US 20220003822A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2022/0003822 A1**

NAITO et al. (43) **Pub. Date: Jan. 6, 2022**

(54) **BATTERY CONTROL DEVICE**

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(73) Assignee: **Vehicle Energy Japan Inc.**, Hitachinaka-shi, Ibaraki (JP)

(21) Appl. No.: **17/288,800**

(22) PCT Filed: **Oct. 1, 2019**

(86) PCT No.: **PCT/JP2019/038752**

§ 371 (c)(1),
(2) Date: **Apr. 26, 2021**

(30) **Foreign Application Priority Data**

Oct. 26, 2018 (JP) 2018-201527

Publication Classification

(51) **Int. Cl.**

G01R 31/3842	(2006.01)
G01R 31/374	(2006.01)
H01M 10/48	(2006.01)
G01R 31/392	(2006.01)
H02J 7/00	(2006.01)
H01M 10/42	(2006.01)

(52) **U.S. Cl.**

CPC ***G01R 31/3842*** (2019.01); ***G01R 31/374*** (2019.01); ***H01M 10/486*** (2013.01); *H01M 2010/4278* (2013.01); ***H02J 7/0048*** (2020.01); ***H02J 7/005*** (2020.01); ***H01M 10/425*** (2013.01); ***G01R 31/392*** (2019.01)

(57) **ABSTRACT**

A battery control device which obtains a state of charge of a secondary battery from characteristics representing a relationship of a state of charge and a voltage of the secondary battery comprises a calling unit which calls a first characteristic among a plurality of the characteristics stored in advance based on use history information of the secondary battery, a correction limit width designation unit which designates a correction limit width for prescribing a tolerance level of correcting the first characteristic, and a direct detection correction unit which creates a second characteristic in which the first characteristic has been corrected according to the correction limit width based on a current value and a voltage value of the secondary battery, wherein the state of charge of the secondary battery is obtained using the second characteristic.

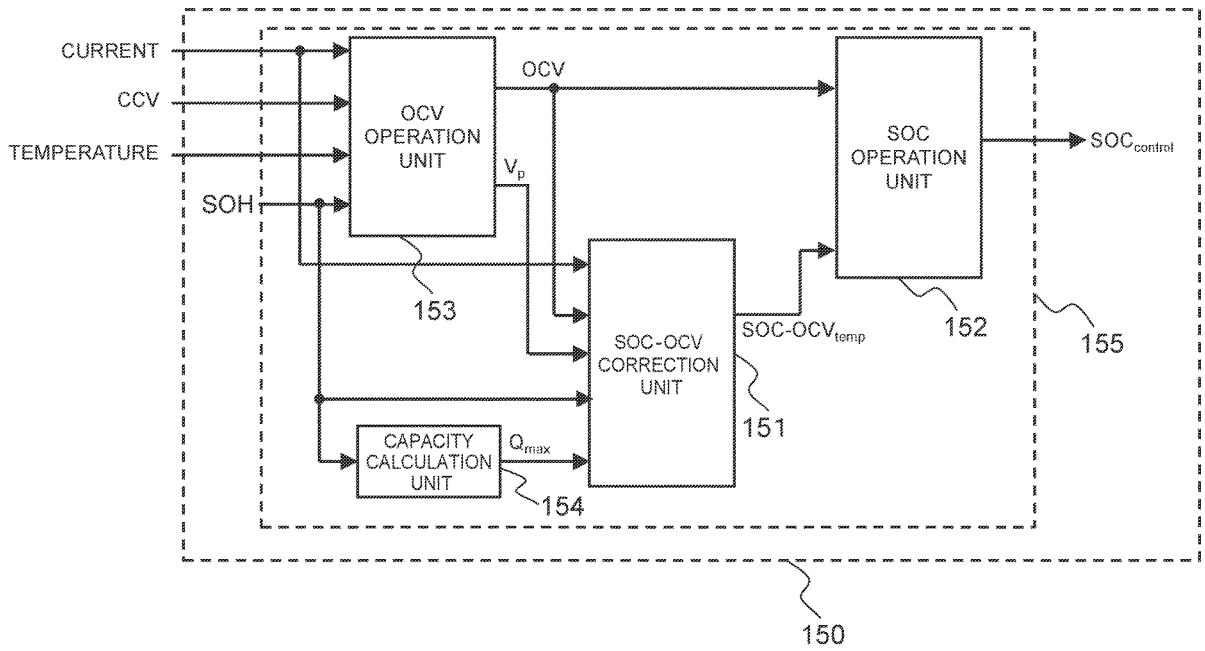


FIG. 1

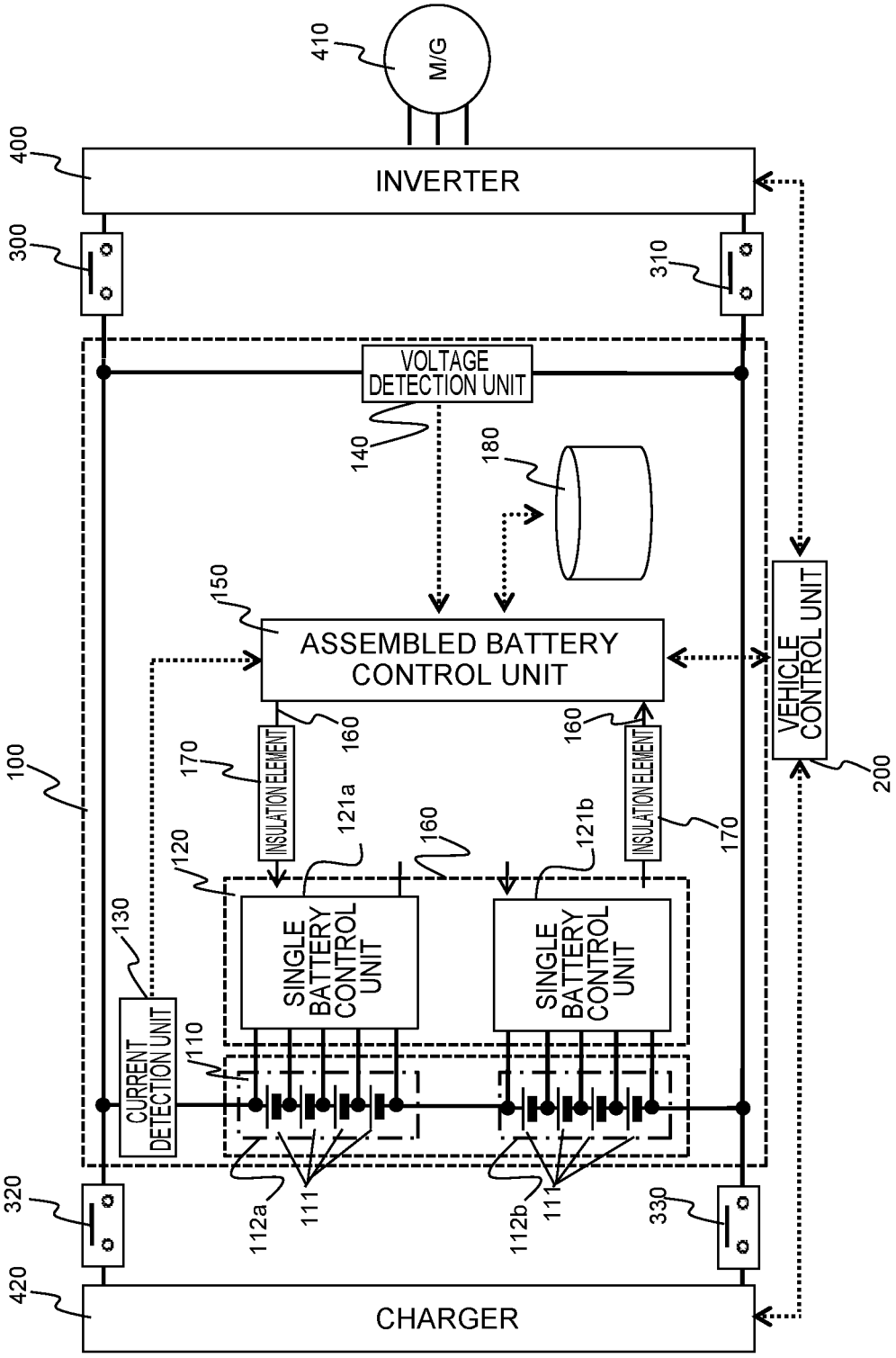

M/G
410
INVERTER
400
300
310
VOLTAGE DETECTION UNIT
140
180
150
ASSEMBLED BATTERY CONTROL UNIT
160
160
VEHICLE CONTROL UNIT
200
100
170
INSULATION ELEMENT
121a
160
121b
INSULATION ELEMENT
170
120
130
SINGLE BATTERY CONTROL UNIT
SINGLE BATTERY CONTROL UNIT
CURRENT DETECTION UNIT
110
320
112a
111
112b
111
330
420
CHARGER

FIG. 2

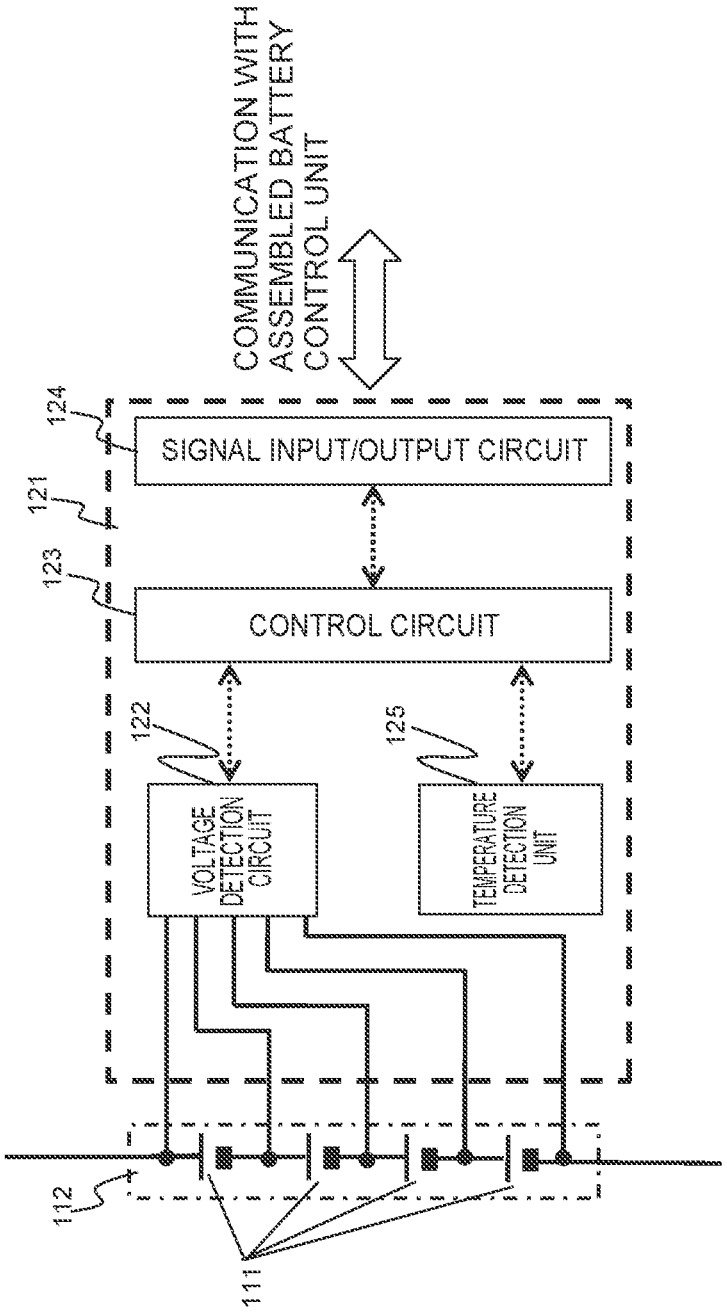

COMMUNICATION WITH ASSEMBLED BATTERY CONTROL UNIT
124
SIGNAL INPUT/OUTPUT CIRCUIT
121
123
CONTROL CIRCUIT
122
125
VOLTAGE DETECTION CIRCUIT
TEMPERATURE DETECTION UNIT
112
111

FIG. 3

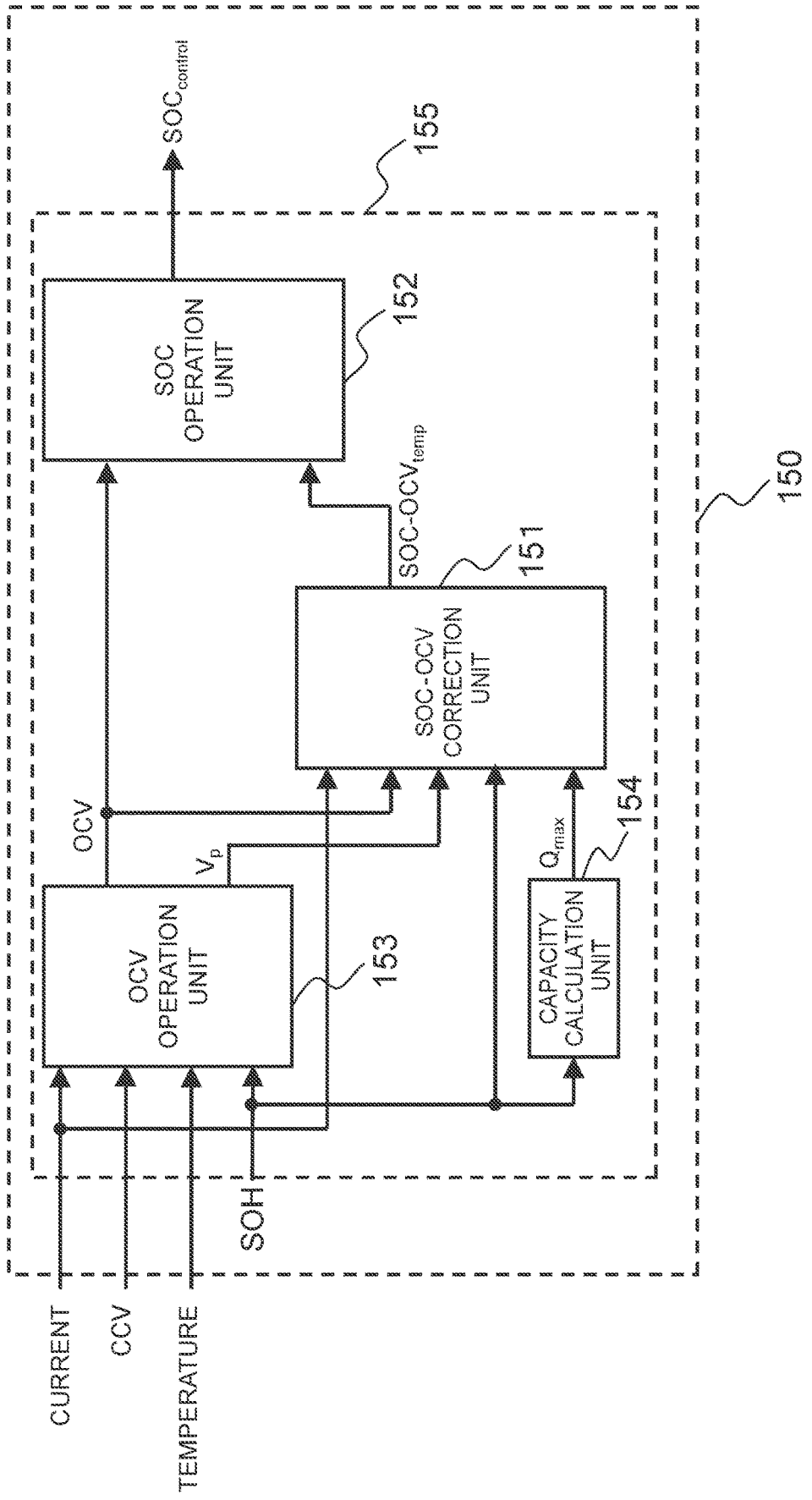

CURRENT
CCV
TEMPERATURE
SOH
OCV
V_p
OCV OPERATION UNIT
153
SOC OPERATION UNIT
152
SOC-OCV CORRECTION UNIT
151
SOC-OCV_{temp}
CAPACITY CALCULATION UNIT
154
Q_{max}
$SOC_{control}$
155
150

FIG. 4

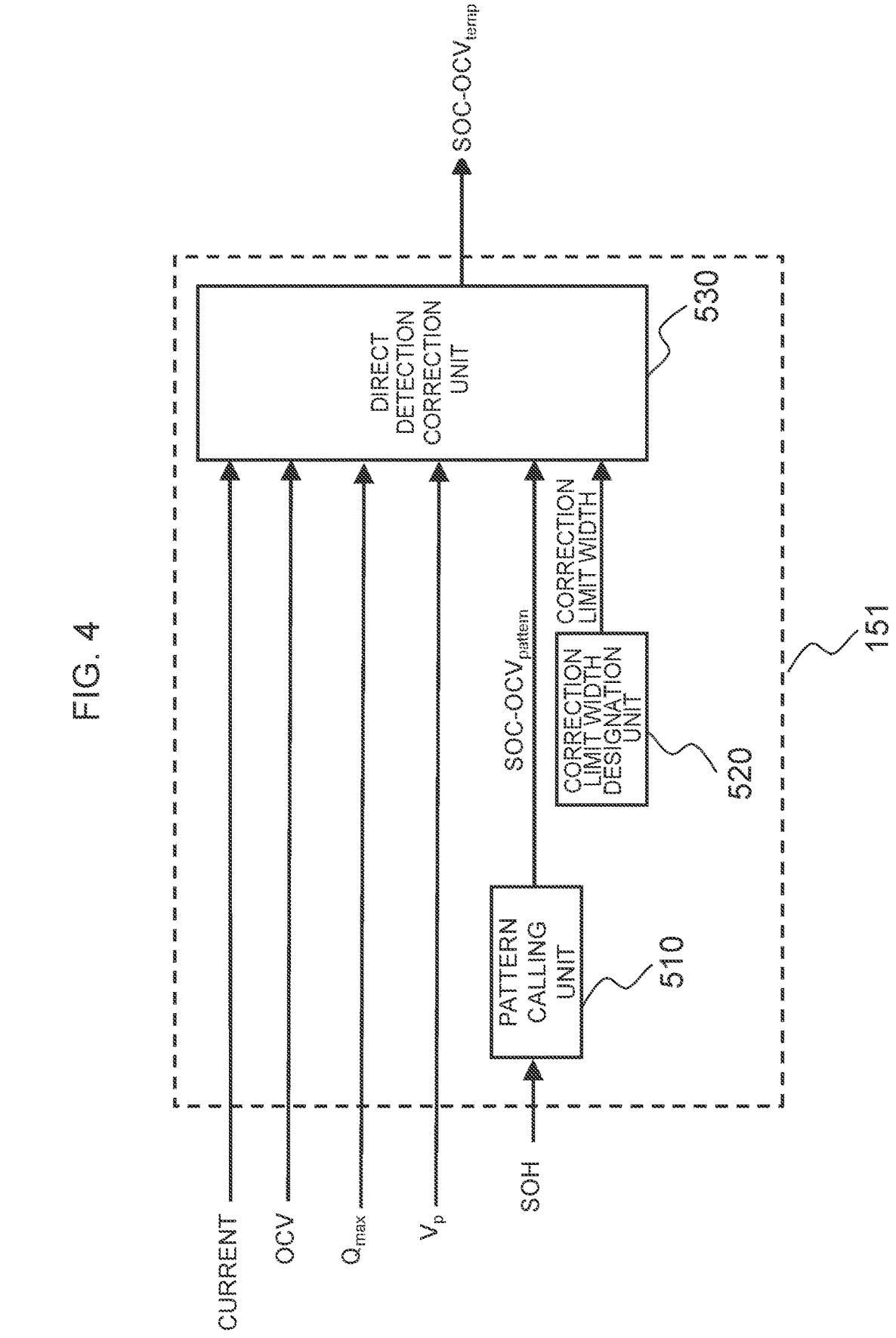

SOC-OCV$_{temp}$
DIRECT DETECTION CORRECTION UNIT
530
CURRENT
OCV
Q_{max}
V_p
SOH
SOC-OCV$_{pattern}$
CORRECTION LIMIT WIDTH
CORRECTION LIMIT WIDTH DESIGNATION UNIT
520
PATTERN CALLING UNIT
510
151

FIG. 5

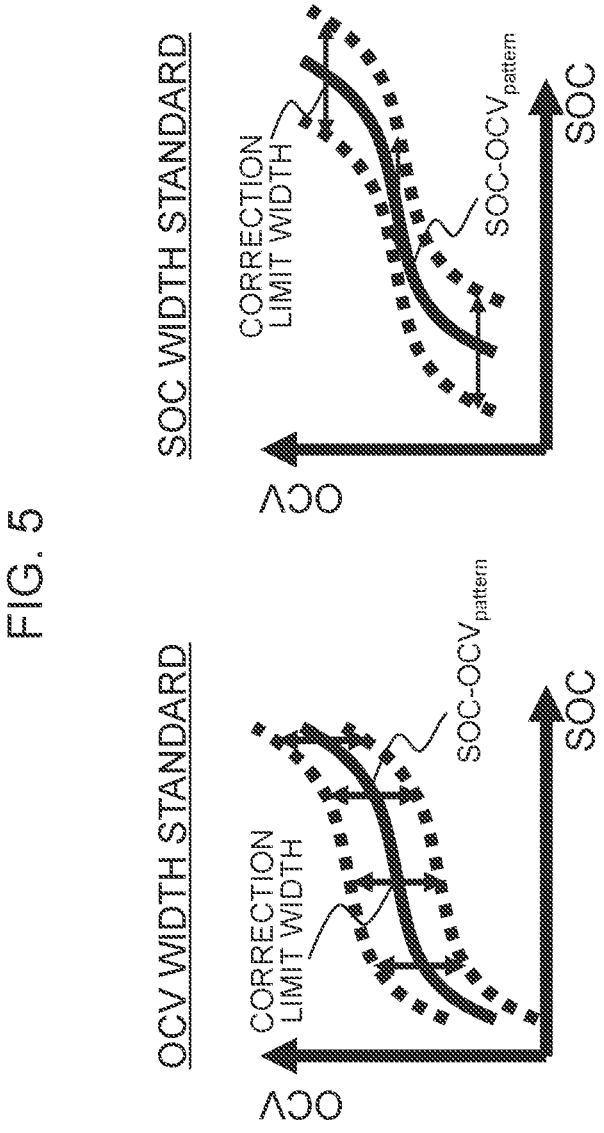
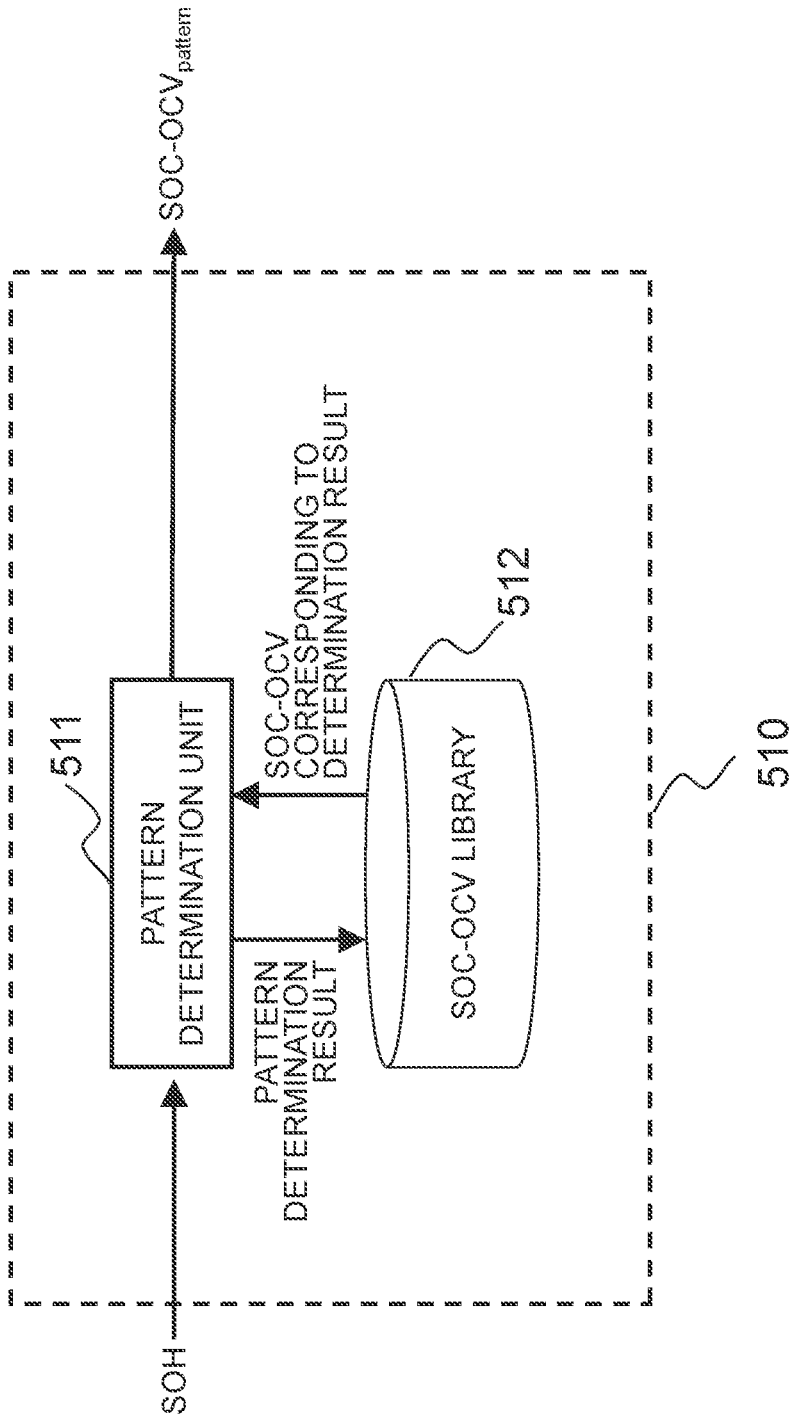

SOC WIDTH STANDARD
CORRECTION LIMIT WIDTH
SOC-OCV pattern
SOC
OCV
OCV WIDTH STANDARD
CORRECTION LIMIT WIDTH
SOC-OCV pattern
SOC
OCV

FIG. 6


SOC-OCV$_{pattern}$
511
PATTERN DETERMINATION UNIT
SOC-OCV CORRESPONDING TO DETERMINATION RESULT
PATTERN DETERMINATION RESULT
512
SOC-OCV LIBRARY
510
SOH

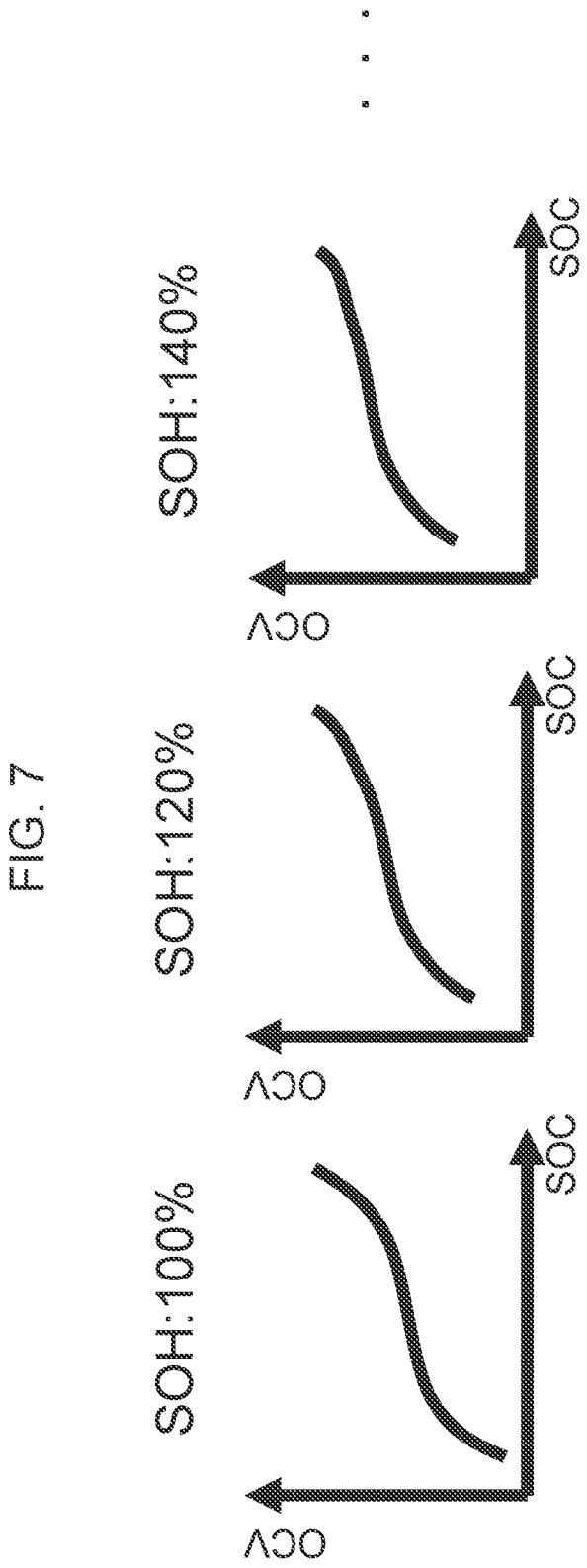


FIG. 7

FIG. 8

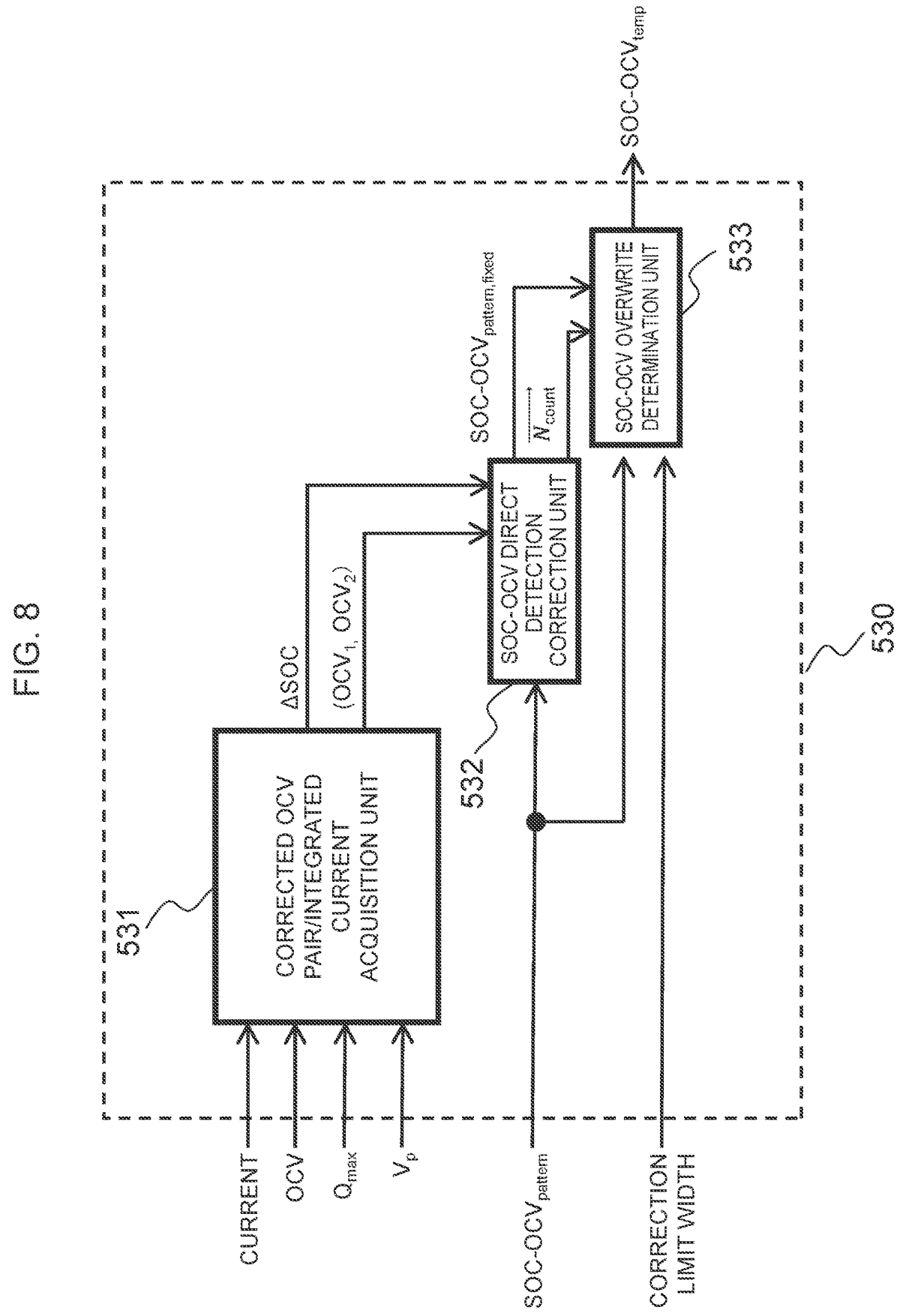

CURRENT
OCV
Q_{max}
V_p
CORRECTED OCV PAIR/INTEGRATED CURRENT ACQUISITION UNIT
531
ΔSOC
(OCV_1, OCV_2)
SOC-OCV DIRECT DETECTION CORRECTION UNIT
532
$SOC\text{-}OCV_{pattern,fixed}$
$\overrightarrow{N_{count}}$
SOC-OCV OVERWRITE DETERMINATION UNIT
533
$SOC\text{-}OCV_{temp}$
530
$SOC\text{-}OCV_{pattern}$
CORRECTION LIMIT WIDTH

FIG. 9

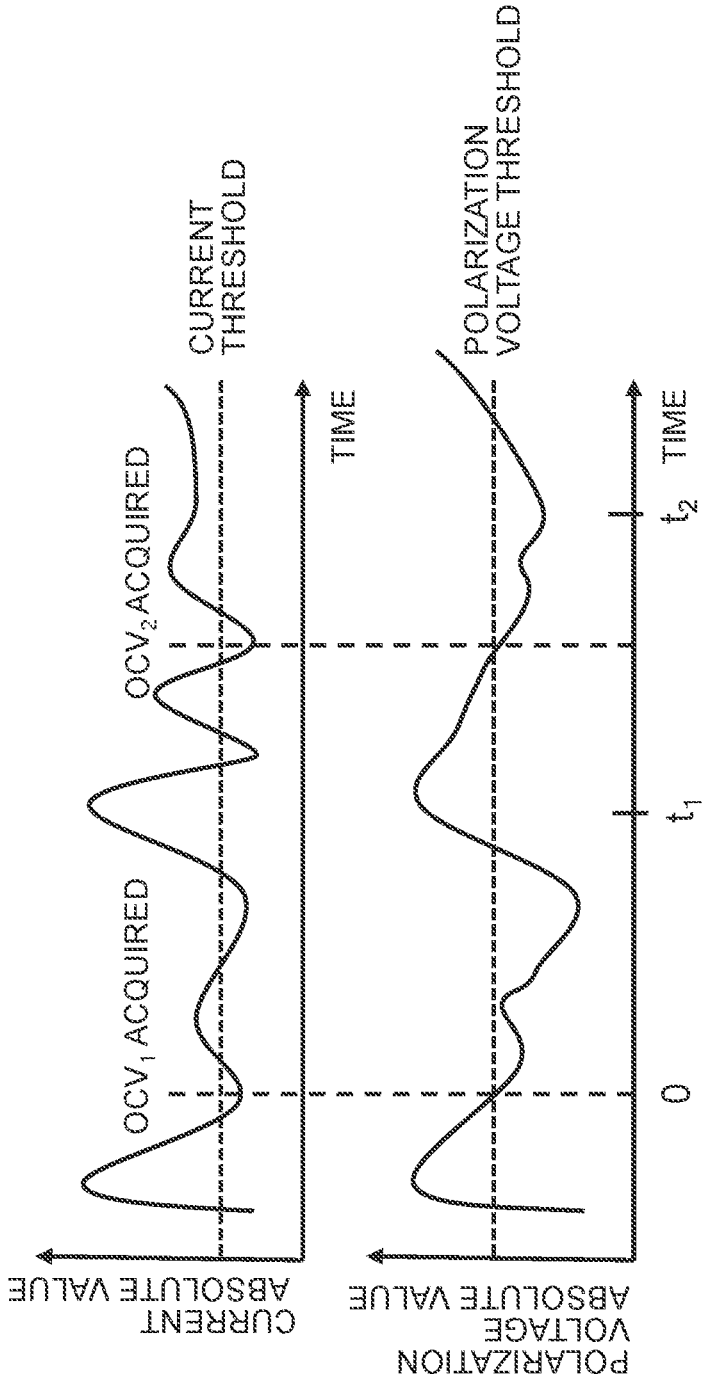

CURRENT ABSOLUTE VALUE
POLARIZATION VOLTAGE ABSOLUTE VALUE
OCV1 ACQUIRED
OCV2 ACQUIRED
CURRENT THRESHOLD
POLARIZATION VOLTAGE THRESHOLD
TIME
TIME
0
t1
t2

FIG. 10

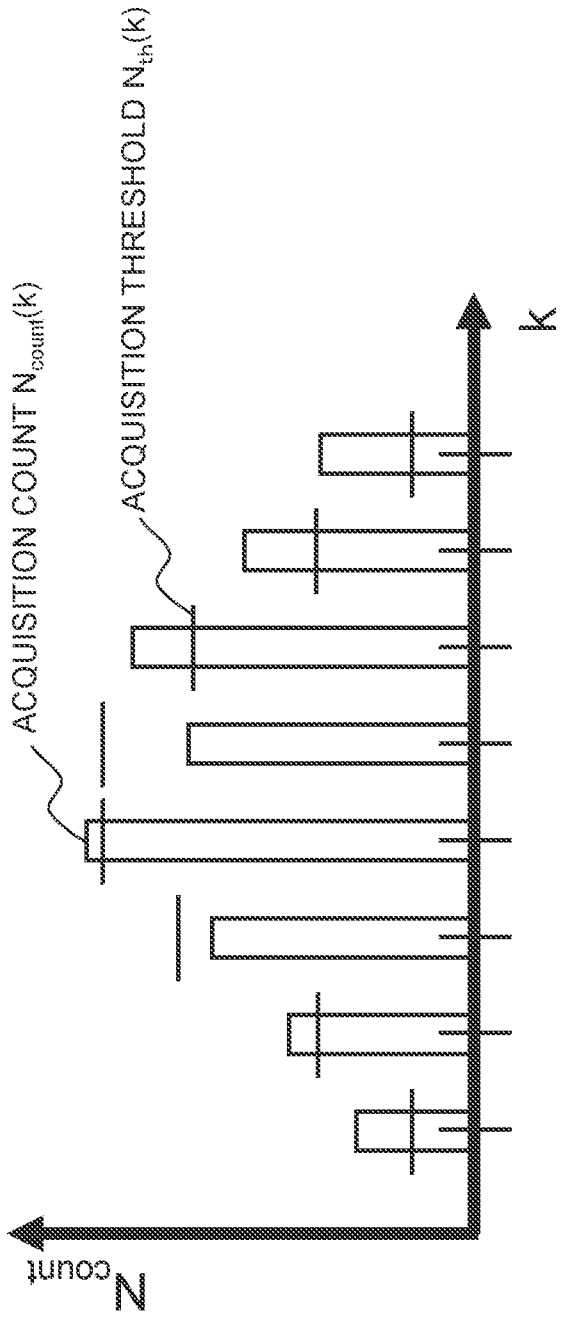

ACQUISITION COUNT $N_{count}(k)$
ACQUISITION THRESHOLD $N_{th}(k)$
K
N_{count}

FIG. 11

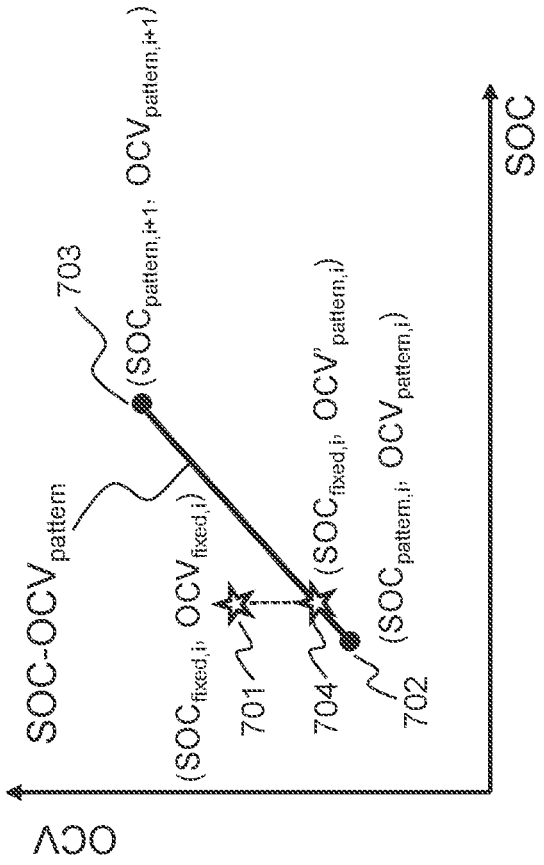

OCV
SOC
SOC-OCV pattern
703
(SOC pattern,i+1, OCV pattern,i+1)
(SOC fixed,i, OCV fixed,i)
701
704
(SOC fixed,i, OCV' pattern,i)
(SOC pattern,i, OCV pattern,i)
702

FIG. 12

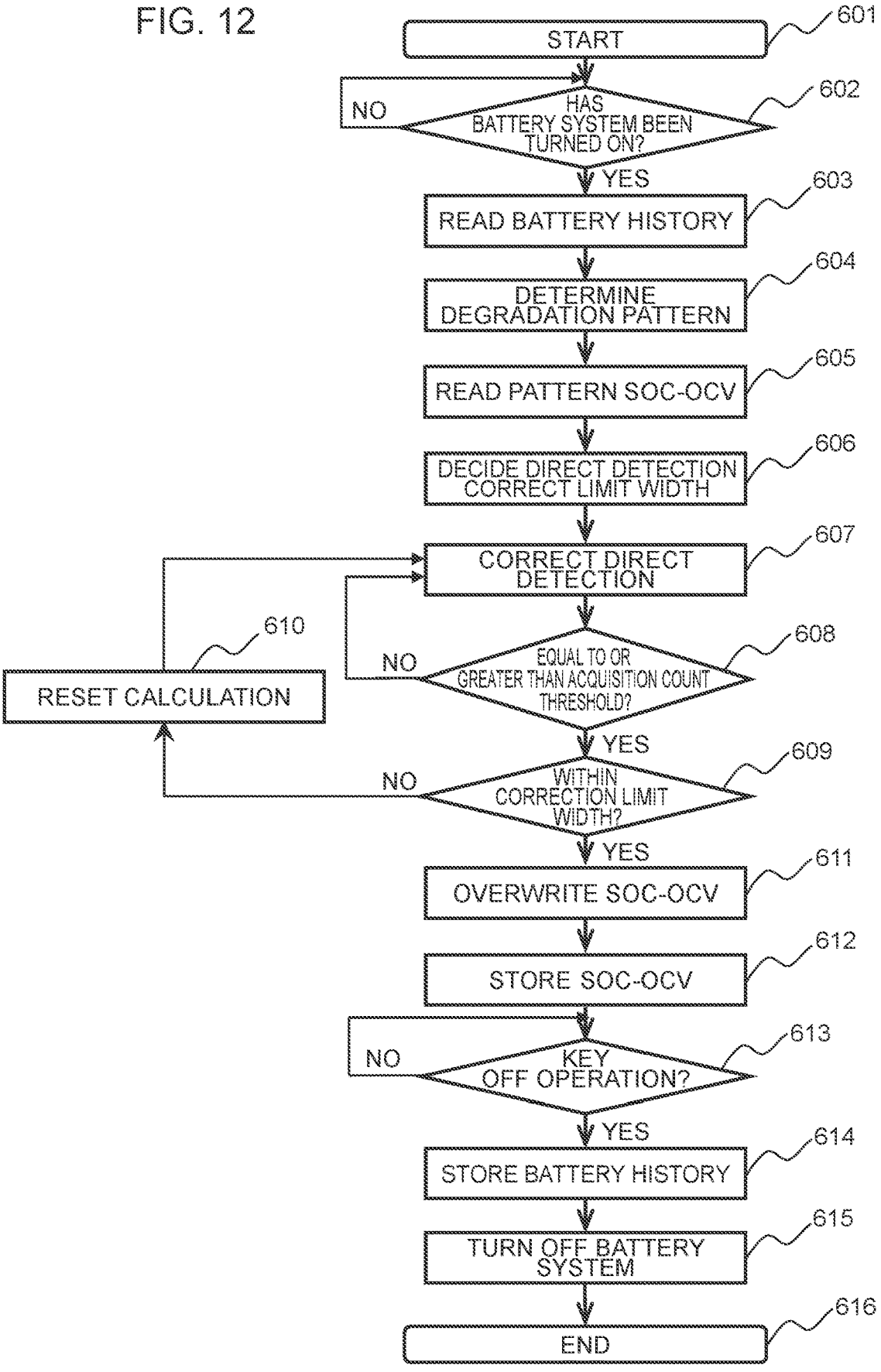

START
601
HAS BATTERY SYSTEM BEEN TURNED ON?
602
NO
YES
READ BATTERY HISTORY
603
DETERMINE DEGRADATION PATTERN
604
READ PATTERN SOC-OCV
605
DECIDE DIRECT DETECTION CORRECT LIMIT WIDTH
606
CORRECT DIRECT DETECTION
607
EQUAL TO OR GREATER THAN ACQUISITION COUNT THRESHOLD?
608
NO
YES
WITHIN CORRECTION LIMIT WIDTH?
609
NO
YES
RESET CALCULATION
610
OVERWRITE SOC-OCV
611
STORE SOC-OCV
612
KEY OFF OPERATION?
613
NO
YES
STORE BATTERY HISTORY
614
TURN OFF BATTERY SYSTEM
615
END
616

FIG. 13

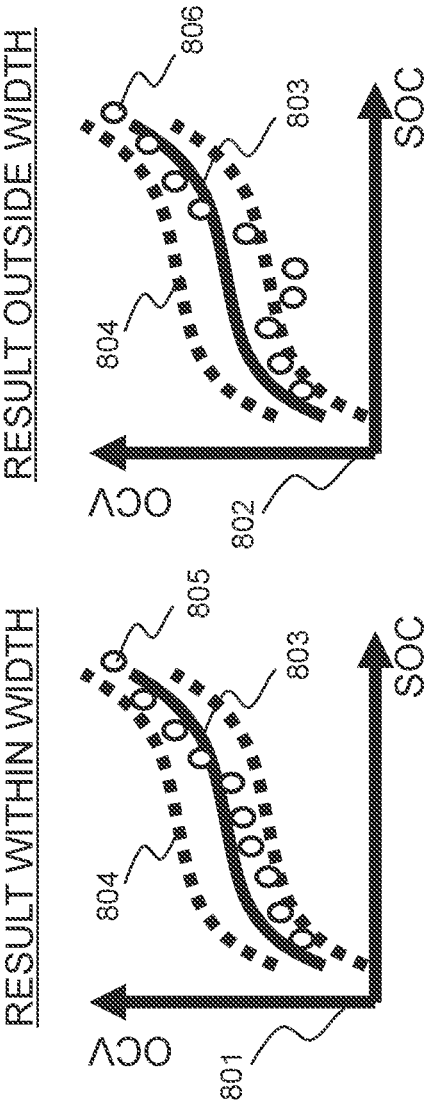

RESULT WITHIN WIDTH
OCV
SOC
801
804
805
803
RESULT OUTSIDE WIDTH
OCV
SOC
802
804
806
803

FIG. 14

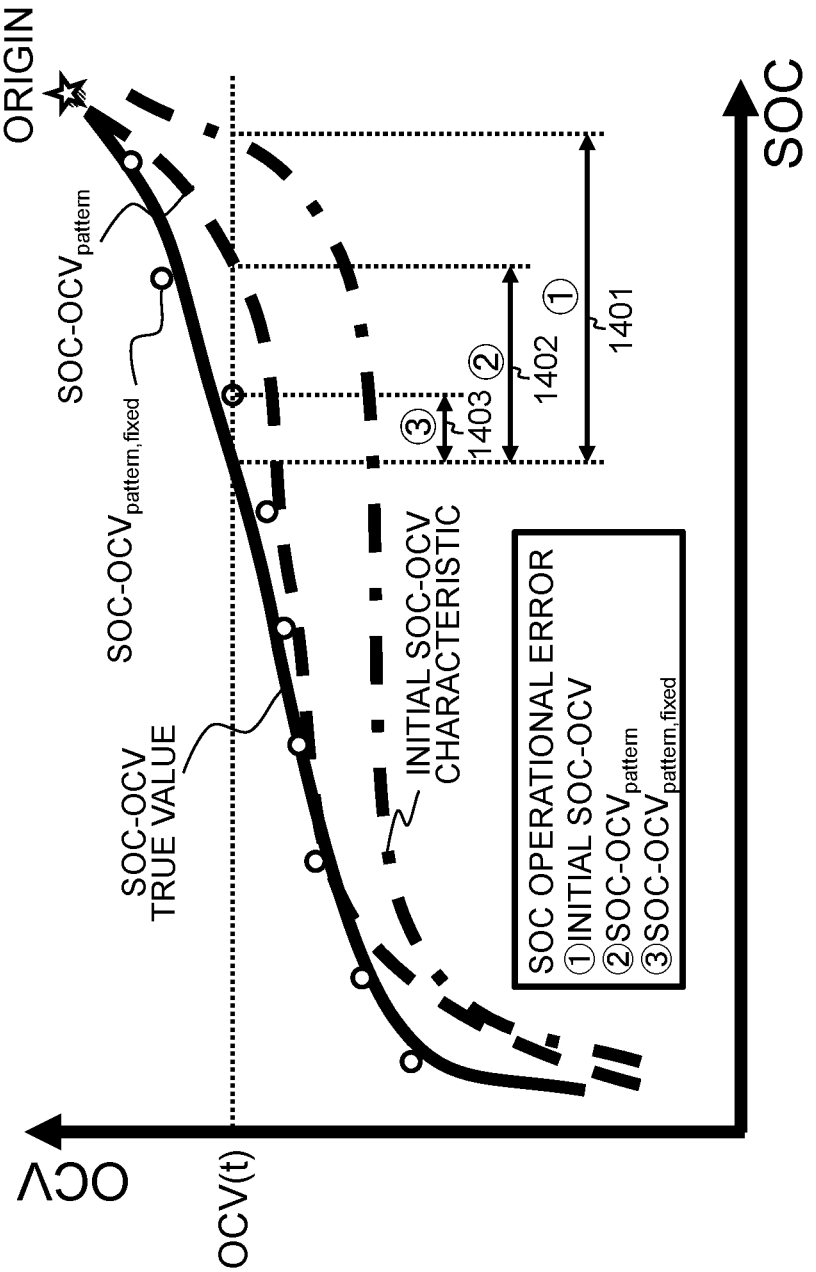

ORIGIN
SOC-OCV$_{pattern}$
SOC-OCV$_{pattern,fixed}$
SOC-OCV TRUE VALUE
INITIAL SOC-OCV CHARACTERISTIC
1401
1402
1403
①
②
③
SOC OPERATIONAL ERROR
①INITIAL SOC-OCV
②SOC-OCV$_{pattern}$
③SOC-OCV$_{pattern,fixed}$
OCV
OCV(t)
SOC

FIG. 15

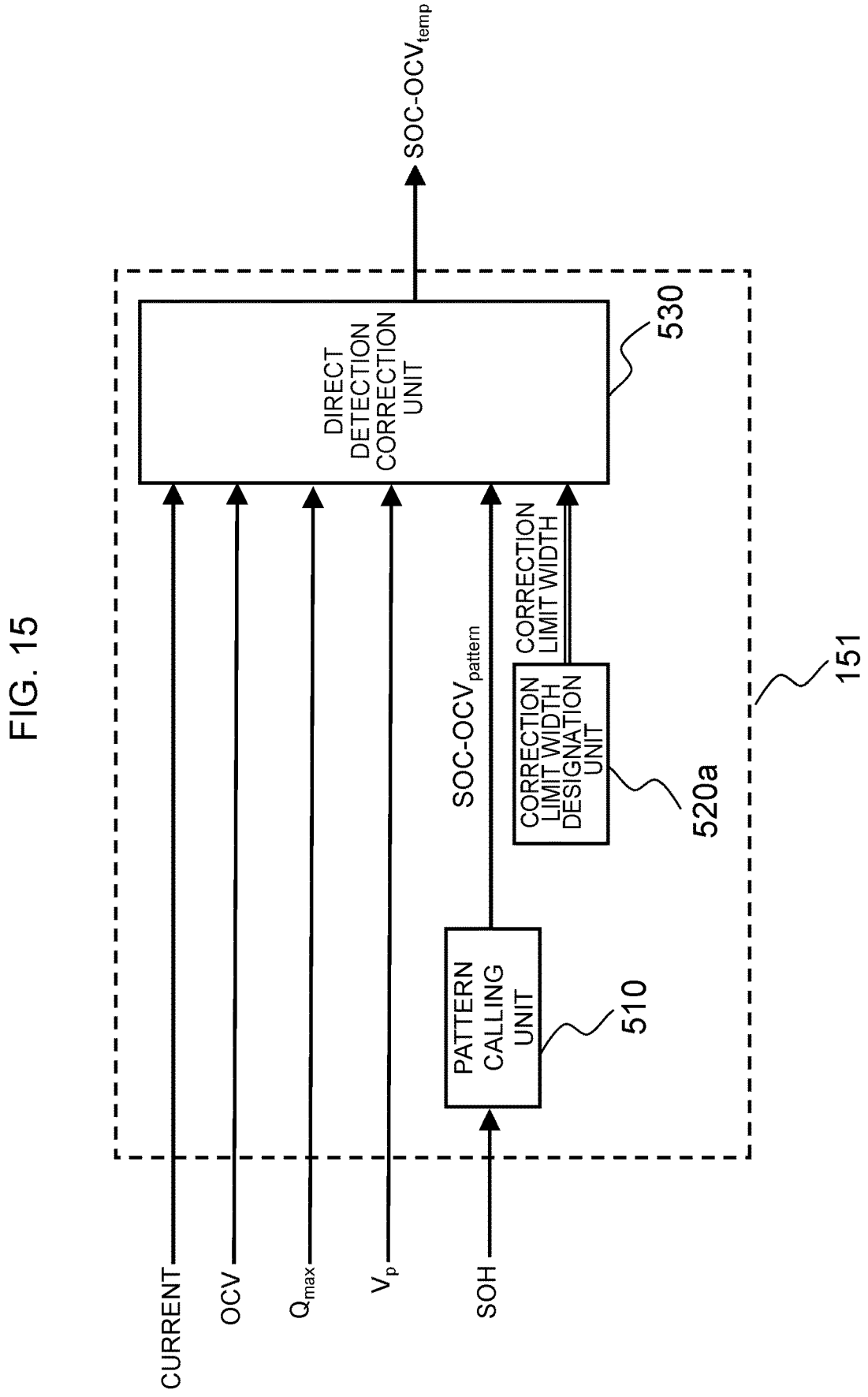

SOC-OCV$_{temp}$
DIRECT DETECTION CORRECTION UNIT
530
CORRECTION LIMIT WIDTH
SOC-OCV$_{pattern}$
CORRECTION LIMIT WIDTH DESIGNATION UNIT
520a
151
PATTERN CALLING UNIT
510
CURRENT
OCV
Q_{max}
V_p
SOH

FIG. 16

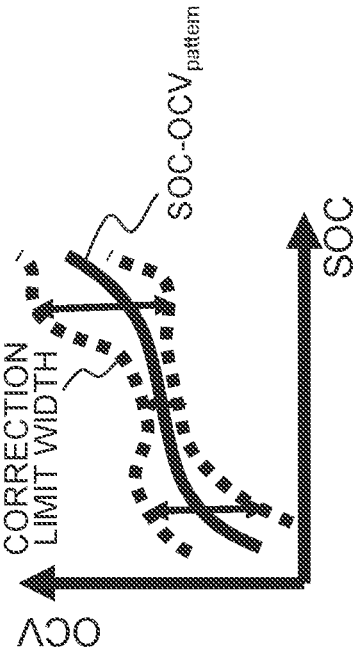


FIG. 17

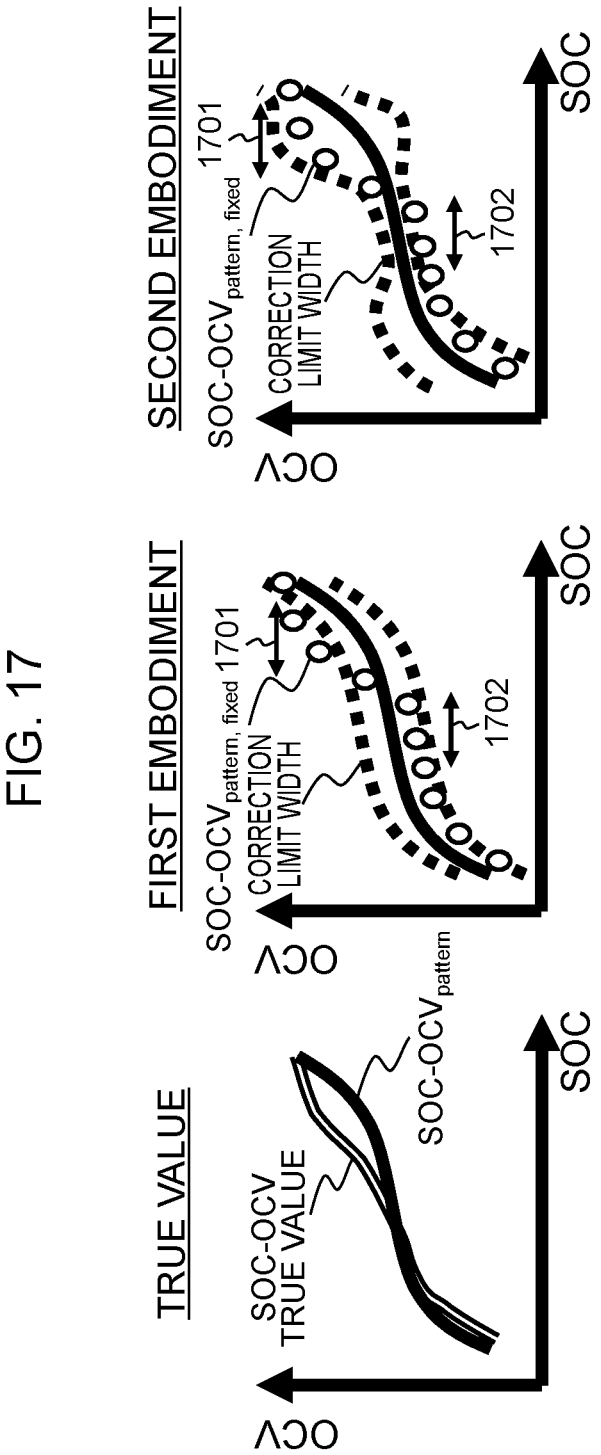

TRUE VALUE
SOC-OCV TRUE VALUE
SOC-OCV pattern
OCV
SOC
FIRST EMBODIMENT
SOC-OCV pattern, fixed
1701
CORRECTION LIMIT WIDTH
1702
OCV
SOC
SECOND EMBODIMENT
SOC-OCV pattern, fixed
1701
CORRECTION LIMIT WIDTH
1702
OCV
SOC

FIG. 18

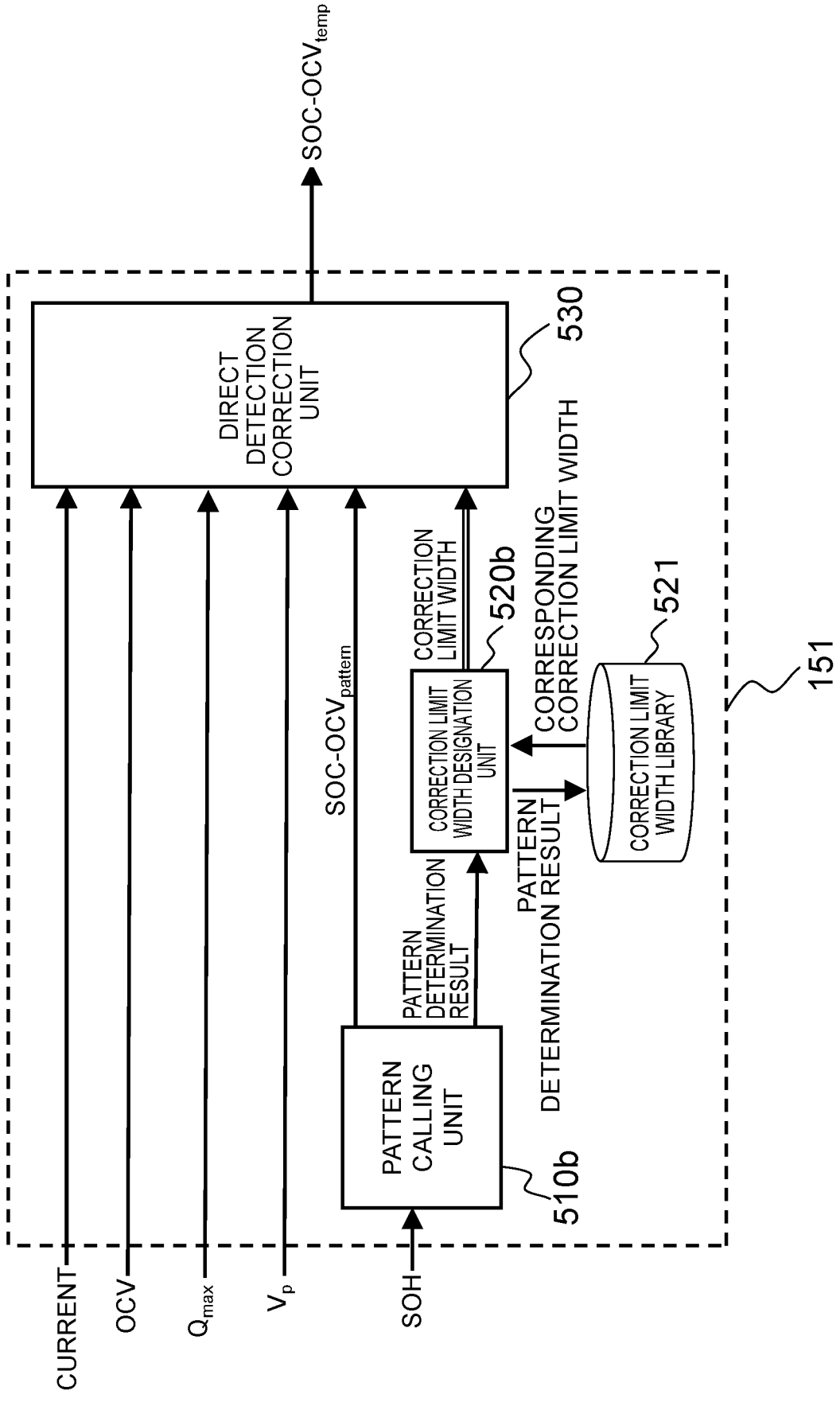

SOC-OCV$_{temp}$
DIRECT DETECTION CORRECTION UNIT
530
CURRENT
OCV
Q_{max}
V_p
SOH
SOC-OCV$_{pattern}$
PATTERN CALLING UNIT
510b
PATTERN DETERMINATION RESULT
CORRECTION LIMIT WIDTH DESIGNATION UNIT
520b
CORRECTION LIMIT WIDTH
PATTERN DETERMINATION RESULT
CORRESPONDING CORRECTION LIMIT WIDTH
CORRECTION LIMIT WIDTH LIBRARY
521
151

FIG. 19

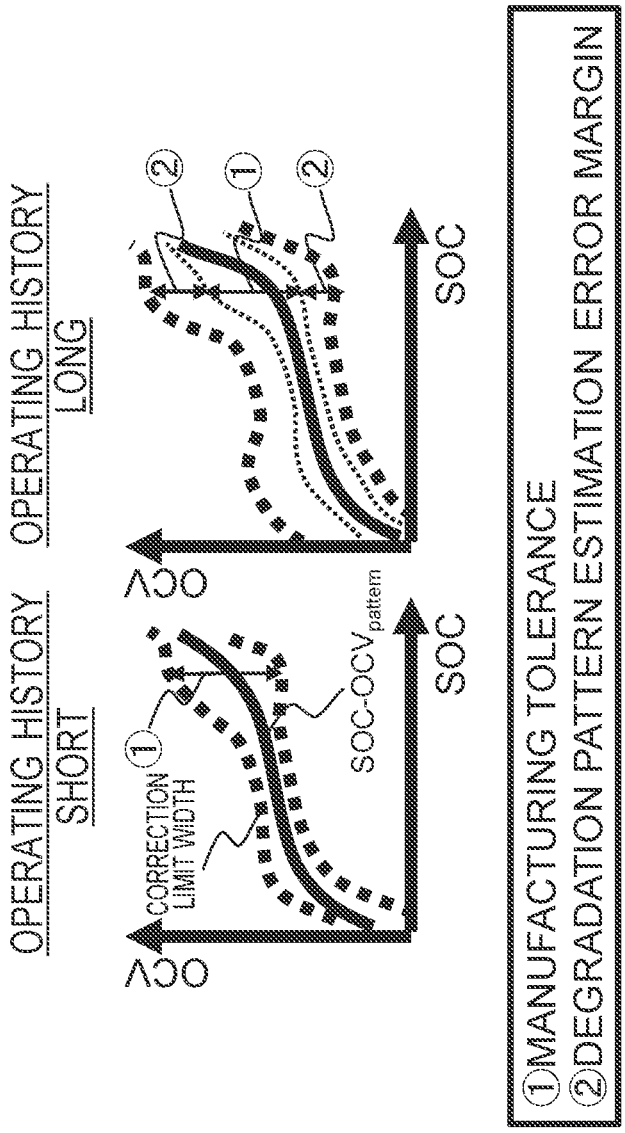

OPERATING HISTORY
SHORT
OPERATING HISTORY
LONG
OCV
SOC
CORRECTION LIMIT WIDTH
SOC-OCV pattern
①MANUFACTURING TOLERANCE
②DEGRADATION PATTERN ESTIMATION ERROR MARGIN

FIG. 20

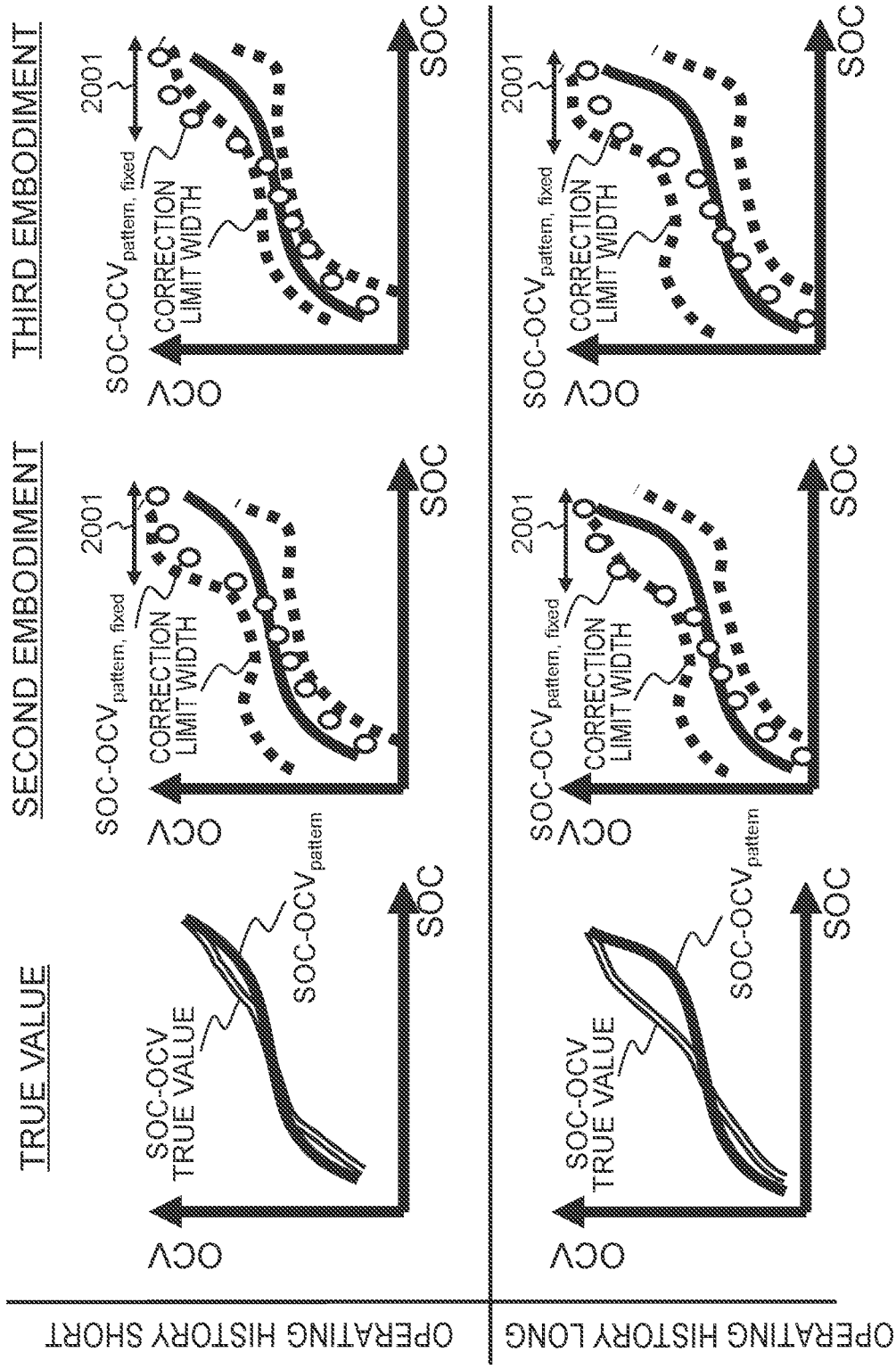

TRUE VALUE
SECOND EMBODIMENT
THIRD EMBODIMENT
OPERATING HISTORY SHORT
OPERATING HISTORY LONG
OCV
SOC
SOC-OCV TRUE VALUE
SOC-OCV pattern
SOC-OCV pattern, fixed
CORRECTION LIMIT WIDTH
2001

FIG. 21

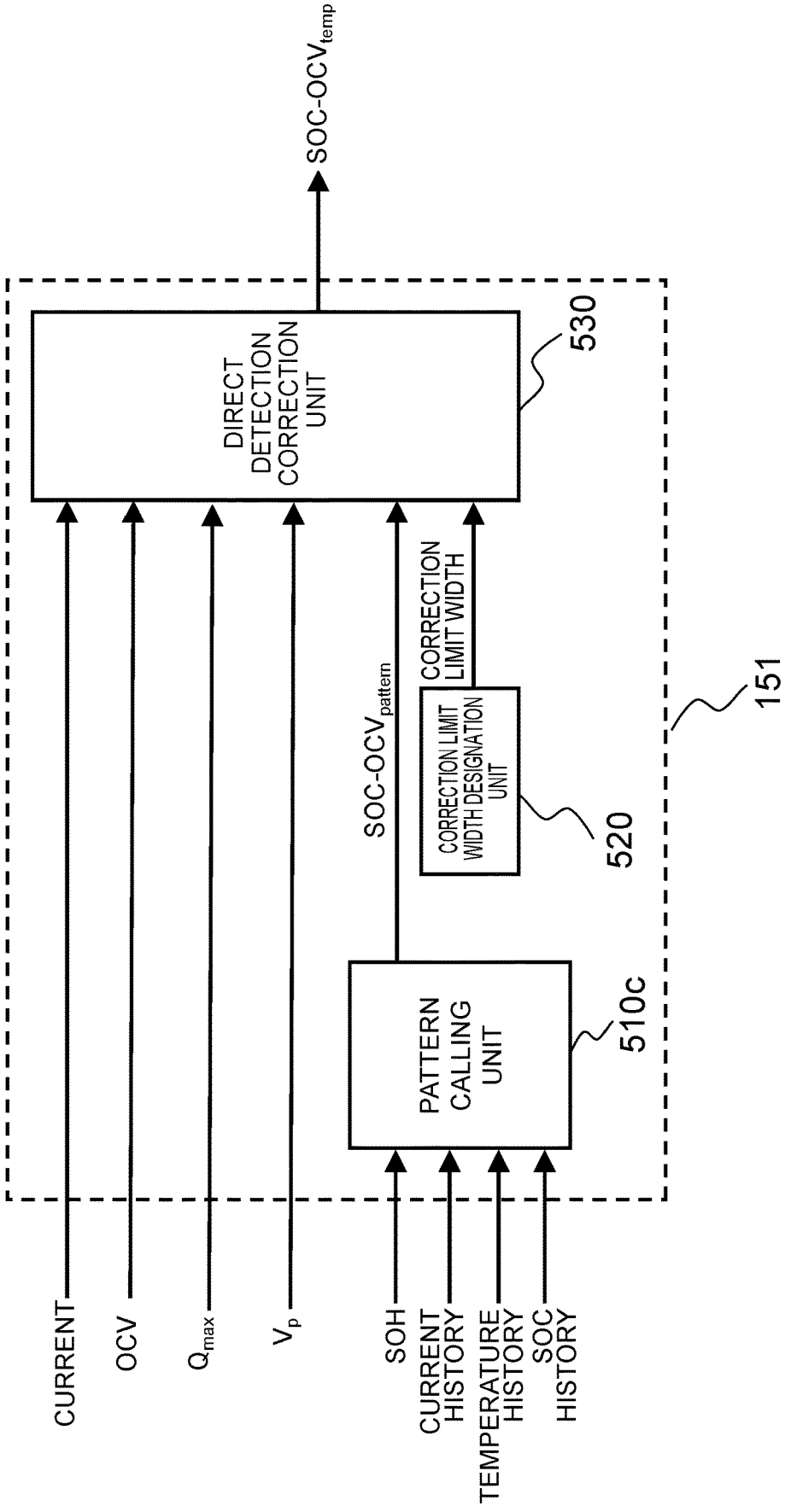

SOC-OCV$_{temp}$
DIRECT DETECTION CORRECTION UNIT
530
CORRECTION LIMIT WIDTH
SOC-OCV$_{pattern}$
CORRECTION LIMIT WIDTH DESIGNATION UNIT
520
151
PATTERN CALLING UNIT
510c
CURRENT
OCV
Q_{max}
V_p
SOH
CURRENT HISTORY
TEMPERATURE HISTORY
SOC HISTORY

FIG. 22

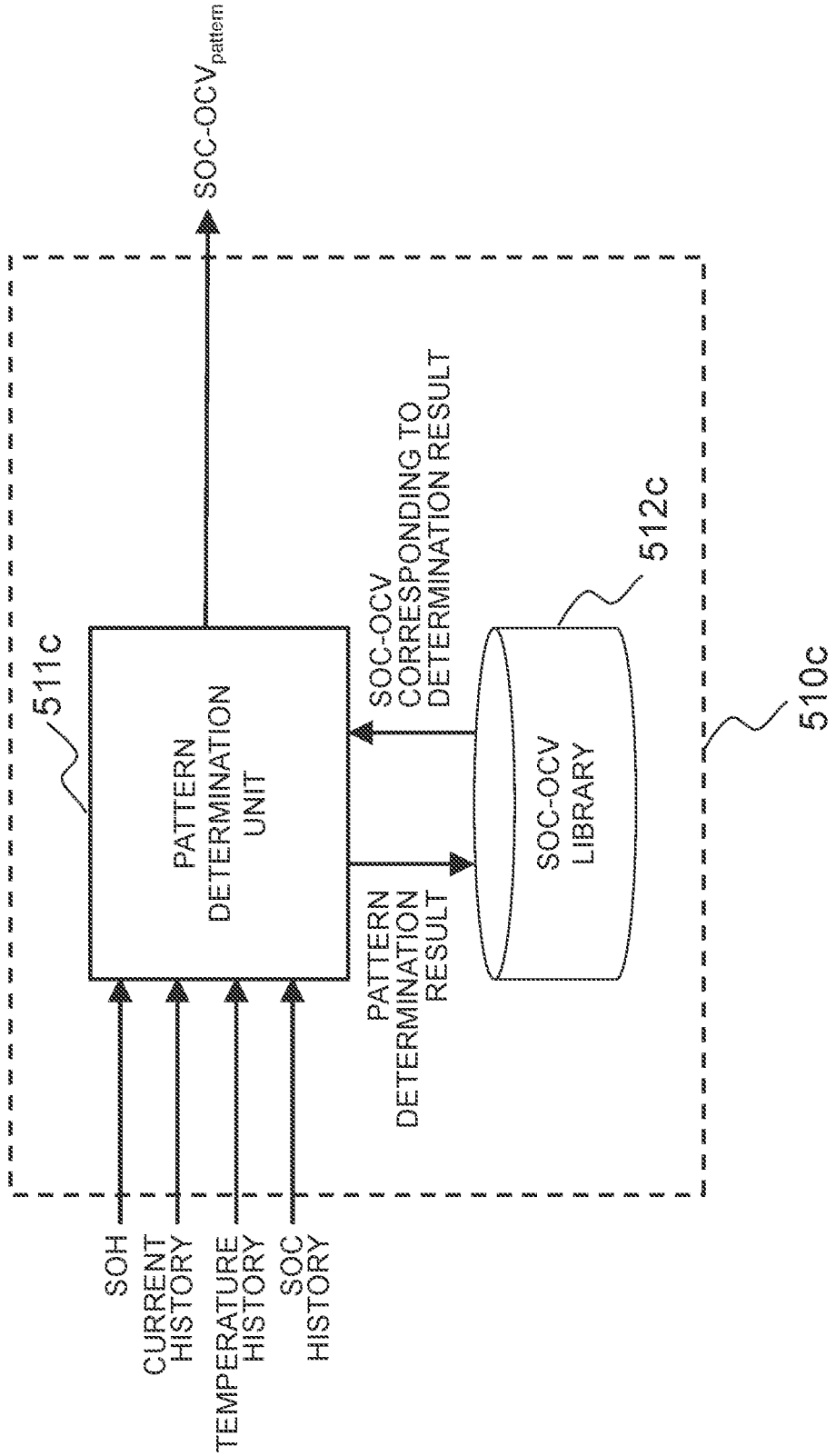

SOC-OCV$_{pattern}$
511c
PATTERN DETERMINATION UNIT
SOC-OCV CORRESPONDING TO DETERMINATION RESULT
512c
SOC-OCV LIBRARY
510c
PATTERN DETERMINATION RESULT
SOH
CURRENT HISTORY
TEMPERATURE HISTORY
SOC HISTORY

FIG. 23

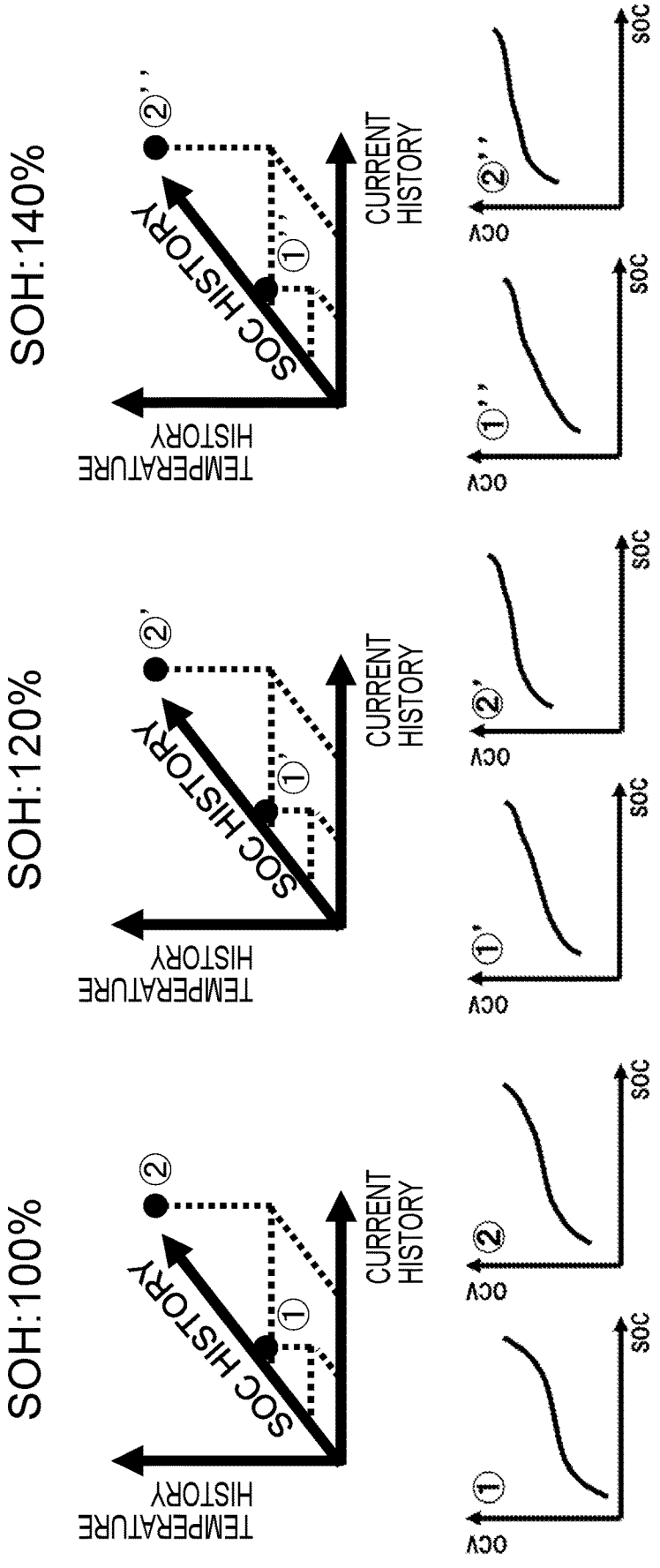

SOH:140%
SOH:120%
SOH:100%
TEMPERATURE HISTORY
SOC HISTORY
CURRENT HISTORY
①
①'
①''
②
②'
②''
OCV
SOC

FIG. 24

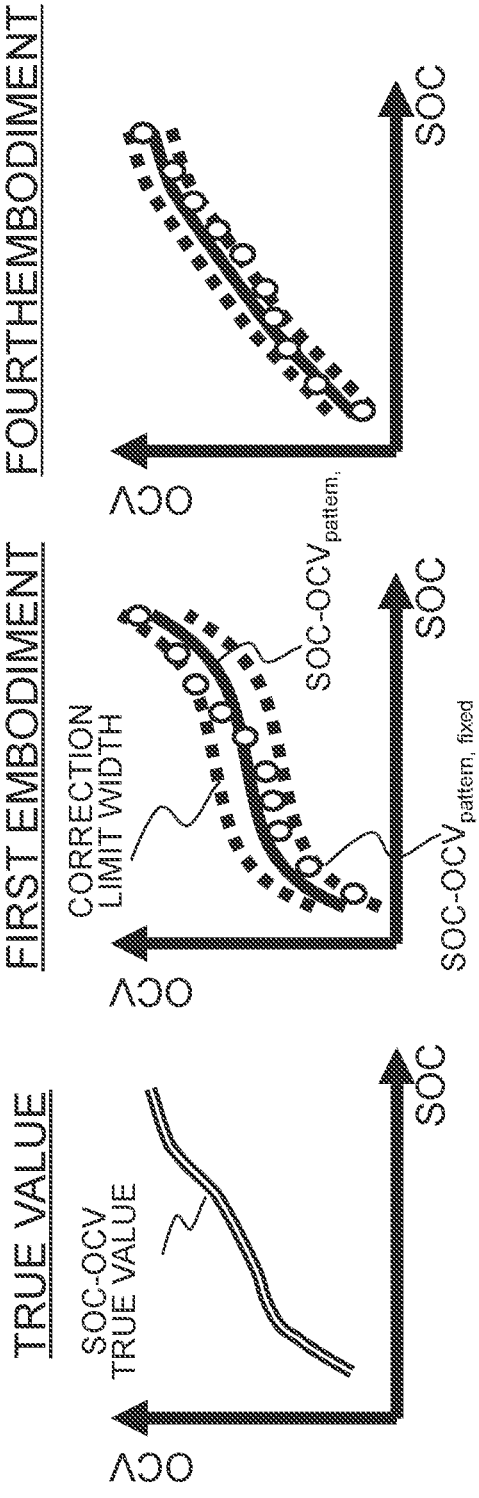

TRUE VALUE
SOC-OCV TRUE VALUE
OCV
SOC
FIRST EMBODIMENT
CORRECTION LIMIT WIDTH
SOC-OCV pattern,
SOC-OCV pattern, fixed
OCV
SOC
FOURTHEMBODIMENT
OCV
SOC

FIG. 25

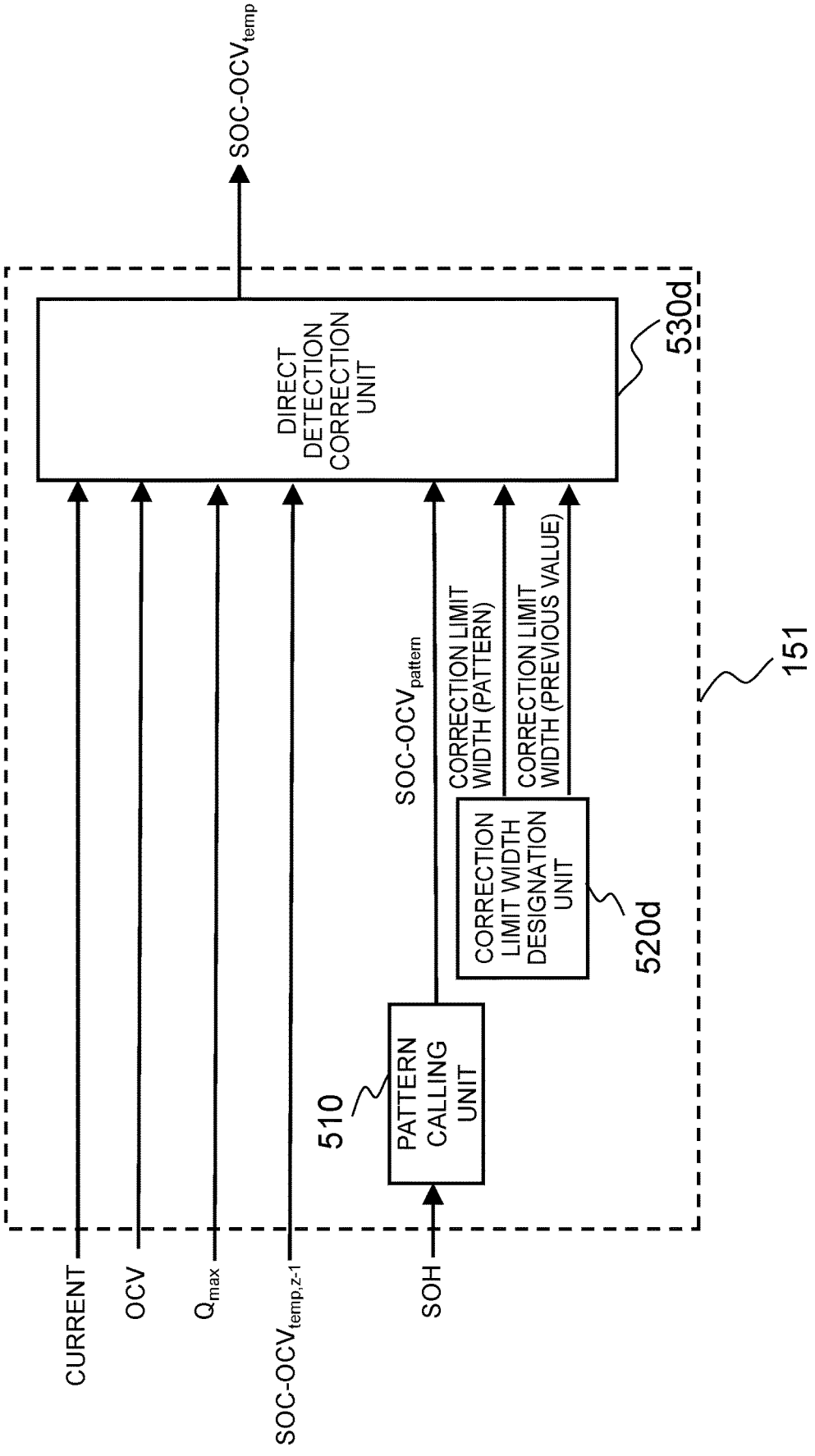

SOC-OCV$_{temp}$
DIRECT DETECTION CORRECTION UNIT
530d
151
SOC-OCV$_{pattern}$
CORRECTION LIMIT WIDTH (PATTERN)
CORRECTION LIMIT WIDTH (PREVIOUS VALUE)
CORRECTION LIMIT WIDTH DESIGNATION UNIT
520d
510
PATTERN CALLING UNIT
CURRENT
OCV
Q_{max}
SOC-OCV$_{temp,z-1}$
SOH

FIG. 26

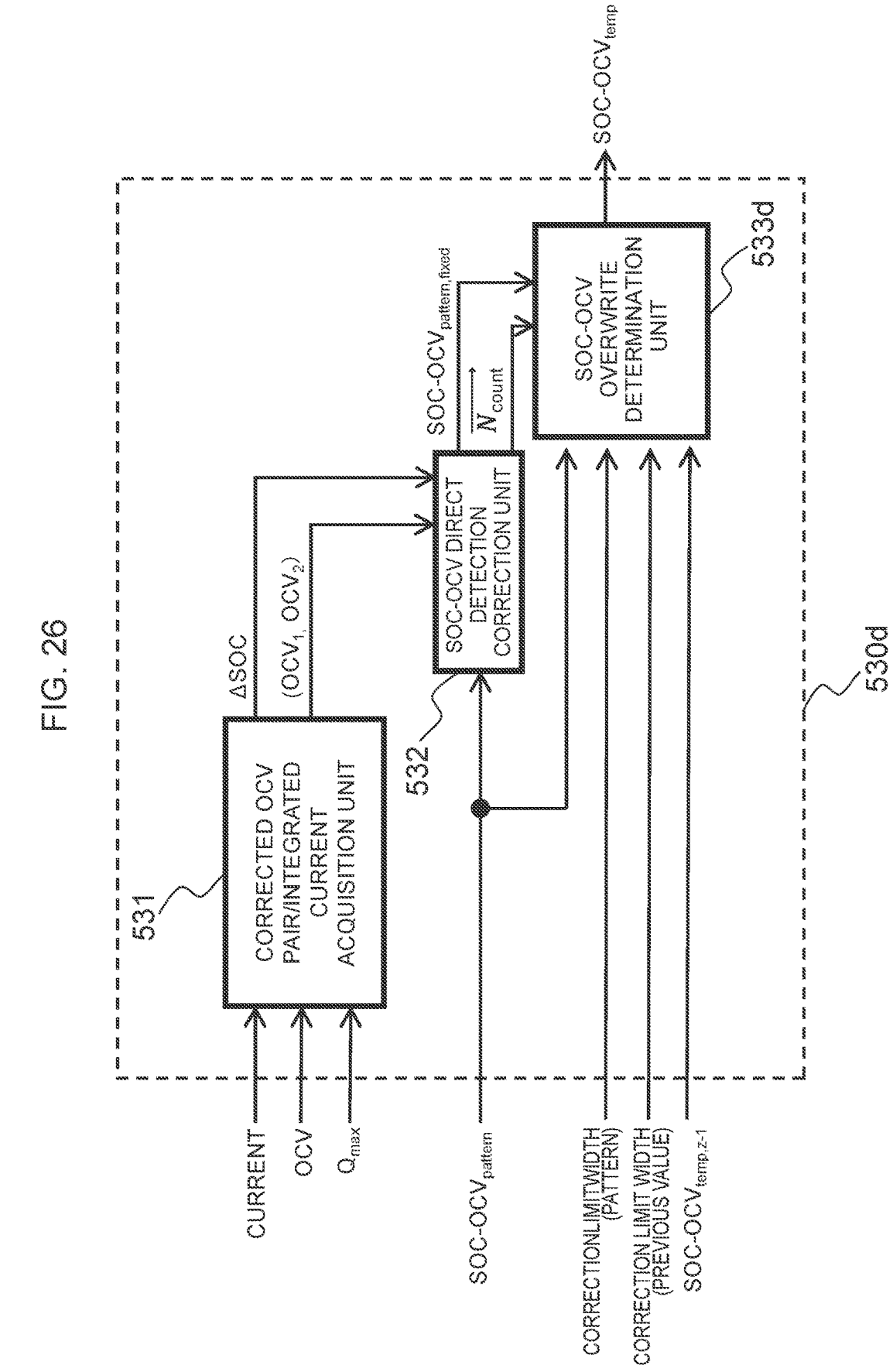

530d
531
CORRECTED OCV PAIR/INTEGRATED CURRENT ACQUISITION UNIT
ΔSOC
(OCV1, OCV2)
532
SOC-OCV DIRECT DETECTION CORRECTION UNIT
SOC-OCV pattern,fixed
N count
533d
SOC-OCV OVERWRITE DETERMINATION UNIT
SOC-OCV temp
CURRENT
OCV
Qmax
SOC-OCV pattern
CORRECTION LIMIT WIDTH (PATTERN)
CORRECTION LIMIT WIDTH (PREVIOUS VALUE)
SOC-OCV temp,z-1

FIG. 27

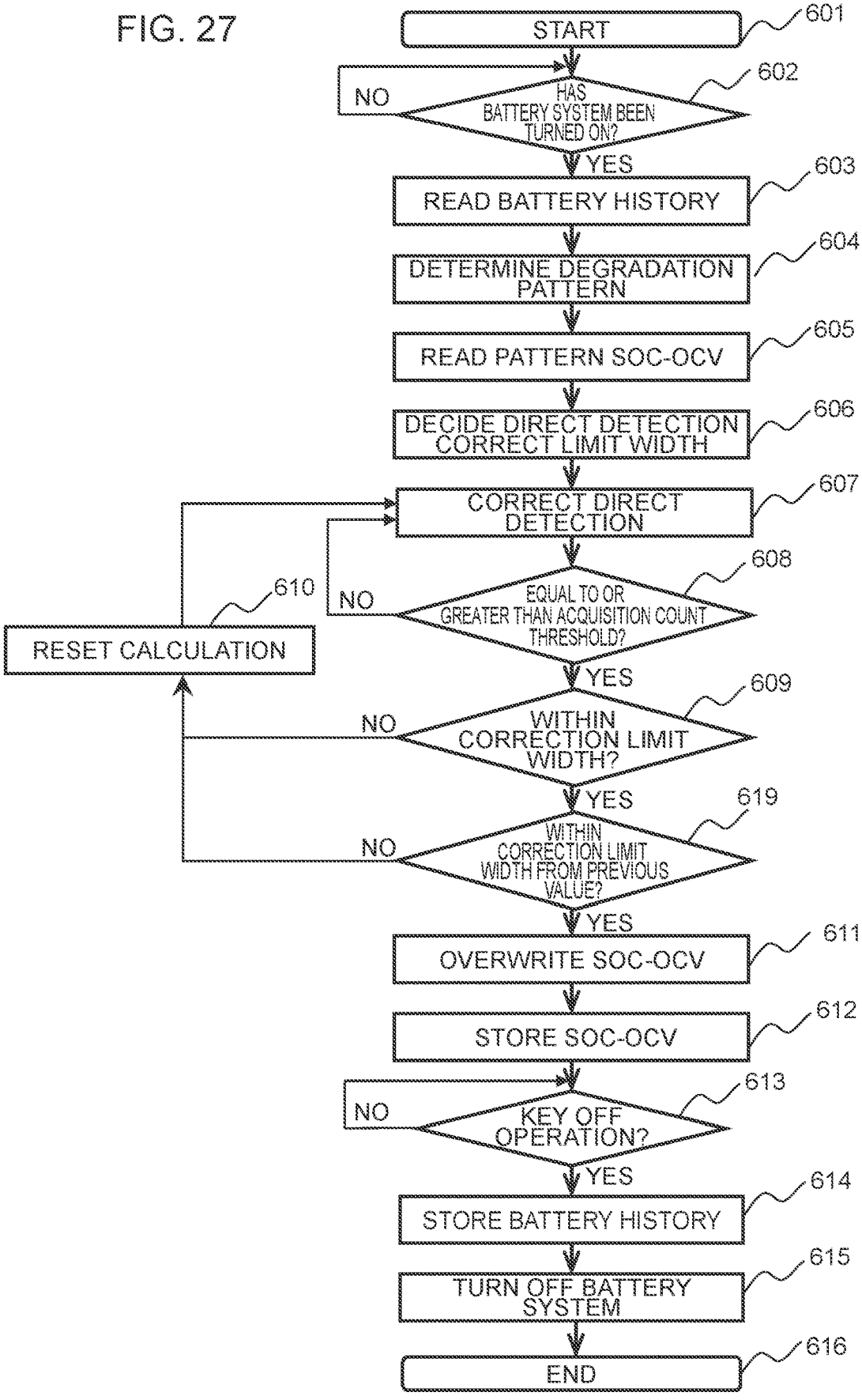

START
601
HAS BATTERY SYSTEM BEEN TURNED ON?
602
NO
YES
READ BATTERY HISTORY
603
DETERMINE DEGRADATION PATTERN
604
READ PATTERN SOC-OCV
605
DECIDE DIRECT DETECTION CORRECT LIMIT WIDTH
606
CORRECT DIRECT DETECTION
607
EQUAL TO OR GREATER THAN ACQUISITION COUNT THRESHOLD?
608
NO
YES
WITHIN CORRECTION LIMIT WIDTH?
609
NO
YES
WITHIN CORRECTION LIMIT WIDTH FROM PREVIOUS VALUE?
619
NO
YES
RESET CALCULATION
610
OVERWRITE SOC-OCV
611
STORE SOC-OCV
612
KEY OFF OPERATION?
613
NO
YES
STORE BATTERY HISTORY
614
TURN OFF BATTERY SYSTEM
615
END
616

FIG. 28

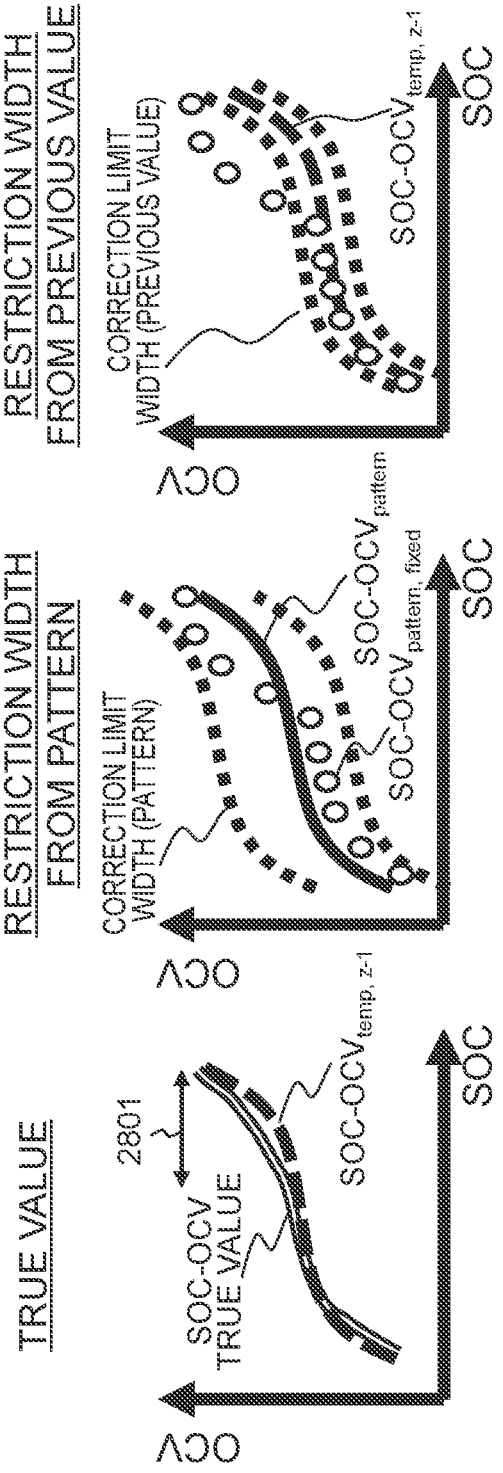

TRUE VALUE
SOC-OCV TRUE VALUE
2801
SOC-OCV temp, z-1
OCV
SOC
RESTRICTION WIDTH FROM PATTERN
CORRECTION LIMIT WIDTH (PATTERN)
SOC-OCV pattern
SOC-OCV pattern, fixed
OCV
SOC
RESTRICTION WIDTH FROM PREVIOUS VALUE
CORRECTION LIMIT WIDTH (PREVIOUS VALUE)
SOC-OCV temp, z-1
OCV
SOC

FIG. 29

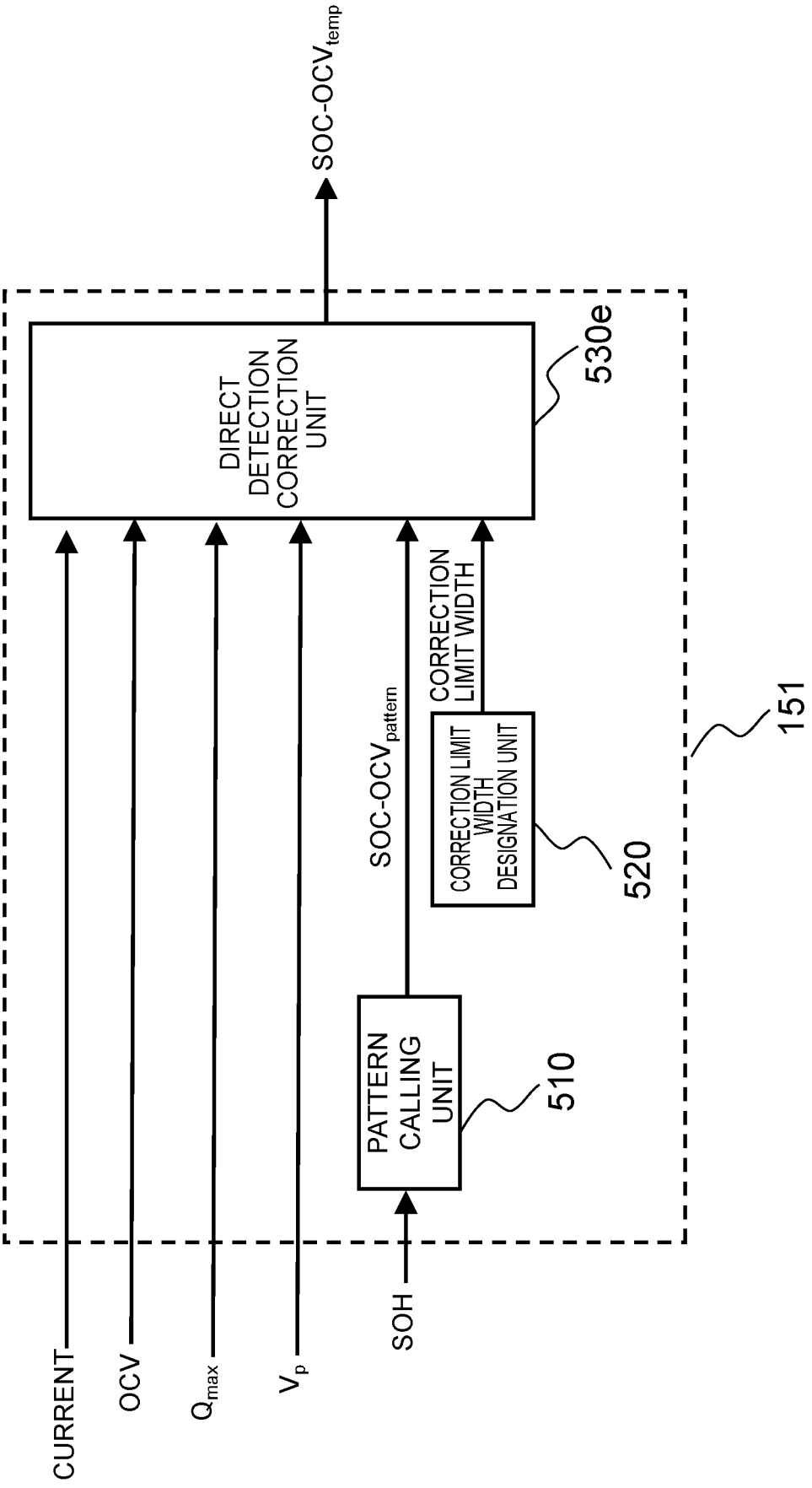

SOC-OCV$_{temp}$
DIRECT DETECTION CORRECTION UNIT
530e
CORRECTION LIMIT WIDTH
SOC-OCV$_{pattern}$
CORRECTION LIMIT WIDTH DESIGNATION UNIT
520
151
PATTERN CALLING UNIT
510
CURRENT
OCV
Q_{max}
V_p
SOH

FIG. 30

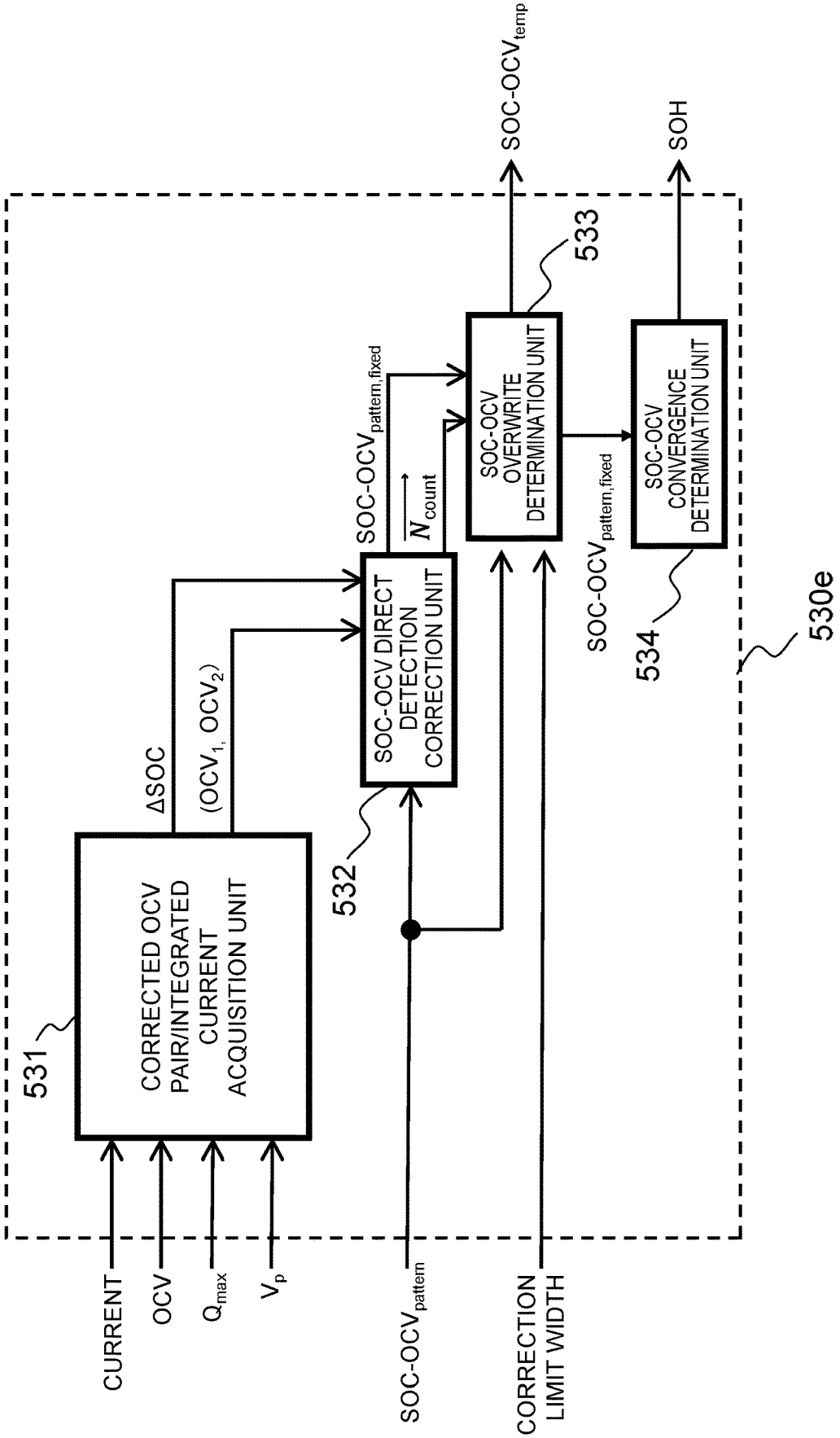

CURRENT
OCV
Q_{max}
V_p
$SOC\text{-}OCV_{pattern}$
CORRECTION LIMIT WIDTH
531
CORRECTED OCV PAIR/INTEGRATED CURRENT ACQUISITION UNIT
ΔSOC
(OCV_1, OCV_2)
532
SOC-OCV DIRECT DETECTION CORRECTION UNIT
$SOC\text{-}OCV_{pattern,fixed}$
$\overrightarrow{N_{count}}$
533
SOC-OCV OVERWRITE DETERMINATION UNIT
$SOC\text{-}OCV_{temp}$
$SOC\text{-}OCV_{pattern,fixed}$
534
SOC-OCV CONVERGENCE DETERMINATION UNIT
SOH
530e

FIG. 31

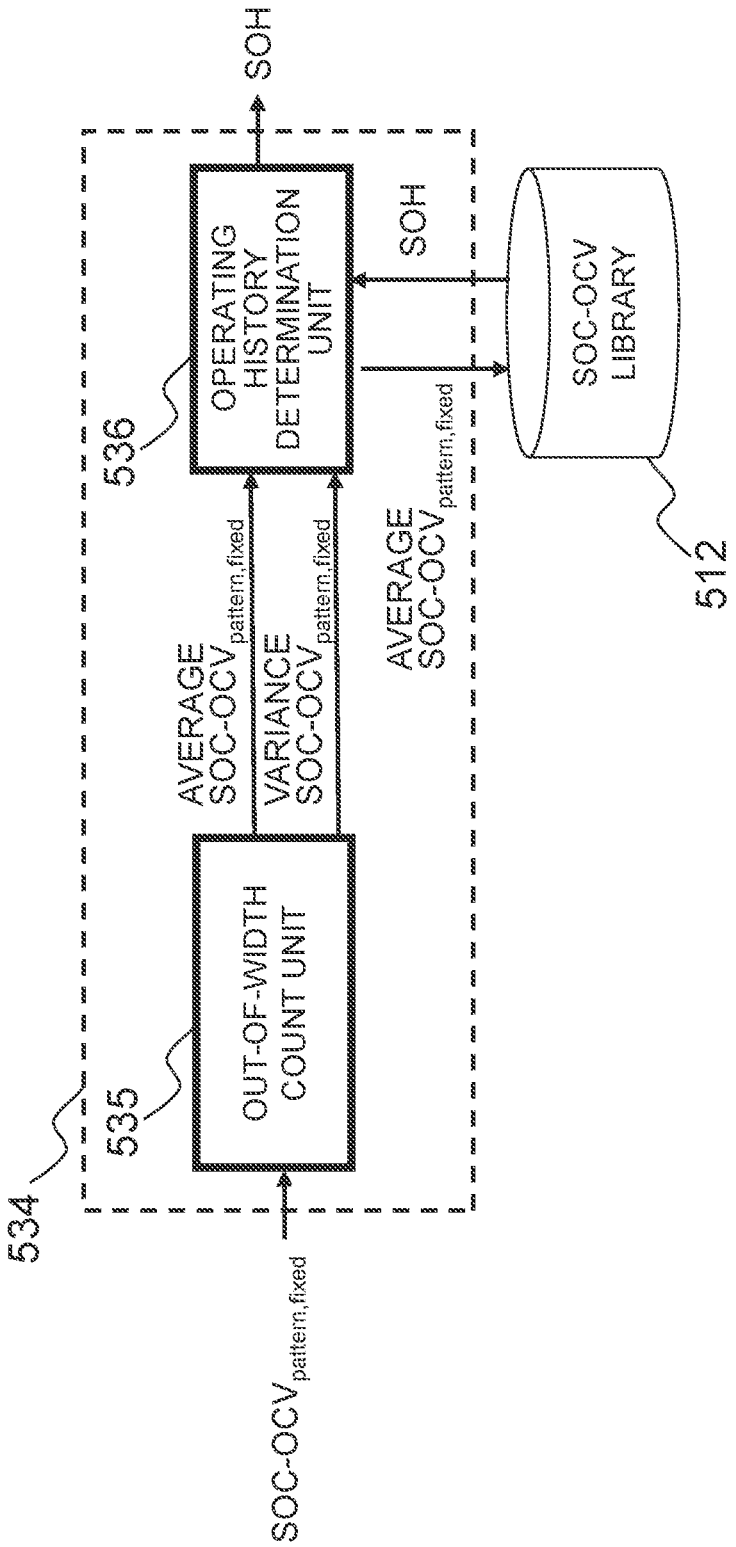

534
535
536
512
OUT-OF-WIDTH COUNT UNIT
OPERATING HISTORY DETERMINATION UNIT
SOC-OCV LIBRARY
SOC-OCV pattern,fixed
AVERAGE SOC-OCV pattern,fixed
VARIANCE SOC-OCV pattern,fixed
AVERAGE SOC-OCV pattern,fixed
SOH
SOH

FIG. 32

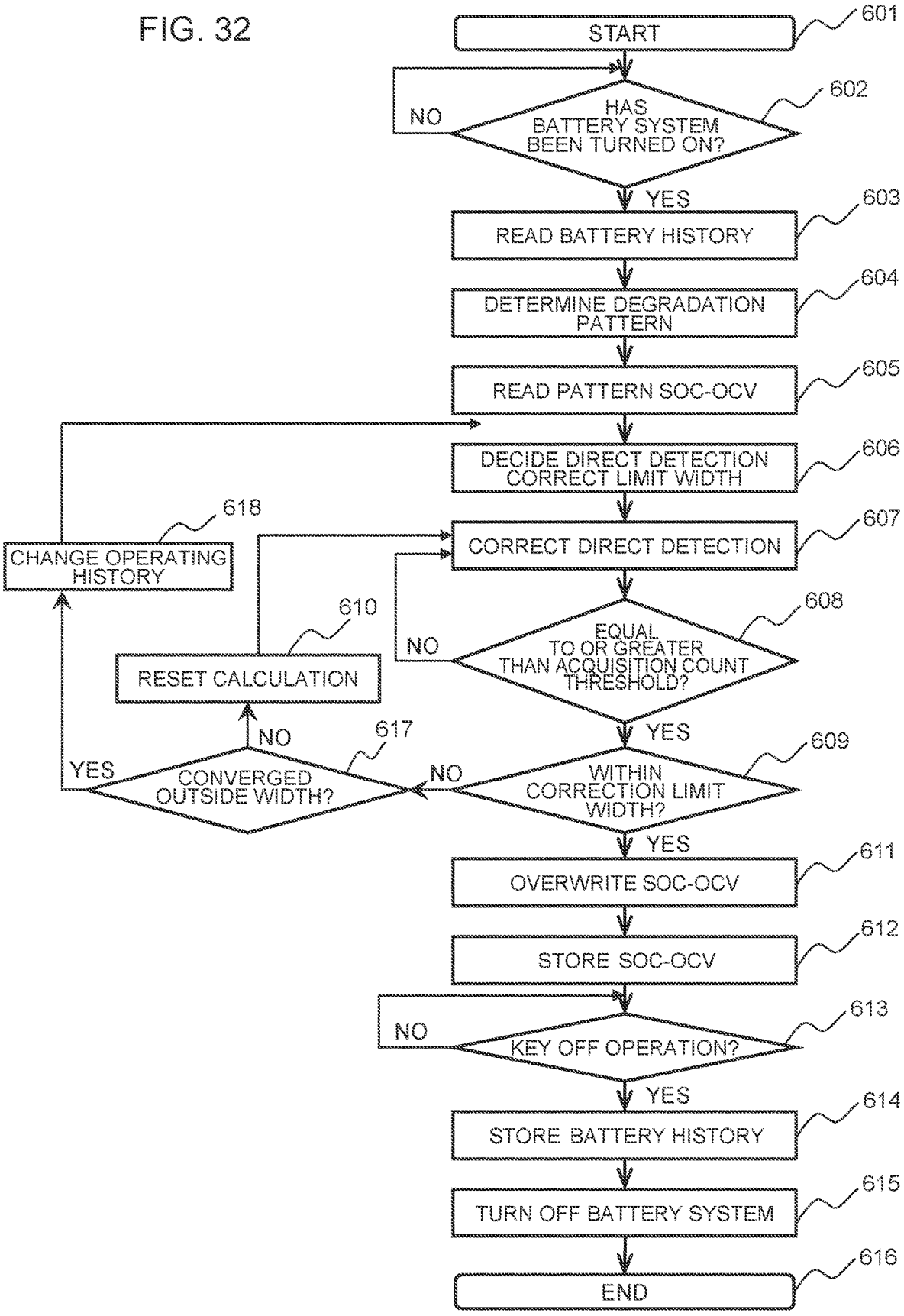
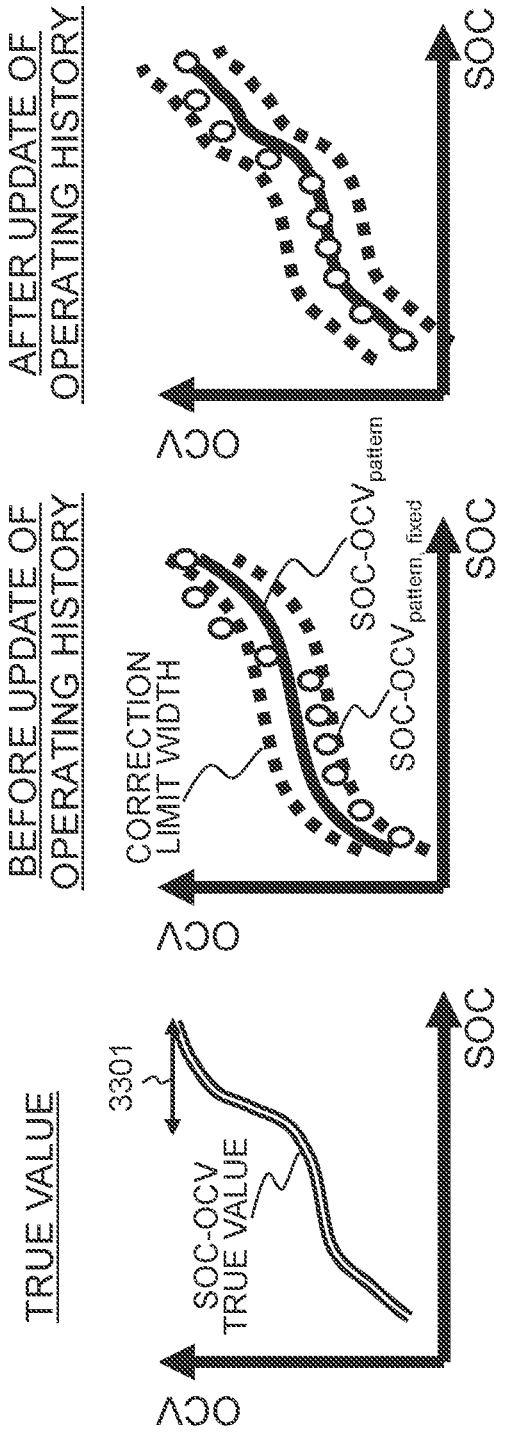

START
601
HAS BATTERY SYSTEM BEEN TURNED ON?
602
NO
YES
READ BATTERY HISTORY
603
DETERMINE DEGRADATION PATTERN
604
READ PATTERN SOC-OCV
605
DECIDE DIRECT DETECTION CORRECT LIMIT WIDTH
606
CORRECT DIRECT DETECTION
607
EQUAL TO OR GREATER THAN ACQUISITION COUNT THRESHOLD?
608
NO
YES
WITHIN CORRECTION LIMIT WIDTH?
609
NO
YES
CONVERGED OUTSIDE WIDTH?
617
NO
YES
RESET CALCULATION
610
CHANGE OPERATING HISTORY
618
OVERWRITE SOC-OCV
611
STORE SOC-OCV
612
KEY OFF OPERATION?
613
NO
YES
STORE BATTERY HISTORY
614
TURN OFF BATTERY SYSTEM
615
END
616

FIG. 33


TRUE VALUE
3301
SOC-OCV TRUE VALUE
OCV
SOC
BEFORE UPDATE OF OPERATING HISTORY
CORRECTION LIMIT WIDTH
SOC-OCV pattern
SOC-OCV pattern_fixed
OCV
SOC
AFTER UPDATE OF OPERATING HISTORY
OCV
SOC

BATTERY CONTROL DEVICE

TECHNICAL FIELD

[0001] The present invention relates to a battery control device.

BACKGROUND ART

[0002] Conventionally, chargeable/dischargeable secondary batteries have been used in a variety of fields including mobile phones and other mobile terminals, and in the stabilization of power system interconnections. Furthermore, in recent years, electric vehicles, hybrid vehicles and other vehicles that use the power of secondary batteries as its power source are attracting attention in light of global warming countermeasures, emission controls, and measures for preventing the depletion of fossil fuels. A system equipped with these secondary batteries generally comprises a battery control device for using the batteries safely and for maximizing the performance of the batteries. A battery control device detects the voltage, temperature and current of the batteries, and operates battery parameters such as the state of charge (SOC) and the state of health (SOH) of the batteries based on the results of such detection.

[0003] The state of charge (SOC) of a battery can generally be acquired using an SOC-OCV characteristic, which is the relationship between the SOC and the open circuit voltage (OCV) of the battery. Nevertheless, the SOC-OCV characteristic is known to change depending on the degradation or individual variation of the battery. In recent years, inclination of the SOC-OCV characteristic is decreasing due to the improvement of electrode materials, and the degradation or individual variation of the SOC-OCV characteristic is becoming a problem as the cause of an SOC error. Thus, in order to calculate the SOC accurately, a logic for detecting and correcting the changes in the SOC-OCV characteristic is required.

[0004] As methods of operating the SOC according to the changes in the SOC-OCV characteristic, for example, known are the technologies described in PTL 1 and PTL 2 below. PTL 1 discloses a controller of an electricity storage system which calculates, by using an average SOC and an average battery temperature of a period in which a full charge capacity has not been estimated (unestimated period) from the time that the full charge capacity was previously calculated to date and a decrease rate map in which a decrease rate that changes according to the average SOC and the average battery temperature is prescribed in advance, the decrease rate during the unestimated period, and calculates a first elapsed time of an electrical storage device when the full charge capacity was previously calculated based on the decrease rate during the unestimated period and an initial full charge capacity. PTL 1 further discloses that the controller of the electricity storage system calculates a present full charge capacity based on a present second elapsed period of the electrical storage device calculated from the first elapsed period and the unestimated period, the decrease rate during the unestimated period, and the initial full charge capacity. PTL 2 discloses a method of estimating a state of charge of a secondary battery based on an open voltage value and a current integrated value including the steps of updating an instantaneous state of charge map which prescribes a relationship of an instantaneous open voltage value when estimating a state of charge and a state of charge estimated value based on charge/discharge characteristic data after start of use of the secondary battery, calculating an instantaneous state of charge estimated value when estimating a state of charge based on the updated instantaneous state of charge map, calculating the state of charge estimated value based on an integrated value of a current flowed through the secondary battery, and calculating a control state of charge estimated value for use in controlling the secondary battery based on the instantaneous state of charge estimated value and the state of charge estimated value based on the current integrated value.

CITATION LIST

Patent Literature

[0005] [PTL 1] Japanese Unexamined Patent Application Publication No. 2015-40832

[0006] [PTL 2] Japanese Unexamined Patent Application Publication No. 2016-114469

SUMMARY OF THE INVENTION

Problems to be Solved by the Invention

[0007] With the method of PTL 1, it is not possible to deal with differences in the SOC-OCV characteristics based on individual variations that occur during the manufacture of the batteries. Moreover, when the actual conditions of use of the battery and the degradation condition prescribed in the decrease rate map stored in the controller are different, an error will occur between the prediction result of the SOC-OCV characteristic and the actual SOC-OCV characteristic. Thus, there is a problem in that the operational precision of the SOC will be low. Meanwhile, with the method of PTL 2, when there is a measurement error in the OCV or the current integrated value, there is a problem in that it is not possible to accurately update the instantaneous state of charge map corresponding to the SOC-OCV characteristic, and that a gross error will consequently occur in the operation result of the SOC. In particular, with hybrid vehicles that do not perform charge/discharge externally, since the operational range of the SOC is generally narrow, it is difficult to update the instantaneous state of charge map with a high degree of accuracy.

Means to Solve the Problems

[0008] The battery control device according to the present invention obtains a state of charge of a secondary battery from characteristics representing a relationship of a state of charge and a voltage of the secondary battery, and comprises a calling unit which calls a first characteristic among a plurality of the characteristics stored in advance based on use history information of the secondary battery, a correction limit width designation unit which designates a correction limit width for prescribing a tolerance level of correcting the first characteristic, and a direct detection correction unit which creates a second characteristic in which the first characteristic has been corrected according to the correction limit width based on a current value and a voltage value of the secondary battery, wherein the state of charge of the secondary battery is obtained using the second characteristic.

Advantageous Effects of the Invention

[0009] According to the present invention, the SOC can be operated with a high degree of accuracy even when the SOC-OCV characteristic changes due to the degradation or individual variation of a battery.

BRIEF DESCRIPTION OF DRAWINGS

[0010] FIG. **1** is a diagram showing the battery system according to an embodiment of the present invention and the peripheral configuration thereof.

[0011] FIG. **2** is a diagram showing the circuit configuration of the single battery control unit.

[0012] FIG. **3** is a diagram showing the functional configuration of the SOC operation system.

[0013] FIG. **4** is a diagram showing the functional configuration of the SOC-OCV correction unit according to the first embodiment of the present invention.

[0014] FIG. **5** is a diagram showing an example of the correction limit width designated by the correction limit width designation unit according to the first embodiment of the present invention.

[0015] FIG. **6** is a diagram showing the functional configuration of the pattern calling unit according to the first embodiment of the present invention.

[0016] FIG. **7** is a diagram showing an example of the SOC-OCV characteristics of the SOC-OCV library according to the first embodiment of the present invention.

[0017] FIG. **8** is a diagram showing the functional configuration of the direct detection correction unit according to the first embodiment of the present invention.

[0018] FIG. **9** is a diagram explaining the acquisition method of a stable OCV pair.

[0019] FIG. **10** is a diagram explaining the overwrite timing of the SOC-OCV characteristic.

[0020] FIG. **11** is a diagram explaining the method of determining whether the corrected SOC-OCV characteristic is within the correction limit width.

[0021] FIG. **12** is a flowchart showing the processing flow of the SOC-OCV correction unit according to the first embodiment of the present invention.

[0022] FIG. **13** is a diagram explaining the divergence inhibiting effect of the SOC-OCV characteristics according to the present invention.

[0023] FIG. **14** is a diagram explaining the improvement of the SOC operational precision according to the present invention.

[0024] FIG. **15** is a diagram showing the functional configuration of the SOC-OCV correction unit according to the second embodiment of the present invention.

[0025] FIG. **16** is a diagram showing an example of the correction limit width designated by the correction limit width designation unit according to the second embodiment of the present invention.

[0026] FIG. **17** is a diagram explaining the effect based on the second embodiment of the present invention in comparison to the effect of the first embodiment.

[0027] FIG. **18** is a diagram showing the functional configuration of the SOC-OCV correction unit according to the third embodiment of the present invention.

[0028] FIG. **19** is a diagram showing an example of the correction limit width designated by the correction limit width designation unit according to the third embodiment of the present invention.

[0029] FIG. **20** is a diagram explaining the effect based on the third embodiment of the present invention in comparison to the effect of the second embodiment.

[0030] FIG. **21** is a diagram showing the functional configuration of the SOC-OCV correction unit according to the fourth embodiment of the present invention.

[0031] FIG. **22** is a diagram showing the configuration of the pattern calling unit according to the fourth embodiment of the present invention.

[0032] FIG. **23** is a diagram showing an example of the SOC-OCV characteristics of the SOC-OCV library according to the fourth embodiment of the present invention.

[0033] FIG. **24** is a diagram explaining the effect based on the fourth embodiment of the present invention in comparison to the effect of the first embodiment.

[0034] FIG. **25** is a diagram showing the functional configuration of the SOC-OCV correction unit according to the fifth embodiment of the present invention.

[0035] FIG. **26** is a diagram showing the functional configuration of the direct detection correction unit according to the fifth embodiment of the present invention.

[0036] FIG. **27** is a flowchart showing the processing flow of the SOC-OCV correction unit according to the fifth embodiment of the present invention.

[0037] FIG. **28** is a diagram explaining the effect based on the fifth embodiment of the present invention.

[0038] FIG. **29** is a diagram showing the functional configuration of the SOC-OCV correction unit according to the sixth embodiment of the present invention.

[0039] FIG. **30** is a diagram showing the functional configuration of the direct detection correction unit according to the sixth embodiment of the present invention.

[0040] FIG. **31** is a diagram showing the functional configuration of the SOC-OCV convergence determination unit.

[0041] FIG. **32** is a flowchart showing the processing flow of the SOC-OCV correction unit according to the sixth embodiment of the present invention.

[0042] FIG. **33** is a diagram explaining the effect based on the sixth embodiment of the present invention.

DESCRIPTION OF EMBODIMENTS

[0043] An embodiment of the present invention is now explained with reference to the appended drawings. In the following embodiment, explained is a case of applying the present invention to a battery system configuring a power source of a plug-in hybrid electric vehicle (PHEV). However, the present invention is not limited to the configuration of the embodiment explained below, and the present invention can also be applied to a capacitor control circuit of an electrical storage device configuring the power source of passenger vehicles such as hybrid electric vehicles (HEV) and electric vehicles (EV), and industrial vehicles such as hybrid railway vehicles.

[0044] Moreover, while the following embodiment explains a case of adopting a lithium ion battery, other batteries such as a nickel hydride battery, a lead battery, an electric double-layer capacitor, and a hybrid capacitor may also be used so long as it is a chargeable/dischargeable secondary battery. Furthermore, in the following embodiment, while an assembled battery is configured by connecting a plurality of single batteries in series, the assembled battery may also be configured by additionally connecting in series a plurality of assembled batteries configured by connecting a plurality of single batteries in parallel, or the

assembled battery may also be configured by connecting in parallel a plurality of assembled batteries configured by connecting a plurality of single batteries in series.

<System Configuration>

[0045] FIG. **1** is a diagram showing the battery system **100** according to an embodiment of the present invention and the peripheral configuration thereof. The battery system **100** is connected to an inverter **400** via relays **300**, **310**, and connected to a charger **420** via relays **320**, **330**. The battery system **100** comprises an assembled battery **110**, a single battery management unit **120**, a current detection unit **130**, a voltage detection unit **140**, an assembled battery control unit **150**, and a storage unit **180**.

[0046] The assembled battery **110** is configured from a plurality of single batteries **111**. The single battery management unit **120** monitors the state of the single battery **111**. The current detection unit **130** detects the current flowing through the battery system **100**. The voltage detection unit **140** detects the total voltage of the assembled battery **110**. The assembled battery control unit **150** detects and manages the state of the assembled battery **110**.

[0047] The assembled battery control unit **150** receives the battery voltage and the temperature of the single batteries **111** sent from the single battery management unit **120**, the current value flowing through the battery system **100** sent from the current detection unit **130**, and the total voltage value of the assembled battery **110** sent from the voltage detection unit **140**. The assembled battery control unit **150** detects the state of the assembled battery **110** based on the received information. The results of the state detected by the assembled battery control unit **150** are sent to the single battery management unit **120** and the vehicle control unit **200**.

[0048] The assembled battery **110** is configured by electrically connecting in series a plurality of single batteries **111** capable of storing and releasing electrical energy (charging/discharging DC power). The single batteries **111** configuring the assembled battery **110** are grouped into a predetermined number of units upon managing and controlling the state. The grouped single batteries **111** are electrically connected in series and configure single battery groups **112***a*, **112***b*. The number of single batteries **111** configuring the single battery group **112** may be the same in all single battery groups **112**, or the number of single batteries **111** may differ for each single battery group **112**.

[0049] The single battery management unit **120** monitors the state of the single batteries **111** configuring the assembled battery **110**. The single battery management unit **120** comprises a single battery control unit **121** provided for each single battery group **112**. In FIG. **1**, single battery control units **121***a* and **121***b* are provided in correspondence to the single battery groups **112***a* and **112***b*. The single battery control unit **121** monitors and controls the state of the single batteries **111** configuring the single battery group **112**.

[0050] In this embodiment, in order to simplify the explanation, the single battery groups **112***a* and **112***b* are configured by electrically connecting four single batteries **111** in series, and the single battery groups **112***a* and **112***b* are further electrically connected in series to configure the assembled battery **110** comprising a total of eight single batteries **111**.

[0051] The assembled battery control unit **150** and the single battery management unit **120** send and receive signals via an insulation element **170** as represented by a photocoupler and a signal communication means **160**. The reason why the insulation element **170** is provided is because the assembled battery control unit **150** and the single battery management unit **120** use different operating power sources. In other words, while the single battery management unit **120** operates by using the power from the assembled battery **110**, the assembled battery control unit **150** uses an in-vehicle auxiliary battery (such as a 14V-system battery) as its power source. The insulation element **170** may be mounted on a circuit board configuring the single battery management unit **120**, or may be mounted on a circuit board configuring the assembled battery control unit **150**. Note that the insulation element **170** may be omitted depending on the system configuration.

[0052] The communication means between the assembled battery control unit **150** and the single battery control units **121***a* and **121***b* configuring the single battery management unit **120** is now explained. The single battery control units **121***a* and **121***b* are connected in series in descending order of the potential of the single battery groups **112***a* and **112***b* that are respectively monitored by the single battery control units **121***a* and **121***b*. The signals sent by the assembled battery control unit **150** to the single battery management unit **120** are input to the single battery control unit **121***a* via the insulation element **170** and the signal communication means **160**. The output of the single battery control unit **121***a* is input to the single battery control unit **121***b* via the signal communication means **160**, and the output of the single battery control unit **121***b* of the lowest numerical position is transmitted to the assembled battery control unit **150** via the insulation element **170** and the signal communication means **160**. In this embodiment, while the insulation element **170** is not provided between the single battery control unit **121***a* and the single battery control unit **121***b*, the signals may also be sent and received via the insulation element **170**.

[0053] The storage unit **180** stores information such as the internal resistance characteristics, full charge capacity, polarization characteristics, degradation characteristics, individual difference information, and characteristics of the SOC and the OCV of the assembled battery **110**, the single battery **111**, and the single battery group **112**. Note that, in this embodiment, while the storage unit **180** is configured to be disposed outside the assembled battery control unit **150** or the single battery management unit **120**, the configuration may also be such that the assembled battery control unit **150** or the single battery management unit **120** comprises a storage unit, and the foregoing information may be stored therein.

[0054] The vehicle control unit **200** controls the inverter **400** connected to the battery system **100** via the relay **300** by using the information sent by the assembled battery control unit **150**. Moreover, the vehicle control unit **200** controls the charger **420** connected to the battery system **100** via the relays **320** and **330**. While the vehicle is running, the battery system **100** is connected to the inverter **400**, and drives the motor generator **410** using the energy stored in the assembled battery **110**. When charging the batteries, the battery system **100** is connected to the charger **420**, and charged with the power supplied from a household power source or a charging station.

[0055] The charger **420** is used for charging the assembled battery **110** using an external power source as represented by a household power source or a charging station. In this

embodiment, while the charger **420** is configured to control the charging voltage and the charging current based on commands from the vehicle control unit **200**, the charging voltage and the charging current may also be controlled based on commands from the assembled battery control unit **150**. Moreover, the charger **420** may be installed within the vehicle according to the vehicle configuration, performance or purpose of use of the charger **420**, or installation condition of the external power source, or may be installed outside the vehicle.

[0056] When a vehicle system equipped with the battery system **100** is to be activated and driven, based on the management of the vehicle control unit **200**, the battery system **100** is connected to the inverter **400**, the motor generator **410** is driven using the energy stored in the assembled battery **110**, and the assembled battery **110** is charged based on the generated power of the motor generator **410** during regeneration. When a vehicle comprising the battery system **100** is connected to an external power source as represented by a household power source or a charging station, the battery system **100** and the charger **420** are connected based on the information transmitted by the vehicle control unit **200**, and the assembled battery **110** is charged until reaching a predetermined condition. The energy stored in the assembled battery **110** based on charging is used when the vehicle is subsequently driven, or used for operating the electrical components inside and outside the vehicle. Furthermore, in certain cases such energy is released to an external power source as represented by a household power source as needed.

[0057] FIG. **2** is a diagram showing the circuit configuration of the single battery control unit **121**. The single battery control unit **121** comprises a voltage detection circuit **122**, a control circuit **123**, a signal input/output circuit **124**, and a temperature detection unit **125**. The voltage detection circuit **122** measures the inter-terminal voltage of each single battery **111**. The control circuit **123** receives the measurement results from the voltage detection circuit **122** and the temperature detection unit **125**, and sends the received measurement results to the assembled battery control unit **150** via the signal input/output circuit **124**. Note that the circuit configuration that is generally equipped in the single battery control unit **121** for equalizing the voltage variation and the SOC variation between the single batteries **111** that occur pursuant to a self-discharge or consumption current variation is well known, and the explanation thereof has been omitted.

[0058] The temperature detection unit **125** equipped in the single battery control unit **121** shown in FIG. **2** includes a function of measuring the temperature of the single battery group **112**. The temperature detection unit **125** measures one temperature of the single battery group **112** as a whole, and treats the representative temperature value of the single batteries **111** configuring the single battery group **112** as the temperature of the single battery group **112**. The temperature measured by the temperature detection unit **125** is used for various types of operations for detecting the state of the single batteries **111**, the single battery group **112**, or the assembled battery **110**. In FIG. **2**, based on the foregoing premise, one temperature detection unit **125** is provided to the single battery control unit **121**. While it is also possible to provide the temperature detection unit **125** to each single battery **111** and measure the temperature for each single battery **111** and execute various types of operations based on the temperature of each single battery **111**, in the foregoing case, since the number of temperature detection units **125** will increase, the configuration of the single battery control unit **121** will become complicated.

[0059] FIG. **2** shows the temperature detection unit **125** in a simplified manner. In effect, a temperature sensor is installed on the temperature measuring object, the installed temperature sensor outputs the temperature information as a voltage, the measurement result is sent to the signal input/output circuit **124** via the control circuit **123**, and the signal input/output circuit **124** outputs the measurement result outside the single battery control unit **121**. The function for realizing the series of processes is mounted on the single battery control unit **121** as the temperature detection unit **125**, and the voltage detection circuit **122** may also be used for measuring the temperature information (voltage).

[0060] FIG. **3** is a diagram showing the functional configuration of the SOC operation system **155** in the assembled battery control unit **150**. The assembled battery control unit **150** is the part that determines the state of each single battery **111** in the assembled battery **110** and the power that can be input to and output from each single battery **111** based on the current value and the voltage value of each single battery **111** detected while the vehicle is moving, and includes the SOC operation system **155** shown in FIG. **3** as one functional constituent element thereof. The SOC operation system **155** is the part that assumes the function corresponding to the battery control device according to an embodiment of the present invention, and has the function of operating the state of charge (SOC) of each single battery **111**. Note that, while the assembled battery control unit **150** is also equipped with various functions required for controlling the assembled battery **10** in addition to the SOC operation system **155**, such as the function of operating the state of health (SOH) of each single battery **111** and the function of the determining the input/output power of each single battery **111**, since these functions are well known and not directly related to the present invention, the detailed explanation thereof is omitted.

[0061] The SOC operation system **155** includes, as its functions, the respective functional blocks of an OCV operation unit **153**, a capacity calculation unit **154**, an SOC-OCV correction unit **151**, and an SOC operation unit **152**. The SOC operation system **155** operates, based on these functional blocks, the SOC of each single battery **111** based on the current of the assembled battery **110**, or the current of each single battery **111**, detected by the current detection unit **130**, and the voltage and the temperature of each single battery **111** detected by the single battery management unit **120**. Specifically, the SOC operation system **155** foremost obtains, based on the OCV operation unit **153**, the open circuit voltage (OCV) of each single battery **111** based on the current, the close circuit voltage (CCV), the temperature and the state of health (SOH) of each single battery **111**. Note that the SOH of each single battery **111** can be obtained, for example, with the SOH operation unit (not shown) in the assembled battery control unit **150**. Next, the SOC-OCV correction unit **151** corrects the predetermined characteristic representing the relationship of the SOC and the OCV (SOC-OCV characteristic) of each single battery **111** based on the OCV of each single battery **111** obtained by the OCV operation unit **153**. Finally, the SOC operation unit **152** calculates the SOC of each single battery **111** using the SOC-OCV characteristic corrected by the SOC-OCV cor-

rection unit **151**. The value of the thus calculated SOC of each single battery **111** is output as the $SOC_{control}$ from the SOC operation system **155** and used in the various types of control of the assembled battery **110**.

[0062] Note that, while a case of the SOC operation system **155** calculating the SOC of each single battery **111** was explained above, the SOC of a plurality of single batteries **111** may also be calculated collectively. For example, the SOC may be calculated for each of the single battery groups **112***a*, **112***b* or the SOC may be calculated for the assembled battery **110** as a whole. Even in the foregoing cases, the SOC can be calculated based on the same processing as the single batteries **111**. Moreover, the SOC of each single battery **111** can be calculated based on the same processing. Accordingly, in the following explanation, the operation of the SOC operation system **155** will be explained by referring to the calculation target of the SOC simply as a "battery".

[0063] The OCV operation unit **153** uses the CCV, the current I, the temperature T, and the SOH of the battery as the inputs, and outputs the OCV and the polarization voltage (overvoltage) V_p of the battery based on these inputs. Specifically, the OCV operation unit **153** operates the OCV using Formula (1) below according to an equivalent circuit model of the battery. Note that the polarization voltage V_p is operated as the voltage value of each equivalent circuit component when multiplying the equivalent circuit model of the battery by the current I, and is generally configured from a plurality of elements such as a direct current resistance component and a polarization component. Here, the value of each element of the equivalent circuit model of the battery is generally dependent on the temperature T and the SOH of the battery. Moreover, as the SOH of the battery, generally used is the SOHR which indicates the increase rate of the direct current resistance of the battery, or the SOHQ which indicates the decrease rate of the battery capacity. In this embodiment, while the explanation is provided by using the SOHR as the SOH, the same applies to cases where the SOHQ is used as the SOH.

[0064] [Math 1]

$$OCV=CCV-\Sigma V_p(I,T,SOH) \quad (1)$$

[0065] The capacity calculation unit **154** uses the SOH as the input, and outputs the battery capacity Q_{max}. In this embodiment, for example, based on the known empirical rule that the battery capacity takes on an inverse relationship of the SOH, the battery capacity Q_{max} corresponding to the input SOH is acquired by the capacity calculation unit **154**.

[0066] The SOC-OCV correction unit **151** corrects the pre-stored SOC-OCV characteristic based on the current I and the SOH input to the SOC operation system **155**, the OCV and the polarization voltage V_p calculated by the OCV operation unit **153**, and the battery capacity Q_{max} calculated by the capacity calculation unit **154**. The SOC-OCV correction unit **151** subsequently outputs the corrected SOC-OCV characteristic as the $SOC\text{-}OCV_{temp}$, which is the SOC-OCV characteristic to be temporarily used in the SOC operation unit **152**.

[0067] The SOC operation unit **152** calculates the SOC corresponding to the OCV calculated by the OCV operation unit **153** using the $SOC\text{-}OCV_{temp}$ calculated by the SOC-OCV correction unit **151**. The SOC operation unit **152** subsequently outputs the $SOC_{control}$ to be used for controlling the battery based on the value of the calculated SOC.

[0068] The SOC-OCV correction unit **151** is now explained in detail. The SOC-OCV correction unit **151** can be realized based on various embodiments as explained below.

First Embodiment

[0069] FIG. **4** is a diagram showing the functional configuration of the SOC-OCV correction unit **151** according to the first embodiment of the present invention. The SOC-OCV correction unit **151** in this embodiment includes a pattern calling unit **510**, a correction limit width designation unit **520**, and a direct detection correction unit **530**.

[0070] The pattern calling unit **510** determines the degradation pattern of the battery based on the use history information of the battery, and calls the SOC-OCV characteristic corresponding to that degradation pattern among a plurality of SOC-OCV characteristics stored in advance. The pattern calling unit **510** subsequently outputs the information of the called SOC-OCV characteristic as the $SOC\text{-}OCV_{pattern}$. The use history information of a battery is information representing the previous use history (operating history) of the battery in the battery system **100**, and is used as the index for indicating the state of health (SOH) of the battery. In this embodiment, the SOH is used as the use history information of the battery.

[0071] The correction limit width designation unit **520** designates the correction limit width for prescribing the tolerance level of the correction to be performed by the direct detection correction unit **530** to the $SOC\text{-}OCV_{pattern}$. FIG. **5** is a diagram showing an example of the correction limit width designated by the correction limit width designation unit **520** according to the first embodiment of the present invention. In this embodiment, for example, as shown in the left diagram of FIG. **5**, the correction limit width designation unit **520** designates a certain OCV width for each SOC of the $SOC\text{-}OCV_{pattern}$ as the correction limit width. This OCV width is set, for example, according to the tolerance of the OCV based on the production tolerance of the battery. In other words, when a change in the OCV that is greater than the production tolerance occurs in the battery, the correction limit width designation unit **520** designates the correction limit width so that the direct detection correction unit **530** can exclude such change as an operational error. Otherwise, for example, as shown in the right diagram of FIG. **5**, the correction limit width designation unit **520** may also designate a certain SOC width for each OCV of the $SOC\text{-}OCV_{pattern}$ as the correction limit width. In the foregoing case, the range of correction to be performed by the direct detection correction unit **530** to the $SOC\text{-}OCV_{pattern}$ is limited to be within the range of the SOC width designated based on the correction limit width.

[0072] The direct detection correction unit **530** corrects the $SOC\text{-}OCV_{pattern}$ output from the pattern calling unit **510** based on the current I and the OCV according to the correction limit width designated by the correction limit width designation unit **520**. The direct detection correction unit **530** subsequently outputs the correction result as the $SOC\text{-}OCV_{temp}$ explained above.

[0073] FIG. **6** is a diagram showing the functional configuration of the pattern calling unit **510** according to the first embodiment of the present invention. The pattern calling unit **510** includes a pattern determination unit **511**, and an SOC-OCV library **512**.

[0074] The SOC-OCV library **512** has a database of the SOC-OCV characteristics corresponding to various types of SOH. FIG. **7** is a diagram showing an example of the SOC-OCV characteristics of the SOC-OCV library **512** according to the first embodiment of the present invention. FIG. **7** shows that, in each case where the value of the SOH is 100%, 120%, 140%, . . . , respectively different SOC-OCV characteristics are stored in the SOC-OCV library **512**. Here, the SOC-OCV library **512** can be realized, for example, by conducting a degradation test of each single battery **111** and acquiring in advance the relationship of the SOC and the OCV when the degradation of each single battery **111** advances and the value of the SOH changes, and compiling a database of the relationship.

[0075] The pattern determination unit **511** performs pattern determination to the input SOH, and calls the SOC-OCV characteristic corresponding to that pattern determination result by searching the SOC-OCV library **512**. The pattern determination unit **511** subsequently generates the $SOC\text{-}OCV_{pattern}$ from the called SOC-OCV characteristic and outputs the generated $SOC\text{-}OCV_{pattern}$. Here, it is also possible to call the SOC-OCV characteristic of the SOH condition that is closest to the input SOH, and directly output the called SOC-OCV characteristic as the $SOC\text{-}OCV_{pattern}$. Otherwise, it is also possible to identify two mutually adjacent SOH values (SOH_1, SOH_2) that become $SOH_1<SOH<SOH_2$ in relation to the input SOH, call the SOC-OCV characteristics respectively corresponding to such SOH values from the SOC-OCV library **512** and operate the SOC-OCV characteristic based on interpolation, and output the obtained SOC-OCV characteristic as the $SOC\text{-}OCV_{pattern}$. The SOC-OCV from the pattern output pattern determination unit **511** is stored, for example, in a memory not shown, and read by the direct detection correction unit **530**.

[0076] FIG. **8** is a diagram showing the functional configuration of the direct detection correction unit **530** according to the first embodiment of the present invention. The direct detection correction unit **530** includes a corrected OCV pair/integrated current acquisition unit **531**, an SOC-OCV direct detection correction unit **532**, and an SOC-OCV overwrite determination unit **533**.

[0077] The corrected OCV pair/integrated current acquisition unit **531** uses the current I, the OCV, the battery capacity Q_{max} and the polarization voltage V_p that respectively change with time according to the battery state as the inputs, and outputs a difference ΔSOC of the SOC based on direct detection and a pair (OCV_1, OCV_2) of the OCV based on these inputs. Specifically, the corrected OCV pair/integrated current acquisition unit **531** acquires the OCV pair (OCV_1, OCV_2) by acquiring two points of an OCV value which is stable within a range of a predetermined duration. The corrected OCV pair/integrated current acquisition unit **531** subsequently uses Formula (2) below to calculate a difference ΔSOC of the SOC based on direct detection by obtaining a current integrated value in a period from the acquisition of the OCV_1 to the acquisition of the OCV_2 and dividing the obtained current integrated value by the battery capacity Q_{max}. Note that, in Formula (1), $t(OCV_1)$ and $t(OCV_2)$ represent the time that the OCV_1 was acquired and the time that the OCV_2 was acquired, respectively.

[Math 2]

$$\Delta SOC = \frac{\int_{t(OCV_1)}^{t(OCV_2)} Idt}{Q_{max}} \tag{2}$$

[0078] FIG. **9** is a diagram explaining the acquisition method of a stable OCV pair (OCV_1, OCV_2). The corrected OCV pair/integrated current acquisition unit **531** determines that the OCV value is stable, for example, as shown in FIG. **9**, when the absolute value of the current I is smaller than a predetermined current threshold, and the absolute value of the polarization voltage V_p is smaller than a predetermined polarization voltage threshold. When the period between two points of time $t(OCV_1)$ and $t(OCV_2)$ which satisfy these stable conditions is equal to or greater than a predetermined time threshold **t1** and equal to or less than a predetermined time threshold **t2** (**t1**<**t2**), the two OCV values at time $t(OCV_1)$ and time $t(OCV_2)$ are acquired as the OCV_1 and the OCV_2. Note that three or more OCV values that satisfy these conditions may also be acquired as a combination of stable OCVs.

[0079] The SOC-OCV direct detection correction unit **532** corrects the $SOC\text{-}OCV_{pattern}$ based on the OCV pair (OCV_1, OCV_2) detected by the corrected OCV pair/integrated current acquisition unit **531** and the ΔSOC calculated based thereon, and outputs the correction result as the $SOC\text{-}OCV_{pattern,\ fixed}$. Specifically, in this embodiment, the SOC-OCV direct detection correction unit **532** uses at least one point on the SOC-OCV characteristic indicated by the input $SOC\text{-}OCV_{pattern}$ as the origin (reference point), and, each time that it acquires the ΔSOC and the OCV_1, OCV_2 from the corrected OCV pair/integrated current acquisition unit **531**, the SOC-OCV direct detection correction unit **532** corrects the $SOC\text{-}OCV_{pattern}$ based thereon and creates the $SOC\text{-}OCV_{pattern,\ fixed}$.

[0080] For example, when the point (OCV_1, SOC_1) corresponding to the OCV_1 in the SOC-OCV characteristic indicated by the $SOC\text{-}OCV_{pattern}$ is used as the reference point, the value of the SOC in the directly detected OCV_2 can be obtained based on Formula (3) below.

[0081] [Math 3]

$$SOC(OCV_2)=SOC_1+\Delta SOC \tag{3}$$

[0082] Similarly, the $SOC\text{-}OCV_{pattern,\ fixed}$ can also be created by correcting the SOC-OCV characteristic indicated by the $SOC\text{-}OCV_{pattern}$ one point at a time using a plurality of combinations of the OCV and the SOC respectively obtained based on direct detection. Specifically, when the SOC-OCV characteristic indicated by the $SOC\text{-}OCV_{pattern}$ is divided into k-number of SOC-OCV characteristics on the SOC axis and the n-th acquisition point is located at the k-th point, the $SOC\text{-}OCV_{pattern,\ fixed}$ can be obtained by correcting the SOC-OCV characteristic using the recurrence formula shown in Formula (4) below. In Formula (4), k represents the fineness of the interval for expressing the SOC-OCV characteristic as a sequence, and the SOC-OCV characteristic will be smoother as the k is greater. Moreover, the $OCV_{k,\ 0}$ and the $SOC_{k,\ 0}$ respectively represent the OCV value and the SOC value at the reference point set on the SOC-OCV characteristic indicated by the $SOC\text{-}OCV_{pattern}$. Moreover, no represents the weight when the $SOC\text{-}OCV_{pattern}$ takes on an initial value, and is a value that is equal to

or greater than 0. When $n_0=0$, the SOC-OCV$_{pattern,\ fixed}$ is created by using the SOC-OCV$_{pattern}$ only at the origin. In this embodiment, as a result of creating the SOC-OCV$_{pattern,\ fixed}$ by using this kind of recurrence formula, it is possible to reduce the memory for storing the point (OCV, SOC) obtained based on direct detection.

[Math 4]

$$\overline{OCV}_{k,n}=\frac{n_0+n-1}{n_0+n}\overline{OCV}_{n-1}+\frac{1}{n_0+n}OCV_n \qquad (4)$$
$$\overline{SOC}_{k,n}=\frac{n_0+n-1}{n_0+n}\overline{SOC}_{n-1}+\frac{1}{n_0+n}SOC_n$$

[0083] Note that the SOC-OCV direct detection correction unit **532** may also create the SOC-OCV$_{pattern,\ fixed}$ based on the SOC-OCV characteristic expressed as the sum average of a plurality of points obtained based on direct detection rather than using the recurrence formula of Formula (4) above. Specifically, for example, the SOC-OCV$_{pattern,\ fixed}$ can be obtained by correcting the SOC-OCV characteristic indicated by the SOC-OCV$_{pattern}$ using Formula (5) below. In the foregoing case, while the number of calculations performed is less in comparison to the case of using Formula (4), the data volume of the point (OCV, SOC) to be stored in the memory will increase. It would be preferable to use this calculation method when it is desirable to concentrate the calculation load in a single time step.

[Math 5]

$$\overline{OCV}_{k,n}=\frac{n_0OCV_0+\sum_{i=1}^{i=n}OCV_i}{n_0+n} \qquad (5)$$
$$\overline{SOC}_{k,n}=\frac{n_0SOC_0+\sum_{i=1}^{i=n}SOC_i}{n_0+n}$$

[0084] The SOC-OCV direct detection correction unit **532** outputs the SOC-OCV$_{pattern,\ fixed}$ obtained by correcting the SOC-OCV$_{pattern}$ in the manner described above, and additionally outputs a sequence N_{count} representing the correction count at each point k on the SOC-OCV characteristic.

[0085] The SOC-OCV overwrite determination unit **533** determines the timing of overwriting the SOC-OCV$_{temp}$ (overwrite timing of the SOC-OCV characteristic) based on the SOC-OCV$_{pattern,\ fixed}$ by using the correction limit width input from the correction limit width designation unit **520**. The SOC-OCV overwrite determination unit **533** determines the overwrite timing of the SOC-OCV characteristic, for example, in the following manner based on the sequence N_{count} output from the SOC-OCV direct detection correction unit **532**.

[0086] FIG. **10** is a diagram explaining the overwrite timing of the SOC-OCV characteristic. Foremost, as shown in FIG. **10**, the SOC-OCV overwrite determination unit **533** determines whether the sequence N_{count} is equal to or greater than a predetermined threshold sequence N_{th} at all points k. Note that, in FIG. **10**, N_{count}(k) represents the value of the sequence N_{count} at each point k, and N_{th}(k) represents the value of the threshold sequence N_{th} at each point k. Consequently, the SOC-OCV overwrite determination unit **533** continues to correct the SOC-OCV$_{pattern}$ without overwriting the SOC-OCV$_{temp}$ when the sequence N_{count} is less than the threshold sequence N_{th} in at least one point k, and determines whether the SOC-OCV$_{pattern,\ fixed}$ is within the correction limit width when the sequence N_{count} becomes equal to or greater than the threshold sequence N_{th} at all points k. Here, the value of the threshold sequence N_{th} can be set according to the frequency that the SOC and the OCV are acquired while the vehicle is actually moving, or the likelihood of the individual variation of the battery. Consequently, when the SOC-OCV$_{pattern,\ fixed}$ is within the correction limit width, the SOC-OCV overwrite determination unit **533** determines that it is the overwrite timing of the SOC-OCV characteristic, overwrites the SOC-OCV$_{temp}$ with the SOC-OCV$_{pattern,\ fixed}$, and outputs the result. Meanwhile, when the SOC-OCV$_{pattern}$, fixed is exceeding the correction limit width, the SOC-OCV overwrite determination unit **533** resets the previously stored SOC-OCV$_{pattern,\ fixed}$, and re-performs the operation.

[0087] FIG. **11** is a diagram explaining the method of determining whether the SOC-OCV$_{pattern,\ fixed}$, which is the corrected SOC-OCV characteristic, is within the correction limit width based on the SOC-OCV overwrite determination unit **533**. When obtaining the SOC-OCV$_{pattern,\ fixed}$ by correcting the SOC-OCV$_{pattern}$, each point may move in both the SOC axis direction and the OCV axis direction. Thus, as shown in FIG. **11**, when a point **701** on the SOC-OCV$_{pattern,\ fixed}$ is located between two points **702**, **703** on the SOC-OCV$_{pattern}$, a perpendicular line is drawn downward from the point **701** relative to the line segment that connects these two points, and an intersection point **704** of the perpendicular line and the line segment is obtained. In other words, when the values of the SOC and the OCV at the point **701** are expressed as (SOC$_{fixed,\ i}$, OCV$_{fixed,\ i}$) the values of the SOC and the OCV at the point **702** are expressed as (SOC$_{pattern,\ i}$, OCV$_{pattern,\ i}$) and the values of the SOC and the OCV at the point **703** are expressed as (SOC$_{pattern,\ i+1}$, OCV$_{pattern,\ i+1}$), the values of the SOC and the OCV on the intersection point **704** can be expressed as (SOC$_{fixed,\ i}$, OCV'$_{pattern,\ i}$). Here, the value of the OCV'$_{pattern,\ i}$ exists between the OCV$_{pattern,\ i}$ and the OCV$_{pattern,\ i+1}$ and can be decided according to the ratio of the difference between the SOC$_{fixed,\ i}$ and the SOC$_{pattern,\ i}$ and the difference between the SOC$_{fixed,\ i}$ and the SOC$_{pattern,\ i+1}$.

[0088] Once the values of the SOC and the OCV on the intersection point **704** have been acquired in the manner described above, the squared difference of the OCV at the point **701** and the intersection point **704** is evaluated by being compared with the correction limit width based on Evaluation Formula (6) below. Consequently, it is determined that the point **701** is within the correction limit width when Evaluation Formula (6) is satisfied, and it is determined that the point **701** is exceeding the correction limit width when Evaluation Formula (6) is not satisfied. As a result of performing the foregoing evaluation to all points k on the SOC-OCV$_{pattern,\ fixed}$, it is possible to determine whether the SOC-OCV$_{pattern,\ fixed}$ is within the correction limit width.

[0089] [Math 6]

$$(OCV_{fixed,i}-OCV'_{pattern,i})^2 \leq 修正限界幅 \qquad (6)$$

修正限界幅 : correction limit width

[0090] Note that the determination method explained above is an example of a determination method in a case where, as shown in the left diagram of FIG. **5** explained

above, a certain OCV width for each SOC of the SOC-$OCV_{pattern}$ has been designated as the correction limit width. When a certain SOC width for each OCV of the SOC-$OCV_{pattern}$ has been designated as the correction limit width as shown in the right diagram of FIG. **5**, it is possible to determine whether the SOC-$OCV_{pattern, fixed}$ is within the correction limit width based on a similar method by switching the SOC and the OCV in the foregoing determination method.

[0091] The overall operation of the SOC-OCV correction unit **151** is now explained with reference to the flowchart of FIG. **12**. FIG. **12** is a flowchart showing the processing flow of the SOC-OCV correction unit **151** according to the first embodiment of the present invention. As the previous step of the processing flow of FIG. **12**, let it be assumed that the SOC-OCV correction unit **151** has acquired the SOC-OCV characteristic for each state of health corresponding to the operating history of the battery (SOH in this embodiment) from the results of the degradation test of the battery conducted in advance, and such acquired SOC-OCV characteristics are stored in the SOC-OCV library **512**.

[0092] In initial START step **601** of FIG. **12**, the processing of step **602** onward is performed by causing the SOC-OCV correction unit **151** to start a predetermined SOC-OCV characteristic correction logic.

[0093] In battery system ON determination step **602**, whether the key of the vehicle has been turned ON and the battery system **100** has been consequently turned ON is determined. Step **602** is repeated when the battery system **100** is OFF, and the processing is advanced to subsequent step **603** when it is confirmed that the battery system **100** has been turned ON.

[0094] In battery history reading step **603**, the use history information of the battery is read. Here, the values of the $SOC_{control}$, the SOC-OCV_{temp}, the SOH and the like at the time that the previous processing was ended are read from the storage unit **180** as the use history information of the battery, and read into the memory.

[0095] In degradation pattern determination step **604**, the degradation pattern is determined from the battery history read in step **603**. Here, the pattern determination unit **511** of the pattern calling unit **510** determines the degradation pattern according to the SOH read in step **603** based on the method described above.

[0096] In pattern SOC-OCV reading step **605**, the SOC-OCV characteristic corresponding to the degradation pattern obtained in step **604** is read. Here, the SOC-OCV characteristic corresponding to the degradation pattern determined in step **604** is called among the various SOC-OCV characteristics stored in the SOC-OCV library **512** of the pattern calling unit **510**, and stored in the memory as the SOC-$OCV_{pattern}$.

[0097] In direct detection correction limit width decision step **606**, the correction limit width designation unit **520** decides the correction limit width for the SOC-$OCV_{pattern}$ read from the SOC-OCV library **512** in step **605**.

[0098] In direct detection correction step **607**, the direct detection correction unit **530** corrects the SOC-$OCV_{pattern}$ based on direct detection by using the respective state measurement values of the battery capacity Q_{max}, the current I, the OCV, and the polarization voltage V_p obtained from the battery system **100**, and the SOC-$OCV_{pattern}$ read from the SOC-OCV library **512** in step **605**. Here, foremost, the corrected OCV pair/integrated current acquisition unit **531** of the direct detection correction unit **530** acquires a stable OCV pair (OCV_1, OCV_2) as described above based on the respective state measurement values of the battery, and obtains the difference ΔSOC of the SOC therebetween. Subsequently, based on these values, the SOC-OCV direct detection correction unit **532** calculates the SOC-$OCV_{pattern, fixed}$, which is the SOC-OCV characteristic obtained by correcting the SOC-$OCV_{pattern}$, and the sequence N_{count} representing the correction count at each point based on the method described above.

[0099] In direct detection correction count determination step **608**, the acquisition count of the SOC and the OCV based on direct detection; that is, whether the correction count of the SOC-OCV characteristic based thereon is equal to or greater than a predetermined threshold is determined. Here, the SOC-OCV overwrite determination unit **533** of the direct detection correction unit **530** determines whether the sequence N_{count} of the correction count calculated in step **607** is equal to or greater than a predetermined threshold sequence N_{th} at all points. If the N_{count} is consequently less than the N_{th} in at least one point, the processing is returned to step **607** and the correction of the SOC-$OCV_{pattern}$ based on direct detection is continued. Meanwhile, the processing is advanced to step **609** when the N_{count} is equal to or greater than the N_{th} at all points.

[0100] In correction limit width determination step **609**, whether the SOC-$OCV_{pattern, fixed}$ obtained as the corrected SOC-OCV characteristic in step **607** is within the range of the correction limit width decided in step **606** is determined. Here, the SOC-OCV overwrite determination unit **533** determines whether the SOC-$OCV_{pattern, fixed}$ is within the correction limit width based on the method described above. The processing is advanced to calculation reset step **610** when the SOC-$OCV_{pattern, fixed}$ is outside the correction limit width, the previously obtained values of the SOC-$OCV_{pattern, fixed}$ and the N_{count} are reset in step **610**, and the operation is thereafter re-performed from step **607**. Meanwhile, the processing is advanced to step **611** when the SOC-$OCV_{pattern, fixed}$ is within the correction limit width.

[0101] In SOC-OCV characteristic overwrite step **611**, the SOC-OCV overwrite determination unit **533** overwrites the SOC-OCV_{temp} to be used for the operation of the $SOC_{control}$ with the SOC-$OCV_{pattern, fixed}$ obtained in step **607**, and outputs the result.

[0102] In SOC-OCV characteristic storage step **612**, the SOC-OCV_{temp} overwritten in step **611** is stored in the storage unit **180**.

[0103] In key OFF determination step **613**, whether the key OFF operation of the vehicle has been performed is determined. When the key OFF operation has not been performed and the key of the vehicle is still ON, this step is repeated. When the key OFF operation is detected, the processing is advanced to subsequent step **614**.

[0104] In battery history storage step **614**, the values of the $SOC_{control}$, the SOC-OCV_{temp}, the SOH and the like when the key OFF operation was performed are stored in the storage unit **180** as the use history information of the battery.

[0105] In battery system OFF step **615**, the power source of the battery system **100** is turned OFF.

[0106] In final END step **616**, the operation of FIG. **12** is ended, and the operation of the SOC-OCV correction unit **151** is stopped.

[0107] Note that, in this embodiment, the correction of the SOC-OCV characteristic performed by the SOC-OCV cor-

rection unit **151** may be performed to one SOC-OCV characteristic representing the overall assembled battery **110** as described above, or may be performed individually to all single batteries **111** in the assembled battery **110**. With the assembled battery **110**, generally speaking, since the internal temperature distribution is not uniform and the temperature of the center part becomes highest, differences in the progress of degradation will occur for each single battery **111**. Accordingly, by correcting the SOC-OCV characteristic for each single battery **111**, it is possible to obtain an accurate SOC-OCV characteristic according to the temperature distribution.

[0108] The effect of the present invention is now explained with reference to FIG. **13** and FIG. **14**.

[0109] FIG. **13** is a diagram explaining the divergence inhibiting effect of the SOC-OCV characteristics according to the present invention. In FIG. **13**, a conceptual diagram **801** on the left side shows a case where the $SOC\text{-}OCV_{pattern, fixed}$ is within the range of the correction limit width. In this conceptual diagram **801**, the $SOC\text{-}OCV_{pattern}$ before correction is shown with a curved line **803**, and the correction limit width designated for this $SOC\text{-}OCV_{pattern}$ is shown with two broken lines **804**. Moreover, each point on the $SOC\text{-}OCV_{pattern, fixed}$ is shown with each point as represented by a point **805**. In the foregoing case, since all points on the $SOC\text{-}OCV_{pattern, fixed}$ exist within the range of the correction limit width shown with the broken lines **804**, in correction limit width determination step **609** of the processing flow of FIG. **12**, it is determined that the $SOC\text{-}OCV_{pattern, fixed}$ is within the correction limit width. Consequently, the processing is advanced to SOC-OCV characteristic overwrite step **611**, and the $SOC\text{-}OCV_{temp}$ is overwritten with the $SOC\text{-}OCV_{pattern, fixed}$ in this step. It is thereby possible to perform battery control based on a SOC-OCV characteristic that is close to the true value which reflects the individual variation and the degradation variation of the battery.

[0110] Meanwhile, when a measurement data error is included in the values of the OCV and the SOC obtained based on direct detection, a part or all of the $SOC\text{-}OCV_{pattern, fixed}$ may fall outside the range of the correction limit width. In FIG. **13**, a conceptual diagram **802** on the right side shows a case where the $SOC\text{-}OCV_{pattern, fixed}$ is outside the correction limit width. In this conceptual diagram **802**, similar to the conceptual diagram **801** on the left side, the $SOC\text{-}OCV_{pattern}$ before correction is shown with a curved line **803**, and the correction limit width designated for this $SOC\text{-}OCV_{pattern}$ is shown with two broken lines **804**. Moreover, each point on the $SOC\text{-}OCV_{pattern, fixed}$ iS shown with each point as represented by a point **806**. In the foregoing case, since certain points on the $SOC\text{-}OCV_{pattern, fixed}$ exist outside the range of the correction limit width shown with the broken lines **804**, in correction limit width determination step **609** of the processing flow of FIG. **12**, it is determined that the $SOC\text{-}OCV_{pattern, fixed}$ is outside the correction limit width. Consequently, the processing is not advanced to SOC-OCV characteristic overwrite step **611**, and the value of the $SOC\text{-}OCV_{pattern, fixed}$ is reset in calculation reset step **610**.

[0111] In cases where the SOC-OCV characteristic is corrected by overwriting the $SOC\text{-}OCV_{temp}$ with the $SOC\text{-}OCV_{pattern, fixed}$ containing an error, when the error of the SOC obtained based on direct detection relative to the actual SOC of the battery is great, there is a possibility that such error may contrarily expand. Nevertheless, as shown in the conceptual diagram **802**, the present invention compares the corrected SOC-OCV characteristic with the correction limit width, and does not reflect the correction result in the calculation of the SOC when the corrected SOC-OCV characteristic is outside the range of the correction limit width. Accordingly, it is possible to suppress the divergence of the SOC-OCV characteristic.

[0112] FIG. **14** is a diagram explaining the improvement of the SOC operational precision according to the present invention. The assembled battery control unit **150** calculates the OCV of the battery in a predetermined operation period from the respective state values of the current, the voltage, the temperature, the SOH and the like according to the state of the battery, and the $SOC_{control}$ is output using the $SOC\text{-}OCV_{temp}$. Here, as shown in FIG. **14**, let it be assumed that the true value of the SOC-OCV characteristic has changed from the initial SOC-OCV characteristic shown with the dashed-dotted line to that of the solid line in the diagram due to the degradation or individual variation of the battery. When the value of the OCV acquired here is expressed as OCV(t), the SOC operational error in cases where the SOC-OCV characteristic is not corrected and the initial SOC-OCV characteristic is directly used as the $SOC\text{-}OCV_{temp}$ will be the value of the range shown with reference numeral **1401** in the diagram. In other words, in the foregoing case, the degradation and variation of the SOC-OCV characteristic are not dealt with, and a gross error will occur in the operation result of the SOC.

[0113] Moreover, the SOC operational error in cases where the $SOC\text{-}OCV_{pattern}$ read according to the SOH among the SOC-OCV characteristics stored in advance in the SOC-OCV library **512** is used as the $SOC\text{-}OCV_{temp}$ will be the value of the range shown with reference numeral **1402** in the diagram. In other words, in the foregoing case, while the operational error of the SOC will be smaller in comparison to the case of directly using the initial SOC-OCV characteristic as a result of using the SOC-OCV characteristic which gives consideration to the degradation of the battery, the error resulting from the prediction error of the individual variation and degradation pattern of the battery will remain.

[0114] Meanwhile, as explained in this embodiment, the SOC operational error in cases where the $SOC\text{-}OCV_{pattern, fixed}$, which was obtained by correcting the $SOC\text{-}OCV_{pattern}$ based on the values of the SOC and the OCV obtained based on direct detection, is used as the $SOC\text{-}OCV_{temp}$ will be the value of the range shown with reference numeral **1403** in the diagram. In other words, in the foregoing case, since the error resulting from the prediction error of the individual variation and degradation pattern of the battery is corrected, the value of the SOC operational error can be further reduced in comparison to the case of directly using the read $SOC\text{-}OCV_{pattern}$ as the $SOC\text{-}OCV_{temp}$.

[0115] Note that, when correcting the $SOC\text{-}OCV_{pattern}$ based on direct detection, a point to become the origin (reference point) of the ΔSOC is required as described above, and in this embodiment a point on the $SOC\text{-}OCV_{pattern}$ is used as the origin. Thus, it is possible to reduce the offset error in the corrected SOC-OCV characteristic in comparison to the case of obtaining the origin from the initial SOC-OCV characteristic.

[0116] According to the first embodiment of the present invention explained above, the pattern of the SOC-OCV characteristic according to the state of health of the battery

is called, the corresponding correction limit width is prescribed, and the SOC-OCV characteristic is corrected from the actual measurement data of the battery. It is thereby possible to resolve the conventional problem of not being able to deal with the pattern calling of the SOC-OCV characteristic according to the state of health in the following manner.

[0117] First, the present invention can deal with errors caused by the individual variation and degradation prediction of the battery. The degradation prediction of a secondary battery is generally obtained by subjecting a certain charge/discharge pattern to cycle testing in a thermostatic bath. Nevertheless, it is known that the SOC-OCV characteristics of secondary batteries differ due to variations during the manufacture thereof, and it is not possible to deal with this problem based on conventional pattern calling. Moreover, since the actual use history (temperature, SOC, current and the like) of the battery will never coincide with the conditions of the cycle testing, an error will invariably occur in the degradation prediction of the battery. Meanwhile, the present invention can obtain a SOC-OCV characteristic that coincides with the actual characteristic of the secondary battery by combining direct detection with pattern calling.

[0118] Second, the present invention can determine the divergence of the SOC-OCV characteristic by using the pattern calling and correction limit width based on the operating history that is not influenced by direct detection or indirect detection. Thus, it is possible to correct the SOC-OCV characteristic only based on the signals of the battery system while the vehicle is being driven without having to use a power source or sensors outside the vehicle.

[0119] According to the first embodiment of the present invention explained above, the following operation and effect are yielded.

[0120] (1) An SOC operation system **155** functions as a battery control device which obtains a state of charge (SOC) of a single battery **111**, which is a secondary battery, and an assembled battery **110** based on a SOC-OCV characteristic representing a relationship of the SOC and a voltage of these batteries. An SOC-OCV correction unit **151** in the SOC operation system **155** comprises a pattern calling unit **510** which calls a first characteristic ($SOC\text{-}OCV_{pattern}$) among a plurality of SOC-OCV characteristics stored in advance based on use history information of the battery, a correction limit width designation unit **520** which designates a correction limit width for prescribing a tolerance level of correcting the $SOC\text{-}OCV_{pattern}$, and a direct detection correction unit **530** which creates a second characteristic ($SOC\text{-}OCV_{temp}$) in which the $SOC\text{-}OCV_{pattern}$ has been corrected according to the correction limit width based on a current value I and a voltage value OCV of the battery. An operation unit **152** in the SOC operation system **155** obtains the SOC of the battery using the $SOC\text{-}OCV_{temp}$. As a result of adopting the foregoing configuration, the SOC can be operated with a high degree of accuracy even when the SOC-OCV characteristic changes due to the degradation or individual variation of a battery.

[0121] (2) The pattern calling unit **510** calls the $SOC\text{-}OCV_{pattern}$ by using the state of health (SOH) of the battery as the use history information of the battery. As a result of adopting the foregoing configuration, an appropriate $SOC\text{-}OCV_{pattern}$ can be easily called according to the state of health of the battery.

[0122] (3) As shown in FIG. **5**, the correction limit width designation unit **520** designates, as the correction limit width, a certain OCV width for each SOC or a certain SOC width for each OCV. As a result of adopting the foregoing configuration, the correction limit width can be easily designated according to the production tolerance of the battery or the variation in the state of health.

[0123] (4) The SOC operation system **155** additionally comprises an OCV operation unit **153** which calculates an open voltage value OCV and a polarization voltage value V_p of the battery based on the current value I and the voltage value CCV of the battery. As explained in FIG. **9**, the direct detection correction unit **530** acquires, a plurality of times within a predetermined time range, an open voltage value OCV (OCV_1, OCV_2) of the battery when the current value I and the polarization voltage value V_p are respectively smaller than a predetermined threshold, obtains the SOC based on Formula (2) and Formula (3) described above by using each of the acquired open voltage values OCV_1, OCV_2, a current integrated value in an acquisition period of each of the open voltage values, and the $SOC\text{-}OCV_{pattern}$, creates the $SOC\text{-}OCV_{pattern}$, fixed based thereon, and thereby creates the $SOC\text{-}OCV_{temp}$. As a result of adopting the foregoing configuration, it is possible to correct the $SOC\text{-}OCV_{pattern}$ from the values of the OCV and the SOC acquired based on direct detection, and create an appropriate $SOC\text{-}OCV_{temp}$ according to the state of the battery.

[0124] (5) Based on the configuration shown in FIG. **8**, the direct detection correction unit **530** corrects the $SOC\text{-}OCV_{pattern}$ based on the current value I and the voltage value OCV of the battery, and creates the $SOC\text{-}OCV_{temp}$ by limiting the $SOC\text{-}OCV_{pattern,\ fixed}$, which represents the corrected $SOC\text{-}OCV_{pattern}$, to be within a range of the correction limit width. As a result of adopting the foregoing configuration, it is possible to suppress the divergence of the correction result while appropriately correcting the $SOC\text{-}OCV_{pattern}$ according to the state of the battery.

Second Embodiment

[0125] The second embodiment of the present invention is now explained. The foregoing first embodiment explained an example where the correction limit width designation unit **520** designates a certain OCV width for all SOCs or designates a certain SOC width for all OCVs as the correction limit width. Meanwhile, the following second embodiment explains an example where an OCV width which is different for each SOC or an SOC width which is different for each OCV is designated as the correction limit width.

[0126] FIG. **15** is a diagram showing the functional configuration of the SOC-OCV correction unit **151** according to the second embodiment of the present invention. The SOC-OCV correction unit **151** in this embodiment is configured in the same manner as the first embodiment other than the point of comprising a correction limit width designation unit **520***a* in substitute for the correction limit width designation unit **520**.

[0127] The correction limit width designation unit **520***a* designates the correction limit width for prescribing the tolerance level of the correction to be performed by the direct detection correction unit **530** to the $SOC\text{-}OCV_{pattern}$. FIG. **16** is a diagram showing an example of the correction limit width designated by the correction limit width designation unit **520***a* according to the second embodiment of the present invention. In this embodiment, the correction limit

width designation unit **520***a* designates as the correction limit width, for example, as shown in FIG. **16**, an OCV width that differs for each value of the SOC for each SOC of the SOC-OCV$_{pattern}$. This OCV width is set, for example, by acquiring in advance the SOC-OCV characteristics of a plurality of batteries in their brand new state and based on their state of health, and setting the OCV width in correspondence with the individual difference thereof. It is thereby possible to set a relatively large correction limit width in an SOC region where variation is likely to occur and appropriately correct the SOC-OCV$_{pattern}$ in correspondence with the actual variation, and set a relatively small correction limit width in an SOC region where the variation is small and more finely prevent the divergence of the correction result of the SOC-OCV$_{pattern}$ caused by the various errors.

[0128] Note that, while FIG. **16** shows an example of designating an OCV width that differs for each value of the SOC as the correction limit width, as shown in the right diagram of FIG. **5** in the first embodiment, it is also possible to designate an SOC width that differs for each value of the OCV as the correction limit width upon designating the range of the SOC relative to each OCV of the SOC-OCV$_{pattern}$ as the correction limit width. Even in the foregoing case, it is also possible to appropriately correct the SOC-OCV$_{pattern}$ in correspondence with the actual variation, and more finely prevent the divergence of the correction result of the SOC-OCV$_{pattern}$ caused by the various errors.

[0129] FIG. **17** is a diagram explaining the effect based on the second embodiment of the present invention in comparison to the effect of the first embodiment. Here, as shown in the left diagram of FIG. **17**, considered is a case where the SOC-OCV$_{pattern}$ as shown with a solid line in the first embodiment and this embodiment is each called relative to the SOC-OCV true value shown with a double line, and the same SOC-OCV$_{pattern, fixed}$ is operated.

[0130] In the first embodiment, as shown in the center diagram of FIG. **17**, the correction limit width is assigned based on a certain OCV width. Here, let it be assumed that the region having a high SOC shown with reference numeral **1701** is a region where the variation in the SOC-OCV characteristic caused by degradation or manufacturing errors is great. In this region **1701**, considered is a case where the points on the SOC-OCV$_{pattern, fixed}$ in the diagram have fallen outside the SOC-OCV$_{pattern}$. In the foregoing case, since the correction limit width is assigned based on a fixed OCV width in the first embodiment, when the correction limit width is small, the points on the SOC-OCV$_{pattern, fixed}$ in the region **1701** will fall outside the range of the correction limit width, and the correction of the SOC-OCV$_{pattern}$ is not performed. Accordingly, it is not possible to overwrite the SOC-OCV$_{temp}$.

[0131] Meanwhile, in this embodiment, as shown in the right diagram of FIG. **17**, the correction limit width is assigned based on an OCV width corresponding to the variation in the SOC-OCV characteristics of each SOC. Thus, as a result of the points on the SOC-OCV$_{pattern, fixed}$ in the region **1701** falling within the range of the correction limit width, it is possible to correct the SOC-OCV$_{pattern}$ and obtain the SOC-OCV$_{temp}$. Consequently, it is possible to obtain the SOC-OCV characteristic, which more accurately reflects the state of battery, as the overwritten SOC-OCV$_{temp}$, and the SOC can be operated accurately.

[0132] Moreover, let it be assumed that the region where the SOC is midrange as shown with reference numeral **1702** is a region where the variation in the SOC-OCV characteristics is small. Since the correction limit width is assigned based on a fixed OCV width in the first embodiment, in order for the correction of the SOC-OCV$_{pattern}$ to be performed in the region **1701** described above, the correction limit width also needs to be set broadly in this region **1702**. Accordingly, there is a possibility that the SOC-OCV$_{pattern}$ may be corrected excessively.

[0133] Meanwhile, in this embodiment, as shown in the right diagram of FIG. **17**, the correction limit width is assigned based on an OCV width corresponding to the variation in the SOC-OCV characteristics of each SOC. Thus, it is possible to set the correction limit width broadly in the region **1701** and set the correction limit width narrowly in the region **1702**, and the possibility of the SOC-OCV$_{pattern}$ being corrected excessively can be eliminated. In other words, when the relationship of the OCV and the SOC that deviates from the true value is acquired based on direct detection due to measurement errors or other reasons, it is possible to eliminate the possibility of the SOC-OCV characteristic being corrected based thereon. Consequently, it is possible to prevent an SOC-OCV characteristic containing a gross error from being used as the SOC-OCV$_{temp}$, and the SOC can be operated accurately.

[0134] In this embodiment, the two effects explained above are obtained and, consequently, the SOC-OCV$_{temp}$ can be overwritten using the SOC-OCV$_{pattern, fixed}$ which is closer to the true value of the SOC-OCV in comparison to the first embodiment.

[0135] According to the second embodiment of the present invention explained above, the following operation and effect are yielded in addition to those explained in the first embodiment.

[0136] (6) As shown in FIG. **16** and FIG. **17**, the correction limit width designation unit **520***a* designates, as the correction limit width, an OCV width which differs for each predetermined SOC or an SOC width which differs for each predetermined OCV. As a result of adopting the foregoing configuration, since it is possible to designate the correction limit width in detail according to the actual production tolerance of the battery or the variation in the actual state of health of the battery, the SOC can be operated with a higher degree of accuracy.

Third Embodiment

[0137] The third embodiment of the present invention is now explained. The foregoing first and second embodiments explained an example where the correction limit width designation units **520**, **520***a* respectively designate a certain correction limit width without depending on the state of health of the battery. Meanwhile, the following third embodiment explains an example where the correction limit width is changed according to the operating history of the battery.

[0138] FIG. **18** is a diagram showing the functional configuration of the SOC-OCV correction unit **151** according to the third embodiment of the present invention. The SOC-OCV correction unit **151** in this embodiment is configured in the same manner as the first embodiment other than the point of comprising a pattern calling unit **510***b* and a correction limit width designation unit **520***b* in substitute for the pattern calling unit **510** and the correction limit width

designation unit **520**, respectively, and the point of additionally comprising a correction limit width library **521**.

[0139] The pattern calling unit **510***b* outputs the SOC-$OCV_{pattern}$ in the same manner as the pattern calling unit **510** in the first embodiment. In addition, the pattern calling unit **510***b* outputs, as the pattern determination result, the determination result of the degradation pattern of the battery when the SOC-$OCV_{pattern}$ was called from the SOC-OCV library **512**.

[0140] The correction limit width designation unit **520***b* inputs the foregoing pattern determination result, and calls and acquires the correction limit width corresponding to that degradation pattern among a plurality of correction limit widths stored in advance in the correction limit width library **521** based thereon. The correction limit width designation unit **520***b* subsequently designates the acquired correction limit width in the direct detection correction unit **530**.

[0141] The correction limit width library **521** has a database of the correction limit widths corresponding to various degradation patterns of the battery. For example, the correction limit width library **521** can be built by acquiring in advance the correction limit width according to the degradation pattern as a result of conducting a degradation test of different conditions to a plurality of batteries and obtaining the difference between the SOC-OCV characteristics of the batteries having the same SOH, and compiling a database of the relationship. In other words, the contents of the correction limit width library **521** can be decided by acquiring in advance the variation of the SOC, which can be acquired relative to the same OCV based on the actual degradation and individual variation of the battery, according to the state of health of the battery.

[0142] The correction limit width is decided as the error that is anticipated between the SOC-$OCV_{pattern}$ and the true SOC-OCV characteristic. This error occurs due to the determination error of the manufacturing variation and degradation pattern of the battery. Since the determination error of the degradation pattern will expand as the operating history of the battery becomes longer, in the first and second embodiments, the estimation error margin of the degradation pattern needs to be included in the correction limit width so that the correction limit width will properly function under both conditions where the operating history is short and where the operating history is long.

[0143] Meanwhile, the correction limit width decided by the correction limit width designation unit **520***b* in this embodiment changes according to the operating history of the battery. FIG. **19** is a diagram showing an example of the correction limit width designated by the correction limit width designation unit **520***b* according to the third embodiment of the present invention. In this embodiment, as shown in FIG. **19**, in order to deal with the estimation error margin of the degradation pattern that expands according to the progress of the degradation of the battery, the correction limit width designated by the correction limit width designation unit **520***b* is gradually expanded according to the operating history of the battery. Consequently, it is possible to reduce the correction limit width and suppress the divergence of the SOC-OCV characteristics in a state where the battery is basically brand new where the difference in the SOC-OCV characteristics among the batteries is small, and increase the correction limit width and perform control corresponding to the variation of each battery in a state of health where the difference in the SOC-OCV characteristics among the batteries is great.

[0144] FIG. **20** is a diagram explaining the effect based on the third embodiment of the present invention in comparison to the effect of the second embodiment. Here, as shown respectively in the upper left diagram and the lower left diagram of FIG. **20**, considered is a case where the SOC-$OCV_{pattern}$ as shown with a solid line in the second embodiment and this embodiment is each called relative to the SOC-OCV true value shown with a double line, and the same SOC-$OCV_{pattern,\ fixed}$ is operated. Here, let it be assumed that the SOC-$OCV_{pattern,\ fixed}$, due to some kind of error factor, has an OCV that is higher than the SOC-OCV true value in a region having a high SOC respectively shown with reference numeral **2001** in the upper and lower center diagram and right diagram of FIG. **20**. Thus, in the region **2001**, it is necessary to set the correction limit width by increasing the estimation error margin of the degradation pattern.

[0145] In the second embodiment, the correction limit width is set by fixing the estimation error margin of the degradation pattern irrespective of the operating history of the battery. Thus, when the operating history of the battery is short, as shown in the upper center diagram of FIG. **20**, the correction limit width is set relatively broadly in the region **2001**, and the points on the SOC-$OCV_{pattern,\ fixed}$ shown in the diagram fall within the range of the correction limit width. Consequently, the correction of the SOC-$OCV_{pattern}$ is performed and the SOC-OCV_{temp} is overwritten.

[0146] Meanwhile, in this embodiment, when the operating history of the battery is short, the correction limit width is set by reducing the estimation error margin of the degradation pattern. Thus, in the foregoing case, as shown in the upper right diagram of FIG. **20**, the correction limit width is set in the region **2001** to be narrower than the second embodiment, and the points on the SOC-$OCV_{pattern,\ fixed}$ shown in the diagram will fall outside the range of the correction limit width. Consequently, the correction of the SOC-$OCV_{pattern}$ is not performed, and the SOC-OCV_{temp} is not overwritten. Accordingly, this embodiment is able to obtain a more accurate SOC.

[0147] Moreover, in the second embodiment, when the operating history of the battery is sufficiently long, as shown in the lower center diagram of FIG. **20**, the correction limit width is set to be relatively narrow in the region **2001**, and the points on the SOC-$OCV_{pattern,\ fixed}$ shown in the diagram will fall outside the correction limit width. Consequently, the correction of the SOC-$OCV_{pattern}$ is not performed, and the SOC-OCV_{temp} is not overwritten.

[0148] Meanwhile, in this embodiment, when the operating history of the battery is sufficiently long, the correction limit width is set by increasing the estimation error margin of the degradation pattern. Thus, in the foregoing case, as shown in the lower right diagram of FIG. **20**, the correction limit width is set in the region **2001** to be broader than the second embodiment, and the points on the SOC-$OCV_{pattern,\ fixed}$ shown in the diagram will fall within the range of the correction limit width. Consequently, the correction of the SOC-$OCV_{pattern}$ is performed, and the SOC-OCV_{temp} is overwritten. Accordingly, this embodiment is able to obtain a more accurate SOC.

[0149] According to the third embodiment of the present invention explained above, the following operation and effect are yielded in addition to those explained in the first and second embodiments.

[0150] (7) As shown in FIG. **19** and FIG. **20**, the correction limit width designation unit **520***b* changes the correction limit width according to the use history of the battery. Specifically, the correction limit width designation unit **520***b* changes the correction limit width according to the use history of the battery by selecting one among a plurality of correction limit widths stored in advance in the correction limit width library **521** based on the SOC-OCV$_{pattern}$. As a result of adopting the foregoing configuration, since it is possible to change the correction limit width according to changes in the determination error of the degradation pattern that occurs according to the operating history of the battery, the SOC can be operated with a higher degree of accuracy.

Fourth Embodiment

[0151] The fourth embodiment of the present invention is now explained. The foregoing first to third embodiments explained an example of the pattern calling unit **510** determining the degradation pattern of the battery by using the SOH as the use history information of the battery, calling the SOC-OCV characteristic corresponding to that degradation pattern, and outputting the SOC-OCV$_{pattern}$. Meanwhile, the following fourth embodiment explains an example of determining the degradation pattern by using a plurality of pieces of information, and not only the SOH, as the use history information of the battery.

[0152] FIG. **21** is a diagram showing the functional configuration of the SOC-OCV correction unit **151** according to the fourth embodiment of the present invention. The SOC-OCV correction unit **151** in this embodiment is configured in the same manner as the first embodiment other than the point of comprising a pattern calling unit **510***c* in substitute for the pattern calling unit **510**.

[0153] The pattern calling unit **510***c* uses a plurality of pieces of information, such as the SOH, the current history, the temperature history and the SOC history, as the user history information of the battery as the inputs, determines the degradation pattern of the battery based on the foregoing information, and calls the SOC-OCV characteristic corresponding to that degradation pattern among a plurality of SOC-OCV characteristics stored in advance. The pattern calling unit **510***c* subsequently outputs the information of the called SOC-OCV characteristic as the SOC-OCV$_{pattern}$.

[0154] FIG. **22** is a diagram showing the configuration of the pattern calling unit **510***c* according to the fourth embodiment of the present invention. The pattern calling unit **510***c* includes a pattern determination unit **511***c*, and an SOC-OCV library **512***c*.

[0155] The pattern determination unit **511***c* performs pattern determination based on each piece of information that was input as the use history information of the battery; that is, based on the input SOH, current history, temperature history and SOC history, and calls the SOC-OCV characteristic corresponding to that pattern determination result by searching the SOC-OCV library **512***c*. The pattern determination unit **511***c* subsequently generates the SOC-OCV$_{pattern}$ from the called SOC-OCV characteristic and outputs the generated SOC-OCV$_{pattern}$.

[0156] The SOC-OCV library **512***c* has a database of the SOC-OCV characteristics for each combination of the values of each piece of information input to the pattern determination unit **511***c*; that is, the values of the SOH, the current history, the temperature history and the SOC history. For example, the foregoing information is associated respectively with four axes, and the result of associating the SOC-OCV characteristics for each coordinate value expressed with the four axes is stored as the database of the SOC-OCV characteristics. In the foregoing case, the pattern determination unit **511***c* acquires the SOC-OCV characteristic corresponding to the input use history information by identifying the coordinate value based on the pattern determination result and calling the SOC-OCV characteristic corresponding to the coordinate value by searching the SOC-OCV library **512***c*.

[0157] FIG. **23** is a diagram showing an example of the SOC-OCV characteristics of the SOC-OCV library **512***c* according to the fourth embodiment of the present invention. FIG. **23** shows that, in each case where the value of the SOH is 100%, 120%, 140%, . . . , respectively different SOC-OCV characteristics are stored in the SOC-OCV library **512***c* for each combination of values of the current history, the temperature history and the SOC history. Here, the SOC-OCV library **512***c* can be realized, for example, by conducting a degradation test of each single battery **111** by respectively changing the four conditions of the SOH, the current, the temperature, and the SOC and acquiring in advance the relationship of the SOC and the OCV when the degradation of each single battery **111** advances, and compiling a database of the relationship.

[0158] Note that, in the foregoing explanation, while a case was explained where the pattern calling unit **510***c* calls the SOC-OCV$_{pattern}$ corresponding to the state of health of the battery by using the SOH, the current history, the temperature history and the SOC history as the use history information of the battery, it is not necessary to use all of the foregoing information. In other words, the pattern calling unit **510***c* can call the SOC-OCV$_{pattern}$ corresponding to the state of health of the battery by using at least one piece of use history information of the battery among the SOH, the current history, the temperature history and the SOC history. Note that the SOC-OCV library **512***c* may store the SOC-OCV characteristics for each combination of information that is input to the pattern calling unit **510***c* as the use history information of the battery and used for the pattern determination in the pattern determination unit **511***c*.

[0159] Here, the pattern calling unit **510** explained in the first embodiment corresponds to the case of using only the SOH as the use history information of the battery. Moreover, information other than the SOH, the current history, the temperature history and the SOC history may also be used as the use history information of the battery.

[0160] FIG. **24** is a diagram explaining the effect based on the fourth embodiment of the present invention in comparison to the effect of the first embodiment. Here, considered is a case where, in the first embodiment and the fourth embodiment, a different SOC-OCV$_{pattern}$ has been called as respectively shown in the center diagram and the right diagram of FIG. **24** relative to the SOC-OCV true value shown with a double line in the left diagram of FIG. **24**.

[0161] In this embodiment, since a plurality of pieces of information are used as the use history information of the battery, the operating history of the battery can be captured in detail. Thus, as evident from FIG. **24**, a SOC-OCV$_{pattern}$ that is closer to the SOC-OCV true value can be called in

comparison to the first embodiment. Note that, since the SOC-OCV$_{pattern, fixed}$ is acquired from the SOC-OCV$_{pattern}$ with at least one point as the origin, generally speaking, these will not coincide if the SOC-OCV$_{pattern}$ is different.

[0162] Accordingly, as shown in the respective points of the center diagram and the right diagram of FIG. **24**, the SOC-OCV$_{pattern, fixed}$ is different in the first embodiment and in this embodiment.

[0163] In this embodiment, as a result of using a plurality of pieces of information as the use history information of the battery, it is possible to conduct a more detailed prediction of the degradation pattern, and call an SOC-OCV$_{pattern}$ that is closer to the true value. Thus, it is possible to set the correction limit width by reducing the estimation error margin of the degradation pattern, and cause the correction limit width to be narrow. Accordingly, even when an operational error occurs in which the points on the SOC-OCV$_{pattern, fixed}$ fall within the range of the correction limit width and the SOC-OCV$_{temp}$ is consequently overwritten in the first embodiment, this embodiment is able to prevent the overwriting of the SOC-OCV$_{temp}$. Consequently, this embodiment is able to obtain a more accurate SOC.

[0164] According to the fourth embodiment of the present invention explained above, the following operation and effect are yielded in addition to those explained in the first to third embodiments.

[0165] (8) As explained in FIG. **23** and FIG. **24**, the pattern calling unit **510***c* calls the SOC-OCV$_{pattern}$ by using at least one among the state of health (SOH), the current history, the temperature history and the state of charge (SOC) history of the battery as the use history information of the battery. As a result of adopting the foregoing configuration, since it is possible to call a more appropriate SOC-OCV$_{pattern}$ according to the state of health of the battery, the SOC can be operated with a higher degree of accuracy.

Fifth Embodiment

[0166] The fifth embodiment of the present invention is now explained. The foregoing first to fourth embodiments explained an example of the direct detection correction unit **530** determining whether the SOC-OCV$_{pattern, fixed}$, which was obtained by correcting the SOC-OCV$_{pattern}$ based on the OCV and the SOC obtained based on direct detection, is within the correction limit width, and overwriting the SOC-OCV$_{temp}$ when the SOC-OCV$_{pattern, fixed}$ is within the correction limit width. Meanwhile, the following fifth embodiment explains a case of determining whether to overwrite the SOC-OCV$_{temp}$ by giving further consideration to the difference in comparison to the SOC-OCV$_{temp}$ being used in the present control.

[0167] FIG. **25** is a diagram showing the functional configuration of the SOC-OCV correction unit **151** according to the fifth embodiment of the present invention. The SOC-OCV correction unit **151** in this embodiment is configured in the same manner as the first embodiment other than the point of comprising a correction limit width designation unit **520***d* and a direct detection correction unit **530***d* in substitute for the correction limit width designation unit **520** and the direct detection correction unit **530**, respectively.

[0168] As with the correction limit width designation unit **520** in the first embodiment, the correction limit width designation unit **520***d* calls and acquires the correction limit width corresponding to the degradation pattern of the battery among a plurality of correction limit widths stored in advance. The correction limit width designation unit **520***d* subsequently outputs, to the direct detection correction unit **530***d*, the acquired correction limit width as the correction limit width (pattern). In addition, the correction limit width designation unit **520***d* outputs, as the correction limit width (previous value), the correction limit width when the SOC-OCV$_{temp}$ was overwritten in the previous processing. This correction limit width (previous value) is used as an index for detecting, in the direct detection correction unit **530***d*, the occurrence of a large fluctuation on a short-term basis due to a sensor error in the OCV and the SOC acquired based on direct detection or other reasons.

[0169] The direct detection correction unit **530***d* corrects the SOC-OCV$_{pattern}$ output from the pattern calling unit **510** according to the correction limit width (pattern) and the correction limit width (previous value) designated by the correction limit width designation unit **520***d* based on the current I and the OCV. The direct detection correction unit **530***d* subsequently outputs the correction result as the SOC-OCV$_{temp}$.

[0170] FIG. **26** is a diagram showing the functional configuration of the direct detection correction unit **530***d* according to the fifth embodiment of the present invention. The direct detection correction unit **530***d* is configured in the same manner as the direct detection correction unit **530** explained in the first embodiment other than the point of comprising an SOC-OCV overwrite determination unit **533***d* in substitute for the SOC-OCV overwrite determination unit **533**.

[0171] The SOC-OCV overwrite determination unit **533***d* determines the overwrite timing of the SOC-OCV characteristics by using the correction limit width (pattern) and the correction limit width (previous value) input from the correction limit width designation unit **520***d*, the sequence N$_{count}$ representing the correction count at the respective points input from the SOC-OCV direct detection correction unit **532**, and the SOC-OCV$_{temp, z-1}$ as the value of the SOC-OCV$_{temp}$ in the previous processing. When it is determined that the overwrite timing has arrived, the SOC-OCV overwrite determination unit **533***d* overwrites the SOC-OCV$_{temp}$ with the SOC-OCV$_{pattern, fixed}$ and outputs the result.

[0172] The SOC-OCV overwrite determination unit **533***d* is now explained in detail with reference to the flowchart shown in FIG. **27**. FIG. **27** is a flowchart showing the processing flow of the SOC-OCV correction unit **151** according to the fifth embodiment of the present invention.

[0173] In steps **601** to **609**, the same processing as the flowchart of FIG. **12** explained in the first embodiment is performed. Here, in correction limit width determination step **609**, the SOC-OCV overwrite determination unit **533***d* performs the determination explained in the first embodiment by using the correction limit width (pattern) input from the correction limit width designation unit **520***d*. Consequently, the processing is advanced to step **619** when it is determined that the SOC-OCV$_{pattern, fixed}$ is within the range of the correction limit width (pattern), and the processing is advanced to step **610** when it is determined that the SOC-OCV$_{pattern, fixed}$ is outside the range of the correction limit width (pattern).

[0174] In previous correction limit width determination step **619**, the SOC-OCV overwrite determination unit **533***d* determines whether the SOC-OCV$_{pattern, fixed}$ is within the range of the correction limit width (previous value). Here,

for example, upon substituting the $OCV'_{pattern,\ i}$ of Evaluation Formula (6) explained in the first embodiment with the $OCV'_{temp,\ z-1,\ i}$, with regard to a point on the $SOC\text{-}OCV_{pattern,\ fixed}$ and the intersection point of the perpendicular line drawn downward from such point and the line segment connecting two points on the $SOC\text{-}OCV_{temp,\ z-1}$, the squared difference of the OCV of these points is evaluated by being compared with the correction limit width (previous value) based on Evaluation Formula (7) below. Note that the value of the $OCV'_{temp,\ z-1,\ i}$ in Evaluation Formula (7) represents the value of the OCV of the foregoing intersection point.

[0175] [Math 7]

$$\sqrt{(OCV_{\mathrm{fixed},i}-\overline{OCV'_{\mathrm{temp},z-1,i}})^2} \leq \text{修正限界幅（前回値）} \tag{7}$$

修正限界幅（前回値）: correction limit width (previous value)

[0176] When it is determined in step **619** that the $SOC\text{-}OCV_{pattern}$, outside the range of fixed is the correction limit width (previous value), the processing is advanced to calculation reset step **610**, the previously obtained values of the $SOC\text{-}OCV_{pattern,\ fixed}$ and the N_{count} are reset in step **610**, and the operation is thereafter re-performed from step **607**. Meanwhile, the processing is advanced to subsequent step **611** when the $SOC\text{-}OCV_{pattern,\ fixed}$ is within the range of the correction limit width (previous value). In step **611** onward, the same processing as the flowchart of FIG. **12** explained in the first embodiment is performed.

[0177] In this embodiment, by performing the foregoing processing in step **619**, whether the $SOC\text{-}OCV_{pattern,\ fixed}$ obtained based on direct detection has changed considerably from the $SOC\text{-}OCV_{temp,\ z-1}$; that is, the $SOC\text{-}OCV_{temp}$ obtained in the previous processing is determined. When the $SOC\text{-}OCV_{pattern,\ fixed}$ has changed considerably, it is determined that the SOC-OCV characteristic has fluctuated due to reasons that are not based on the state of the battery that arose from a sensor error or the like, and the processing is returned to step **607** and the operation is re-performed without executing SOC-OCV characteristic overwrite step **611**. It is thereby possible to suppress the divergence of the operation result of the SOC even when the SOC-OCV characteristic changes suddenly in comparison to the first embodiment.

[0178] Note that, when the battery is not used for a long period, it is anticipated that the state of the battery will change considerably from the time that the previous processing was performed. Thus, when the elapsed time from the previous processing is longer than a predetermined threshold, the processing of step **619** may be omitted.

[0179] FIG. **28** is a diagram explaining the effect based on the fifth embodiment of the present invention. Here, considered is a case where the SOC-OCV characteristic shown with a broken line in the left diagram of FIG. **28** has been obtained in the previous processing relative to the SOC-OCV true value shown with a double line, and is used as the $SOC\text{-}OCV_{temp,\ z-1}$. Moreover, considered is a case where, in a region having a high SOC shown with reference numeral **2801** in the left diagram of FIG. **28**, a combination of the OCV and the SOC having a higher OCV than the $SOC\text{-}OCV_{temp,\ z-1}$ has been detected as the $SOC\text{-}OCV_{pattern,\ fixed}$ as respectively shown with the respective points of the center diagram and right diagram of FIG. **28**.

[0180] As shown in the center diagram of FIG. **28**, when the points on the $SOC\text{-}OCV_{pattern}$, fixed are within the range of the correction limit width (pattern), in the first to fourth embodiments, the correction of the $SOC\text{-}OCV_{pattern}$ is performed and the $SOC\text{-}OCV_{temp}$ is overwritten. Accordingly, if an OCV containing a gross error is detected in the foregoing region **2801** for some reason, the operational precision of the SOC in that region will deteriorate in comparison to the case of using the $SOC\text{-}OCV_{temp,\ z-1}$ obtained in the previous processing.

[0181] Meanwhile, in this embodiment, since the processing of step **619** explained in FIG. **27** is additionally performed, whether the points on the $SOC\text{-}OCV_{pattern,\ fixed}$ are within the range of the correction limit width (previous value) for the $SOC\text{-}OCV_{temp,\ z-1}$ is determined. Consequently, as shown in the right diagram of FIG. **28**, when the points on the $SOC\text{-}OCV_{pattern,\ fixed}$ are outside the range of the correction limit width (previous value), the correction of the $SOC\text{-}OCV_{pattern}$ is not performed, and the $SOC\text{-}OCV_{temp}$ is not overwritten. Accordingly, this embodiment is able to improve the operational precision of the SOC.

[0182] According to the fifth embodiment of the present invention explained above, the following operation and effect are yielded in addition to those explained in the first to fourth embodiments.

[0183] (9) The correction limit width designation unit **520***d* designates the correction limit width (previous value) for prescribing the tolerance level of the correction to the $SOC\text{-}OCV_{temp,\ z-1}$, which is the $SOC\text{-}OCV_{temp}$ created by the direct detection correction unit **530***d* in the past (previously). As explained in FIG. **27** and FIG. **28**, the direct detection correction unit **530***d* creates the $SOC\text{-}OCV_{temp}$ by using the correction limit width (pattern) designated by the correction limit width designation unit **520***d* for the present $SOC\text{-}OCV_{pattern}$, and the correction limit width (previous value) designated by the correction limit width designation unit **520***d* for the past $SOC\text{-}OCV_{temp,\ z-1}$. As a result of adopting the foregoing configuration, since it is possible to suppress the divergence of the operation result of the SOC even when the SOC-OCV characteristic changes suddenly due to a sensor error or other reasons, the SOC can be operated with a higher degree of accuracy.

Sixth Embodiment

[0184] The sixth embodiment of the present invention is now explained. The foregoing first to fifth embodiments explained an example of resetting the calculation result and re-performing the operation when the $SOC\text{-}OCV_{pattern,\ fixed}$, which was obtained from the OCV and the SOC obtained based on direct detection, is outside the range of the correction limit width. Meanwhile, the following sixth embodiment explains an example of determining that there was an error in the determination of the degradation pattern of the battery when the $SOC\text{-}OCV_{pattern,\ fixed}$ is converging outside the range of the correction limit width, and updating the operating history of the battery.

[0185] FIG. **29** is a diagram showing the functional configuration of the SOC-OCV correction unit **151** according to the sixth embodiment of the present invention. The SOC-OCV correction unit **151** in this embodiment is configured in the same manner as the first embodiment other than the point of comprising a direct detection correction unit **530***e* in substitute for the direct detection correction unit **530**.

[0186] As with the direct detection correction unit **530** in the first embodiment, the direct detection correction unit **530***e* corrects the $SOC\text{-}OCV_{pattern}$ output from the pattern calling unit **510** according to the correction limit width designated by the correction limit width designation unit

520*d* based on the current I and the OCV. The direct detection correction unit **530***e* subsequently outputs the correction result as the $SOC\text{-}OCV_{temp}$. In addition, the direct detection correction unit **530***e* determines whether the $SOC\text{-}OCV_{pattern,\ fixed}$ determined to be outside the range of the correction limit width satisfies a predetermined convergence condition, and updates the operating history of the battery upon determining that the $SOC\text{-}OCV_{pattern,\ fixed}$ determined to be outside the range of the correction limit width satisfies a convergence condition.

[0187] FIG. **30** is a diagram showing the functional configuration of the direct detection correction unit **530***e* according to the sixth embodiment of the present invention. The direct detection correction unit **530***e* is configured in the same manner as the direct detection correction unit **530** explained in the first embodiment other than the point of additionally comprising an SOC-OCV convergence determination unit **534**.

[0188] Input to the SOC-OCV convergence determination unit **534** are, among the $SOC\text{-}OCV_{pattern,\ fixed}$ output from the SOC-OCV direct detection correction unit **532**, those determined to be outside the range of the correction limit width by the SOC-OCV overwrite determination unit **533**. The SOC-OCV convergence determination unit **534** stores the input $SOC\text{-}OCV_{pattern,\ fixed}$ a plurality of times, and determines whether these satisfy a predetermined convergence condition. When it is consequently determined that the convergence condition is satisfied, the SOC-OCV convergence determination unit **534** updates the SOH as the use history information of the battery based on the stored $SOC\text{-}OCV_{pattern,\ fixed}$, and outputs the updated SOH. Note that, as explained in the fourth embodiment, when information other than the SOH such as the current history, the temperature history, and the SOC history is to be used as the use history information of the battery, such information may also be updated.

[0189] FIG. **31** is a diagram showing the functional configuration of the SOC-OCV convergence determination unit **534**. The SOC-OCV convergence determination unit **534** includes an out-of-width count unit **535** and an operating history determination unit **536**.

[0190] The out-of-width count unit **535** stores, a predetermined number of times, the immediate $SOC\text{-}OCV_{pattern,\ fixed}$ determined to be outside the range of the correction limit width by the SOC-OCV overwrite determination unit **533**. The out-of-width count unit **535** subsequently counts the consecutive storage of the $SOC\text{-}OCV_{pattern,\ fixed}$; that is, the consecutive count N_{error} in which the $SOC\text{-}OCV_{pattern,\ fixed}$ was determined to be outside the range of the correction limit width, and, when this consecutive count N_{error} exceeds a predetermined threshold, the average and variance of previously stored multiple $SOC\text{-}OCV_{pattern,\ fixed}$ are calculated, and the respective calculation results thereof are output as the average $SOC\text{-}OCV_{pattern,\ fixed}$ and the variance $SOC\text{-}OCV_{pattern,\ fixed}$.

[0191] With the average $SOC\text{-}OCV_{pattern,\ fixed}$ and the variance $SOC\text{-}OCV_{pattern,\ fixed}$ calculated and output by the out-of-width count unit **535** as the inputs, the operating history determination unit **536** outputs the updated use history information (for example, SOH) of the battery based on the foregoing inputs. Specifically, the operating history determination unit **536** determines whether the variance $SOC\text{-}OCV_{pattern,\ fixed}$ is within a predetermined threshold and, when it is within the threshold, determines that the $SOC\text{-}OCV_{pattern,\ fixed}$ is converging outside the range of the correction limit width. The operating history determination unit **536** subsequently searches for the SOC-OCV characteristic that is most similar to the average $SOC\text{-}OCV_{pattern,\ fixed}$ from the SOC-OCV library **512**, and outputs the SOH corresponding to that SOC-OCV characteristic as the updated use history information. Here, the search of the SOC-OCV characteristic that is most similar to the average $SOC\text{-}OCV_{pattern,\ fixed}$ can be performed, for example, based on the same method as Evaluation Formula (6) explained in the first embodiment. In other words, the SOC-OCV characteristic that is most similar to the average $SOC\text{-}OCV_{pattern,\ fixed}$ can be obtained by searching the SOC-OCV library **512** for the SOC-OCV characteristic in which the square sum of the OCV differences at the respective SOC points becomes smallest relative to the average $SOC\text{-}OCV_{pattern,\ fixed}$.

[0192] The SOC-OCV convergence determination unit **534** is now explained in detail with reference to the flowchart shown in FIG. **32**. FIG. **32** is a flowchart showing the processing flow of the SOC-OCV correction unit **151** according to the sixth embodiment of the present invention.

[0193] In steps **601** to **609**, the same processing as the flowchart of FIG. **12** explained in the first embodiment is performed. The processing is advanced to step **611** when it is determined in correction limit width determination step **609** that the $SOC\text{-}OCV_{pattern}$, fixed is within the range of the correction limit width, and the processing is advanced to step **617** when it is determined in correction limit width determination step **609** that the $SOC\text{-}OCV_{pattern,\ fixed}$ is outside the range of the correction limit width. Upon proceeding to step **611**, in step **611** onward, the same processing as the flowchart of FIG. **12** explained in the first embodiment is performed.

[0194] In convergence determination step **617**, the out-of-width count unit **535** and the operating history determination unit **536** determine whether the $SOC\text{-}OCV_{pattern,\ fixed}$ has converged outside the range of the correction limit width. Here, convergence determination step **617** is performed using the convergence condition described above. In other words, the out-of-width count unit **535** compares the consecutive count N_{error}, which is the number of times that the $SOC\text{-}OCV_{pattern,\ fixed}$ was consecutively determined as being outside the range of the correction limit width, with a predetermined threshold, and determines that the convergence condition has been satisfied when the consecutive count N_{error} exceeds the threshold. Moreover, the operating history determination unit **536** compares the variance $SOC\text{-}OCV_{pattern}$, fixed calculated by the out-of-width count unit **535** with a predetermined threshold, and determines that the convergence condition has been satisfied when the variance $SOC\text{-}OCV_{pattern,\ fixed}$ is within the threshold. Consequently, the processing is advanced to step **618** when the convergence condition is satisfied, and the processing is advanced to step **610** when the convergence condition is not satisfied. Upon advancing to step **610**, the previously obtained values of the $SOC\text{-}OCV_{pattern,\ fixed}$ and the N_{count} are reset in step **610**, and the operation is thereafter re-performed from step **607**.

[0195] In operating history change step **618**, the operating history determination unit **536** changes the use history information representing the operating history of the battery. Here, as described above, the use history information is changed by searching for the SOC-OCV characteristic that

is most similar to the average SOC-OCV$_{pattern,\ fixed}$ calculated by the out-of-width count unit **535** and outputting the SOH corresponding to that SOC-OCV characteristic. Once the change of the use history information is completed in step **618**, the processing is returned to pattern SOC-OCV reading step **605**, the SOC-OCV characteristic searched in step **618** is stored in the memory as the SOC-OCV$_{pattern}$, and the processing of step **606** onward is thereafter repeated.

[0196] In this embodiment, by performing the foregoing processing in step **617** and step **618**, whether the SOC-OCV$_{pattern,\ fixed}$ is converging outside the range of the correction limit width is determined. Consequently, when the SOC-OCV$_{pattern,\ fixed}$ is converging outside the range of the correction limit width, it is determined that there was an error in the determination of the degradation pattern of the battery, and the operating history of the battery is updated. It is thereby possible to correct the estimation error of the degradation pattern of the battery while suppressing the divergence of the operation result of the SOC in comparison to the first embodiment. Moreover, as a result of adopting this method, it is possible to detect an unexpected degradation of the battery based on the difference between the degradation pattern of the battery determined from the operating history and the operating history anticipated from the SOC-OCV$_{pattern,\ fixed}$. Thus, it is possible to use this for determining the malfunction of a battery.

[0197] FIG. **33** is a diagram explaining the effect based on the sixth embodiment of the present invention. Here, considered is a case where, in a region having a high SOC shown with reference numeral **3301** in the left diagram of FIG. **33**, a combination of the OCV and the SOC outside the range of the correction limit width has been detected as the SOC-OCV$_{pattern,\ fixed}$ relative to the SOC-OCV true value shown with a double line.

[0198] As shown in the center diagram of FIG. **33**, when the points on the SOC-OCV$_{pattern}$, fixed are outside the range of the correction limit width, in the first to fifth embodiments, the correction of the SOC-OCV$_{pattern}$ is not performed, and the SOC-OCV$_{temp}$ is not overwritten. Here, when the difference between the SOC-OCV$_{pattern}$ and the SOC-OCV$_{pattern,\ fixed}$ was not caused by a short-term fluctuation due to a measurement error or other reasons and was rather caused by a determination error of the degradation pattern caused by an error or insufficiency of the operating history of the battery, a negative determination will be repeatedly obtained in step **609** in FIG. **12** and FIG. **27**. Consequently, the cycle of steps **607** to **610** will be repeated, and this may result in the suspension of the update of the SOC-OCV$_{temp}$.

[0199] Meanwhile, in this embodiment, when a negative determination is obtained in step **609**, whether the SOC-OCV$_{pattern,\ fixed}$ has converged outside the range of the correction limit width is determined as a result of the processing of step **617** explained in FIG. **32** being performed. As a result of the processing of step **618** being additionally performed when it is determined that the SOC-OCV$_{pattern,\ fixed}$ has converged outside the range of the correction limit width, the operating history of the battery is updated based on the previously detected SOC-OCV$_{pattern,\ fixed}$. Consequently, as shown in the right diagram of FIG. **33**, the SOC-OCV$_{pattern,\ fixed}$ will fall within the range of the correction limit width that was set according to the updated operating history, the SOC-OCV$_{temp}$ is updated, and the operation of the SOC can be continued.

[0200] Note that the SOC-OCV$_{pattern,\ fixed}$ is acquired with at least one point on the SOC-OCV$_{pattern}$ as the origin. Thus, generally speaking, the SOC-OCV$_{pattern,\ fixed}$ will not coincide before the update and after the update of the operating history. Accordingly, the SOC-OCV characteristic can be corrected based on the update of the operating history, and the operational precision of the SOC can thereby be improved.

[0201] According to the sixth embodiment of the present invention explained above, the following operation and effect are yielded in addition to those explained in the first to fifth embodiments.

[0202] (10) The direct detection correction unit **530***e* updates the use history information of the battery based on the SOC-OCV$_{pattern}$ after correction including parts outside the range of the correction limit width; that is, based on the SOC-OCV$_{pattern,\ fixed}$. Specifically, as explained in FIG. **32** and FIG. **33**, the direct detection correction unit **530***e* determines whether the SOC-OCV$_{pattern,\ fixed}$ is within the range of the correction limit width (step **609**), and, when the SOC-OCV$_{pattern,\ fixed}$ determined to be outside the range of the correction limit width satisfies a predetermined convergence condition (step **617**: YES), updates the use history information of the battery (step **618**). As a result of adopting the foregoing configuration, since the SOC-OCV characteristics can be corrected and the operation of the SOC can be continued even when the degradation pattern of the battery is erroneously determined, the operational precision of the SOC can be improved.

[0203] (11) The convergence condition used in the determination of step **617** includes at least one of either a first condition in which a number of times that the SOC-OCV$_{pattern}$, fixed was continuously determined to be outside the range of the correction limit width is equal to or greater than a predetermined number of times, or a second condition in which a variance in the SOC-OCV$_{pattern,\ fixed}$ (variance SOC-OCV$_{pattern,\ fixed}$) is equal to or less than a predetermined threshold. As a result of adopting the foregoing configuration, it is possible to accurately determine whether the SOC-OCV$_{pattern,\ fixed}$ determined to be outside the range of the correction limit width satisfies a predetermined convergence condition.

[0204] Note that the respective embodiments and various modified examples explained above are merely examples, and the present invention is not limited to the subject matter thereof so as long as the features of the present invention are not impaired. Moreover, the respective embodiments explained above may also be used by being arbitrarily combined. In addition, while various embodiments and modified examples were explained above, the present invention is not limited to the subject matter thereof. Other modes considered to fall within the scope of the technical concept of the present invention are also included in the scope of the present invention.

[0205] The disclosure of the following priority application is incorporated herein by reference. Japanese Patent Application No. 2018-201527 (filed on Oct. 26, 2018)

REFERENCE SIGNS LIST

[0206] **100**: battery system

[0207] **110**: assembled battery

[0208] **111**: single battery

[0209] **112**: single battery group

[0210] **120**: single battery management unit

[0211] **121**: single battery control unit
[0212] **122**: voltage detection circuit
[0213] **123**: control circuit
[0214] **124**: signal input/output circuit
[0215] **125**: temperature detection unit
[0216] **130**: current detection unit
[0217] **140**: voltage detection unit
[0218] **150**: assembled battery control unit
[0219] **151**: SOC-OCV correction unit
[0220] **152**: SOC operation unit
[0221] **153**: OCV operation unit
[0222] **154**: capacity calculation unit
[0223] **155**: SOC operation system
[0224] **160**: signal communication means
[0225] **170**: insulation element
[0226] **180**: storage unit
[0227] **200**: vehicle control unit
[0228] **300** to **330**: relay
[0229] **400**: inverter
[0230] **410**: motor generator
[0231] **420**: charger
[0232] **510**, **510***b*, **510***c*: pattern calling unit
[0233] **511**, **511***c*: pattern determination unit
[0234] **512**, **512***c*: SOC-OCV library
[0235] **520**, **520***a*, **520***b*, **520***d*: correction limit width designation unit
[0236] **521**: correction limit width library
[0237] **530**, **530***d*, **530***e*: direct detection correction unit
[0238] **531**: corrected OCV pair/integrated current acquisition unit
[0239] **532**: SOC-OCV direct detection correction unit
[0240] **533**, **533***d*: SOC-OCV overwrite determination unit
[0241] **534**: SOC-OCV convergence determination unit
[0242] **535**: out-of-width count unit
[0243] **536**: operating history determination unit

1. A battery control device which obtains a state of charge of a secondary battery from characteristics representing a relationship of a state of charge and a voltage of the secondary battery, comprising:

a calling unit which calls a first characteristic among a plurality of the characteristics stored in advance based on use history information of the secondary battery;

a correction limit width designation unit which designates a correction limit width for prescribing a tolerance level of correcting the first characteristic; and

a direct detection correction unit which creates a second characteristic in which the first characteristic has been corrected according to the correction limit width based on a current value and a voltage value of the secondary battery,

wherein the state of charge of the secondary battery is obtained using the second characteristic.

2. The battery control device according to claim **1**,

wherein the calling unit calls the first characteristic by using at least one among a state of health, a current history, a temperature history and a state of charge history of the secondary battery as the use history information.

3. The battery control device according to claim **1**,

wherein the correction limit width designation unit designates, as the correction limit width, a certain voltage width for each state of charge or a certain state of charge width for each voltage.

4. The battery control device according to claim **1**,

wherein the correction limit width designation unit designates, as the correction limit width, a voltage width which differs for each predetermined state of charge or a state of charge width which differs for each predetermined voltage.

5. The battery control device according to claim **1**,

wherein the correction limit width designation unit changes the correction limit width according to an operating history of the secondary battery.

6. The battery control device according to claim **5**,

wherein the correction limit width designation unit changes the correction limit width according to the operating history of the secondary battery by selecting one correction limit width among a plurality of the correction limit widths stored in advance based on the first characteristic.

7. The battery control device according to claim **1**, further comprising:

a voltage operation unit which calculates an open voltage value and a polarization voltage value of the secondary battery based on a current value and a voltage value of the secondary battery,

wherein the direct detection correction unit acquires, a plurality of times within a predetermined time range, an open voltage value of the secondary battery when the current value and the polarization voltage value are respectively smaller than a predetermined threshold, and creates the second characteristic by using each of the acquired open voltage values, a current integrated value in an acquisition period of each of the open voltage values, and the first characteristic.

8. The battery control device according to claim **1**,

wherein:

the correction limit width designation unit designates a second correction limit width for prescribing a tolerance level of correcting the second characteristic created in a past by the direct detection correction unit; and

the direct detection correction unit creates the second characteristic by using the correction limit width designated by the correction limit width designation unit for a present first characteristic and the second correction limit width designated by the correction limit width designation unit for a past second characteristic.

9. The battery control device according to claim **1**,

wherein the direct detection correction unit corrects the first characteristic based on a current value and a voltage value of the secondary battery, and limits the first characteristic after correction to be within a range of the correction limit width.

10. The battery control device according to claim **9**,

wherein the direct detection correction unit updates the use history information based on the first characteristic after correction including parts outside the range of the correction limit width.

11. The battery control device according to claim **10**,

wherein the direct detection correction unit determines whether the first characteristic after correction is within the range of the correction limit width, and updates the use history information when the first characteristic after correction determined to be outside the range of the correction limit width satisfies a predetermined convergence condition.

12. The battery control device according to claim **11**, wherein the convergence condition includes at least one of either a first condition in which a number of times that the first characteristic after correction was continuously determined to be outside the range of the correction limit width is equal to or greater than a predetermined number of times, or a second condition in which a variance in the first characteristic after correction is equal to or less than a predetermined threshold.

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