

“Method and system for managing the electrochemical batteries of an electric vehicle in the event of battery failure”

5 The present invention relates to a method for managing the electrochemical batteries of an electric vehicle in the event of battery failure. It also relates to a system implementing such a method and an electric vehicle implementing such a method or such a system.

10 The field of the invention is the field of electric vehicles comprising several electrochemical batteries, in particular of the LMP[®] type (for “Lithium Metal Polymer”), mounted in parallel, for supplying said vehicle.

Background of the invention

15 Electric vehicles are known, supplied by several electricity storage modules mounted in parallel and each comprising one or more electrochemical batteries, in particular of the LMP[®] type. Each module delivers a high-voltage signal for supplying the electric motor(s) of the vehicle.

20 In order to provide an electric vehicle with sufficient range, several batteries are needed on board the vehicle, allowing storage of the electrical energy necessary for the desired range. Depending on the power desired for the drive train of the vehicle, and the power available from each battery, it may be necessary to use several batteries in parallel for supplying the drive
25 train of the vehicle.

At the same time, it is known that electrochemical batteries are not suited to a slow discharge.

However, at present there is no method for managing the rechargeable electrical energy storage modules of an electric vehicle, in
30 which these modules are arranged in parallel, allowing optimization of the life span of said modules while retaining the functionality of the vehicle.

An aim of the present invention is to overcome this drawback.

Another aim of the invention is to propose a method and a system allowing better management of the electrical energy storage modules of an electric vehicle, mounted in parallel, in the event of failure of at least one of the modules.

5 It is also an aim of the invention to propose a method and a system for managing the electrical energy storage modules of an electric vehicle, allowing the life span of said modules to be optimized, while still maintaining normal operation of the vehicle in the event of failure of at least one of said modules.

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Summary of the invention

The invention makes it possible to achieve at least one of these aims by a method for managing a plurality of rechargeable electrical energy storage modules in an electric vehicle, said modules each comprising at least one rechargeable electrochemical battery, in particular of the LMP[®] type, and being arranged in parallel with one another, said method comprising:

- separating said modules into at least two groups, and
- supplying from one of said groups at once, and in particular in turn, and even more particularly alternately;

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said method also comprising a step of replacing a failing module of a group, called active group, in the process of supply, by an available module of another group, called available group.

Thus, the method according to the invention proposes to separate, virtually, the rechargeable electrical energy storage modules into several, in particular two, groups used in turn for supplying, in particular, a drive train of an electric vehicle. Thus, it is possible to apply rapid discharge cycles to each group and thus to optimize the life span of each module.

At the same time, in the event of failure of one or more modules, the method according to the invention proposes a "virtual" management of at least one of the groups. In particular, when a module initially forming part of a first group is failing, the method proposes to replace it, in particular on the fly, by a module initially forming part of another group. Thus, it is possible

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to continue to deliver the power demanded and thus to operate the vehicle normally, even in the event of failure of one or more modules, without degrading the electrical energy storage modules.

- 5 In the present application, by "separation" is meant a virtual grouping of the modules, independently of their physical arrangement.

In the present application, it is considered that a storage module is failing when said module presents:

- 10 - a malfunction, in particular an abnormal temperature or an abnormal voltage at its terminals; or
 - a remaining charge level (RCL) that is zero or very low.

The remaining charge level can be identical with a gauge level indicating a percentage or an amount of charge remaining in the storage
15 module.

According to a version of the method according to the invention, the replacement step can be carried out as soon as one of the groups includes a failing module.

- 20 In other words, in this first version, when a first module is failing in any one of the groups, the replacement step is carried out, even if no module is failing in the other groups. The failing module of the group is then replaced by an available module of another group.

The module replacing the failing module of the active group can be
25 chosen from each of the other groups in turn.

In addition, within an available group, the module used to replace the failing module of an active group can be chosen from the modules of said available group in turn.

- 30 According to another, preferred, version of the method according to the invention, the replacement step can be carried out only when each group includes a failing module, i.e. when there is no longer any group all of the modules of which are operational.

In this case, when a first active group includes a failing module, the supply can be switched over to another group that does not include any failing module, this other group then becoming the active group, and so on.

5 The group including the failing module may no longer be used for the supply while there exist other groups all the modules of which are operational, i.e. not failing. The supply can be provided with only the group(s) all the modules of which are operational, in particular in turn, without using the group the module of which is failing.

10 Optionally, when the group(s) all the modules of which are operational, is(are) fully discharged, then the group the module of which is failing can be used to provide a degraded supply in a degraded operation mode.

15 In a preferred version of the method according to the invention, the replacement step can be carried out such that the total number of modules in the active group is kept constant, and equal to a predetermined number.

In other words, the replacement step can be carried out such that the power delivered during the supply is kept constant, and equal to a predetermined value.

20 Thus, the method according to the invention makes it possible to maintain the power supplied by the active group, which allows a normal operation mode to be maintained, without suffering any degradation.

25 According to a non-limitative embodiment, the method according to the invention can comprise switching the supply from one group to another, carried out as a function of the remaining charge levels of said groups.

30 More particularly, switching from one group to another can be carried out when the remaining charge level of the active group is less than or equal to the remaining charge level of at least one available group, in particular by a predetermined value.

Advantageously, the predetermined value can correspond to a percentage of a maximum charge capacity (MCC) or of a remaining charge level (RCL) of at least one of the groups.

According to a first embodiment, the predetermined value can be constant.

For example, the predetermined value can be equal to 5% of the MCC of a group.

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According to another example embodiment, the predetermined value can be variable.

More particularly, the predetermined value can be a function of the available total charge level of each group.

10 In particular, the predetermined value can decrease when the total charge level of each group decreases.

According to a non-limitative example embodiment, the predetermined value can be equal to:

- 15
- 10% of the MCC of a group when all the groups have a RCL greater than 70%;
 - 8% of the MCC of a group when the group with the least charge has a RCL comprised between 50% and 70%;
 - 5% of the MCC of a group when the group with the least charge
- 20
- has a RCL comprised between 30% and 50%; and
 - 3% of the MCC of a group when the group with the least charge has a RCL less than 30%.

25 In a preferred version, each group can comprise an identical number of modules.

The number of modules can be determined as a function of a desired total power during the supply step and of the power that can be delivered by each module.

30 In a preferred version, all the modules can be identical, and each deliver one and the same nominal power.

The method according to the invention can also comprise detection of a failure, and in particular a malfunction, of a storage module as a function of:

- a temperature of said module, and/or
- 5 - a voltage at the terminals of said module.

In particular, a module can be failing when it has:

- a remaining charge level that is low or zero, or less than or equal to a predetermined value, for example 0.1% of the MCC of said module;
- 10 - a temperature that is not comprised within a predetermined temperature range, such as for example 50°C to 120°C; and/or
- a voltage at the terminals of said module that is not comprised within a predetermined voltage range, such as for example 190 V
- 15 to 470 V.

The method according to the invention can also comprise, for each module, measuring at least one, in particular each, of the following parameters:

- 20 - a remaining charge level (RCL) of said module, for example by a battery fuel gauge;
- a temperature of said module, for example by a thermometer or a thermocouple; and/or
- a voltage at the terminals of said module, for example by a
- 25 voltmeter.

At least one of these parameters can be used for determining if the module is failing or not.

Alternatively or in addition, at least one of these parameters, for example the remaining charge level (RCL) can be used for determining if

30 switching to another group must be carried out or not.

According to another aspect of the same invention, a system is proposed for managing a plurality of rechargeable electrical energy storage modules in an electric vehicle, said modules each comprising at least one rechargeable electrochemical battery, in particular of the LMP[®] type, and being arranged in parallel with one another, said system comprising:

- for each module, a means for individual connection/disconnection, making it possible to place said module on discharge independently of the other modules; and
- at least one controller for controlling, directly or indirectly, each of said means of connection/disconnection;

said at least one controller being configured to implement all the steps of the method according to the invention.

According to another aspect of the same invention, an electric vehicle is proposed, having on board a plurality of electrical energy storage modules supplying said vehicle, said modules each comprising at least one rechargeable electrochemical battery, in particular of the LMP[®] type, and being arranged in parallel with one another, said modules being managed:

- according to the method according to the invention; or
- by a system according to the invention.

The vehicle according to the invention can for example be a public transport vehicle of the bus, coach or tyred tram type.

In the present invention, the term "tyred tram" denotes an electric public transport land vehicle mounted on wheels and which recharges at each station, so as to avoid the need for heavy infrastructure of the rails and catenaries type on the highway. Such an electric vehicle recharges at each station by means of charging elements of the station and a connector linking said vehicle to said station.

In the case of a vehicle of the tyred tram type, the vehicle can also comprise supercapacitors, to which the principle of the present invention is not applicable.

Advantageously, in the vehicle according to the invention, the step of replacing a failing module by an available module can be carried out while the vehicle is stationary.

Thus, the vehicle according to the invention makes it possible to
5 minimize any risks, or malfunctions, which could be associated with such a replacement when the vehicle is moving.

For similar reasons, switching the supply from one group to another can advantageously be carried out when the vehicle is stationary.

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Description of the figures and embodiments

Other advantages and characteristics will become apparent from the
15 detailed description of embodiments which are in no way limitative, and the attached drawings, in which:

- Figure 1 is a diagrammatic representation of a non-limitative example of an electric vehicle according to the invention;
- Figures 2a and 2b are diagrammatic representations of two
20 non-limitative examples of parallel connection of the electrical energy storage modules of a vehicle according to the invention, and in particular of the vehicle in Figure 1;
- Figure 3 is a diagrammatic representation, in the form of a flow chart, of a first non-limitative example of the method according to
25 the invention;
- Figure 4 is a diagrammatic representation, in the form of a flow chart, of a second non-limitative example of the method according to the invention; and
- Figures 5a-5f are diagrammatic representations of the principle
30 of an example of the application of the method in Figure 3 in the case of the vehicle in Figure 1.

It is well understood that the embodiments that will be described hereinafter are in no way limitative. Variants of the invention can be

considered in particular, comprising only a selection of the characteristics described hereinafter, in isolation from the other characteristics described, if this selection of characteristics is sufficient to confer a technical advantage or to differentiate the invention with respect to the state of the prior art.

5 This selection comprises at least one, preferably functional, characteristic without structural details, or with only a part of the structural details if this part alone is sufficient to confer a technical advantage or to differentiate the invention with respect to the state of the prior art.

10 In the figures, elements common to several figures retain the same reference.

FIGURE 1 is a diagrammatic representation of a non-limitative example of an electric vehicle according to the invention.

15 The electric vehicle 100, shown in FIGURE 1, is an electric bus including one or more electric motors (not shown).

The vehicle comprises a first group 102 and a second group 104 each comprising four rechargeable electrical energy storage modules, namely modules 106₁-106₄ for the group 102 and modules 106₅-106₈ for the group 104. The group 102 is arranged on the side of a rear wall of the bus 100.
20 The group 104 is arranged in a housing arranged on an upper wall of the bus 100.

The electric bus 100 is driven exclusively by the electrical energy supplied by groups 102 and 104.

25 Each rechargeable electrical energy storage module 106 comprises one or more batteries of the LMP[®] type (for "Lithium Metal Polymer"). The modules 106 are all identical and supply one and the same nominal power.

30 FIGURE 2a is a diagrammatic representation of a non-limitative example of parallel connection of electrical energy storage modules in a vehicle according to the invention, in particular in the bus 100 in Figure 1.

In the example shown in Figure 2a, the modules 106₁-106₄ of the group 102 are connected to a management module 202₁, also called group

controller, and the modules 106₅-106₈ of the group 104 are connected to a management module 202₂, also called group controller.

The group controllers 202₁ and 202₂ are in turn connected to a central controller 204, which itself is connected directly or indirectly to the electric motor(s) 208 with a view to its(their) supply by the modules 106.

In particular, each module 106₁-106₄ of the group 102 is connected to the group controller 202₁ via a contactor, 206₁-206₄ respectively, that can be controlled by the group controller 202₁ or by the central controller 204. Similarly, each module 106₅-106₈ of the group 104 is connected to the group controller 202₂ via a contactor, 206₅-206₈ respectively, that can be controlled by the group controller 202₂ or by the central controller 204.

Each contactor 206_i can be controlled individually by the central controller 204, directly or via group controllers 202₁-202₂, in order to be placed either in a closed state allowing the current supplied by the module 106_i to pass, or in an open state preventing the passage of the current supplied by the module 106_i.

The central controller 204 comprises:

- a means (not shown) for measuring individually a current, or remaining, charge level of each module 106,
- a means (not shown) for measuring individually a temperature of each module 106, and/or
- a means (not shown) for measuring individually a voltage at the terminals of each module 106.

The central controller 204 is also configured to compare each of the measured values for each module to one or more predetermined values, in order to determine if said module is failing or operational.

Of course, measuring and comparing these parameters can alternatively be carried out by a unit other than the central controller, such as for example by each group controller 202₁-202₂.

FIGURE 2b is a diagrammatic representation of another non-limitative example of parallel connection of electrical energy storage modules in a

vehicle according to the invention, and in particular in the bus 100 in FIGURE 1.

The example shown in FIGURE 2b comprises all the elements of the example in FIGURE 2a, apart from the group controller 202₁ and 202₂.

5 In the example shown in FIGURE 2b, the modules 106₁-106₈ are directly connected to the central controller 204 by the contactors 206₁-206₈, without using the group controllers 202₁ and 202₂. The modules 106_i are then all arranged in parallel.

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FIGURE 3 is a diagrammatic representation of a first non-limitative example of a management method according to the invention.

The method 300, shown in FIGURE 3, comprises a step 302 of separating the modules into several groups, for example into exactly two
15 groups, such as the groups 102 and 104.

During this separation step 302, the physical arrangement of the modules can be taken into account for constituting the groups, for example as shown in FIGURE 2a. Alternatively, it is possible not to take into account a physical arrangement of the modules, for example as shown in FIGURE 2b.

20 During a step 304, the method 300 carries out an alternate supply from each of the groups in turn. To this end, a step 304₁ carries out a supply from one of the groups. The group in the process of supply is called active group, the other group(s) being called available group(s). The remaining charge level (RCL) of the active group is monitored during the supply step
25 304₁. Then, as a function of a predetermined rule, a step 304₂ carries out switching the supply to another available group, and so on.

Switching from one group to another, during step 304₂, can be carried out as a function of the remaining charge levels (RCL) of each group and the maximum charge capacity (MCC) of the groups.

30 In particular, switching from the active group to an available group can be carried out when the RCL of the active group becomes less than or equal to the RCL of an available group by a predetermined value, which is equal to:

- 10% of the MCC of a group when all the groups have a RCL greater than 70% of the MCC;
- 8% of the MCC of a group when the group with the least charge has a RCL comprised between 50% and 70% of the MCC;
- 5 - 5% of the MCC when the group with the least charge has a RCL comprised between 30% and 50% of the MCC; and
- 3% of the MCC when the group with the least charge has a RCL less than 30% of the MCC.

10 In the case of an electric vehicle, such as the bus 100 in FIGURE 1, switching the supply from one group to another, can preferentially be carried out while the vehicle is stationary, in order to avoid any risk associated with said switching.

15 Such switching makes it possible to optimize the discharge of the set of modules and to have a substantially equivalent remaining charge level for each module.

During a step 306, a failure is detected in a charge module of the active group, for at least one of the following reasons:

- the module has an insufficient RCL,
- the module has an abnormal voltage at its terminals, and/or
- 20 - the temperature of the module is abnormal.

25 Following the detection of a failing module, a step 308 carries out switching the supply to an available group which becomes the new active group. In the case of an electric vehicle, such as the bus 100 in FIGURE 1, this switching step 308 can be carried out while the bus is stationary, in order to avoid any risk associated with said switching.

If after the step 308, there is still at least one other available group all the modules of which are operational, in addition to the new active group, then the method 300 resumes at alternate supply step 304 without taking the failing group into account.

30 If after the step 308, there is no other available group all the modules of which are operational, in addition to the new active group, then the method continues with a step 310 that carries out the supply from said active group only. There is no further switching of supply.

After the step 310, a failure is detected in a charge module of the active group, during a step 312, for at least one of the following reasons:

- the module has an insufficient RCL,
- the module has an abnormal voltage at its terminals, and/or
- 5 - the temperature of the module is abnormal.

Following the detection of a failing module in the active group, and as there is no longer any other group all the modules of which are not failing, the method 300 comprises a step 314 of replacing the failing module in the active group by a module that is not failing, from another group. The active
10 group is then reconstituted virtually with a module of another group.

The method 300 then resumes at step 310 with the reconstituted active group.

In the method 300 in FIGURE 3, the replacement of a failing module
15 of a group is then carried out only when each group comprises a failing module. Of course, the invention is not limited to this version of the method.

FIGURE 4 is a diagrammatic representation of a second non-limitative
20 example of a management method according to the invention.

The method 400, shown in FIGURE 4, comprises the steps 302-306 of the method 300 in FIGURE 3.

However, in the method 400 in FIGURE 4, the step 306 of detecting a failing module in an active module is followed by the step 314 of replacing
25 the failing module in the active group, even if there remains at least one other group all the modules of which are operational.

In other words, in the method 400 in FIGURE 4, replacing a failing module of an active group is carried out as soon as a first failing module is detected.

30 In the method 400, during the replacement step 314, the operational module used to replace the failing module of an active group can be chosen alternately from the other available groups in turn.

Alternatively or in addition, in the method 400, during the replacement step 314, the operational module for replacing the failing module of an active group can be chosen alternately from the operational modules of another group, in turn.

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FIGURESs 5a-5f are diagrammatic representations of the principle of an example of the application of the method 300 in FIGURE 3 in the case of the vehicle in FIGURE 1.

FIGURES 5a-5c show an alternate supply from groups 102 and 104.

10 Thus:

- in FIGURE 5a: the group 102 is the active group used for the supply and the group 104 is the available group;
- in FIGURE 5b: the supply is switched over to the group 104, which becomes the active group, and the group 102 becomes the
- 15 available group; and
- in FIGURE 5c: the supply is switched over again to the group 102, which again becomes the active group, and the group 104 again becomes the available group;
- and so on.

20 FIGURE 5d shows the case in which the module 106₁ of the group 102 is failing. The supply is switched over to the group 104, without replacing the failing module 106₁. As there is no other group that is fully operational, the supply is then provided continuously by the group 104.

FIGURE 5e shows the case in which a module, namely the module
25 106₆ of the group 104 is failing. As there is no other group that is fully operational, the failing module 106₆ is replaced by any one of the operational modules 106₂-106₄ of the group 102, namely the module 106₄ in FIGURE 5e. The group 104 is then reconstituted virtually and comprises the modules 106₄, 106₅, 106₇ and 106₈.

30 FIGURE 5f shows the case in which another module, namely the module 106₇ of the (virtually reconstituted) group 104 is failing. As there is no other group that is fully operational, the failing module 106₇ is replaced by any one of the operational modules 106₂ or 106₃ of the group 102,

namely the module 106₃ in Figure 5f. The group 104 is then reconstituted and comprises the modules 106₃, 106₄, 106₅ and 106₈.

5 Of course, the invention is not limited to the examples detailed above. In particular, the number of storage modules, the number of groups of modules, and the number of modules for each group are not limited to those given in the examples described above, and correspond to the maximum
10 number of energy storage modules depending in particular on the weight of the vehicle and the desired range of the vehicle.

CLAIMS

1. A method (300;400) for managing a plurality of rechargeable electrical energy storage modules (106₁-106₈) in an electric vehicle (100), said modules (106) each comprising at least one rechargeable electrochemical battery, and being arranged in parallel with one another, said method (300;400) comprising:
- separating (302) said modules (106) into at least two groups (102,104), and
 - supplying (304) from one of said groups (102,104) at a time;
- 10 said method (300;400) also comprising a step (314) of replacing a failing module (106₆,106₇) of a group (104), called active group, in the process of supply, by an available module (106₃,106₄) of another group (102), called available group.
- 15 2. The method (400) according to the preceding claim, characterized in that the replacement step (314) is carried out as soon as one of the groups includes a failing module.
- 20 3. The method (300) according to claim 1, characterized in that the replacement step (314) is carried out only when each group (102,104) includes a failing module.
- 25 4. The method (300; 400) according to any one of the preceding claims, characterized in that the replacement step (314) is carried out so as to maintain a constant number of modules (106) in the active group (102, 104).
- 30 5. The method (300; 400) according to any one of the preceding claims, characterized in that it comprises switching (304₂) of the supply from one group (102;104) to another (104;102) carried out when the remaining charge level of the active group is less than or equal to the remaining charge level of at least one available group, by a predetermined value.

6. The method (300;400) according to claim 5, characterized in that the predetermined value corresponds to a percentage of a maximum charge capacity, or of a remaining charge level, of at least one of the groups (102;104).

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7. The method (300; 400) according to any one of claims 5 or 6, characterized in that the predetermined value is variable as a function of the available total charge level of each group (102;104).

10 8. The method (300; 400) according to any one of the preceding claims, characterized in that each group (102;104) comprises an identical number of modules.

15 9. The method (300; 400) according to any one of the preceding claims, characterized in that it comprises detecting (306;312) failure of a storage module as a function of:

- a temperature of said module, and/or
- a voltage at the terminals of the module.

20 10. The method (300; 400) according to any one of the preceding claims, characterized in that it comprises measuring, for each module, at least one of the following parameters:

- a remaining charge level of said module,
- a temperature of said module, and/or
- 25 - a voltage at its terminals.

11. A system for managing a plurality of rechargeable electrical energy storage modules (106₁-106₈) in an electric vehicle (100), said modules (106₁-106₈) each comprising at least one rechargeable electrochemical
30 battery, and being arranged in parallel with one another, said system comprising:

- for each module (106₁-106₈), a means (206₁-206₈) for individual connection/disconnection, making it possible to place said module on discharge independently of the other modules; and
- at least one controller (202₁-202₂, 204) for controlling, directly or
5 indirectly, each of said connection/disconnection means (206₁-206₈);
said at least one controller (202₁-202₂, 204) being configured to implement all the steps of the method (300; 400) according to any one of the preceding claims.

10 12. An electric vehicle (100) with a plurality of on-board rechargeable electrical energy storage modules (106₁-106₈) supplying said vehicle (100), said modules (106₁-106₈) each comprising at least one rechargeable electrochemical battery, and being arranged in parallel with one another, said modules (106₁-106₈) being managed:

15 - according to the method (300; 400) according to any one of claims 1 to 10;
- by a system according to claim 11.

20 13. The vehicle (100) according to the preceding claim, characterized in that it is a public transport vehicle of the bus or tyred tram type.

14. The vehicle (100) according to either of claims 12 or 13, characterized in that the step (314) of replacing a failing module by an available module is carried out while the vehicle (100) is stationary.

25 15. The vehicle (100) according to any one of claims 12 to 14, characterized in that switching (304₂) from one group to another, during the supply step, is carried out while the vehicle (100) is stationary.