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(54) **BATTERY MANAGEMENT DEVICE**

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(57) **ABSTRACT**

The battery management device includes: a calculation unit that calculates SOC and the coefficient from the measured values of the current and the voltage of the battery based on an SOC of the battery and an estimation model that estimates the polarization voltage according to a coefficient relating to an increase in a voltage corresponding to SOC among the polarization voltages caused by discharging of the battery; and a notification unit that, when SOC is equal to or less than a threshold value, notifies the user of charge of the battery, and the notification unit decreases the threshold value as the coefficient decreases.

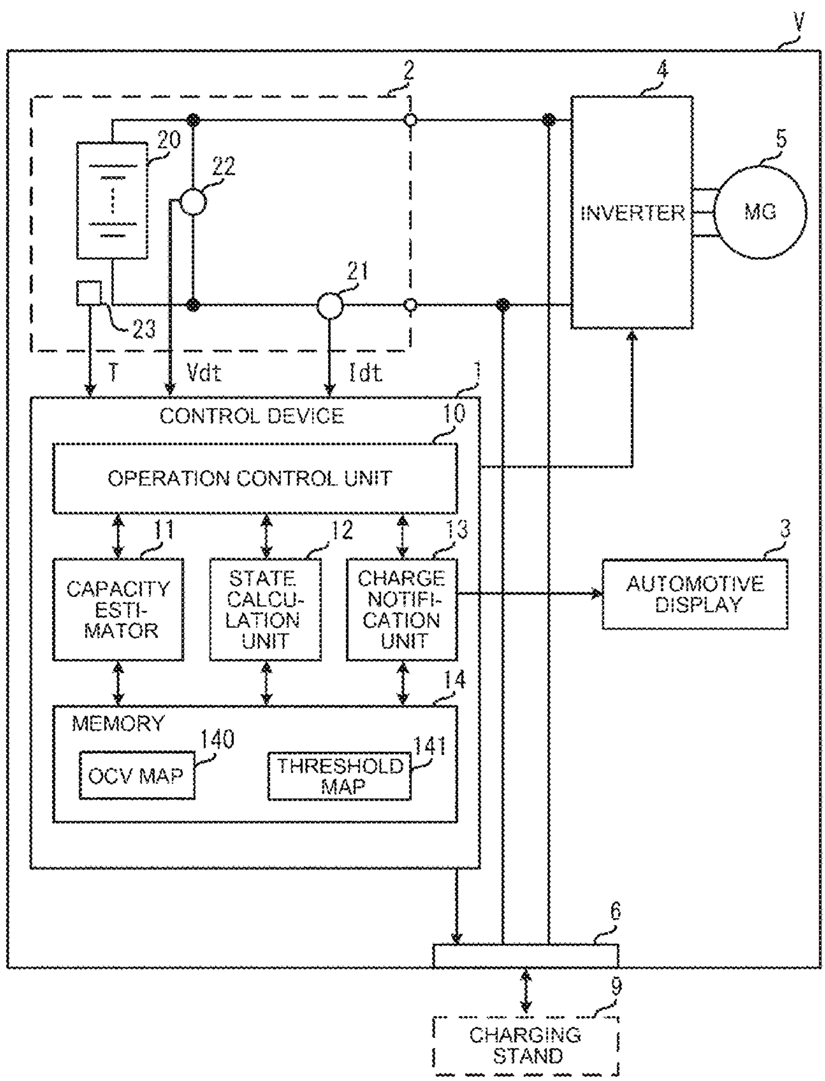


FIG. 1

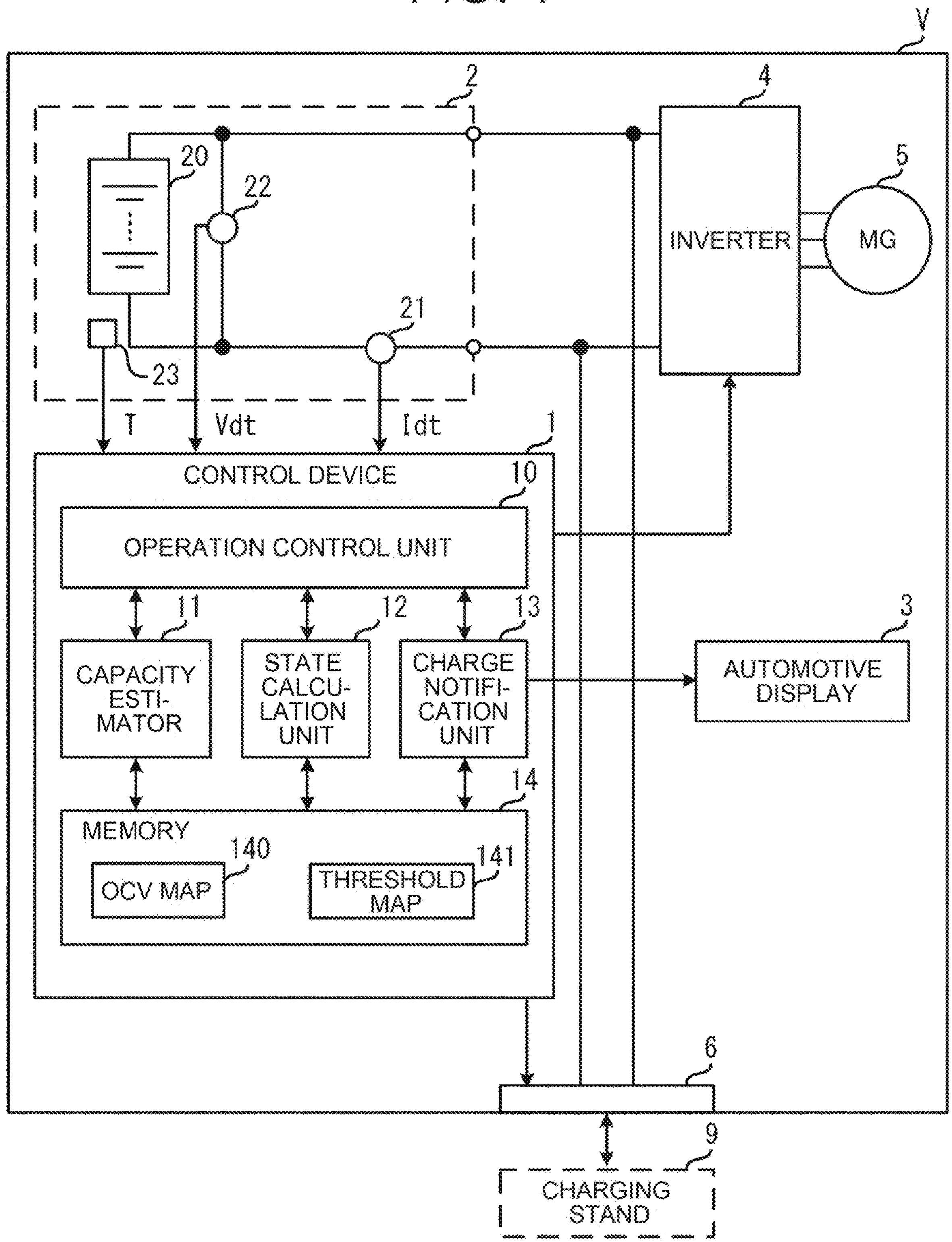

V
2
20
22
21
23
4
INVERTER
5
MG
T
Vdt
Idt
1
CONTROL DEVICE
10
OPERATION CONTROL UNIT
11
12
13
CAPACITY ESTI-MATOR
STATE CALCU-LATION UNIT
CHARGE NOTIFI-CATION UNIT
3
AUTOMOTIVE DISPLAY
14
MEMORY
140
OCV MAP
141
THRESHOLD MAP
6
9
CHARGING STAND

FIG. 2

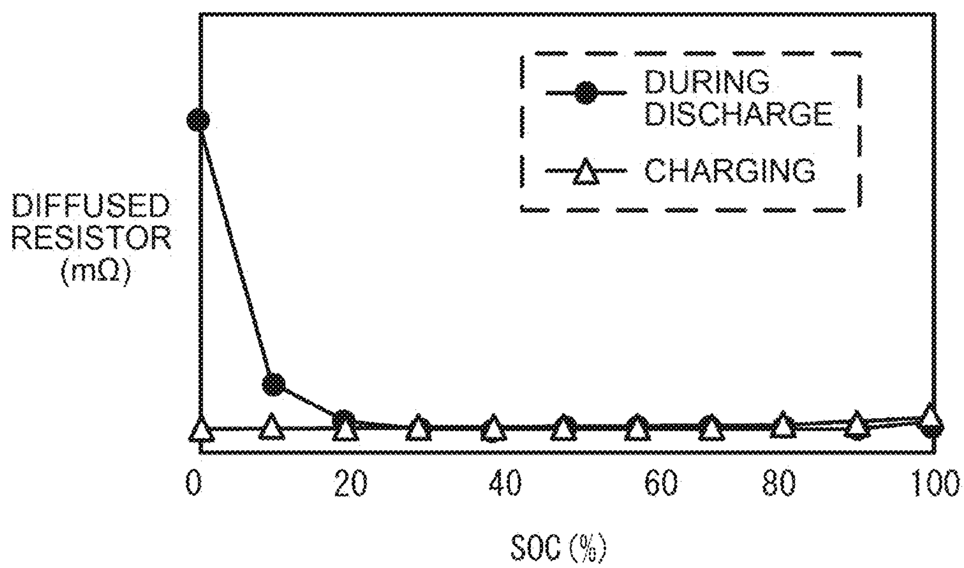

DURING DISCHARGE
CHARGING
DIFFUSED RESISTOR (mΩ)
0
20
40
60
80
100
SOC (%)

FIG. 3A

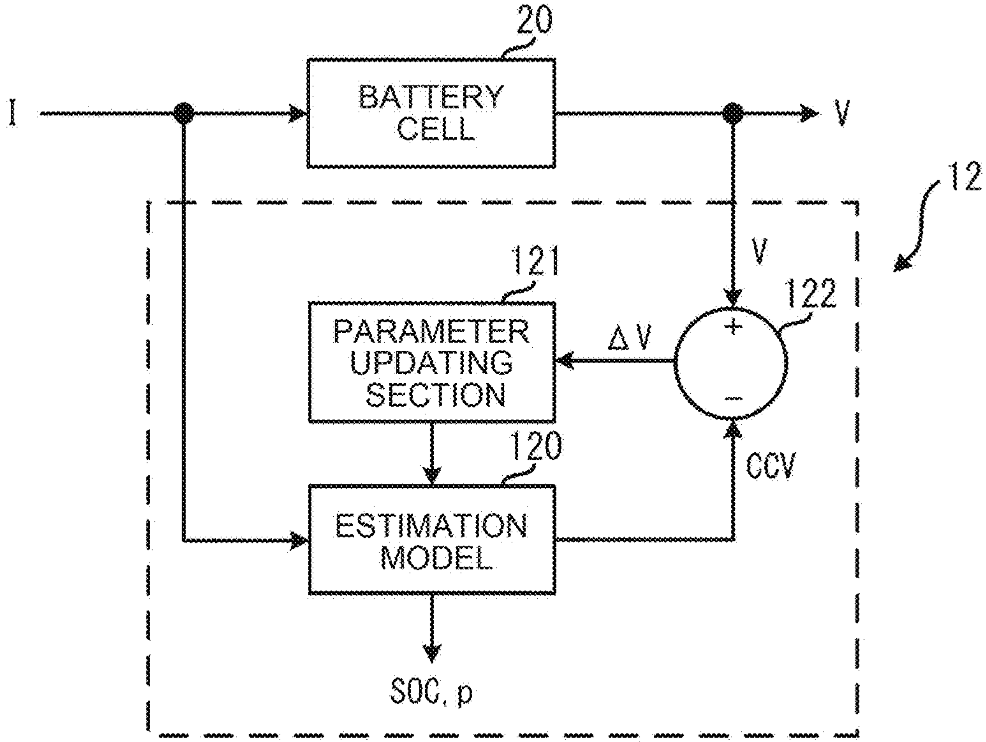

20
I
BATTERY CELL
V
12
V
121
122
PARAMETER UPDATING SECTION
ΔV
+
−
120
CCV
ESTIMATION MODEL
SOC, p

FIG. 3B

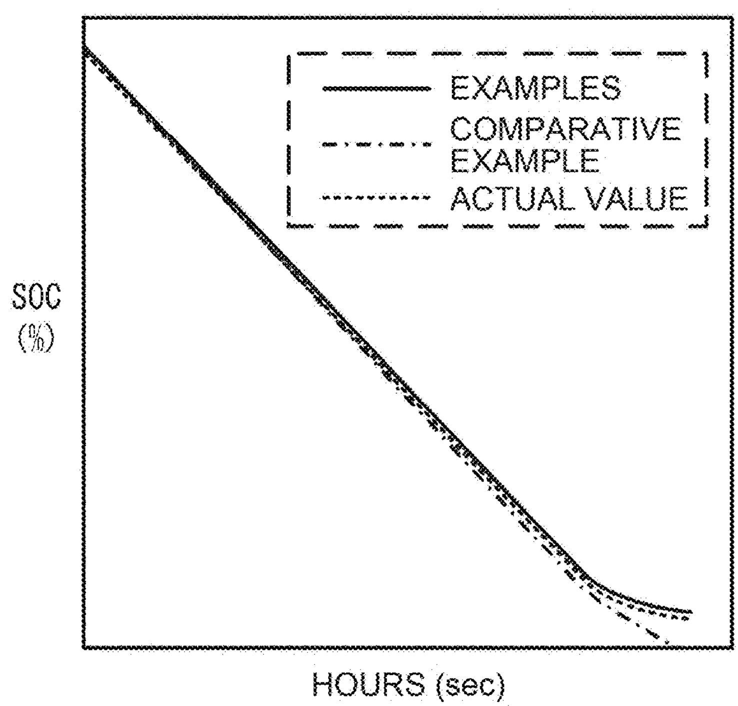

EXAMPLES
COMPARATIVE EXAMPLE
ACTUAL VALUE
SOC (%)
HOURS (sec)

FIG. 4

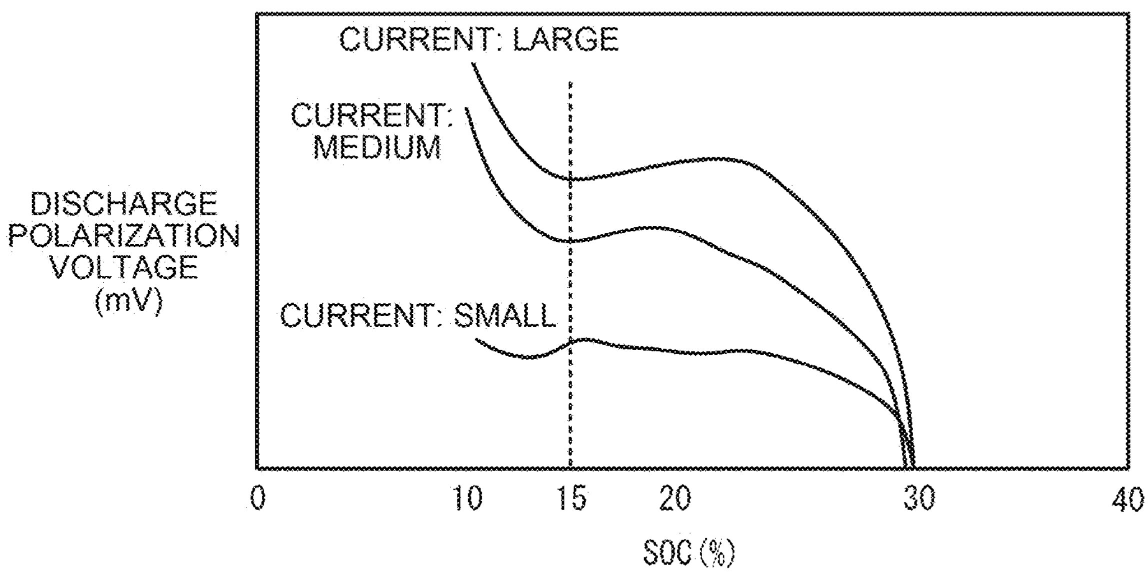

CURRENT: LARGE
CURRENT: MEDIUM
CURRENT: SMALL
DISCHARGE POLARIZATION VOLTAGE (mV)
0
10
15
20
30
40
SOC (%)

FIG. 5

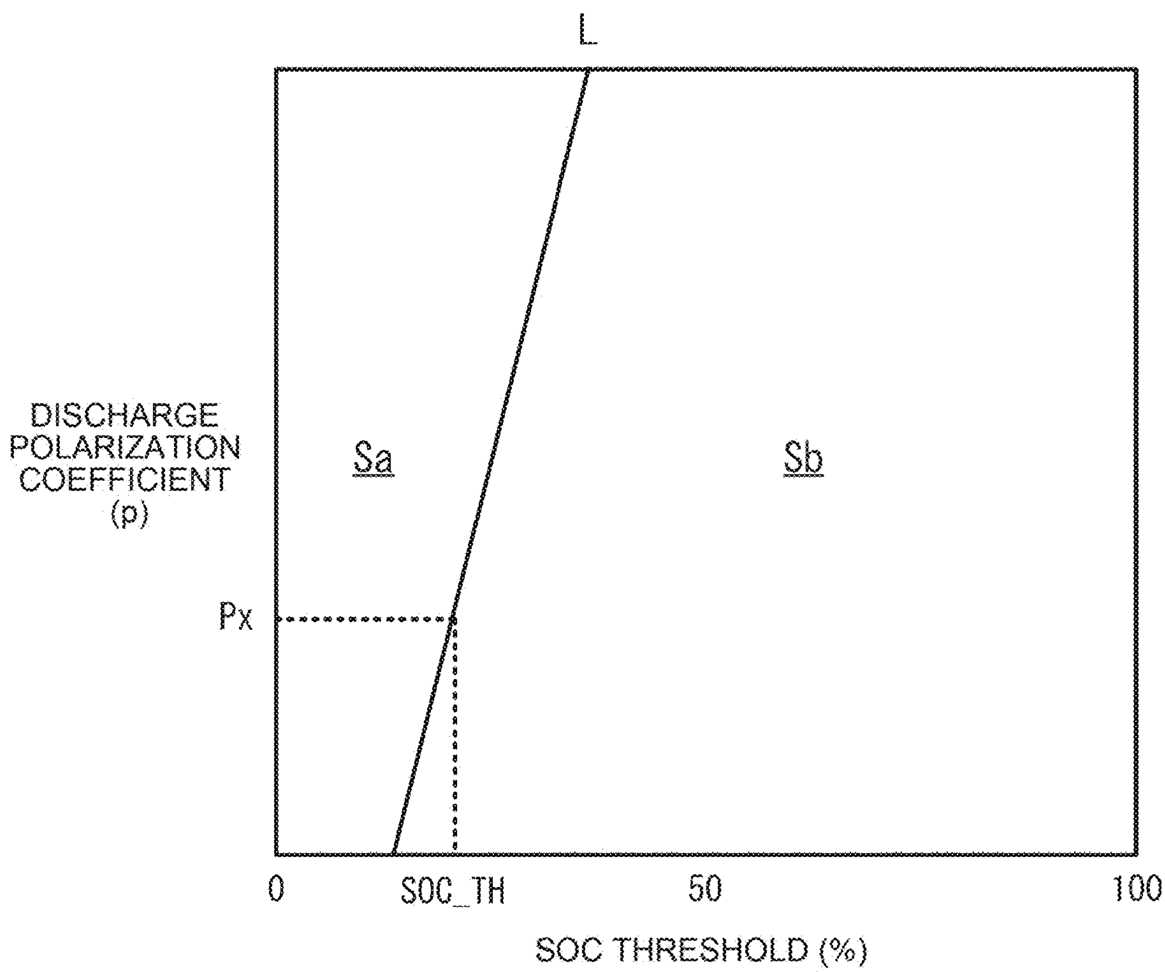
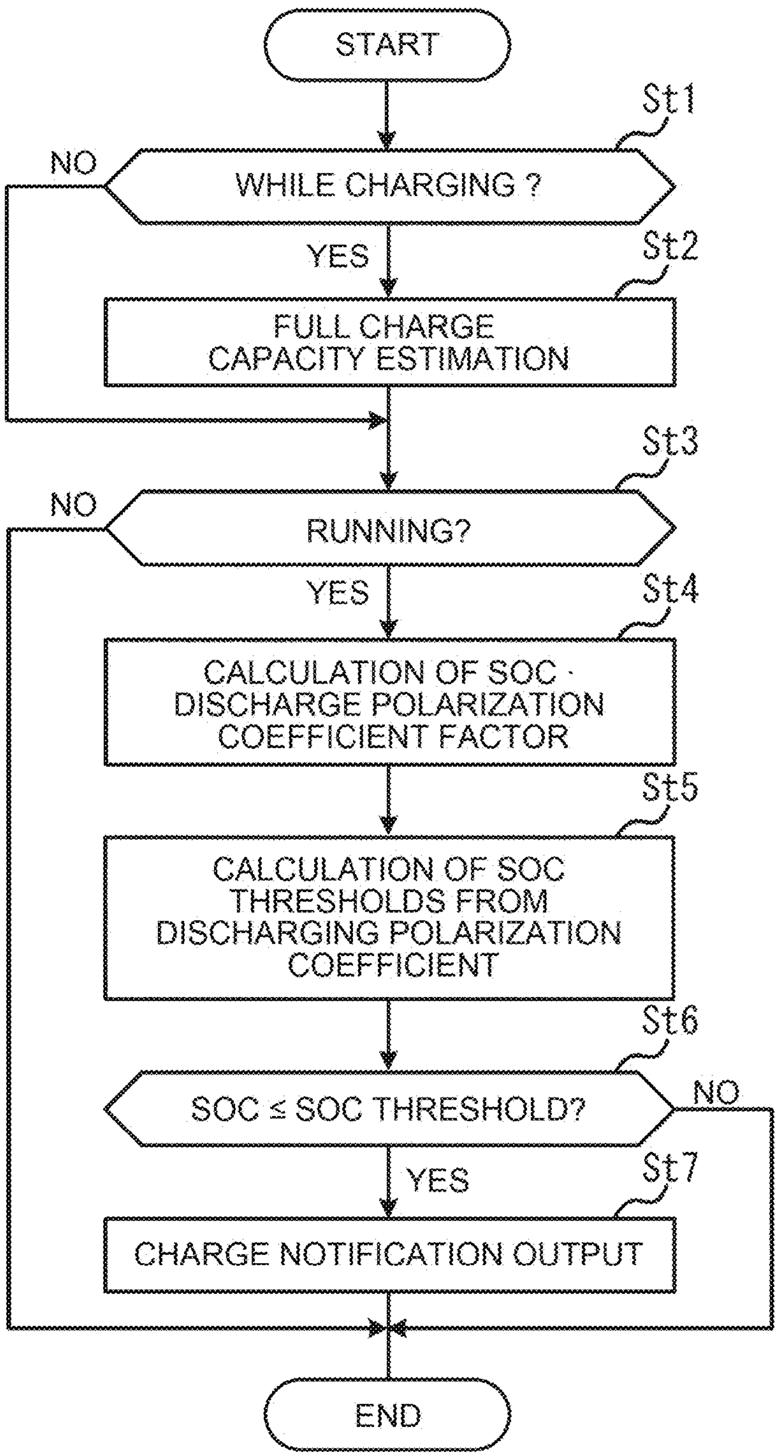

L
DISCHARGE POLARIZATION COEFFICIENT (p)
Sa
Sb
Px
0
SOC_TH
50
100
SOC THRESHOLD (%)

FIG. 6


START
St1
WHILE CHARGING ?
NO
YES
St2
FULL CHARGE CAPACITY ESTIMATION
St3
RUNNING?
NO
YES
St4
CALCULATION OF SOC · DISCHARGE POLARIZATION COEFFICIENT FACTOR
St5
CALCULATION OF SOC THRESHOLDS FROM DISCHARGING POLARIZATION COEFFICIENT
St6
SOC ≤ SOC THRESHOLD?
NO
YES
St7
CHARGE NOTIFICATION OUTPUT
END

BATTERY MANAGEMENT DEVICE

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to Japanese Patent Application No. 2024-023849 filed on Feb. 20, 2024, incorporated herein by reference in its entirety.

BACKGROUND

1. Technical Field

[0002] The disclosure relates to a battery management device.

2. Description of Related Art

[0003] Japanese Unexamined Patent Application Publication No. 2018-77199 (JP 2018-77199 A), for example, discloses technology for estimating a charge rate (State Of Charge (SOC)) of a battery using an equivalent-circuit model of a battery for a vehicle, and managing the battery. The SOC serves as an indication for prompting a user to charge the battery.

SUMMARY

[0004] For example, in a lithium-ion battery, diffusion resistance due to polarization increases in a region in which the SOC is low (e.g., 20% or lower) during discharging. When the diffusion resistance increases, available power of the battery is decreases, and accordingly, even when the user is prompted to charge the battery in accordance with a decrease in the SOC, there conceivably may be cases in which there actually is an excessive surplus in the power of the battery, or conversely, cases in which the power is excessively insufficient and operations of loads are adversely affected.

[0005] Accordingly, the disclosure provides a battery management device that can appropriately prompt a user to charge a battery.

[0006] A battery management device according to the disclosure includes a calculation unit that, based on an estimation model that estimates a polarization voltage in accordance with a state of charge (SOC) of a battery and a coefficient relating to increase in voltage corresponding to the SOC out of polarization voltage due to discharging of the battery, calculates the SOC and the coefficient from measured values of current and voltage of the battery, and

a notification unit that, when the SOC is no greater than a threshold value, gives a notification to prompt a user to charge the battery, in which

the smaller the coefficient is, the lower the notification unit sets the threshold value.

[0007] In the above battery management device, the notification unit may change the threshold value such that a linear relationship is established with the coefficient.

[0008] In the above battery management device, the calculation unit may periodically calculate the voltage of the battery using the estimation model, and calculate the SOC and the coefficient such that a difference between a calculated value of the voltage of the battery and the measured value of the voltage of the battery converges.

[0009] In the above battery management device, the battery may be a lithium-ion battery.

[0010] In the battery management device, the battery may supply electric power to an electric motor that drives a vehicle.

[0011] According to the disclosure, the user can be appropriately prompted to charge the battery.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] Features, advantages, and technical and industrial significance of exemplary embodiments of the disclosure will be described below with reference to the accompanying drawings, in which like signs denote like elements, and wherein:

[0013] FIG. **1** is a configuration diagram schematically illustrating an example of a battery system of a vehicle V;

[0014] FIG. **2** is a diagram illustrating an exemplary change in the diffusion-resistance of a lithium-ion battery during charging and discharging of SOC;

[0015] FIG. **3**A is a functional block diagram illustrating an example of a state calculation unit;

[0016] FIG. **3**B is a diagram illustrating an example of a temporal change in SOC during discharging of a battery cell;

[0017] FIG. **4** is a diagram illustrating an exemplary change in the discharge-polarization voltage with respect to SOC;

[0018] FIG. **5** is a diagram illustrating an exemplary threshold map; and

[0019] FIG. **6** is a flowchart illustrating an example of an operation of the control device.

DETAILED DESCRIPTION OF EMBODIMENTS

Battery System Configuration

[0020] FIG. **1** is a configuration diagram schematically illustrating an example of a battery system of a vehicle V. The vehicle V comprises a control device **1** comprising one or more ECU (Electronic Control Unit) and a battery pack **2**, which is a power supply. The vehicle V includes an in-vehicle display **3** that displays various types of information notified to the occupant (user), an inlet **6** for charging and discharging the battery pack **2**, an inverter **4** that converts a direct current into an alternating current, and an electric motor (MG) **5** that is a power source of the vehicle V.

[0021] The battery pack **2** includes a battery cell **20** that is an example of a battery, a current sensor **21** that detects a current flowing in the battery cell **20**, a voltage sensor **22** that detects a voltage of the battery cell **20**, and a temperature sensor **23** that detects a temperature T of the battery cell **20**. The detected values of the current sensor **21**, the voltage sensor **22**, and the temperature sensor **23** are output to the control device **1**. Examples of the battery cell **20** include, but are not limited to, a lithium ion battery.

[0022] The control device **1** is an example of a battery management device. The control device **1** is a computer including CPU (Central Processing Unit), ROM (Read Only Memory), and RAM (Random Access Memory). ECU **1** operates CPU according to the program stored in ROM.

[0023] The control device **1** controls the inverter **4**. The inverter **4** is connected between the battery pack **2** and the electric motor **5**. The inverter **4** converts a direct current into an alternating current by switching operation of a plurality of switching elements such as MOS-FET (Metal-Oxide-Semiconductor Field Effect Transistor). The control device

1 PWM (Pulse Width Modulation) the duty cycle according to the driving condition of the vehicle V to the inverter **4**.

[0024] Further, the control device **1** controls charging of the battery cell **20**. The battery cell **20** has, for example, a configuration in which a plurality of lithium ion batteries are connected in series. The battery cell **20** supplies DC power to the inverter **4**. Thus, the electric motor **5** is driven. The battery cell **20** is charged from an external charging station **9** via an inlet **6**. The control device **1** instructs, for example, a target value of a current output to the charging station **9** at the time of charging.

[0025] The control device **1** includes an operation control unit **10**, a capacity estimation unit **11**, a state calculation unit **12**, and a charge notification unit **13** as software functions formed by a program operation. Note that the operation control unit **10**, the capacity estimation unit **11**, the state calculation unit **12**, and the charge notification unit **13** may be implemented by hardware such as an integrated circuit.

[0026] In addition, the control device **1** includes a non-volatile memory **14** such as an EEPROM (Electrically Erasable Programmable ROM). The memory **14** holds OCV (Open Circuit Voltage) map data (OCV map) **140** and threshold map data (threshold map) **141**.

[0027] OCV map **140** and the threshold map **141** are generated based on experimental results and simulated results of the properties of the battery cells **20**, and are written in advance in the memory **14**. OCV map **140** shows correlations between OCV and SOC of the battery cells **20**. The threshold map **141** indicates correlations between the threshold value of SOC for promoting the charge of the battery cell **20** and the discharging polarization coefficient to be described later.

[0028] The operation control unit **10** instructs the capacity estimation unit **11**, the state calculation unit **12**, and the charge notification unit **13** to perform an operation in a predetermined sequence. Further, the operation control unit **10** performs control at the time of charging and discharging for the charging station **9** and the inverter **4**.

$$Cap = 100 \div (SOCe - SOCs) \times Is \tag{1}$$

[0029] The capacity estimation unit **11** estimates the full charge capacity Cap of the battery cell **20** when charging is performed by the charging station **9**, for example. For example, the capacity estimation unit **11** calculates the full charge capacity Cap according to Equation (1) above. In Equation (1), Is is an integrated value obtained by integrating the current value of the battery cell **20** for a predetermined period. In Equation (1), SOCs is SOC of the battery cell **20** when the integration of the current of the battery cell **20** is started, and SOCe is SOC of the battery cell **20** when the integration of the current is ended. For example, the capacity estimation unit **11** calculates the integrated value Is from the detected value of the current sensor, and acquires, from OCV map **140**, the detected value of the voltage sensor **22** at the time of charging, that is, SOCe and SOCs corresponding to OCV.

[0030] The state calculation unit **12** is an example of a calculation unit. The state calculation unit **12** calculates SOC and the discharge polarization coefficient from the measured values of the current and the voltage of the battery cell **20** based on the estimation model that estimates the discharge polarization voltage according to SOC of the battery cell **20** and the discharge polarization coefficient related to the increase in the voltage according to SOC among the polarization voltages (discharge polarization voltages) caused by the discharge of the battery cell **20**. The measured values of the current and the voltage are obtained as the detected values of the current sensor **21** and the voltage sensor **22**, for example. The estimation model is constructed, for example, on the basis of the closed-circuit-voltage (CCV: Closed Circuit Voltage) of the battery cell **20** as described below.

[0031] The charge notification unit **13** is an example of a notification unit. When SOC of the battery cell **20** is equal to or less than the threshold value, the charge notification unit **13** notifies the user of the vehicle V that the battery cell **20** is to be charged. The charge notification unit **13** acquires SOC and the discharge polarization coefficient calculated by the state calculation unit **12** through the operation control unit **10**, and acquires the thresholds corresponding to the discharge polarization coefficients from the threshold map **141**. Since the charge notification unit **13** determines whether charging is necessary using a threshold value corresponding to the discharge polarization coefficient, it is possible to appropriately prompt the user to charge the battery cell **20** according to the use state, as will be described later.

[0032] When SOC is less than or equal to the threshold, the charge notification unit **13** causes the in-vehicle display **3** to display a charge notification using, for example, a character or a symbol. Accordingly, the user recognizes that the battery cell **20** needs to be charged at an appropriate timing, and can perform charging at an appropriate timing before the power of the battery cell **20** is not in an excessive state and the power is insufficient. Note that, although the in-vehicle display **3** is described as a means for notifying the user of the charge in the present embodiment, the present disclosure is not limited to this, and other means such as sound notification by a speaker or light emission by LED (Light Emitting Diode) may be used.

Processing of State Calculation Unit

$$CCV = OCV - IR - V_C - p \cdot a \left\{ \frac{\left(SOC - \frac{I \cdot \Delta t \cdot 100}{3600 \cdot Cap} \right) \cdot b - c}{d} \right\} \tag{2}$$

[0033] The state calculation unit **12** uses, for example, the above Equation (2) as an estimation model. In Equation (2), OCV is the open-circuit voltage of the battery cell **20**, and SOC is the charge rate of the battery cell **20**. I is a detection value of the current sensor **21**, and R is an internal resistance value of the battery cell **20**. Cap is the full charge capacity of the battery cell **20** (see Equation (1) above). At is an execution cycle of the calculation according to Equation (2).

[0034] Vc is a voltage (charge/discharge polarization voltage) that does not depend on SOC among the polarization voltages (charge polarization voltage and discharge polarization voltage) generated by the charge/discharge of the battery cell **20**, and p is a discharge polarization coefficient. The values a to d are constants that are set in advance based on pre-experimental results or simulations.

[0035] In Equation (2), the term including the discharge polarization coefficient p, the constants a to d, the detected value I, the full charge capacity Cap, and the execution period Δt (discharge polarization estimation term) is a voltage that depends on the variation of SOC in the execution period Δt among the discharge polarization voltages of the battery cells **20**. The discharge polarization estimation term estimates an increase in the discharge polarization voltage associated with an increase in the diffusion resistance in the low SOC range from a value obtained by multiplying the change amount of SOC in the execution period Δt by the discharge polarization coefficient p, which is a weighting coefficient, calculated from the ratio of the integrated value of the detected value I of the current to the full charge capacity Cap. The constants a to d are determined, for example, from the characteristics of the diffusion resistance at the time of discharge of the battery cell **20** described below.

[0036] FIG. **2** is a diagram illustrating an exemplary change in diffusion resistance (mΩ) of a lithium-ion battery during charge (see "Δ") and discharge (see "•") with respect to SOC (%); The diffusivity during charge is substantially constant regardless of SOC. On the other hand, when SOC is 20 to 100%, the diffusivity is substantially constant, but when SOC is 0 to 20%, the diffusivity is increased as SOC is decreased.

[0037] As the diffusion resistance increases, the polarization voltage of the battery cell **20** increases. The discharge polarization coefficient p is a parameter indicating the degree (weight) of the increase in the discharge polarization voltage depending on SOC, and indicates a value larger than the other range in a range in which SOC is lower (0% to 20% in the above-described example). The state calculation unit **12** can calculate the state-of-charge with high accuracy by using the estimation model including the discharge polarization coefficient p, taking into account an increase in the discharge polarization voltage in a range where SOC is low. Note that the discharge polarization coefficient p is an example of a coefficient.

[0038] The state calculation unit **12** acquires the detected values I, V from the current sensor **21** and the voltage sensor **22** for each run cycle Δt, and calculates CCV by Equation (2). At this time, the state calculation unit **12** acquires the latest full charge capacity Cap from the capacity estimation unit **11**. The state calculation unit **12** updates the internal resistance value R, the charge/discharge polarization voltage Vc, and the discharge polarization coefficient p for each of the execution cycles Δt in accordance with the difference between the detected value V and CCV of the voltage sensor **22**. The state calculation unit **12** calculates SOC and the discharging polarization coefficient p so that the difference between CCV and the detected value V of the voltage sensor is minimized, for example, in accordance with the predictive error method.

[0039] FIG. 3A is a functional block diagram illustrating an example of the state calculation unit **12**. The state calculation unit **12** includes an estimation model **120** represented by Equation (2), a parameter updating unit **121**, and an adder **122**. The estimation model **120** calculates a CCV from Equation (2) in accordance with the detected value I of the current sensor **21** for each run cycle Δt, and outputs the calculated CCV to the adder **122**.

[0040] The adder **122** receives the detected value V of the voltage sensor **22** and CCV calculated by the estimation model **120**. The detected value V of the voltage sensor **22** is a closed circuit voltage corresponding to a current value flowing through the battery cell **20** (the detection value I of the current sensor **21**). The adder **122** outputs the difference ΔV (=V−CCV) between the detected value V and CCV to the parameter updating unit **121**.

$$SOC[t+\Delta t] = SOC[t] - I\times\Delta t/3600/Cap\times 100 + Ga\times\Delta V \tag{3}$$

$$R[t+\Delta t] = R[t]Gb\times\Delta V \tag{4}$$

$$Vc[t+\Delta t] = Vc[t] + Gc\times\Delta V \tag{5}$$

$$p[t+\Delta t] = p[t] + Gd\times\Delta V \tag{6}$$

[0041] The parameter updating unit **121** updates SOC, the internal resistance value R, the charge/discharge polarization voltage Vc, and the discharge polarization coefficient p of the battery cell **20** according to the above Equations (3) to (6) in accordance with the difference ΔV between the detected value V and CCV. SOC, the internal resistance value R, the charge/discharge polarization voltage Vc, and the discharge polarization coefficient p are held in the memory **14** each time the calculation is performed.

[0042] In Equations (3) to (6), Ga, Gb, Gc, and Gd are the gains of the difference ΔV with respect to SOC, the internal resistance value R, the charge/discharge polarization voltage Vc, and the discharge polarization coefficient p, respectively. The gains Ga to Gd are set so that the difference ΔV converges on the basis of a previous experimental result, a simulated result, or the like. The internal resistance value R may be calculated by referring to the map data from the detected value and SOC of the temperature sensor **23** instead of Equation (4). At the beginning of the calculation, the parameter updating unit **121** calculates SOC [t+Δt] from the last held SOC [t] by using Equation (3) as the difference ΔV=0. The most recent values of SOC, the internal resistance value R, the charge/discharge polarization voltage Vc, and the discharge polarization coefficient p are stored in the memory **14** at any time, and the respective initial values are set based on the measured values of the battery cells **20**.

[0043] The parameter updating unit **121** adds the product of the difference ΔV and each of the gains Ga to Gd to each of the values (see [t]) of SOC, the internal resistance value R, the charge/discharge polarization voltage Vc, and the discharge polarization coefficient p at the time t. Thus, the parameter updating unit **121** calculates each value ([t+Δt]) at the time (t+Δt). The parameter updating unit **121** outputs SOC of the time (t+Δt), the internal resistance value R, the charge/discharge polarization voltage Vc, and the discharge polarization coefficient p to the estimation model **120**.

[0044] The estimation model **120** calculates a CCV from the internal resistance value R, the charge/discharge polarization voltage Vc, the discharge polarization coefficient p, and the detected value I of the current sensor **21**, which are inputted from the parameter updating unit **121**. At this time, the state calculation unit **12** calculates an OCV corresponding to SOC based on OCV map **140**. The estimation model **120** outputs the discharging polarization coefficient p and SOC to the charge notification unit **13** via the operation control unit **10**.

[0045] As described above, the state calculation unit **12** periodically calculates CCV of the battery cell **20** using the estimation model **120**, and calculates SOC and the discharging polarization coefficient p in accordance with the prediction error method so that the difference ΔV between the calculated value of CCV and the detected value V of the voltage sensor **22** converges. Therefore, the state calculation unit **12** can calculate SOC and the discharge polarization coefficient p with high accuracy. Note that the state calculation unit **12** may calculate SOC and the discharging polarization coefficient p according to a method other than the predictive error method.

[0046] FIG. **3**B is a diagram illustrating an exemplary temporal change in SOC (%) of the battery cell **20** during discharging. The solid line represents SOC calculated by the estimation model **120** using the above Equation (2) (Example), the dashed-dotted line represents SOC calculated by the estimation model **120** using the equation excluding the discharge-polarization estimation term from Equation (2) (Comparative Example), and the dotted line represents the actual measurement of SOC.

[0047] In the comparative example, since the increase in the discharge polarization voltage due to the increase in the diffusion resistance in the low SOC area as shown in FIG. **2** is not calculated, the error from the measured value is increased at a time when SOC is about 15% or less. On the other hand, in the embodiment, since the increment of the discharge polarization voltage is calculated by the discharge polarization estimation term, the error from the measured value is smaller than that in the comparative example even when SOC is about 15% or less.

[0048] As described above, the state calculation unit **12** can calculate SOC with high accuracy by reflecting the increase in the diffusion resistance at the time of discharge by the discharge polarization estimation term including the discharge polarization coefficient p.

Processing of Charge Notification Unit

$$OCV - CCV - IR = V_C + p \cdot a \left\{ \frac{\left(SOC - \frac{I \cdot \Delta t \cdot 100}{3600 \cdot Cap} \right) \cdot b - c}{d} \right\} \tag{7}$$

[0049] FIG. **4** is a diagram illustrating an exemplary change in discharge-polarization voltage (mV) with respect to SOC (%); This example shows a simulated result obtained by calculating the discharge polarization voltage when the battery cell **20** having a SOC of 30% is discharged while the current is maintained constant, using the left side of the above-described Equation (7) obtained from the Equation (2). Here, the magnitude of the current (I in Equation (7)) is three of "large", "medium", and "small".

[0050] The discharge polarization voltage increases as the current of the battery cell **20** increases. In the regions where SOC is less than about 15%, the discharge-polarization voltage increases with decreasing SOC due to the increase in the diffusion-resistance. At this time, the degree of increase in the discharge polarization voltage is larger as the current of the battery cell **20** is larger. For this reason, in an area where SOC is about 15% or less, the electric power of the battery cell **20** is consumed in accordance with an increase in the voltage corresponding to SOC.

[0051] Therefore, when SOC is low, there is a variation in the effect of the discharging polarization depending on the use condition of the battery cell **20**. If the charge notification unit **13** prompts the user to charge the battery cell **20** when SOC is 15% or less at all times regardless of the magnitude of the current, and if the current is "small", it is considered that there is an excessive margin in the power of the battery cell **20**. For example, when the vehicle V is traveling on a general road, since the current of the battery cell **20** is small (current "small"), the notification of charging is fast, and it is difficult to consume electric power without waste.

[0052] On the other hand, when the current is "large" or "medium", it is considered that the power of the battery cell **20** is excessively insufficient. For example, when the vehicle V is traveling on the expressway, the current of the battery cell **20** is large (current "large"), so that the notification of charging is slow, and there is a possibility that the vehicle V may be hindered from traveling due to insufficient power.

[0053] Therefore, the charge notification unit **13** decreases the threshold value (SOC threshold value) of SOC used for notification of charge as the discharge polarization coefficient p decreases. For example, the charge notification unit **13** acquires a threshold value corresponding to the discharge polarization coefficient p from the threshold map **141**.

[0054] FIG. **5** is a diagram illustrating an example of the threshold map **141**. In FIG. **5**, the horizontal axis represents SOC threshold (%), and the vertical axis represents discharging polarization coefficient p. Line L shows the relation between the discharge-polarization coefficient p and SOC thresholds. In the present embodiment, the discharge-polarization coefficient p and SOC thresholds have a linear relation. The charge notification unit **13** acquires SOC thresholds corresponding to the discharging polarization coefficient p based on the line segment L. For example, when the discharging polarization coefficient p is Px, the SOC_TH is SOC threshold based on the line segment L.

[0055] Charge notification unit **13**, if SOC is equal to or less than SOC threshold value, and displays a notification prompting the charging of the battery cell **20** to the user on the in-vehicle display **3**, if SOC is greater than SOC threshold value, the notification is not displayed on the vehicle-mounted display **3**. That is, the charge notification unit **13** does not perform notification when SOC and the discharge polarization coefficient p calculated by the state calculation unit **12** are located on the side where the region Sb (larger SOC threshold) among the two areas Sa, Sb separated by the line segment L. On the other hand, the charge notification unit **13** executes the notification when SOC and the discharge polarizing coefficient p are located at the area Sa (smaller SOC threshold) among the two areas Sa, Sb separated by the line segment L.

[0056] As described above, the charge notification unit **13** determines whether the charge notification is possible by using the larger SOC thresholds as the discharging polarization coefficient p is larger. Therefore, in the case of the example of FIG. **4**, when the current is "large" or "medium", the possibility of the charge notification is determined based on SOC thresholds larger than the case where the current is "small". Therefore, the control device **1** can prompt the user to charge the battery cell **20** at an appropriate timing according to the use state of the battery cell.

[0057] In addition, the charge notification unit **13** changes SOC thresholds so that a linear relation is established with the discharging polarization coefficient p. Therefore, when the diffusivity of the battery cell **20** during discharging increases linearly with the decrease in SOC, SOC thresholds can be set with high accuracy. The maximal value and the minimal value of SOC thresholds are appropriately set in accordance with the usage conditions of the battery cells **20**.

Operation of Control Device

[0058] FIG. **6** is a flowchart illustrating an example of the operation of the control device **1**. This operation is executed, for example, at regular time intervals.

[0059] First, the operation control unit **10** determines whether the battery cell **20** is being charged (St**1**). When the battery cell **20** is being charged (Yes of St**1**), the capacity estimation unit **11** estimates the full charge capacity Cap of the battery cell **20** (St**2**). When the battery cell **20** is not being charged (No of St**1**), St**2** operation is not performed.

[0060] Next, the operation control unit **10** determines whether the vehicle V is traveling (St**3**). When the vehicle V is not traveling (No of St**3**), the operation ends. When the vehicle V is traveling (Yes of St**3**), the state calculation unit **12** calculates SOC and the discharge polarization coefficient p of the battery cell **20** during discharging by the above-described method (St**4**). During traveling of the vehicle V, electric power is supplied from the battery cell **20** to the electric motor **5**.

[0061] Next, the charge notification unit **13** calculates SOC threshold based on the threshold map **141** from the discharged polarization coefficient p (St**5**). Next, the charge notification unit **13** compares SOC with SOC thresholds (St**6**). When SOC≤SOC threshold is satisfied (Yes of St**6**), the charge notification unit **13** outputs a charge notification to the in-vehicle display **3** (St**7**). When SOC>SOC threshold is satisfied (No of St**6**), the charge notification unit **13** ends the operation without outputting the charge notification. In this way, the control device **1** operates.

[0062] As described above, the state calculation unit **12** calculates SOC and the discharge polarization coefficient p from the detected values I, V of the current and the voltage of the battery cell **20** based on the estimation model **120** that estimates the discharge polarization voltage according to SOC of the battery cell **20** and the discharge polarization coefficient p relating to the increase in the voltage according to SOC among the discharge polarization voltages of the battery cell **20**. When SOC is equal to or less than SOC threshold, the charge notification unit **13** notifies the user of charge of the battery cell **20**, and decreases SOC threshold as the discharge polarization coefficient p decreases.

[0063] Therefore, the state calculation unit **12** can calculate SOC and the discharge polarization coefficient p with high accuracy by reflecting the increase in the discharge polarization voltage accompanying the increase in the diffusion resistance in the low SOC area during the discharge of the battery cell **20**. In addition, the charge notification unit **13** reduces SOC thresholds as the discharge polarization coefficient p decreases, so that the user can appropriately prompt the user to charge the battery in accordance with the increase in the discharge polarization voltage.

[0064] In addition, when a lithium-ion battery is used as the battery cell **20**, it is preferable because it has high versatility. In addition, since the battery cell **20** supplies electric power to the electric motor **5** that drives the vehicle V, it is possible to appropriately urge the user to charge the battery by the operation of the control device **1** described above while the vehicle V is traveling. Note that the control device **1** is not limited to the vehicle V, and may be used, for example, to notify charging of a battery cell of an electronic device such as a smartphone.

[0065] The embodiments described above are examples of preferred embodiments of the present disclosure. However, the present disclosure is not limited to this, and various modifications can be made without departing from the gist of the present disclosure.

What is claimed is:

1. A battery management device, comprising:

a calculation unit that, based on an estimation model that estimates a polarization voltage in accordance with a State Of Charge (SOC) of a battery and a coefficient relating to increase in voltage corresponding to the SOC out of polarization voltage due to discharging of the battery, calculates the SOC and the coefficient from measured values of current and voltage of the battery; and

a notification unit that, when the SOC is no greater than a threshold value, gives a notification to prompt a user to charge the battery, wherein

the smaller the coefficient is, the lower the notification unit sets the threshold value.

2. The battery management device according to claim **1**, wherein the notification unit changes the threshold value such that a linear relationship is established with the coefficient.

3. The battery management device according to claim **1**, wherein the calculation unit periodically calculates the voltage of the battery using the estimation model, and calculates the SOC and the coefficient such that a difference between a calculated value of the voltage of the battery and the measured value of the voltage of the battery converges.

4. The battery management device according to claim **1**, wherein the battery is a lithium-ion battery.

5. The battery management device according to claim **1**, wherein the battery supplies electric power to an electric motor that drives a vehicle.

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