

METHOD OF DETECTING DEFECTIVE BATTERY CELL

TECHNICAL FIELD

[0001] The present invention relates to a method of detecting a defective battery cell, and more specifically, to a method of detecting a defective battery cell, which may increase detection power and does not require additional equipment and an additional test period.

BACKGROUND

[0002] As xEVs, which include a hybrid electric vehicle, a plug-in hybrid electric vehicle, and an electric vehicle, have recently become popular, the quality management of batteries used in the xEVs has become very important. For the battery quality management in a mass production line of a battery system, a method of detecting a defective product by detecting whether an internal resistance and an output of the battery system are matched through an output test of a battery when testing a final product has been used.

[0003] However, in the test method, detection power capable of detecting a defect rate may significantly vary depending on which value of the characteristics of the battery is monitored, and currently, the method quantitatively calculates a direct current internal resistance (DCIR) and a maximum charge output or discharge output through the fluctuation of the entire voltage

of the battery system caused by applying a charge or discharge pulse current for 10 seconds using a high-voltage charge-discharge device and detects a defective product.

[0004] Such a conventional method may detect a DCIR and charge output and discharge output values but has a problem incapable of detecting whether a low-voltage cell is defective.

Documents of Related Art

[0005] (Patent Document 1) Korean Patent Application Laid-Open No. 10-2022-0071007 A (entitled "METHOD OF DIAGNOSING BATTERY PACK" and published on May 31, 2022).

SUMMARY OF THE INVENTION

[0006] The present invention has been made in efforts to solve the above problem and is directed to providing a method of detecting a defective battery cell, which may efficiently detect a defective cell by increasing detection power through the simple subdivision of determination conditions without additional equipment and an additional test time.

[0007] A method of detecting a defective battery cell for solving the above problem includes S1) connecting a charge-discharge device to a battery system and measuring open circuit voltages (OCV) of cells included in the battery system, S2) applying, by the charge-discharge device, a charge pulse or a discharge pulse to each of the cells included in the battery system for n seconds,

S3) performed simultaneously with the operation S2 and measuring closed circuit voltages (CCV) of the cells, and S4) determining whether the cell matches with a predetermined condition using the OCV measured in the operation S1 and the CCV measured in the operation S3 and determining that a battery cell satisfying the predetermined condition is a normal cell and battery cells not satisfying the predetermined condition are defective cells.

[0008] In addition, at least two predetermined conditions in which it is determined that the battery cell is the normal cell or the defective cell in the operation S4 may be provided.

[0009] In addition, when the cell sequentially satisfies all of the predetermined conditions, it may be determined that the cell is the normal cell, and it may be determined that the remaining cells are the defective cells.

[0010] In addition, the predetermined condition may include a first condition in which it is determined whether a difference between a CCV at a time point at which b seconds have elapsed after the charge pulse or the discharge pulse is applied in the operation S2 and an OCV immediately before the charge pulse or the discharge pulse is applied in the operation S2 is smaller than or equal to a first reference value.

[0011] In addition, the predetermined condition may include a second condition in which it is determined whether a difference between a CCV at a time point at which c seconds have elapsed after the charge pulse or the discharge pulse is applied in the

operation S2 and an OCV immediately before the charge pulse or the discharge pulse is applied in the operation S2 is smaller than or equal to a second reference value.

[0012] In addition, the predetermined condition may include a third condition in which it is determined whether a difference between the largest CCV and the smallest CCV among all CCVs of each of the cells at a time point at which the c seconds have elapsed is smaller than or equal to a third reference value.

[0013] In addition, the predetermined condition may include a fourth condition in which it is determined whether a change rate of a CCV from the b seconds to the c seconds after the charge pulse or the discharge pulse is applied in the operation S2 is smaller than or equal to a fourth reference value.

[0014] In addition, the method may further include S5) performed after performing the operation S2 and measuring a voltage of each cell during an idle period after the charge pulse or the discharge pulse is applied, wherein the predetermined condition may include a fifth condition in which it is determined whether a change rate of a voltage from d seconds to e seconds after entering the idle period is less than a fifth reference value (a time ($f > e > d$) until reaching the OCV after entering the idle period).

[0015] In addition, the battery system may include at least two cells connected in parallel, and the operations S1 to S4 may be performed on a cell having a higher voltage among the at least two cells connected in parallel.

[0016] In addition, the battery system may include at least two cells connected in parallel, and the operations S1 to S5 may be performed on a cell having a higher voltage among the at least two cells connected in parallel.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] FIG. 1 is a flowchart illustrating a method of detecting a defective battery cell according to a first embodiment of the present invention.

[0018] FIG. 2 is a view schematically illustrating a battery system to which the method of detecting the defective battery cell according to the first embodiment of the present invention is applied and a charge-discharge device.

[0019] FIG. 3 is a graph illustrating a charge pulse periodically applied to each cell in operation S2.

[0020] FIG. 4 is a view illustrating voltages of cells at a time point a and a time point b illustrated in FIG. 3.

[0021] FIG. 5 is a view illustrating voltages of cells at the time point a and a time point c illustrated in FIG. 3.

[0022] FIG. 6 is a view illustrating voltages of cells at a time point d and a time point e illustrated in FIG. 3.

[0023] FIG. 7 is a view illustrating another example of the battery system.

DETAILED DESCRIPTION OF THE INVENTION

[0024] Hereinafter, a preferred embodiment of a method of detecting a defective battery cell according to the present invention will be described in detail with reference to the accompanying drawings.

[0025] FIG. 1 is a flowchart illustrating a method of detecting a defective battery cell according to a first embodiment of the present invention, and FIG. 2 is a view schematically illustrating a battery system to which the method of detecting the defective battery cell according to the first embodiment of the present invention is applied and a charge-discharge device.

[0026] As illustrated in FIG. 1, the method of detecting the defective battery cell according to the first embodiment of the present invention includes operations S1 to S5.

[0027] As illustrated in FIG. 1, in operation S1, a charge-discharge device is connected to a battery system, and open circuit voltages (hereinafter referred to as "OCV") of cells included in the battery system are measured.

[0028] As illustrated in FIG. 2, a battery system 10 may include a first cell 20-1 to a kth cell 20-k and a battery management system (BMS) 30. A charge-discharge device 40 is connected to an output terminal of the battery system 10. Here, k may be a natural number that is larger than or equal to 1.

[0029] Referring to FIGS. 1 and 2, in operation S1, the charge-discharge device 40 is connected to the battery system 10, and an OCV of each of the first cell 20-1 to the kth cell 20-k is

measured. At this time, the OCV of each of the first cell 20-1 to the kth cell 20-k may be measured by the BMS 30 using various sensors included in the battery system 10.

[0030] Operation S2 is an operation in which the charge-discharge device 40 applies a charge pulse or a discharge pulse to each of the first cell 20-1 to the kth cell 20-k included in the battery system 10 for n seconds. A time when the charge pulse or the discharge pulse is applied in the operation S2 in the embodiment may be 10 seconds. In other words, in the embodiment, n may be 10. However, in the operation S2, the time when the charge pulse or the discharge pulse is applied is not limited to 10 seconds and may be set to various times, as necessary.

[0031] In the operation S2, when the charge pulse or the discharge pulse is applied to the first cell 20-1 to the kth cell 20-k, a voltage of each of the first cell 20-1 to the kth cell 20-k fluctuates. In the operation S2, when the charge pulse is applied, the voltage of each of the first cell 20-1 to the kth cell 20-k increases while the charge pulse is applied, and in the operation S2, when the discharge pulse is applied, the voltage of each of the first cell 20-1 to the kth cell 20-k decreases while the discharge pulse is applied.

[0032] Operation S3 may be performed simultaneously with the operation S2 or performed immediately after the operation S2 starts, and a closed circuit voltage (hereinafter referred to as "CCV") of each of the first cell 20-1 to the kth cell 20-k in a

state in which the charge pulse or the discharge pulse has been applied in the operation S2 is measured. The CCV measured in the operation S3 may have different time points, which will be described below.

[0033] Operation S5 is performed simultaneously with the operation S2 or performed after the operation S2 is performed. In the operation S5, a voltage of each cell is measured during an idle period after the charge pulse or the discharge pulse is applied from the charge-discharge device 40. In the operation S5, a time point at which the voltage is measured during the idle period may be different, which will be described below.

[0034] In the operation S4, whether the first cell 20-1 to the kth cell 20-k match with a predetermined condition using the OCV measured in the operation S1, the CCV measured in the operation S3, and the CCV measured in the operation S3, and it is determined that, among the first cell 20-1 to the kth cell 20k, a cell matching with the predetermined condition is a normal cell and a cell not matching with the condition is a defective cell. In this case, at least two predetermined conditions may be provided, and in the method of detecting the defective battery cell according to the first embodiment of the present invention, a total of five predetermined conditions may be provided. In addition, in the operation S4, among the first cell 20-1 to the kth cell 20-k, sequentially satisfy all predetermined conditions,

it is determined that the corresponding cell is a normal cell, and the remaining cells are defective.

[0035] Hereinafter, the five conditions used in the operation S4 of the method of detecting the defective battery cell according to the first embodiment of the present invention will be described.

[0036] FIG. 3 is a graph illustrating a charge pulse periodically applied to each cell in operation S2, and FIG. 4 is a view illustrating voltages of cells at a time point a and a time point b illustrated in FIG. 3.

[0037] Referring to FIG. 3, in a first condition that is a first one, it is determined whether a difference between a CCV at the time point b at which b seconds have elapsed after the charge pulse is applied in the operation S2 and an OCV at the time point a immediately before the charge pulse is applied in the operation S2 is smaller than or equal to a first reference value. In this case, the first reference value may vary depending on specifications of the battery system 10 or specifications of each of the first cell 20-1 to the kth cell 20-k. The above-described b seconds may be 1 second. In other words, in the operation S4 of the method of detecting the defective battery cell according to the first embodiment of the present invention, in the first condition, it is determined that a cell having a voltage that rapidly increases when the charge pulse is applied is a defective cell. In FIG. 4, actually, it can be seen that defective cell 1

and defective cell 2 have rapidly increasing voltages compared to the other normal cells at the time point b.

[0038] On the contrary, when the discharge pulse is applied, in the first condition, the CCV at the time point b at which the b seconds have elapsed after the discharge pulse is applied becomes lower than the OCV at the time point a, and it is determined that the cell having a rapidly decreasing voltage is a defective cell. In summary, in the first condition in the embodiment, it is determined that when the difference between the CCV at the time point b and the OCV at the time point a is smaller than or equal to the first reference value, the corresponding cell is a normal cell, and when the difference exceeds the first reference value, the corresponding cell is a defective cell. The first reference value may vary depending on repeated experiments.

[0039] FIG. 5 is a view illustrating voltages of cells at the time point a and a time point c illustrated in FIG. 3.

[0040] Referring to FIG. 3, in a second condition that is a second one, it is determined whether a difference between a CCV at a time point at which c seconds have elapsed after the charge pulse or the discharge pulse is applied in the operation S2 and an OCV at the time point a is smaller than or equal to a second reference value. In this case, the second reference value may vary depending on specifications of the battery system 10 or specifications of each of the first cell 20-1 to the kth cell 20-k. The above-described c seconds may be 10 seconds. However,

in the present invention, the c seconds are not limited to 10 seconds, and the c seconds may be smaller than or equal to n seconds, which are a total of the time when the charge pulse or the discharge pulse is applied, and may be larger than the b seconds. In other words, in the operation S4 of the method of detecting the defective battery cell according to the first embodiment of the present invention, in the second condition, it is determined that when a predetermined time has elapsed after the charge pulse or the discharge pulse is applied, a cell having a larger increase in a voltage than the other cells is a defective cell. In FIG. 5, actually, it can be seen that defective cell 1 and defective cell 2 have higher voltages than the other normal cells at the time point c.

[0041] In a third condition that is a third one, it is determined whether a difference between the largest CCV value and the smallest CCV value among all CCVs of each of the cells at the time point c is smaller than or equal to a third reference value, and it is determined that when the difference is smaller than or equal to the third reference value, the first cell 20-1 to the kth cell 20-k are normal cells, and when the difference exceeds the third reference value, a defective cell is included in the first cell 20-1 to the kth cell 20-k.

[0042] Referring to FIGS. 3 and 5, in a fourth condition that is a fourth one, it is determined whether a change rate of a CCV from the time point b to the time point c after the charge pulse

or the discharge pulse is applied in the operation S2 is smaller than or equal to a fourth reference value. This is because when a battery cell is defective, when the charge pulse or the discharge pulse is applied to the corresponding cell, a voltage of the cell increases or decreases rapidly. The change rate may be obtained by dividing a value obtained by subtracting the voltage at the time point b from the voltage at the time point c by a time from the time point b to the time point c.

[0043] FIG. 6 is a view illustrating voltages of cells at a time point d and a time point e illustrated in FIG. 3.

[0044] Referring to FIGS. 3 and 6, in a fifth condition that is a fifth one, it is determined whether a change rate of a voltage from the time point d after d seconds have elapsed and the time point e after e seconds have elapsed after finishing the operation S2 and entering the idle period is smaller than a fifth reference value, and it is determined that when the change rate is smaller than the fifth reference value, the corresponding cell is a normal cell, and when the change rate is larger than or equal to the fifth reference value, the corresponding cell is a defective cell. In this case, a time it takes for each cell to reach an OCV voltage after entering the idle period may be f seconds, and this time point may be referred to as a time point f. In the embodiment, the d seconds may be 1 second, the e seconds may be 10 seconds, and the time point f may be 20 seconds after entering the idle period. However, the above-described set values of d, e, and f

are only examples, and when a condition ($f > e > d$) is satisfied, d, e, and f may be set to any number.

[0045] The reason why the above-described fifth condition is applied to the present invention is that, in the case of a lithium-ion battery, a cell voltage gradually stabilizes during an idle period after charging or discharging, and in the idle period after the charge pulse is applied, the cell voltage stabilizes downward, and in the idle period after the discharge pulse is applied, the cell voltage stabilizes upward. When the cell voltage stabilizes in the idle period as described above, it may be determined that a cell internal defect occurs when a stabilization time is longer than a reference time. In other words, when the change rate of the voltage from the time point d to the time point e is larger than the reference value, it may be determined that the corresponding cell is defective.

[0046] A method of obtaining the change rate of the voltage from the time point d to the time point e used in the fifth condition may be a method of dividing a value obtained by subtracting the voltage at the time point e from the voltage at the time point d by the time from the time point d to the time point e, and in addition, may be a method of comparing a value obtained by subtracting a value obtained by subtracting a minimum value $V_{\min_c(e)}$ among the voltages of the first cell 20-1 to the kth cell 20-k at the time point e from a minimum value $V_{\min_c(d)}$ among the voltages of the first cell 20-1 to the kth cell 20-k at the time point d

from a value obtained by subtracting a maximum value $V_{\max_c(e)}$ among the voltages of the first cell 20-1 to the kth cell 20-k at the time point e from a maximum value $V_{\max_c(d)}$ among the values of the first cell 20-1 to the kth cell 20-k at the time point d with the fifth reference value. This is expressed as an expression as follows.

[0047] $(V_{\max_c(d)} - V_{\max_c(e)}) - (V_{\min_c(d)} - V_{\min_c(e)}) < \text{fifth reference value}$

[0048] The expression may be a case in which the charge pulse is applied in the operation S2, and when the discharge pulse is applied in the operation S2, positions of $V_{\max_c(d)}$ and $V_{\max_c(e)}$ may be changed, and likewise, $V_{\min_c(d)}$ and $V_{\min_c(e)}$ may be changed.

[0049] FIG. 7 is a view illustrating another example of the battery system.

[0050] As illustrated in FIG. 7, the battery system 10 may include battery cells having a configuration in which a total of six groups are connected in series, each of which includes two cells connected in parallel, that is, a two-parallel-and-six-series configuration. In the case of the cells connected in parallel as described above, it is difficult to detect a defective cell when any one of the two cells is defective. To overcome this, the method for detecting the defective battery cell according to the present invention may detect a defective cell by performing the above-described operations S1 to S5 on a cell having a higher voltage among the two cells.

[0051] It may be determined that cells passing all of the above-described first to fifth conditions are normal cells or defective cells after performing subsequent additional tests through DCIR calculation, output calculation, voltage/temperature measurement, etc.

[0052] As described above, according to the present invention, by applying the charge pulse or the discharge pulse to each cell through the charge-discharge device and monitoring a change in a voltage varying depending on whether the pulse is applied, it is possible to detect a failure of the cell, in particular, a low-voltage failure of the cell even without using a separate test device and requiring a separate test time, thereby increasing detection power.

[0053] According to the method of detecting the defective battery cell according to the present invention, since whether the cell is defective may be determined using only the conventional equipment and a separate test is not required, it can be more economical and efficient than the conventional test method.

[0054] In addition, according to the present invention, since it is determined that the cell is the normal cell only when satisfying all of the first condition to the fifth condition, it is possible to increase detection power.

[0055] The present invention is not limited to the above-described embodiments, and not only the scope of applications is diverse but also various modifications may be made without

departing from the gist of the present invention as claimed in the claims.

DESCRIPTION OF REFERENCE NUMERALS

10: battery system 20-1 to 20-k: first cell to kth cell
30: BMS 40: charge-discharge device

WHAT IS CLAIMED IS:

1. A method of detecting a defective battery cell, comprising:

S1) connecting a charge-discharge device to a battery system and measuring open circuit voltages (OCV) of cells included in the battery system;

S2) applying, by the charge-discharge device, a charge pulse or a discharge pulse to each of the cells included in the battery system for n seconds;

S3) performed simultaneously with the operation S2 and measuring closed circuit voltages (CCV) of the cells; and

S4) determining whether the cell matches with a predetermined condition using the OCV measured in the operation S1 and the CCV measured in the operation S3 and determining that a battery cell satisfying the predetermined condition is a normal cell and battery cells not satisfying the predetermined condition are defective cells.

2. The method of claim 1, wherein at least two predetermined conditions in which it is determined that the battery cell is the normal cell or the defective cell in the operation S4 are provided.

3. The method of claim 2, wherein in the operation S4, when the battery cell sequentially satisfies all of the predetermined conditions, it is determined that the battery cell is the normal

cell, and it is determined that the remaining battery cells are the defective cells.

4. The method of any one of claims 1 to 3, wherein the predetermined condition includes a first condition in which it is determined whether a difference between a CCV at a time point at which b seconds have elapsed after the charge pulse or the discharge pulse is applied in the operation S2 and an OCV immediately before the charge pulse or the discharge pulse is applied in the operation S2 is smaller than or equal to a first reference value ($n > b$).

5. The method of claim 4, wherein the predetermined condition includes a second condition in which it is determined whether a difference between a CCV at a time point at which c seconds have elapsed after the charge pulse or the discharge pulse is applied in the operation S2 and an OCV immediately before the charge pulse or the discharge pulse is applied in the operation S2 is smaller than or equal to a second reference value ($n \geq c > b$).

6. The method of claim 5, wherein the predetermined condition includes a third condition in which it is determined whether a difference between a largest CCV and a smallest CCV

among all CCVs of each of the cells at a time point at which the c seconds have elapsed is smaller than or equal to a third reference value.

7. The method of claim 6, wherein the predetermined condition includes a fourth condition in which it is determined whether a change rate of a CCV from the b seconds to the c seconds after the charge pulse or the discharge pulse is applied in the operation S2 is smaller than or equal to a fourth reference value.

8. The method of claim 7, further comprising S5) performed after performing the operation S2 and measuring a voltage of each cell during an idle period after the charge pulse or the discharge pulse is applied,

wherein the predetermined condition includes a fifth condition in which it is determined whether a change rate of a voltage from d seconds to e seconds after entering the idle period is smaller than a fifth reference value (a time ($f > e > d$) until reaching an OCV after entering the idle period).

9. The method of any one of claims 1 to 7, wherein the battery system includes at least two cells connected in parallel, and

the operations S1 to S4 are performed on a cell having a higher voltage among the at least two cells connected in parallel.

10. The method of claim 8, wherein the battery system includes at least two cells connected in parallel, and the operations S1 to S5 are performed on a cell having a higher voltage among the at least two cells connected in parallel.