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ABSTRACT

The invention involves to a battery system comprising two or more battery assemblies (40, 41), wherein each battery assembly comprises two battery assembly terminals (105, 106), wherein the battery assemblies are via the battery assembly terminals connected in parallel to two load terminals (301, 302) of a load and/or a battery charger, wherein each battery assembly comprises a plurality of battery cells (163) connected in series and/or in parallel between the respective battery assembly terminals (105, 106),

- wherein each battery assembly (40, 41) comprises a control assembly (10, 171, 11, 172), and an actuation assembly (175, 176, 177) connected between the respective battery terminals and one or more of the battery cells of the respective battery assembly,
- wherein the respective control assembly is configured to control the respective actuation assembly so as to direct an actual current or voltage at the load terminals (301, 302) towards a desired current or voltage at the load terminals (301, 302),
- wherein one of the control assemblies is a master control assembly,
- wherein the master control assembly is configured to repetitively receive or determine an error value indicative of a difference between the actual current or voltage at the load terminals (301, 302), and the desired current or voltage at the load terminals (301, 302), resulting in a plurality of sequentially received or determined error values,
- wherein the master control assembly is configured to determine an integrated control value in dependence on the plurality of sequentially received or determined error values,
- wherein the master control assembly is configured to send the integrated control value to the remaining control assemblies, wherein the remaining control assemblies are configured to perform said control of the respective actuation assembly in dependence on the received integrated control value.

(Fig. 4)

A BATTERY SYSTEM AND A METHOD FOR CONTROLLING A BATTERY SYSTEM

TECHNICAL FIELD

The present invention relates to a battery system, a method for controlling a battery system, and a computer program.

BACKGROUND

As the application of battery systems, particularly in electric vehicles and energy storage systems, continues to expand, the need for efficient, reliable, and safe operation of these systems becomes increasingly important. Battery systems often comprise one or more battery assemblies, often referred to as battery packs, each with multiple battery cells connected in series and/or parallel. These cells are typically connected to a load or a charger through battery assembly terminals. The current or voltage at these terminals is monitored and controlled to ensure optimal operation of the battery system.

For example, WO2021094010A1 discloses a method for maintaining a target voltage of a battery assembly during charging or discharging. The battery assembly comprises a first battery module capable of outputting a range of voltages, and a plurality of second battery modules, each of which may be switched-on or bypassed.

US2023207898A1 discloses a parameters tuning method of an energy storage system. A PID control module is used to construct a closed-loop control subsystem of energy dispatching. An adaptive model is set in the PID control module, and PID initial parameters are modified through the adaptive model to obtain adjusted and modified PID parameters.

There is nevertheless a desire to improve the stability in battery system control loops while maintaining quick real-time responses in the control loops.

SUMMARY

An object of the invention is to improve the stability in battery system control loops while maintaining quick real-time responses in the control loops.

The object is achieved by a battery system comprising two or more battery assemblies, wherein each battery assembly comprises two battery assembly terminals, wherein the battery assemblies are via the battery assembly terminals connected in parallel to two load terminals of a load and/or a battery charger, wherein each battery assembly comprises a plurality of battery cells connected in series and/or in parallel between the respective battery assembly terminals,

- wherein each battery assembly comprises a control assembly, and an actuation assembly connected between the respective battery terminals and one or more of the battery cells of the respective battery assembly,
- wherein the respective control assembly is configured to control the respective actuation assembly so as to direct an actual current or voltage at the load terminals towards a desired current or voltage at the load terminals,
- wherein one of the control assemblies is a master control assembly,
- wherein the master control assembly is configured to repetitively receive or determine an error value indicative of a difference between the actual current or voltage at the load terminals, and the desired current or voltage at the load terminals, resulting in a plurality of sequentially received or determined error values,
- wherein the master control assembly is configured to determine an integrated control value in dependence on the plurality of sequentially received or determined error values,
- wherein the master control assembly is configured to send the integrated control value to the remaining control assemblies, wherein the remaining control assemblies are configured to perform said control of the respective actuation assembly in dependence on the received integrated control value.

The invention ensures stability where there are parallel controllers and parallel control loops to regulate the voltage on the same load. By the master control assembly determining and sending to the remaining control assemblies, herein also referred to as slaves, the integral control value, the control loops counteracting each other due to individually determined integral control values being different due to differences in input signals, is avoided. Avoiding individual integral control values also reduces the processor capacity needs and makes the process faster.

The respective control assembly may be configured to control the respective actuation assembly so as to adjust the actual current or voltage at the load terminals so as to move towards the desired current or voltage at the load terminals. The actual current or voltage may be measured at the lead terminals, e.g. by use of a voltage meter. In some embodiments a measuring assembly is configured to determine the error values in dependence on the actual current or voltage at the load terminals and the target current or voltage, wherein the master control assembly is configured to receive the error values.

The master control assembly is preferably configured to transmit the integrated control value to the remaining control assemblies.

Preferably, each actuation assembly comprises a DCDC converter, wherein the respective control assembly is configured to control the respective DCDC converter in dependence on the integrated control value. Thereby, the control by the respective control assembly to direct an actual current or voltage at the load terminals towards a desired current or voltage at the load terminals, may be done in a substantially continuous manner without discontinuous outputs of the respective control assembly. However, alternatively, or in addition, each actuation assembly may comprise a plurality of switches configured to selectively connect or disconnect one or more of the battery cells to or from the battery assembly terminals.

Preferably, the configuration of the respective control assembly to control the respective actuation assembly so as to direct the actual current or voltage at the load terminals towards the desired current or voltage at the load terminals comprises a configuration to control the respective actuation assembly so as to direct an actual current or voltage at the respective battery assembly terminals towards a desired current or voltage at the respective battery assembly terminals. Thereby, each battery assembly may independently measure and control the current in its respective battery assembly terminals. Thereby, each battery assembly may contribute to direct the actual current or voltage at the load terminals towards the desired current or voltage at the load terminals. Thereby, a good and fast response may be achieved. Nevertheless, the master control assembly may determine the integral control value for all control assemblies.

Preferably, the master control assembly is configured to perform said control of the actuation assembly of the master battery assembly in dependence on the integrated control value. Thus, in addition to the remaining control assemblies controlling their respective actuation assemblies in dependence on the integrated control value, the actuation assembly of the master control assembly may be controlled in dependence on the integrated control value.

Preferably, one or more of the remaining control assemblies are configured to determine a proportional control value and/or a derivative control value in dependence on one or more of the plurality of sequentially received or determined error values, wherein the one or more of the remaining control assemblies are configured to perform said control of the respective actuation assembly in dependence on the proportional control value and/or the derivative control value.

Thereby, the remaining control assemblies may operate locally with full bandwidth with proportional and/or derivative control values. Thereby stability in the control loops may be maintained. The integral control value may be non-time-critical, and may be sent with lower requirements on bandwidth and latency. Nevertheless, problems with more than one control loop with integral control values are avoided.

The object is also reached with a method for controlling a battery system comprising two or more battery assemblies, each comprising two battery assembly terminals, wherein the battery assemblies are via the battery assembly terminals connected in parallel to two load terminals of a load and/or a battery charger, wherein each battery assembly comprises a plurality of battery cells connected in series and/or in parallel between the respective battery assembly terminals,

- wherein the method comprises
- controlling actuation assemblies of the battery assemblies so as to direct an actual current or voltage at the load terminals towards a desired current or voltage at the load terminals,
- selecting one of the control assemblies as a master control assembly,
- the master control assembly repetitively receiving or determining an error value indicative of a difference between the actual current or voltage at the load terminals, and the desired current or voltage at the load terminals, resulting in a plurality of sequentially received or determined error values,
- the master control assembly determining an integrated control value in dependence on the plurality of sequentially received or determined error values,
- the master control assembly sending the integrated control value to the remaining control assemblies,
- and the remaining control assemblies performing said control of the respective actuation assembly in dependence on the received integrated control value.

Advantages with the method are understood from the description above of embodiments of the battery system according to the invention.

Preferably, said control of the actuation assembly of the master battery assembly is performed in dependence on the integrated control value. Preferably, one or more of the remaining control assemblies determines a proportional control value and/or a derivative control value in dependence on one or more of the plurality of sequentially received or determined error values, wherein the one or more of the remaining control assemblies performs said control of the respective actuation assembly in dependence on the proportional control value and/or the derivative control value.

In some embodiments, subsequently to selecting one of the control assemblies as a master control assembly, another of the control assemblies is selected as a master control assembly. Thereby, a replacement master control assembly may be provided. Thereby, in case of a fault in the original master control assembly, or in the battery assembly controlled by the original master control assembly, the replacement master control assembly may assume the task of repetitively receiving or determining an error value indicative of a difference between the actual current or voltage at the load terminals, and the desired current or voltage at the load terminals, resulting in a plurality of sequentially received or determined error values, determining an integrated control value in dependence on the plurality of sequentially received or determined error values, and sending the integrated control value to the remaining control assemblies, whereupon the remaining control assemblies performs said control of the respective actuation assembly in dependence on the received integrated control value.

The object is also achieved with a computer program comprising program code means for performing the steps of any embodiment of the method according to the invention, when said program is run on a computer.

Further advantages and advantageous features of the invention are disclosed in the following description and in the dependent claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Below, embodiments of the invention will be described with reference to the drawings, in which:

- fig. 1 shows components of a battery system,
- fig. 2 and fig. 3 show components of a battery assembly in the battery system in fig. 1,
- fig. 4 shows control loops for currents and voltages in the battery system in fig. 1,
- fig. 5 is a flow diagram depicting steps in a method according to an embodiment of the invention, and
- fig. 6 shows components of a control assembly for a battery assembly according to an embodiment of the invention.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

Fig. 1 shows a battery system with a plurality of parallel battery assemblies 40, 41. The battery assemblies 40, 41 each comprise a plurality of battery cells, as exemplified below. The battery system may be provided in an electric or hybrid electric vehicle, or in an electric power system. The battery assemblies 40, 41 are connectable to a load and/or charging system which comprises a common load or charging circuit 30. More specifically, the load and/or charging system comprises direct current (DC) voltage bus 15, and the battery assemblies are connected to load terminals 301, 302 of the DC voltage bus. The DC voltage bus can serve many purposes such as delivering or receiving power to or from AC electric motors or the AC grid via inverters, to or from other battery assemblies, to or from DC electric motors, from solar cells, from a fuel cell or the like.

A measuring assembly 20 is connected to the DC voltage bus 15. The measuring assembly 20 is arranged to measure the DC bus voltage or the DC bus current. A DC link capacitor 50 is also connected to the load or charger 30.

Each battery assembly 40, 41 comprises a control assembly comprising a main controller 10, 11. As exemplified further below, each control assembly is arranged to determine for the battery assemblies 40, 41 target values indicative of currents or voltages at battery assembly terminals of the battery assemblies 40, 41, and each control assembly is arranged to receive the information from the measuring assembly 20.

Fig. 2 shows one of the battery assemblies in fig. 1. The battery assembly comprises two battery assembly terminals 105, 106, and comprising a plurality of switched battery modules 170.

The control assembly is configured to provide a voltage control function as exemplified below.

Fig. 3 shows the battery assembly in fig. 2 in more detail. The set of battery modules also comprises an analog battery module 110, e.g. as described in WO2021094011A1 incorporated herein by reference. The analog battery module 110, e.g. a local controller 171 thereof, is configured to receive from the main controller 10 a signal representing a target current to be output through the analog battery module 110. The analog battery module 110 comprises a DCDC converter 177 which forms a part of the actuation assembly of the battery assembly. The local controller 171 is configured to minimize the error between a measured current through the DCDC converter and the target current value. The local controller 171 may be configured to generate one or more pulse width modulated (PWM) signals to be used by the DCDC converter. The DCDC converter may comprise a plurality of switches, and the switches may be controlled by the PWM signal to minimize said error. By controlling the current through the DCDC converter, the PWM signal controls the output voltage over the analog module in relation to the battery assembly's input voltage to the DCDC converter. The local controller 171 thus functions as a controlled current source. Thereby, the current through the DCDC converter is connected to the output voltage over the analog module. Thereby, the PWM signal makes it possible to fine-tune the output voltage of the battery assembly 40 so it is close to a target voltage.

In alternative embodiments, the DCDC converter is configured to receive a signal representing a target voltage over the analog battery module. Thereby, the local controller 171 may be integrated into the main controller.

Each switched battery module 170 comprises sets 163 of two or more battery cells connected in series to output conduits 170C of the respective battery module 170. More specifically, the battery cells of each battery module 170 are connected to a half-bridge comprising at least one switch in the form of a high side (HS) transistor 176 for connecting the battery module in the battery assembly and at least one switch low side (LS) transistor 175 that can bypass the battery module so that the battery cells do not contribute to the total output voltage of the battery assembly. The transistors may be MOSFET transistors. However, instead of transistors some other kind of switches may be used. More generally the HS transistors 176 are referred to as HS switches and the LS transistors 175 are referred to as LS switches.

As indicated in fig. 3, each battery module 170 comprises a local controller 171. The local controllers 171 are arranged to communicate with each other, and with the main controller 10. Further, each local controller 171 is configured to control the HS and LS switches 176, 175 of the respective battery module 170. The main controller 10 is configured to receive, e.g. from the master controller 40 (fig. 1), a target value indicative of a desired current or voltage at the battery assembly terminals 105, 106. The main controller 10 is further configured to send, based on the target value, control signals to the local controllers 171, based on which the local controllers control the switches 175, 176 of the respective battery module. Thereby, the switches 175, 176 may be controlled so that none, one, or more, of the battery modules are by-passed. For each battery module 170, if the LS switch 175 is turned on and the HS switch 176 is turned off, the battery cells 163 on the battery module will be bypassed. If the LS switch 175 is turned off and the HS switch 176 is turned on, the battery cells 163 on the current will pass the set 163 of battery cells. Thereby, by selecting a number of battery cells to the bypassed, an actual current or voltage at the battery assembly terminals 105, 106 can be directed towards the desired current or voltage.

Reference is made to fig. 4 showing control loops for currents and voltages in the battery system in fig. 1. Reference is made also to fig. 5 depicting steps in a method according to an embodiment of the invention.

The method comprises selecting S1 one of the battery assemblies 40 as a master battery assembly, and the control assembly 10, 171 of the master battery assembly as a master control assembly.

The method further comprises the measuring assembly 20 repetitively determining S2 an actual value V(t) indicative of an actual current or voltage at the load terminals 301, 302. The determined actual values may be in an analog form.

The method further comprises the master control assembly 10, 171 repetitively determining S3 a target value Vref indicative of a desired current or voltage at the load terminals. The determined target values may be in a digital form. The target values Vref may be determined by a digital portion 101 of the control assembly 10, 171. The digital portion may be a computer with a processor. The target values Vref may be sent to respective digital-to-analog converters (DAC) of the control assemblies 10, 171, 11, 172. The target values Vref may be converted to an analog form by the digital-to-analog converters (DAC).

The method further comprises each control assembly 10, 171, 11, 172 repetitively determining S41, S42 an error value e(t) in dependence on the actual value V(t) and the target value Vref. Thus, each control assembly repetitively determines an error value indicative of a difference between the actual current or voltage at the load terminals 301, 302, and the desired current or voltage at the load terminals 301, 302, resulting in a plurality of sequentially determined error values. The error values may be in an analog form. The error value e(t) may be converted into a digital form, by means of an analog-to-digital converter (ADC).

The method further comprises controlling the respective actuation assemblies in the battery assemblies 40, 41 in dependence on the converted error value e(t), so as to direct the actual current or voltage towards the desired current or voltage.

For this, the master control assembly 10, 171 has a proportional, integral, and derivative (PID) control unit. The PID control unit determines, in dependence on the error values e(t) a value of a total control current to be produced by battery assemblies 40, 41 to direct the actual current or voltage towards the desired current or voltage. The PID control unit produces S51 a proportional control value using the most recent error value. The PID control unit produces S51 an integral control value as an integral or sum of a plurality of the sequentially determined error values. The PID control unit further produces S51 a derivative control value as a change of the error value. The total control current is determined in dependence on the output of the PID control unit. For example, the total control current may determined in dependence on a sum of the proportional, integral, and derivative control values.

Each of the remaining control assembly(ies) 11, 172, herein also referred to as slave(s), has a proportional and derivative (PD) control unit. The PD control unit may be provided in a digital portion 111 of the respective slave 11, 171. The PD control unit produces S52 in dependence of the error values proportional, and derivative control values, but no integral control value. Instead, the integral control value determined by the PID control unit of the master control assembly is sent S61 from the master control assembly to the remaining control assembly(ies) 11, 172. The integral control value may be sent via a dedicated CAN bus. Based on the output of the PD control unit, and the integral control value received S62 from the master control assembly, each of the remaining control assembly(ies) 11, 172 determines a total control current to be produced by battery assemblies 40, 41 to direct the actual current or voltage towards the desired current or voltage.

The master control assembly 10, 171 is configured to determine respective distribution factors K2, K3 for all battery assemblies 40, 41. The master control assembly 10, 171 is further configured to send respective distribution factor(s) K3 to the remaining control assembly(ies) 11, 172. Each control assembly 10, 171, 11, 172 comprises a distribution factor unit which is configured to determine, in dependence on the determined total control current and the respective distribution factor K2, K3, a respective local control current value Imref, Isref.

The local control current value is converted to an analog form by a digital-to-analog converter (DAC). A respective current measuring unit, e.g. of a respective local controller 172, 172, as exemplified above with reference to fig. 3, determines a respective actual current Im(t), Is(t) at the terminals of the respective battery assembly 40, 41. A respective current error is determined in dependence on the respective local control current value Imref, Isref and the respective actual current Im(t), Is(t). A respective control unit, e.g. of a respective local controller 172, 172, as exemplified above with reference to fig. 3, determines a respective current adjustment control value in dependence on the respective current error. The control unit could be proportional (P) control unit, a proportional and integral (PI) control unit (as indicated in fig. 4), or a proportional, integral, and derivative (PID) control unit. The current at the terminals of the respective battery assembly 40, 41 is adjusted in dependence on the respective current adjustment control value, by control S71, S72 of the respective actuation assembly.

Thus, according to embodiments of the invention, the control assembly in one of the battery assemblies is designated as the master for the integral control value, while all battery assemblies handle the proportional and derivative control value themselves. Each control assembly may have its own measurement of the actual voltage or current at the load terminals. Therefore, the measurements may be not identical. Thereby, individual handling of integral control values may lead to differences between the integral control values building up. This may in turn lead to the control assemblies counteracting each other. This is avoided by the control assembly in one of the battery assemblies being designated as the master for the integral control value. Meanwhile, the proportional and derivative control values, which may be real-time critical terms in the voltage and current control, may remain local, whereby a real-time response is retained regardless of what happens in the master/slave configuration. Thus, with embodiments of the invention, the slaves can work locally with full bandwidth on the proportional and derivative control values. This contributes to maintaining stability in the control loops. Meanwhile, the integral control value, which may have significantly lower bandwidth, can be distributed over from the master control assembly relatively calmly.

Fig. 6 illustrates parts of a control assembly for a battery assembly according to embodiments of the invention. The control assembly may include a computer equipped with various modules to manage the battery assembly's operations. The modules include a processing module 501 for handling data and executing commands. The modules include various specialized modules such as a sending module 510, controlling module 520, determining module 530, and others, which handle specific tasks like sending signals, controlling operations of battery modules, and determining settings based on the battery assembly’s requirements. The modules include an Input/Output module 506 to interact with external commands and data. The control assembly may ensure that the battery assembly maintains a target voltage during charging or discharging. For this a computer program 503 may be provided on a carrier 505, which could be an electronic, optical, or radio signal, or a computer-readable medium. The control assembly may control battery modules 170 of the battery assembly with signals that determine whether each battery module should be active or be bypassed, influencing their combined contribution to the target voltage. The control assembly continuously assesses and adjusts the configurations of these modules, by controlling switches of the modules, to ensure the combined voltage from all active modules matches the target voltage. The control assembly may also receive one or more detection signals from a current detector 178 in the battery assembly 100, which detection signals are indicative of a line current in a detection line 179 in the battery assembly 100 being above a threshold value for the line current, and control, in response to the detection signals, one or more of the switches 175, 176 to disconnect one or more of the modules from the battery assembly terminals 105, 106.

It is to be understood that the present invention is not limited to the embodiments described above and illustrated in the drawings; rather, the skilled person will recognize that many changes and modifications may be made within the scope of the appended claims.

CLAIMS

1. A battery system comprising two or more battery assemblies (40, 41), wherein each battery assembly comprises two battery assembly terminals (105, 106), wherein the battery assemblies are via the battery assembly terminals connected in parallel to two load terminals (301, 302) of a load and/or a battery charger, wherein each battery assembly comprises a plurality of battery cells (163) connected in series and/or in parallel between the respective battery assembly terminals (105, 106),
   - wherein each battery assembly (40, 41) comprises a control assembly (10, 171, 11, 172), and an actuation assembly (175, 176, 177) connected between the respective battery terminals and one or more of the battery cells of the respective battery assembly,
   - wherein the respective control assembly is configured to control the respective actuation assembly so as to direct an actual current or voltage at the load terminals (301, 302) towards a desired current or voltage at the load terminals (301, 302),
   - **characterised** in that one of the control assemblies is a master control assembly,
   - wherein the master control assembly is configured to repetitively receive or determine an error value indicative of a difference between the actual current or voltage at the load terminals (301, 302), and the desired current or voltage at the load terminals (301, 302), resulting in a plurality of sequentially received or determined error values,
   - wherein the master control assembly is configured to determine an integrated control value in dependence on the plurality of sequentially received or determined error values,
   - wherein the master control assembly is configured to send the integrated control value to the remaining control assemblies, wherein the remaining control assemblies are configured to perform said control of the respective actuation assembly in dependence on the received integrated control value.

2. A battery system according to claim 1, wherein each actuation assembly comprises a DCDC converter (177), wherein the respective control assembly is configured to control the respective DCDC converter in dependence on the integrated control value.

3. A battery system according to any one of the preceding claims, wherein the configuration of the respective control assembly to control the respective actuation assembly so as to direct the actual current or voltage at the load terminals (301, 302) towards the desired current or voltage at the load terminals (301, 302) comprises a configuration to control the respective actuation assembly so as to direct an actual current or voltage at the respective battery assembly terminals (105, 106) towards a desired current or voltage at the respective battery assembly terminals (105, 106).

4. A battery system according to any one of the preceding claims, wherein the master control assembly is configured to perform said control of the actuation assembly of the master battery assembly in dependence on the integrated control value.

5. A battery system according to any one of the preceding claims, wherein one or more of the remaining control assemblies are configured to determine a proportional control value in dependence on one or more of the plurality of sequentially received or determined error values, wherein the one or more of the remaining control assemblies are configured to perform said control of the respective actuation assembly in dependence on the proportional control value.

6. A battery system according to any one of the preceding claims, wherein one or more of the remaining control assemblies are configured to determine a derivative control value in dependence on two or more of the plurality of sequentially received or determined error values, wherein the one or more of the remaining control assemblies are configured to perform said control of the respective actuation assembly in dependence on the derivative control value.

7. A method for controlling a battery system comprising two or more battery assemblies (40, 41), each comprising two battery assembly terminals (105, 106), wherein the battery assemblies are via the battery assembly terminals connected in parallel to two load terminals (301, 302) of a load and/or a battery charger, wherein each battery assembly comprises a plurality of battery cells (163) connected in series and/or in parallel between the respective battery assembly terminals (105, 106),
   - wherein the method comprises controlling actuation assemblies (175, 176, 177) of the battery assemblies (40, 41) so as to direct an actual current or voltage at the load terminals (301, 302) towards a desired current or voltage at the load terminals (301, 302),
   - **characterised** by selecting one of the control assemblies as a master control assembly,
   - by the master control assembly repetitively receiving or determining an error value indicative of a difference between the actual current or voltage at the load terminals (301, 302), and the desired current or voltage at the load terminals (301, 302), resulting in a plurality of sequentially received or determined error values,
   - by the master control assembly determining an integrated control value in dependence on the plurality of sequentially received or determined error values,
   - by the master control assembly sending the integrated control value to the remaining control assemblies,
   - and by the remaining control assemblies performing said control of the respective actuation assembly in dependence on the received integrated control value.

8. A method according to claim 7, wherein said control of the actuation assembly of the master battery assembly is performed in dependence on the integrated control value.

9. A method according to any one of claims 7-8, wherein one or more of the remaining control assemblies determines a proportional control value in dependence on one or more of the plurality of sequentially received or determined

error values, wherein the one or more of the remaining control assemblies performs said control of the respective actuation assembly in dependence on the proportional control value.

10. A method according to any one of claims 7-9, wherein one or more of the remaining control assemblies determines a derivative control value in dependence on two or more of the plurality of sequentially received or determined error values, wherein the one or more of the remaining control assemblies performs said control of the respective actuation assembly in dependence on the derivative control value.

11. A method according to any one of claims 7-10, wherein the method comprises, subsequently to selecting one of the control assemblies as a master control assembly, selecting another of the control assemblies as a master control assembly.

12. A computer program comprising program code means for performing the steps of any one of claims 7-11 when said program is run on a computer.

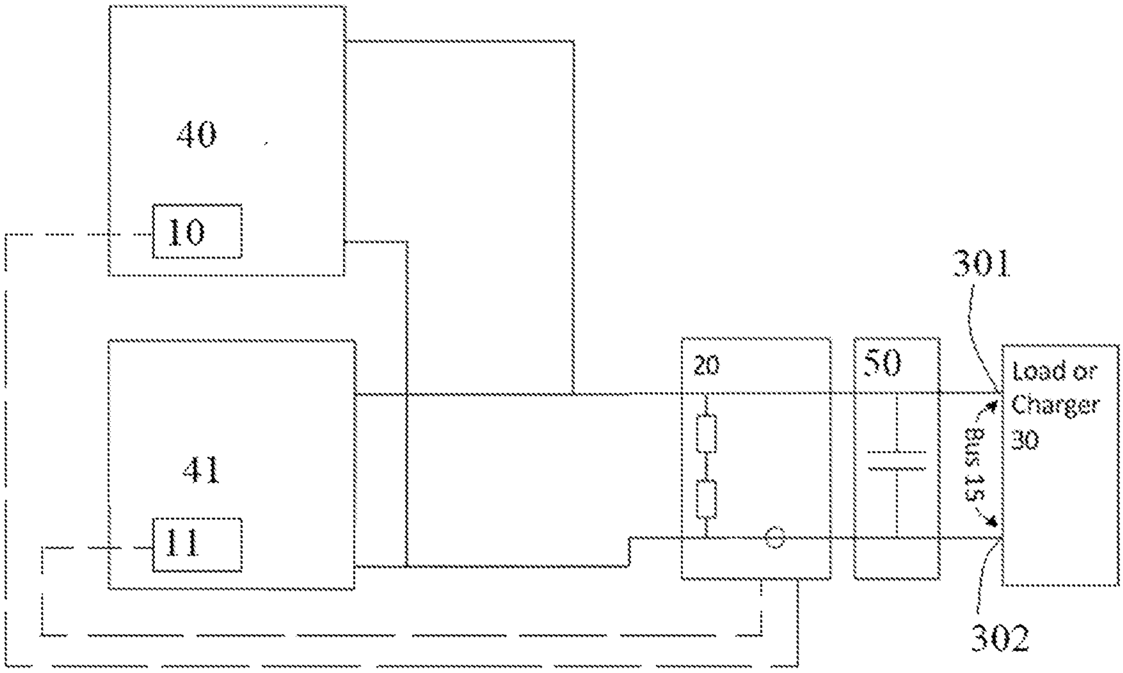
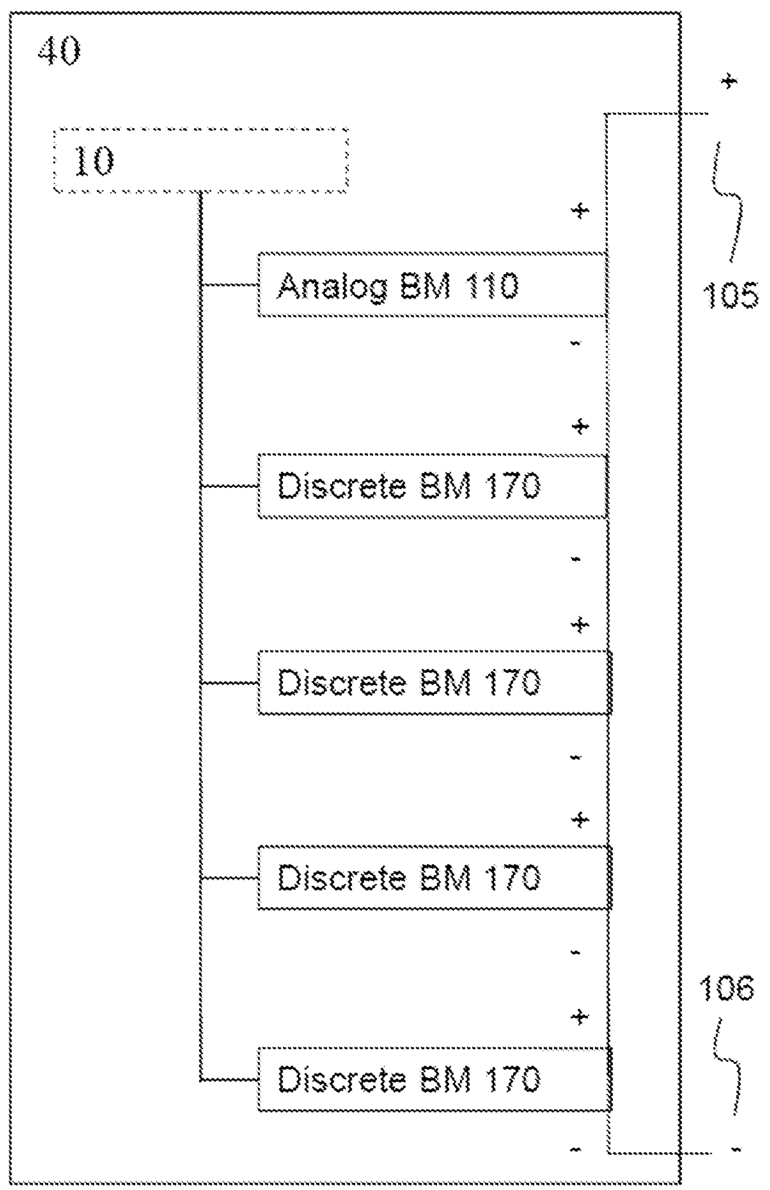


Fig. 1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+
+
Analog BM 110
-
105
+
Discrete BM 170
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Discrete BM 170
-
+
Discrete BM 170
-
106
+
Discrete BM 170
-
-

Fig. 2

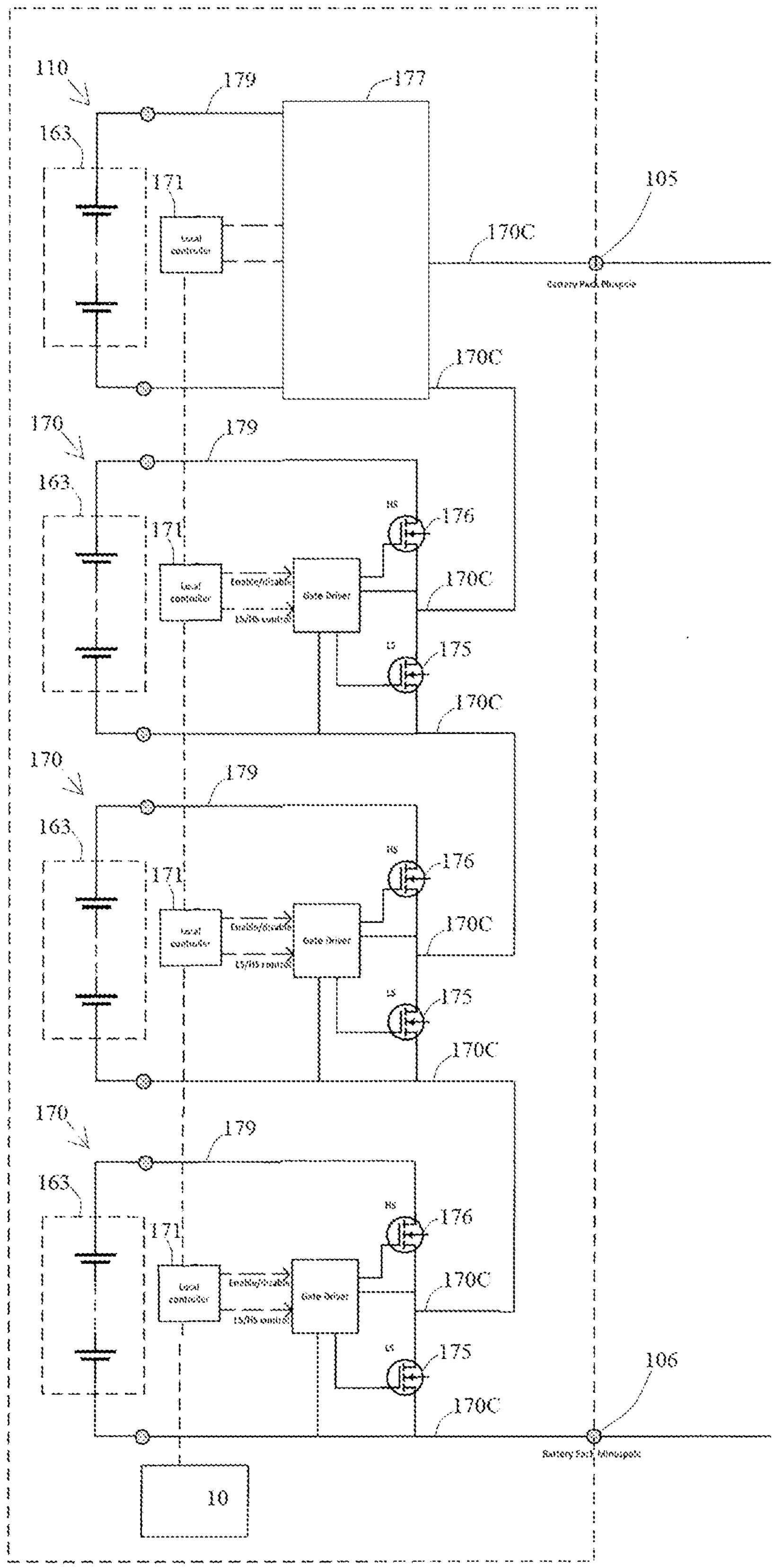
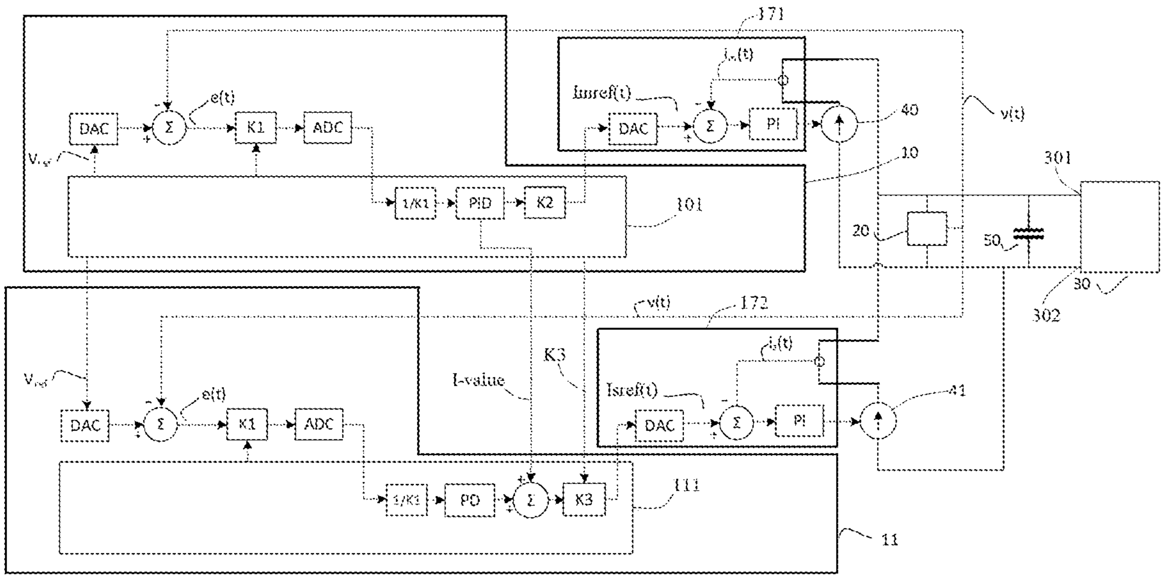


Fig. 3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Σ
K1
ADC
Imref(t)
DAC
Σ
PI
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PID
K2
101
301
20
50
30
302
v(t)
172
e(t)
DAC
Σ
K1
ADC
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PD
Σ
K3
111
11

Fig. 4

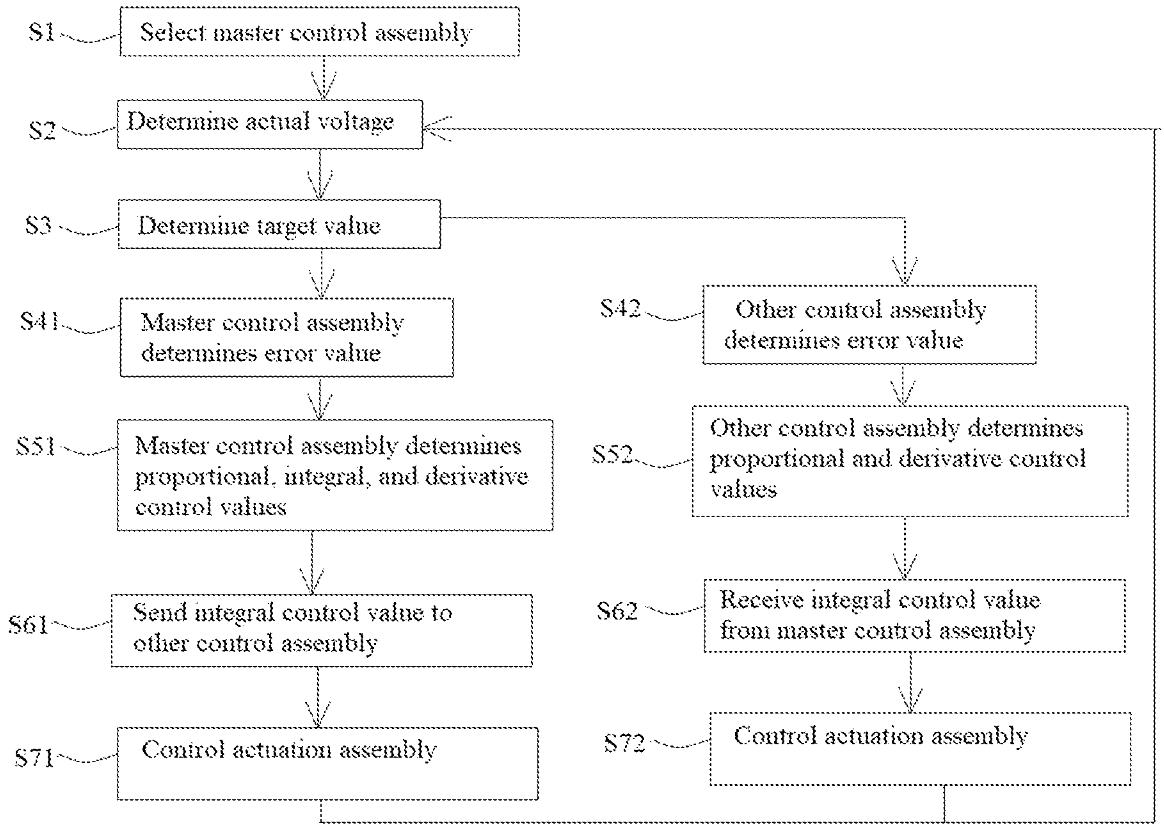
S1
Select master control assembly
S2
Determine actual voltage
S3
Determine target value
S41
Master control assembly determines error value
S42
Other control assembly determines error value
S51
Master control assembly determines proportional, integral, and derivative control values
S52
Other control assembly determines proportional and derivative control values
S61
Send integral control value to other control assembly
S62
Receive integral control value from master control assembly
S71
Control actuation assembly
S72
Control actuation assembly

Fig. 5

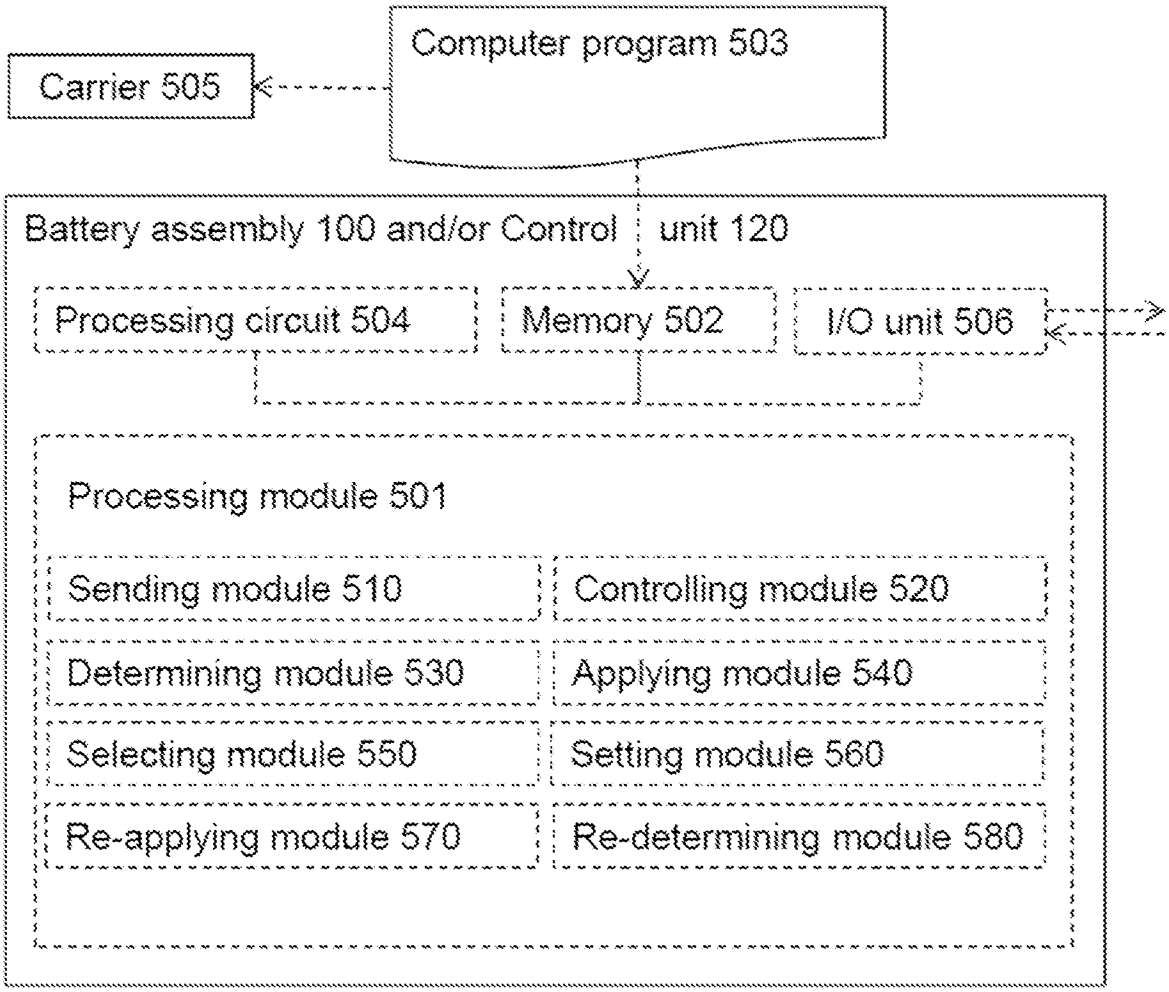
Computer program 503
Carrier 505
Battery assembly 100 and/or Control unit 120
Processing circuit 504
Memory 502
I/O unit 506
Processing module 501
Sending module 510
Controlling module 520
Determining module 530
Applying module 540
Selecting module 550
Setting module 560
Re-applying module 570
Re-determining module 580

Fig. 6