates the charge completion current value Icut corresponding to the battery temperature Tb acquired in S**330** using a calculation formula, mapping information, or the like generated based on a correlation of the charge completion current value Icut with the battery temperature Tb, and sets the calculation result as the charge completion current value Icut.

[0099] In subsequent S**350**, the MPU **620** determines whether the cell voltage value Vnow is larger than or equal to the target voltage value CV. Upon affirmative determination, the MPU **620** proceeds to S**390**; whereas upon negative determination, the MPU **620** proceeds to S**360**. In other words, the MPU **620** performing the process in S**350** compares the cell voltage value Vnow with the target voltage value CV, and determines whether the cell voltage value Vnow is smaller than the target voltage value CV.

[0100] Upon proceeding to S**360** after the negative determination in S**350**, the MPU **620** determines whether the sum of the output current value Inow and the maximum variation ΔIbat (=Inow+ΔIbat: hereinafter also referred to as a provisional current value Ite) is larger than the reference current value Iset. Upon affirmative determination, the MPU **620** proceeds to S**380**; whereas upon negative determination, the MPU **620** proceeds to S**370**. In S**360**, the MPU **620** calculates the provisional current value Ite using the maximum variation ΔIbat read out from the memory device **627**. In other words, the MPU **620** performing the process in S**360** compares the provisional current value Ite with the reference current value Iset, and determines whether the provisional current value Ite is smaller than or equal to the reference current value Iset.

[0101] Upon proceeding to S**370** after the negative determination in S**360**, the MPU **620** sets the sum of the output current value Inow and the maximum variation ΔIbat (i.e., the provisional current value Ite) as a target current value Inext. The target current value Inext corresponds to the magnitude of the charging current required to charge the first cell **60***a*. In other words, the target current value Inext is a target value for the charging current value to be reached. Specifically, the MPU **620** performing the process in S**370** calculates a newest value of the target current value Inext (hereinafter also referred to as a newest value Ine**2**) obtained by adding the maximum variation ΔIbat to the output current value Inow.

[0102] In S**370**, the newest value Ine**2** may be calculated using a previous value of the target current value Inext (hereinafter also referred to as a previous value Ine**1**) calculated last time, instead of using the output current value Inow. In other words, the MPU **620** may calculate the newest value Ine**2** based on the previous value Ine**1** and the maximum variation ΔIbat. The MPU **620** performs the process in S**370** repeatedly in the charge condition setting process, to thereby repeatedly calculate the target current value Inext.

[0103] Upon proceeding to S**380** after the affirmative determination in S**360**, the MPU **620** sets the reference current value Iset as the target current value Inext.

[0104] Upon proceeding to S**390** after the affirmative determination in S**350**, the MPU **620** determines whether the cell voltage value Vnow is larger than or equal to the charge completion voltage value Vcut. Upon affirmative determination, the MPU **620** proceeds to S**430**; whereas upon negative determination, the MPU **620** proceeds to S**400**. The charge completion voltage value Vcut is a determination value for determining completion of charging of the first cell **60***a*, and corresponds to the voltage of the first cell **60***a* when the first cell **60***a* is in the charge completion state.

[0105] Upon proceeding to S**400** after the negative determination in S**390**, the MPU **620** calculates the target current value Inext by subtracting the maximum variation ΔIbat from the output current value Inow. In the present embodiment, the subtraction is performed using the maximum variation ΔIbat; however the subtraction may be performed using another numerical value (e.g., a current decrease reference amount ΔIbat**2**), instead of using the maximum variation ΔIbat, to thereby set the target current value Inext. Specifically, the target current value Inext may be set using different numerical values depending on whether the target current value Inext is to be increased or decreased.

[0106] In subsequent S**410**, the MPU **620** determines whether the target current value Inext is smaller than the charge completion current value Icut. Upon affirmative determination, the MPU **620** proceeds to S**430**; whereas upon negative determination, the MPU **620** proceeds to S**420**.

[0107] In S**420**, the MPU **620** transmits the target current value Inext to the charger-side MPU **611**. Specifically, the MPU **620** transmits the target current value Inext set in any of S**370**, S**380**, and S**400** to the charger-side MPU **611**. The MPU **620** transmits the target current value Inext to the charger-side MPU **611** via the communicator **400** and the charger-side communicator **619**. In this way, the charger **600** is notified of the target current value Inext by the battery pack **100**.

[0108] In S**160**, the charger-side MPU **611** receives the target current value Inext from the MPU **620**. In this step, the charger-side MPU **611** waits until it receives the target current value Inext. Specifically, in S**160**, the charger-side MPU **611** acquires, from the battery pack **100**, the target current value Inext included in charge condition information.

[0109] In subsequent S**170**, the charger-side MPU **611** determines whether the target current value Inext is larger than the upper limit current value Ic**1**. Upon affirmative determination, the charger-side MPU **611** proceeds to S**190**; whereas upon negative determination, the charger-side MPU **611** proceeds to S**180**. In other words, in S**170**, the charger-side MPU **611** determines whether the newest value Ine**2** is smaller than or equal to the upper limit current value Ic**1**.

[0110] Upon proceeding to S**180** after the negative determination in S**170**, the charger-side MPU **611** sets the target current value Inext as an output current Iout. Upon proceeding to S**190**, the charger-side MPU **611** sets the upper limit current value Id**1** as the output current Iout. The charger-side MPU **611** controls a current output by the charger-side power-supply circuit **613** based on the setting of the output current Iout. That is, in the charger **600**, the output current according to the output current Iout is output from the charger-side power-supply circuit **613**.

[0111] In other words, in S**180** and S**190**, the charger-side MPU **611** sets the magnitude of the charging current to be output from the charger-side power-supply circuit **613**. Especially in S**180**, the charger-side MPU **611** sets the magnitude of the charging current to be output from the charger-side power-supply circuit **613** based on the target current value Inext.

[0112] In subsequent S**200**, the charger-side MPU **611** sets the output current Iout as the output current value Inow.

[0113] After performing the process in S**200**, the charger-side MPU **611** proceeds to S**130** again, whereafter the charger-side MPU **611** performs the processes in S**130** to S**200**.

[0114] In S**430**, the MPU **620** determines that charging of the first cell **60***a* is complete, and transmits a charge completion signal Ss for notifying of completion of charging to the charger-side MPU **611**. After performing the process in S**430**, the MPU **620** terminates the charge condition setting process. The charger-side MPU **611** terminates the charge control process upon receiving the charge completion signal Ss.

[0115] As described so far, the battery pack **100** performs the charge condition setting process and the charger **600** performs the charge control process, whereby the battery pack **100** transmits the target current value Inext to the charger **600** (S**420**) and the charger **600** outputs the output current Iout set based on the target current value Inext to the battery pack **100** (S**180**).

[0116] Moreover, the battery pack **100** sets the target current value Inext using the maximum variation ΔIbat set according to the characteristic(s) of the battery pack **100** (S**370**, S**400**). This enables the target current value Inext to be changed according to the characteristic(s) of the battery pack **100**.

[0117] Furthermore, the battery pack **100** sets the reference current value Iset as the target current value Inext if the provisional current value Ite is larger than the reference current value Iset. This inhibits the target current value Inext from excessively increasing.

1-3. Comparison Between the Present Embodiment and Comparative Example 1 in Terms of Earlier Stop of Charging

[0118] Here, an explanation will be given of the ability of the charging system **1** of the present embodiment to inhibit early stop of charging, by comparing the present embodiment with Comparative Example 1.

[0119] As described above, the present embodiment is directed to the charging system **1** configured to perform charging of a battery pack using the maximum variation ΔIbat stored in the battery pack **100**. On the other hand, Comparative Example 1 is directed to a charging system (not shown) configured to perform charging of a battery pack using a maximum variation stored in a charger.

[0120] FIG. **4** shows profiles of the cell voltage value Vnow and the output current value Inow when the battery pack **100** performs the charge condition setting process and the charger **600** performs the charge control process in the present embodiment.

[0121] Specifically, in the present embodiment, upon initiation of charging at time 0 [sec], the output current value Inow is repeatedly increased stepwise by the maximum

variation ΔIbat, and this results in the cell voltage value Vnow also being repeatedly increased stepwise. Then, upon the cell voltage value Vnow exceeding the target voltage value CV (at around time 40 [sec]), the output current value Inow is decreased stepwise by the maximum variation ΔIbat (at around time 44 [sec]).

[0122] Here, if the cell voltage value Vnow exceeds not only the target voltage value CV but also the charge completion voltage value Vcut, the charger determines that the charging is complete, thus stopping the charging. However, in the present embodiment, the maximum variation ΔIbat stored in the battery pack **100** is set according to the characteristic(s) of the battery pack **100**. Thus, the cell voltage value Vnow is inhibited from exceeding the charge completion voltage value Vcut even after the output current value Inow is repeatedly increased stepwise by the maximum variation ΔIbat.

[0123] Subsequently, when the cell voltage value Vnow falls below the target voltage value CV with the decrease in the output current value Inow, the output current value Inow is increased stepwise by the maximum variation ΔIbat (at around time 52 [sec]). Then, when the cell voltage value Vnow exceeds the target voltage value CV, the output current value Inow is decreased stepwise by the maximum variation ΔIbat.

[0124] That is, after the cell voltage value Vnow reaches the target voltage value CV, the output current value Inow is controlled to be increased or decreased by the maximum variation ΔIbat so that the cell voltage value Vnow remains close to the target voltage value CV.

[0125] Subsequently, while the cell voltage value Vnow remains close to the target voltage value CV, the output current value Inow is gradually decreased (over a period approximately from time 52 to time 132 [sec]) with the increase in charged power energy of the first cell **60***a*. Then, when the output current value Inow falls below the charge completion current value Icut, the charger determines that the charging is complete, thus terminating the charging (at time 132 [sec]).

[0126] FIG. **5** shows profiles of the cell voltage value Vnow and the output current value Inow when a charge control is performed by a battery pack and the charger of Comparative Example 1.

[0127] The charge control process performed by the charger of Comparative Example 1 is different from the charge control process of the present embodiment shown in FIG. **2** in that the process of receiving the target current value Inext from the battery pack **100** is not included. The charge control process of Comparative Example 1 is different from the charge control process of the present embodiment in that the output current Iout is set as the target current value Inext using a maximum variation ΔI**2** stored in the charger. A larger value is set as the maximum variation ΔI**2** in Comparative Example 1 than the maximum variation ΔIbat in the present embodiment.

[0128] In Comparative Example 1, upon initiation of charging at time 0 [sec], the output current value Inow is repeatedly increased stepwise by the maximum variation ΔI**2** stored in the charger, and this results in the cell voltage value Vnow also being repeatedly increased stepwise. Here, since a larger value is set as the maximum variation ΔI**2** than the maximum variation ΔIbat, voltage rise in Comparative Example 1 is larger than that in the present embodiment. Thus, the cell voltage value Vnow exceeds not only the target voltage value CV but also the charge completion voltage value Vcut by a single update of the output current value Inow by the maximum variation ΔI**2** (at around time 24 [sec]).

[0129] As described above, when the cell voltage value Vnow exceeds the charge completion voltage value Vcut, the charger determines that the charging is complete, thus stopping the charging (see S**390** and S**430**). That is, in Comparative Example 1, early stop of charging occurs in which, although the battery is in a state not sufficiently charged, the charger erroneously determines that the charging is complete, thus stopping the charging.

[0130] This occurs when the maximum variation ΔI**2** stored in the charger is not suited to a characteristic of the battery pack.

[0131] As seen from the above, as compared with Comparative Example 1, the present embodiment can inhibit occurrence of the early stop of charging, to thereby charge the battery pack **100** sufficiently.

1-4. Comparison Between the Present Embodiment and Comparative Example 2 in Terms of Charging Time

[0132] Here, an explanation will be given of the ability of the charging system **1** of the present embodiment to reduce a charging time (i.e., a time required from initiation to completion of the charging), by comparing the present embodiment with Comparative Example 2.

[0133] As described above, the present embodiment is directed to the charging system **1** configured to perform a battery pack charging using the maximum variation ΔIbat stored in the battery pack **100**. On the other hand, Comparative Example 2 is directed to a charging system (not shown) configured to perform a battery pack charging using a maximum variation stored in a charger.

[0134] FIG. **6** shows profiles of the cell voltage value Vnow, the output current value Inow, and a charge amount QV when the battery pack **100** performs the charge condition setting process and the charger **600** performs the charge control process in the present embodiment. The charge amount QV indicates a charged power energy [Ah] in the first cell **60***a*.

[0135] Specifically, in the present embodiment, upon initiation of charging at time 0 [sec], the output current value Inow is repeatedly increased by the maximum variation ΔIbat, and this results in the cell voltage value Vnow being repeatedly increased and also the charge amount QV being increased. In approximately 44 [sec], the output current value Inow reaches the reference current value Iset. Thereafter, the charging is continued with the output current value Inow controlled to be about the same value as the reference current value Iset, to thereby further increase the charge amount QV.

[0136] FIG. **7** shows profiles of the cell voltage value Vnow, the output current value Inow, and the charge amount QV when a charge control is performed by a battery pack and the charger of Comparative Example 2.

[0137] The charge control process performed by the charger of Comparative Example 2 is different from the charge control process of the present embodiment shown in FIG. **2** in that (i) the process of receiving the target current value Inext from the battery pack **100** is not included, and (ii) the output current Iout is set using the maximum variation ΔI**2** stored in the charger as the target current value Inext. The

maximum variation ΔI**2** in Comparative Example 2 is smaller than the maximum variation ΔIbat in the present embodiment.

[0138] In Comparative Example 2, upon initiation of charging at time 0 [sec], the output current value Inow is repeatedly increased by the maximum variation ΔIbat, and this results in the cell voltage value Vnow being repeatedly increased and also the charge amount QV being increased. However, in Comparative Example 2, the maximum variation ΔIbat is smaller than that in the present embodiment, and thus, an increase rate of the output current value Inow is smaller. It takes approximately 188 [sec] for the output current value Inow to reach the reference current value Iset.

[0139] That is, in the present embodiment, the time required for the output current value Inow to reach the reference current value Iset is shorter than that in Comparative Example 2, and this results in higher increase rate of the charge amount QV. Thus, the charging time of the battery pack **100** can be reduced.

1-5. Effects

[0140] As described so far, in the charging system **1**, the battery pack **100** calculates the newest value Ine**2** using the maximum variation ΔIbat determined according to the characteristic(s) of the battery pack **100**. Thus, the battery pack **100** can control the increase in the target current value Inext within a range according to the characteristic(s) of the battery pack **100**. The MPU **620** notifies the charger-side MPU **611** in the charger **600** of the target current value Inext, thereby enabling the battery pack **100** to notify the charger **600** of the target current value Inext according to the characteristic(s) of the battery pack **100**.

[0141] Thus, the battery pack **100** can inhibit an excessive increase of the charging current supplied from the charger **600** (i.e., the maximum variation ΔIbat). As a result, the variation of the charging voltage caused by the change in the charging current can fall within a range according to the characteristic(s) of the battery pack **100** (specifically, the first cell **60***a*).

[0142] Accordingly, the charging system **1** and the battery pack **100** can inhibit an excessive variation of the charging voltage, thus inhibiting the early stop of charging, damage to the first cell **60***a*, and so on. The early stop of charging refers to, for example, stop of the charging operation caused by extraordinary increase in the charging voltage before completion of charging of the battery as in the case shown in FIG. **5**. The damage to the first cell **60***a* refers to, for example, damage to the first cell **60***a* caused by an impermissible charging voltage.

[0143] Next, the maximum variation ΔIbat is determined based on the characteristics of the battery pack **100**. The characteristics of the battery pack **100** correspond to the impedance Z of the first cell **60***a*, and correspond to the arrangement of the first cell **60***a* and the second cell **60***b*.

[0144] The variation of the charging voltage caused by change in the charging current varies according to, for example, the characteristics of the battery pack **100**. Thus, use of the maximum variation ΔIbat of the present embodiment makes it possible to set the variation of the charging voltage so as to be suited to the characteristics of the first cell **60***a*, and thus to the characteristics of the battery pack **100**. Accordingly, since the variation of the charging voltage can be set according to the characteristics of the first cell **60***a*, the charging system **1** and the battery pack **100** can inhibit an excessive variation of the charging voltage.

[0145] Next, the battery pack **100** is configured to acquire, from the charger **600**, the output current value Inow included in the charging operation information of the charger **600**. In the battery pack **100**, the MPU **620** calculates the newest value Ine**2** using the output current value Inow (see S**370**).

[0146] Since the output current value Inow included in the charging operation information is acquired from the charger **600**, the battery pack **100** can accurately get the magnitude of the charging current that the charger **600** is outputting to the battery pack **100**. Moreover, since the newest value Ine**2** is calculated using the output current value Inow as the previous value Ine**1**, the battery pack **100** can calculate the newest value Ine**2** properly even when an error is caused between the previous value Ine**1** and an actual magnitude of the charging current.

[0147] Accordingly, the battery pack **100** can inhibit an erroneous calculation of the newest value Ine**2**, thus inhibiting an excessive variation of the charging voltage.

[0148] In the battery pack **100**, in response to the determination that the cell voltage value Vnow is smaller than the target voltage value CV (negative determination in S**350**), the MPU **620** calculates the newest value Ine**2**, which is obtained by adding the maximum variation ΔIbat to the output current value Inow (S**370**).

[0149] This enables the battery pack **100** to calculate the newest value Ine**2** so as to increase the charging current while maintaining the cell voltage value Vnow of the first cell **60***a* within tolerance. Accordingly, the battery pack **100** can increase the charging current within tolerance, thus reducing the charging time.

[0150] In the present embodiment, the mode has been described in which, after the negative determination in S**350**, the process proceeds to S**370** via S**360** as shown in the flowchart of FIG. **3**. However, the present disclosure is not limited to this mode and, for example, the process may proceed directly to S**370**, not via S**360**. In the case of omitting S**360**, S**380** may also be omitted.

[0151] In the battery pack **100**, in response to the determination that the cell voltage value Vnow is larger than or equal to the target voltage value CV (affirmative determination in S**350**), the MPU **620** calculates the newest value Ine**2** by subtracting the maximum variation ΔIbat from the output current value Inow (S**400**).

[0152] This enables the battery pack **100** to calculate the newest value Ine**2** while inhibiting the cell voltage value Vnow of the first cell **60***a* beyond tolerance, by reducing the target current value Inext when the cell voltage value Vnow is larger than or equal to the target voltage value CV. Accordingly, use of the battery pack **100** enables continued proper charging operation while inhibiting occurrence of charging stop caused by the impermissible charging voltage.

[0153] In the battery pack **100**, in response to the determination that the provisional current value Ite is smaller than or equal to the reference current value Iset (negative determination in S**360**), the MPU **620** calculates the newest value Ine**2**, which is obtained by adding the maximum variation ΔIbat to the output current value Inow (S**370**). On the other hand, in response to the determination that the provisional current value Ite is larger than the reference current value Iset (affirmative determination in S**360**), the MPU **620** sets the reference current value Iset as the newest value Ine**2** (S**380**).

[0154] This enables the battery pack **100** to calculate the newest value Ine**2** so as to increase the charging current while maintaining the magnitude of the charging current within tolerance. Accordingly, the battery pack **100** can increase the charging current within tolerance, thus reducing the charging time.

[0155] Furthermore, the battery pack **100** can calculate the newest value Ine**2** while inhibiting the magnitude of the charging current beyond tolerance. Accordingly, use of the battery pack **100** enables continued proper charging operation while inhibiting occurrence of charging stop caused by an impermissible magnitude of the charging current.

[0156] In the charging system **1**, the battery pack **100** notifies the charger **600** of the target current value Inext as the charge condition information. The charger **600** supplies the battery pack **100** with the charging current of the magnitude set based on the target current value Inext. Accordingly, the charging system **1** can inhibit an excessive variation of the charging voltage, thus inhibiting the early stop of charging, damage to the battery, and so on.

[0157] In the charger **600** of the charging system **1**, in response to the determination that the target current value Inext is smaller than or equal to the upper limit current value Ic**1** (negative determination in S**170**), the charger-side MPU **611** sets the target current value Inext as the output current Iout (S**180**). On the other hand, in response to the determination that the target current value Inext is larger than the upper limit current value Ic**1** (affirmative determination in S**170**), the charger-side MPU **611** sets the upper limit current value Ic**1** as the output current Iout (S**190**).

[0158] This enables the charging system **1** to inhibit damage to the charger **600** caused by an excessive temperature rise during charging of the battery pack **100** by the charger **600**.

1-6. Correspondence Between Terms

[0159] The MPU **620** performing the processes in S**370**, S**380**, and S**400** corresponds to one example of a target current calculator of the present disclosure. The MPU **620** and the communicator **400** performing the process in S**420** correspond to one example of an information notifier of the present disclosure. The MPU **620** and the communicator **400** performing the process in S**330** correspond to one example of an operation information acquirer of the present disclosure. The MPU **620** performing the process in S**350** corresponds to one example of a voltage comparator of the present disclosure. The MPU **620** performing the process in S**360** corresponds to one example of a charging current comparator of the present disclosure.

[0160] The charger-side power-supply circuit **613** corresponds to one example of a current outputter of the present disclosure. The charger-side MPU **611** performing the process in S**160** corresponds to one example of a condition information acquirer of the present disclosure. The charger-side MPU **611** performing the process in S**180** or S**190** corresponds to one example of an output current setter of the present disclosure. The charger-side MPU **611** performing the process in S**170** corresponds to one example of an output current comparator of the present disclosure.

2. Other Embodiments

[0161] The embodiment of the present disclosure has been described in the above; however, the present disclosure is not limited to the above-described embodiment and can be carried out in various modes within the scope not departing from the spirit of the present disclosure.

[0162] (2a) In the above-described embodiment, a specific magnitude of the maximum variation ΔIbat is not explicitly described. However, the maximum variation ΔIbat is set to any given value determined based on the characteristic(s) of the battery pack **100** (e.g., the impedance of the first cell **60***a*, the arrangement of the first cell **60***a* and the second cell **60***b*, and so on). Alternatively, it is one option to measure a variation of the charging voltage caused by change in the charging current using the actual battery pack **100**, thus setting the maximum variation ΔIbat based on the measurement result.

[0163] (2b) In the above-described embodiment, the configuration has been described in which the battery pack **100** acquires the output current value how from the charger **600** (S**320**). However, the present disclosure is not limited to such a configuration. For example, in the charge condition setting process performed by the MPU **620** of the battery pack **100**, the target current value Inext calculated last time may be used as the output current value Inow to calculate the newest value Ine**2**.

[0164] (2c) In the above-described embodiment, the mode has been described in which the serial communication is employed between the battery pack **100** (the communicator **400**) and the charger **600**. However, the present disclosure is not limited to the serial communication, and other types of communication, such as parallel communication and multiplex communication, may be employed. Further, in the above-described embodiment, the mode has been described in which the two-way communication is employed between the battery pack **100** (the communicator **400**) and the charger **600**. However, one-way communication may be employed. In this case, two or more communication paths for the one-way communication may be provided.

[0165] (2d) A function performed by a single element in the above-described embodiments may be performed by two or more elements, and a function performed by two or more elements may be performed by a single element. At least part of a configuration in the above-described embodiments may be replaced by a known configuration having a similar function. Part of a configuration in the above-described embodiments may be omitted. At least part of a configuration in the above-described embodiments may be added to or replace another configuration in the above-described embodiments. Any and all modes encompassed by the technical ideas specified only by the recitations in the appended claims are embodiments of the present disclosure.

What is claimed is:

1. A charging system, comprising:

a battery pack including:

a battery configured to be charged with a charging current supplied from a charger, the battery including cells;

a memory device configured to store a maximum variation ΔIbat of a charging current value Inow, the charging current value Inow corresponding to a magnitude of the charging current, the maximum variation ΔIbat being determined depending on (i) a magnitude of an impedance of each of the cells and (ii) a configuration of the battery; and

a Micro Processing Unit (MPU) configured to perform a charge condition setting process, the charge condition setting process including:

acquiring charging operation information from the charger, the charging operation information relating to an operation required for the charger to charge the battery, the charging operation information including the charging current value Inow,

determining whether a cell voltage value Vnow is larger than or equal to a target voltage value CV, the cell voltage value Vnow corresponding to a magnitude of a voltage of each of the cells, and the target voltage value CV corresponding to the magnitude of the voltage of each of the cells required for the charger to charge the battery,

determining whether a provisional current value (Inow+ΔIbat) is larger than a reference current value Iset, the provisional current value (Inow+ΔIbat) corresponding to a sum of (i) the charging current value Inow included in the charging operation information and (ii) the maximum variation ΔIbat, the reference current value Iset corresponding to an upper limit of the charging current value Inow permissible in the battery,

calculating a target current value Inext by adding the maximum variation ΔIbat to the charging current value Inow included in the charging operation information, in response to (i) the cell voltage value Vnow being determined to be smaller than the target voltage value CV and (ii) the provisional current value (Inow+ΔIbat) being determined to be smaller than or equal to the reference current value Iset, the target current value Inext corresponding to the magnitude of the charging current required to charge the battery,

setting the reference current value Iset as the target current value Inext in response to (i) the cell voltage value Vnow being determined to be smaller than the target voltage value CV and (ii) the provisional current value (Inow+ΔIbat) being determined to be larger than the reference current value Iset,

calculating the target current value Inext by subtracting the maximum variation ΔIbat from the charging current value Inow included in the charging operation information, in response to the cell voltage value Vnow being determined to be larger than or equal to the target voltage value CV, and

transmitting, to the charger, charge condition information including the target current value Inext; and

the charger including:

a charger-side power-supply circuit configured to supply the charging current to the battery pack; and

a charger-side Micro Processing Unit (MPU) configured to perform a charge control process, the charge control process including:

acquiring the charge condition information from the battery pack,

determining whether the target current value Inext included in the charge condition information is larger than an upper limit current value Ic**1**, the upper limit current value Ic**1** corresponding to an upper limit of the charging current value Inow determined according to a temperature of the charger,

setting the target current value Inext included in the charge condition information as the magnitude of the charging current, in response to the target current value Inext included in the charge condition information being determined to be smaller than or equal to the upper limit current value Ic**1**, and

setting the upper limit current value Ic**1** as the magnitude of the charging current, in response to the target current value Inext included in the charge condition information being determined to be larger than the upper limit current value Ic**1**.

2. A battery pack, comprising:

a first cell configured to be charged with a charging current supplied from a charger;

a memory device configured to store a maximum variation of a charging current value, the charging current value corresponding to a magnitude of the charging current, the maximum variation being determined depending on a characteristic of the battery pack;

a target current calculator configured to calculate a newest value of a target current value based on (i) a previous value of the target current value and (ii) the maximum variation, the target current value corresponding to the magnitude of the charging current required to charge the first cell; and

an information notifier configured to transmit charge condition information to the charger, the charge condition information including the newest value.

3. The battery pack according to claim **2**,

wherein the characteristic of the battery pack includes at least a magnitude of an impedance of the first cell.

4. The battery pack according to claim **2**, further comprising:

a second cell configured to be charged with the charging current.

5. The battery pack according to claim **4**,

wherein the first cell is connected in parallel with the second cell.

6. The battery pack according to claim **4**,

wherein the characteristic of the battery pack depends on at least an arrangement of the first cell and the second cell.

7. The battery pack according to claim **2**, further comprising:

an operation information acquirer configured to acquire charging operation information from the charger, the charging operation information relating to an operation required for the charger to charge the first cell, the charging operation information including the charging current value,

wherein the target current calculator is configured to set the charging current value included in the charging operation information as the previous value in order to calculate the newest value.

8. The battery pack according to claim **2**, further comprising:

a voltage comparator configured to determine whether a cell voltage value is smaller than a target voltage value, the cell voltage value corresponding to a magnitude of a voltage of the first cell, and the target voltage value

corresponding to the magnitude of the voltage of the first cell required for the charger to charge the first cell,

wherein the target current calculator is configured to calculate the newest value by adding the maximum variation to the previous value, in response to the voltage comparator determining that the cell voltage value is smaller than the target voltage value.

9. The battery pack according to claim **8**,

wherein the target current calculator is configured to calculate the newest value by subtracting the maximum variation from the previous value, in response to the voltage comparator determining that the cell voltage value is larger than or equal to the target voltage value.

10. The battery pack according to claim **2**, further comprising:

a charging current comparator configured to determine whether a provisional current value is smaller than or equal to a reference current value, the provisional current value corresponding to a sum of the previous value and the maximum variation, the reference current value corresponding to an upper limit of the charging current value permissible in the first cell,

wherein the target current calculator is configured to calculate the newest value by adding the maximum variation to the previous value, in response to the charging current comparator determining that the provisional current value is smaller than or equal to the reference current value, and

wherein the target current calculator is configured to set the reference current value as the newest value, in response to the charging current comparator determining that the provisional current value is larger than the reference current value.

11. A charging system, comprising:

a battery pack including:

a first cell configured to be charged with a charging current supplied from a charger;

a memory device configured to store a maximum variation of a charging current value, the charging current value corresponding to a magnitude of the charging current, the maximum variation being determined depending on a characteristic of the battery pack;

a target current calculator configured to calculate a newest value of a target current value based on (i) a previous value of the target current value and (ii) the maximum variation, the target current value corresponding to the magnitude of the charging current required to charge the first cell; and

an information notifier configured to transmit charge condition information, the charge condition information including the newest value; and

the charger including:

a current outputter configured to supply the charging current to the battery pack;

a condition information acquirer configured to acquire the charge condition information from the battery pack; and

an output current setter configured to set the magnitude of the charging current based on the newest value included in the charge condition information.

12. The charging system according to claim **11**,

wherein the charger further includes:

an output current comparator configured to determine whether the newest value is smaller than or equal to an upper limit current value, the upper limit current value corresponding to an upper limit of the charging current value determined according to a temperature of the charger,

wherein the output current setter is configured to set the newest value as a value corresponding to the magnitude of the charging current, in response to the output current comparator determining that the newest value is smaller than or equal to the upper limit current value, and

wherein the output current setter is configured to set the upper limit current value as a value corresponding to the magnitude of the charging current, in response to the output current comparator determining that the newest value is larger than the upper limit current value.

13. A method for controlling charging of a battery pack, the method comprising:

calculating a newest value of a target current value based on (i) a previous value of the target current value and (ii) a maximum variation, the target current value corresponding to a magnitude of a charging current required to charge a cell in the battery pack, the maximum variation corresponding to a characteristic of the battery pack; and

notifying a charger of charge condition information including the newest value.

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