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- (54) Title: A METHOD AND A MONITORING UNIT FOR MONITORING A BATTERY SYSTEM

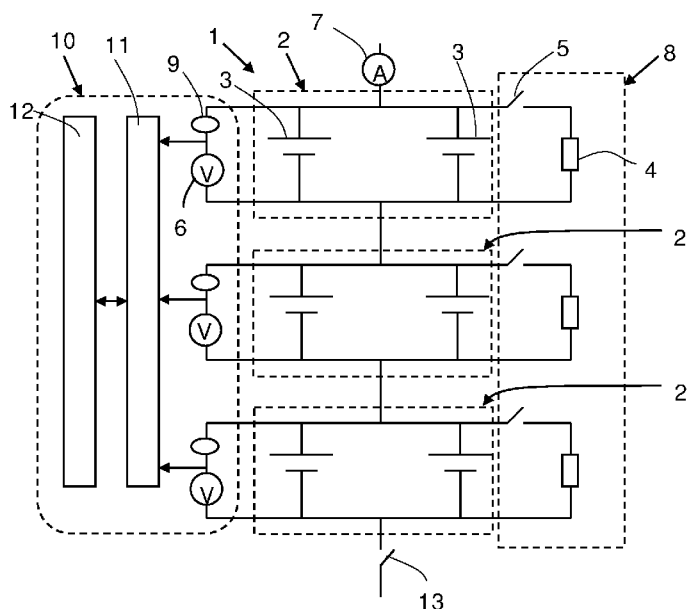


Fig. 1

- (57) Abstract: A method of monitoring a battery system (1) comprising a plurality of battery cell units (2) and a battery balancing module (8). The method comprises collecting measurement data for each of the battery cell units, based thereon determining at least one performance related parameter for each of the battery cell units, storing data relating to said parameter in a database, and based on said stored data, determining a change in at least one of capacity and impedance of the battery system over time. The measurement data used to determine the at least one performance related parameter are collected during a balancing process of the battery system.

A method and a monitoring unit for monitoring a battery system

5 FIELD OF THE INVENTION

The invention relates to a method of monitoring a battery system according to the preamble of claim 1 and to a monitoring unit according to the independent device claim. The invention is particularly intended for use with battery systems in electrified vehicles. The invention also relates to a computer program, a computer program product, an electronic control unit, and a motor vehicle.

15 BACKGROUND AND PRIOR ART

Electrified vehicles, both hybrid vehicles and pure electric drive vehicles, use batteries comprising a number of individual battery cell units connected in series, each comprising one or more battery cells connected in parallel. Internal sensors are used to monitor parameters such as temperature, current and voltage within the battery, and those parameters are used to determine the present condition of the battery. Depending on the application, different aspects of the battery's condition are of interest, e.g. the ability to deliver a particular electric power or to support a desired load when requested, or the state of charge (SOC) of the battery.

The individual battery cell units of the battery typically have slightly different capacities and may be at different levels of state

of charge. In order to minimize wear on the battery and maximize battery life and run time, the battery periodically needs to be balanced. In other words, energy is transferred to or from individual cell units until all cell units are at the same level of
5 state of charge.

Today's batteries for electrified vehicles have a limited battery life that depends on the use of the battery. It is therefore difficult to predict when it will be necessary to replace a battery in an
10 electrified vehicle. In order to avoid a situation in which a worn-out battery starts to cause problems in the vehicle, it is common to set a shorter period for battery replacement than necessary. Due to the high costs associated with battery replacement, it is however desirable to be able to more accurately predict when a
15 battery replacement will be necessary.

US 2012/0068715 discloses a battery system comprising a plurality of battery cell units and a battery balancing module for balancing the battery. The battery system is further provided with
20 monitoring units arranged to monitor performance related parameters for individual battery cell units, such as state of charge, output voltage, temperature, impedance, etc. Those parameters are thereafter stored in a memory on the monitoring unit and can be used to estimate battery life.

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SUMMARY OF THE INVENTION

It is an object of the present invention to provide an, in at least some aspect, improved solution for accurate prediction of the
30 state-of-health of a battery system.

This object is, according to a first aspect of the invention, achieved by the initially defined method of monitoring a battery system. The method is characterized in that the measurement data used to determine the at least one performance related parameter are collected during a balancing process of the battery system. By using measurement data collected during the balancing process of the battery system, the determination of the capacity and/or impedance of the battery system will be accurate, since the current in the battery system is low during the balancing process. Problems originating from short and irregular current pulses of large magnitude, common during operation of the battery, are thereby avoided. The impedance and the capacity can be used on their own, or preferably together, to predict the state-of-health of the battery system. When the impedance becomes too high, e.g. when it exceeds a predetermined threshold level, the battery system is no longer able to deliver sufficient power. When the capacity is reduced, the run time of the battery decreases and it needs more frequent recharging.

The method according to the invention is particularly suitable for use in hybrid vehicles, in which the battery system is generally used in a relatively narrow state of charge range, i.e. it is rarely fully charged or fully discharged. Typically, the battery system of a hybrid vehicle operates at a state of charge of 20–50% of full charge.

The determined change in capacity and/or impedance of the battery system over time may be stored in a database in a

vehicle comprising the battery system, or transferred to an external database, e.g. at a service center. The transfer of data may be either by continuous wireless transfer, or upon service of the vehicle. Since data relating to each individual cell unit are
5 stored, it is also possible to use stored data to see if an individual battery cell unit is impaired, and not only to monitor the overall capacity and/or impedance of the battery system.

According to an embodiment of the invention, said measurement
10 data are collected at least at the start and/or at the end of the balancing process. At the start and at the end of the balancing process, a known resistance is switched in parallel with each battery cell unit and a step in voltage and current occurs. The voltage and current characteristics following the step may be
15 used to accurately determine the impedance of the individual battery cell unit. This may be done either at the start or at the end of the balancing process, or for an even more accurate determination, both at the start and at the end. For determination of the capacity of the battery system, it is useful to use
20 measurement data from the start and the end of the balancing process, and from comparison with a known discharge curve of the battery system determine a change in state of charge, from which the capacity may be determined.

25 According to another embodiment of the invention, said measurement data relate to at least voltage, current and temperature. Using these measurement data, it is possible to determine both the impedance and the capacity of the battery system with sufficient accuracy.

According to another embodiment of the invention, a learning process is used in the step of determining the change in capacity and/or in impedance of the battery system over time. This is very useful for battery types having a flat discharge curve within a certain state of charge window, for which it is generally difficult to determine the state of charge by measuring the voltage at the start of the balancing process. By using a learning process, such as a neural network or a support vector machine (SVM), it is possible to improve the accuracy of the determination over time.

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According to another embodiment of the invention, the at least one performance related parameter includes at least one of state of charge of the battery cell unit and impedance of the battery cell unit. These performance related parameters are both possible to directly determine from the available measurement data, such as current, temperature and voltage. The state of charge may preferably be used for the determination of the capacity of the battery system while the impedance of the individual battery cell units is used to obtain the overall impedance of the battery system.

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According to another embodiment of the invention, said measurement data are collected both at the start and at the end of the balancing process, and a change in capacity of the battery system over time is determined based on stored data relating to a change in state of charge of each of the battery cell units from the start to the end of the balancing process. The state of charge of each battery cell unit at the end of the balancing process is well known through the measured voltage and is therefore suitable to use as a reference point. The state of charge at the

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start of the balancing process may or may not be easy to define by the measured cell voltage, depending on battery chemistry, and it may be necessary to use a learning process to more accurately determine the state of charge at the beginning of the
5 balancing process.

According to another embodiment of the invention, the impedance of each of the battery cell units is determined based on measurement data collected in connection with switching in
10 and out a known resistance in parallel with each of the battery cell units. This is practical, since a step in current and voltage results upon switching, and the quotient between the voltage and current characteristics following the switch, e.g. during the second immediately following the switch, are suitable for use to
15 accurately determine the impedance of the individual battery cell units. Since balancing resistors of the battery system are switched in at the start and out at the end of the balancing process, it is suitable to determine the impedance based on measurement data collected at the start and at the end of the
20 balancing process.

According to another embodiment of the invention, a change in impedance of the battery system over time is determined based on stored data relating to the impedance of each of the battery
25 cell units. This is an efficient way to determine the change in impedance of the battery system over time.

According to another aspect of the present invention, the above defined object is achieved by a monitoring unit for monitoring a
30 battery system as initially defined. The monitoring unit is

characterized in that it is configured to use measurement data collected during a balancing process of the battery system to determine said at least one performance related parameter. The advantages of such a unit as well as preferred embodiments thereof are apparent from the above discussion relating to the proposed method.

In other aspects, the invention also relates to a computer program having the features of claim 10, a computer program product having the features of claim 11, an electronic control unit having the features of claim 12 and a motor vehicle according to claims 13 and 14.

Other advantageous features as well as advantages of the present invention will appear from the following detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

- Fig. 1 schematically shows a monitoring unit according to an embodiment of the invention and a battery system,
- Fig. 2 is a flow chart showing a method according to an embodiment of the invention,
- Fig. 3 is a flow chart showing a method according to another embodiment of the invention, and
- Fig. 4 schematically shows an electronic control unit according to an embodiment of the invention.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

5 A battery system 1 is schematically shown in fig. 1. The battery system 1 comprises three battery cell units 2 connected in series. Each individual battery cell unit 2 comprises two battery cells 3 connected in parallel. The battery system 1 comprises a balancing module 8, comprising a known resistance in the form of
10 a resistor 4 connected in parallel with each of the battery cell units 2 via a switch 5. A switch 13 is provided for connecting and disconnecting the battery system 1 to a load (not shown), such as an electric motor, and/or a battery charging unit (not shown). Of course, the number of battery cells 3 within each battery cell
15 unit 2 may vary, as well as the number of battery cell units 2. The number of battery cell units 2 may be several hundred in practical applications, such as in the battery system of a hybrid vehicle. The shown battery system 1 for simplicity and ease of illustration only comprises a limited number of individual battery
20 cell units 2 and battery cells 3. Furthermore, individual components of the battery cell unit 2 are in fig. 1 for clarity only marked in one of the shown battery cell units 2.

The battery system 1 is provided with a monitoring unit 10
25 according to an embodiment of the invention. The monitoring unit 10 comprises measurement means for collecting measurement data, including voltmeters 6 for measuring the voltage across each of the battery cell units 2, an ammeter 7 for measuring the current through the battery system 1, and temperature sensors 9
30 for measuring the temperature within individual battery cell units

2. The monitoring unit 10 further comprises data storage means 11 and processing means 12. In the data storage means 11, collected measurement data and data calculated by means of the processing means 12 may be stored in a database. The
5 processing means 12 is configured to, based on stored data relating to voltage, current and temperature, determine at least one performance related parameter for each of the battery cell units 2, such as state of charge (SOC) and/or impedance. The processing means 12 is further configured to determine a change
10 in capacity and/or impedance of the battery system 1 over time based on stored data relating to state of charge and/or impedance of individual battery cell units 2.

The monitoring unit and the method according to the invention is
15 suitably used for monitoring a battery system in a hybrid vehicle, used for powering an electric motor. The method is performed during balancing of the battery system 1, when the electric motor is inactive.

20 Reference is now made to fig. 2 illustrating a method according to an embodiment of the invention, in which the capacity of the battery system 1 is monitored. According to the shown embodiment, the method is initiated at the start of a balancing process of the battery system 1. In a first step A1, measurement
25 data relating to temperature in, current through and voltage across each individual battery cell unit 2 are collected using the temperature sensors 9, ammeter 7, and the voltmeters 6. In a step A2, the state of charge (SOC) for each of the individual battery cell units 2 is determined based on the collected
30 measurement data using the processing means 12. The

determined states of charge are stored in a database in the data storage means 11 in a step A3. At least at the end of the balancing process, steps A1–A3 are repeated. It is also possible to repeat steps A1–A3 several times during the balancing process, until the balancing process ends. A time series of data is thereby stored in the database. In a step A4, a change in state of charge ΔSOC from the beginning of the balancing process to the end of the balancing process is calculated in the processing means 12. From the change ΔSOC of each individual battery cell unit 2, the current capacity of the battery system 1 can be calculated in a step A5.

At the end of the balancing process, the state of charge of each battery cell unit 2 can be easily determined from the measured voltage across the battery cell unit 2 by comparison with a known discharge curve of the battery system 1. Depending on the battery type, the state of charge at the beginning of the balancing process can be more difficult to determine from the measured voltage. This is the case e.g. for battery types with a relatively flat discharge curve, for which a particular voltage across the battery cell unit 2 cannot be unambiguously associated with a particular state of charge. A learning process, such as a neural network or a support vector machine (SVM) may therefore be used to more accurately be able to determine the state of charge at the beginning of the balancing process. For battery types with a more steep discharge curve, it is not necessary to use a learning process. For such battery types, a particular voltage across the battery cell unit 2 is closely associated with a particular state of charge. The state of charge of individual

battery cell units 2 may of course also be determined in other ways known in the art.

Another embodiment of the method according to the invention is shown in fig. 3. According to this embodiment, the method is used to monitor the impedance of the battery system 1. The method is initiated at the start of a balancing process of the battery system 1. At this point, the resistors 4 are switched in using the switch 5, resulting in a step in current through and voltage across each individual battery cell unit 2. Alternatively, or additionally, the method is initiated at the end of the balancing process, when the resistors 4 are switched out and another step in current and voltage occurs. In a step B1, measurement data relating to temperature in, current through and voltage across each individual battery cell unit 2 during the time period immediately following the switch are collected. In a step B2, the quotient between the voltage and current characteristics following the switch are used to determine the impedance of the individual battery cell units 2. The determined impedance of each individual battery cell unit 2 is stored in a database in a step B3. Thereafter, in a step B4, the impedance of the battery system 1 is determined using the stored data relating to the impedance of each individual battery cell unit 2.

Since balancing resistors 4 of the battery system are switched in at the start and out at the end of the balancing process, it is suitable to determine the impedance based on measurement data collected at the start and at the end of the balancing process. It is also possible to determine the impedance based on data measured only on one occasion during the balancing process. In

that case, the collection of measurement data is preferably done at the end of the balancing process, when the battery cell unit 2 is at a well-known state of charge.

- 5 Of course the method according to the embodiments shown in fig. 2 and 3 may be combined, so that both the capacity and the impedance of the battery system 1 is monitored.

The determined impedance and/or capacity of the battery system
10 1 may be stored in a central database to allow a comparison over time. This database may be located at e.g. a service center of a vehicle in which the battery system 1 is mounted. Data may be transferred either continuously using wireless transmission, or upon service of the vehicle. The monitored changes in
15 impedance and/or capacity over time allow a vehicle supplier to predict when the battery system of the vehicle will need to be exchanged. On one hand, this allows prevention of a situation in which the determined capacity of the battery system is found to be too low or the impedance is found to be too high for
20 satisfactory operation of the battery. On the other hand, it also prevents too frequent battery system exchanges, thus reducing the total cost per travelled kilometer.

Computer program code for implementing a method according to
25 the invention is suitably included in a computer program which is readable into an internal memory of a computer, such as the internal memory of an electronic control unit of a motor vehicle. Such a computer program is suitably provided through a computer program product comprising a data storing medium read-
30 able by an electronic control unit, which data storing medium has

the computer program stored thereon. Said data storing medium is for example an optical data storing medium in the form of a CD-ROM-disc, a DVD-disc, etc., a magnetic data storing medium in the form of a hard disc, a diskette, a tape etc., or a Flash
5 memory or a memory of the type ROM, PROM, EPROM or EEPROM.

Fig. 4 illustrates very schematically an electronic control unit 40 comprising an execution means 41, such as a central processor unit (CPU), for executing a computer program. The execution
10 means 41 communicates with a memory 42, for example of the type RAM, through a data bus 43. The control unit 40 comprises also a non-transitory data storing medium 44, for example in the form of a Flash memory or a memory of the type ROM, PROM,
15 EPROM or EEPROM. The execution means 41 communicates with the data storing medium 44 through the data bus 43. A computer program comprising computer program code for implementing a method according to the invention is stored on the data storing medium 44.

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The invention is of course not in any way restricted to the embodiments described above, but many possibilities to modifications thereof would be apparent to a person with skill in the art without departing from the scope of the invention as defined in
25 the appended claims.

CLAIMS

1. A method of monitoring a battery system (1) comprising a plurality of battery cell units (2) and a battery balancing module
5 (8), the method comprising:

- collecting measurement data for each of the battery cell units (2),
- based on said measurement data, determining at least one performance related parameter for each of the battery cell
10 units (2),
- storing data relating to said at least one performance related parameter in a database,
- based on said stored data, determining a change in at least one of capacity and impedance of the battery system (1)
15 over time,

characterized in

that said measurement data used to determine the at least one performance related parameter are collected during a balancing process of the battery system (1).

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2. The method according to claim 1, wherein said measurement data are collected at least at the start and/or at the end of the balancing process.

25 3. The method according to claim 1 or 2, wherein said measurement data relate to at least voltage, current and temperature.

4. The method according to any one of the preceding claims,
30 wherein a learning process is used in the step of determining the

change in capacity and/or in impedance of the battery system (1) over time.

5 5. The method according to any of the preceding claims, wherein the at least one performance related parameter includes at least one of state of charge of the battery cell unit (2) and impedance of the battery cell unit (2).

10 6. The method according to any of the preceding claims, wherein said measurement data are collected both at the start and at the end of the balancing process, and wherein a change in capacity of the battery system (1) over time is determined based on stored data relating to a change in state of charge of each of the battery cell units (2) from the start to the end of the balancing
15 process.

20 7. The method according to any of the preceding claims, wherein the impedance of each of the battery cell units (2) is determined based on measurement data collected in connection with switching in and out a known resistance (4) in parallel with each of the battery cell units (2).

25 8. The method according to claim 7, wherein a change in impedance of the battery system (1) over time is determined based on stored data relating to the impedance of each of the battery cell units (2).

30 9. A monitoring unit (10) for monitoring a battery system (1) comprising a plurality of battery cell units (2) and a battery balancing module (8), the monitoring unit (10) comprising:

- measurement means (6, 7, 9) configured to collect measurement data from each of the battery cell units (2),
- data storage means (11) for storing data in a database,
- processing means (12) configured to, based on said measurement data, determine at least one performance related parameter for each of the battery cell units (2), and based on stored data relating to said at least one performance related parameter, determine a change in at least one of capacity and impedance of the battery system (1) over time,

characterized in

that the monitoring unit (10) is configured to use measurement data collected during a balancing process of the battery system (1) to determine said at least one performance related parameter.

10. A computer program comprising computer program code for causing a computer to implement a method according to any one of the claims 1–8 when the computer program is executed in the computer.

11. A computer program product comprising a data storage medium (44) which can be read by a computer and on which the program code of a computer program according to claim 10 is stored.

12. An electronic control unit (40) in a motor vehicle comprising an execution means (41), a memory (42) connected to the execution means (41) and a data storage medium (44) which is connected to the execution means (41) and on which the

computer program code of a computer program according to claim 10 is stored.

13. A motor vehicle comprising an electronic control unit (40)
5 according to claim 12.

14. A motor vehicle according to claim 13, wherein the motor vehicle is a truck, a bus or a passenger car.

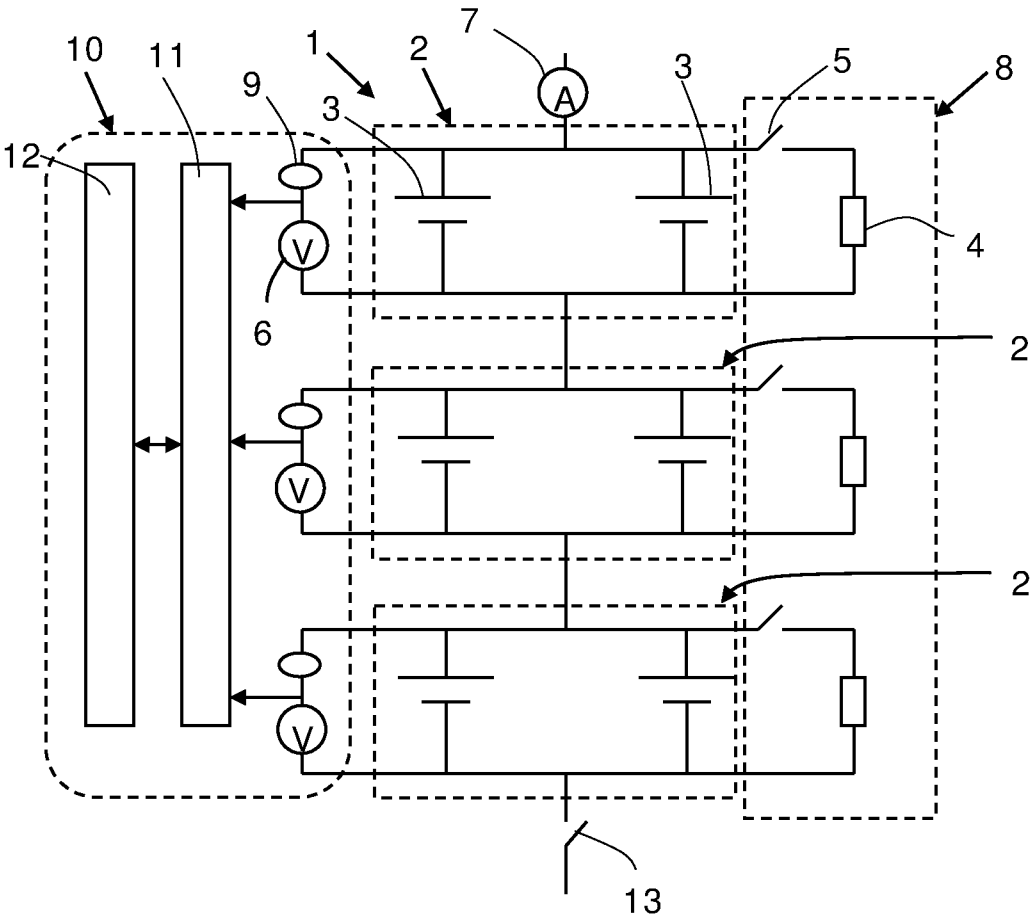


Fig. 1

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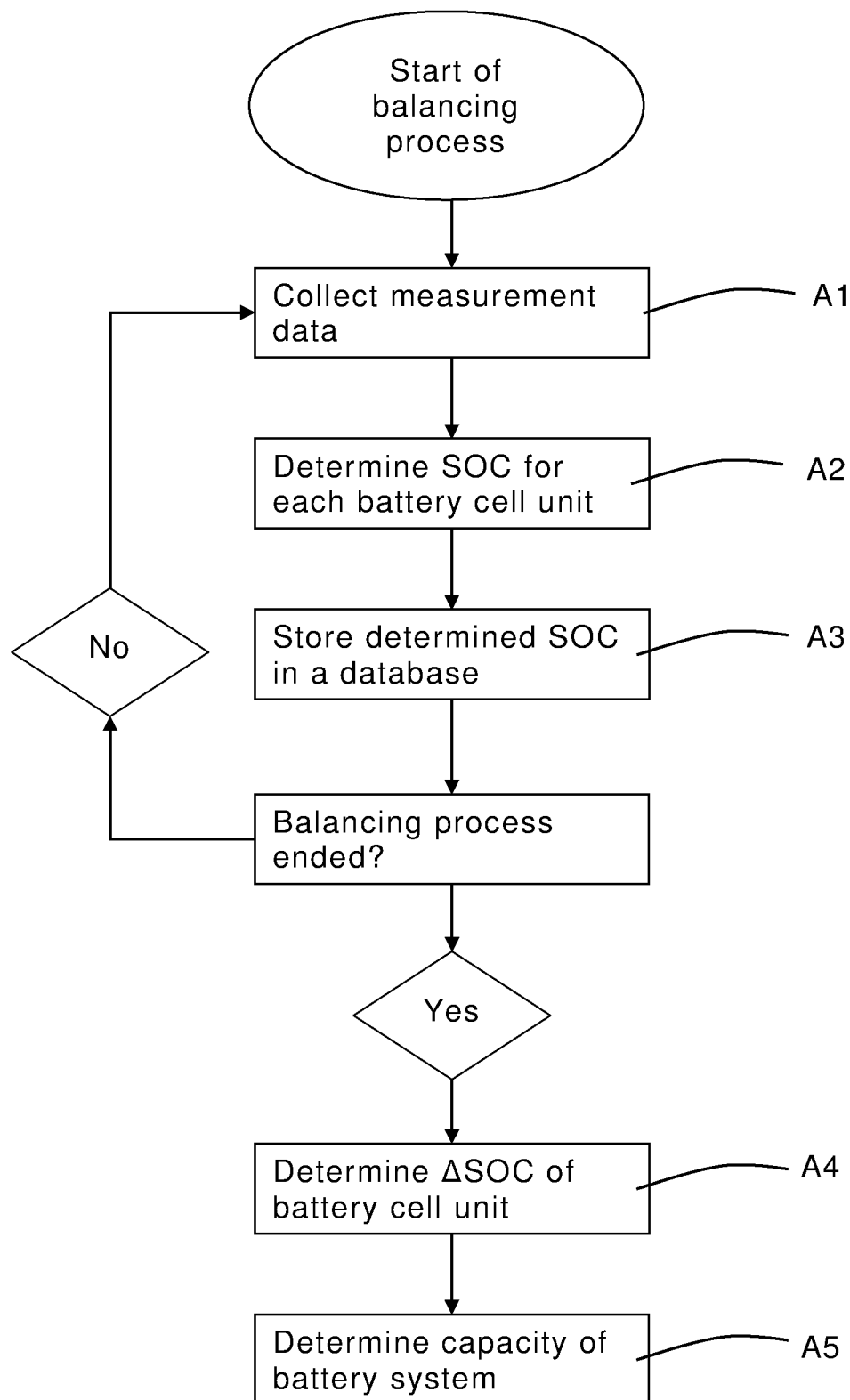


Fig. 2

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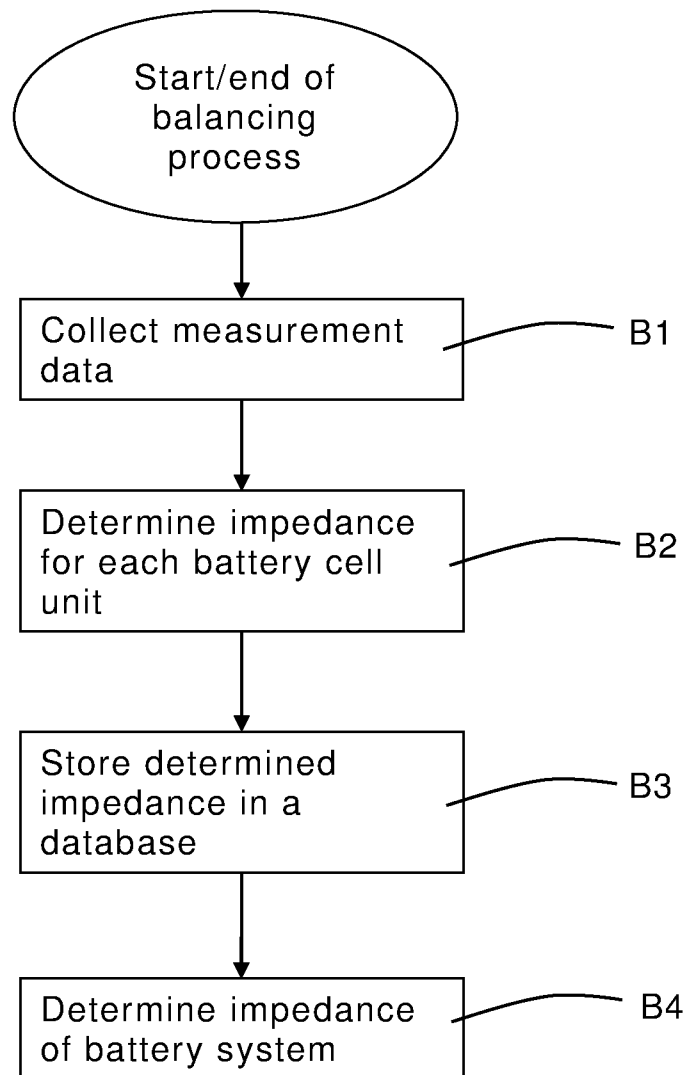


Fig. 3

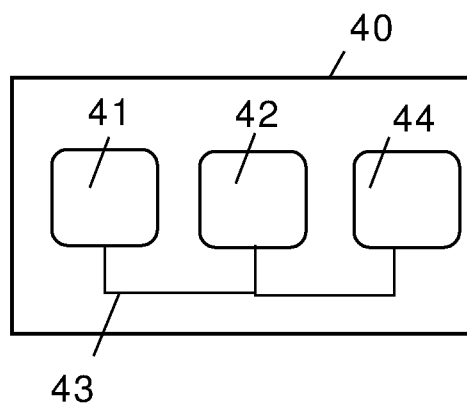


Fig. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2016/050540

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: B60L, G01R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE, DK, FI, NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, PAJ, WPI data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2014109895 A2 (JOHNSON CONTROLS TECH CO), 17 July 2014 (2014-07-17); paragraphs [0059], [0019]-[0021], [0057]-[0058] --	1-14
A	US 20120068715 A1 (MARTAENG JESPER), 22 March 2012 (2012-03-22); paragraphs [0008]-[0030] --	1-14
A	US 20120119746 A1 (MACRIS ERIC), 17 May 2012 (2012-05-17); abstract -- -----	1-14

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:

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“O” document referring to an oral disclosure, use, exhibition or other means

“P” document published prior to the international filing date but later than the priority date claimed

“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

“&” document member of the same patent family

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Continuation of: second sheet

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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