(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
03 August 2023 (03.08.2023)

WIPO | PCT

(10) International Publication Number
WO 2023/144835 A1

(51) International Patent Classification:
B60L 58/22 (2019.01) *H01M 10/44* (2006.01)
B60L 58/13 (2019.01)

(21) International Application Number:
PCT/IN2022/051069

(22) International Filing Date:
13 December 2022 (13.12.2022)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
202241004849 28 January 2022 (28.01.2022) IN

(71) Applicant: **TVS MOTOR COMPANY LIMITED** [IN/IN]; "Chaitanya" No.12 Khader Nawaz Khan Road, Nungambakkam Chennai Tamil Nadu - 600006 India, Chennai 600006 (IN).

(72) Inventors: **HARIDAS, Anjali**; "Chaitanya" No 12 Khader Nawaz Khan Road, Nungambakkam Chennai Tamil Nadu 600006 India, Chennai 600006 (IN). **MAZUMDAR, Dipanjan**; "Chaitanya" No 12 Khader Nawaz Khan Road, Nungambakkam Chennai Tamil Nadu 600006 India, Chennai 600006 (IN).

(74) Agent: **KHAITAN & CO**; One Indiabulls Centre, 13th Floor, 841, Senapati Bapat Marg, Elphinstone Road, Mumbai 400013, Maharashtra, Mumbai 400013 (IN).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CV, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(54) Title: A SYSTEM AND METHOD FOR BALANCING CHARGE BETWEEN PLURALITY OF BATTERY PACKS

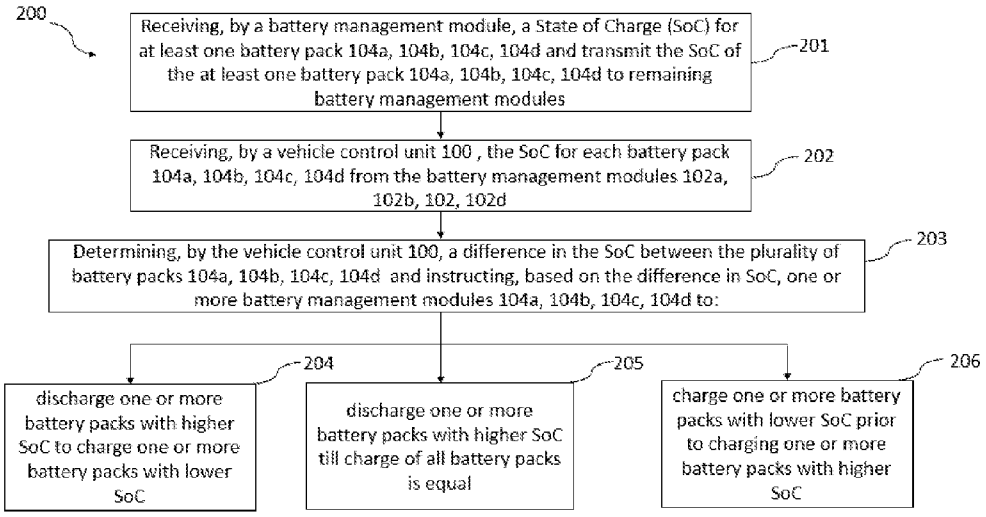


Figure 2

(57) **Abstract:** The present invention provides a system and method for balancing charge between plurality of battery packs. The system comprises a plurality of battery packs, a plurality of battery management modules operably coupled to at least one battery pack, and a vehicle control unit (VCU) operably coupled to all the battery management modules. Each of the battery management module is configured to receive a State of Charge (SoC) for at least one battery pack. On receiving the SoC for one or more battery packs, the battery management module transmits the SoC of one or more battery packs to remaining battery management modules and to the VCU. On receiving the SoC for each battery pack, the VCU is configured to determine a difference in SoC between the plurality of battery packs. The VCU, on determination of the difference in SoC between the plurality of battery packs, instructs the battery management modules to allow or prohibit charge/discharge of the one or more battery packs. On receiving such instructions, the battery management modules allow or prohibit charge/discharge of the one or more battery packs.

WO 2023/144835 A1

[Continued on next page]

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, CV, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, ME, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *of inventorship (Rule 4.17(iv))*

Published:

— *with international search report (Art. 21(3))*

— *in black and white; the international application as filed contained color or greyscale and is available for download from PATENTSCOPE*

TITLE OF INVENTION

A SYSTEM AND METHOD FOR BALANCING CHARGE BETWEEN PLURALITY OF BATTERY PACKS

FIELD OF THE INVENTION

[001] The present invention relates to battery packs in a vehicle. More particularly, the present invention relates to balancing charge between plurality of battery packs in the vehicle.

BACKGROUND OF THE INVENTION

[002] Electric vehicles or Hybrid vehicles comprises a plurality of battery packs connected in parallel to achieve "Range" of the vehicle. "Range" refers to a distance an electric or hybrid vehicle can travel before the battery needs to be recharged. As the plurality of battery packs are connected in parallel, while driving the vehicle, all the battery packs will discharge independently and a sum of a discharge current will operate the electric motor of the electric/hybrid vehicle. For example, when the battery packs in the vehicle are fully charged, the State of Charge (SoC) for a first battery pack and a second battery pack is 100 percent. Once the driver starts driving the vehicle, the battery packs start discharging and each battery pack will discharge independently. However, there is no guarantee that all the battery packs discharge equally during the driving and the battery packs may have different State of Charge at the end of the driving which leads to pack-to-pack imbalance. For example, after first phase of driving, the SoC for first battery pack is 50 percent whereas the SoC for second battery pack is 10 percent. In this situation, if the driver continues to drive, the second battery pack will enter a deep discharge mode and only the first battery pack will be available for

discharging. In such a scenario, the power of the vehicle is decreased which will leads to customer dissatisfaction. This will also result in overloading of the first battery pack and negatively affect the life of second battery pack which is undesirable. Hence, the overall efficiency of the vehicle is reduced.

[003] Alternatively, if the user charges the vehicle after the first phase of driving, the first battery pack with 50 percent SoC will get fully charged first and go for overcharging. This will also negatively affect the life of the first battery pack which is undesirable.

[004] Further, as the battery packs are connected in parallel, in case of pack-to-pack imbalance, there is a chance of current flow between battery packs. For example, if the first battery pack is at 50 percent SoC and the second battery pack is at 10 percent SoC, there is a chance that the battery pack with higher SoC i.e. first battery pack charges the battery pack with lower SoC i.e. the second battery pack which damages the second battery pack (or battery pack with lower SoC) due to overcharging current. This will negatively affect the life of the second battery pack which is undesirable.

[005] The pack-to-pack imbalance may be due to various reason. In one non- limiting example, the imbalance is due to resistance of wiring harness such as lose connections which may result in one battery pack being discharged earlier than another battery pack.

[006] In view of the foregoing, it is desirable to overcome the above-mentioned disadvantages of the existing art by providing a system and method for balancing a charge between plurality of battery packs in the vehicle.

SUMMARY OF THE INVENTION

[007] In one aspect of the invention, a system for balancing charge between plurality of battery packs in a vehicle is disclosed. The system comprises a plurality of battery packs, a

plurality of battery management modules and a vehicle control unit (VCU). Each of the battery management modules is operably coupled to at least one battery pack. The VCU is operably coupled to all the battery management modules. In one non-limiting example, each of the battery management module is operably coupled to one battery pack and controls the charging/discharging of the battery pack in accordance with instructions from the VCU. In another non-limiting example, each of the battery management module is operably coupled to more than one battery pack and controls the charging/discharging of the battery pack in accordance with instructions from the VCU.

[008] Each of the battery management modules is configured to receive a State of Charge (SoC) for at least one battery pack. On receiving the SoC for one or more battery packs, the battery management module transmits the SoC of one or more battery packs to remaining battery management modules and to the VCU. On receiving the SoC for each battery pack, the VCU is configured to determine a difference in SoC between the plurality of battery packs. The VCU, on determination of the difference in SoC between the plurality of battery packs, instructs the battery management modules to allow or prohibit charge/discharge of the one or more battery packs. On receiving such instructions, the battery management modules allow or prohibit charge/discharge of the one or more battery packs.

[009] In an embodiment, the one or more battery management modules are instructed by the VCU to discharge the one or more battery packs with higher SoC, to charge the one or more battery packs with lower SoC. Such an instruction is provided by the VCU to the one or more battery management modules on satisfaction of the following conditions: (a) the difference in SoC between the plurality of battery packs is less than a first pre-determined value, (b) an ignition switch of the vehicle is switched ON, and (c) a charger for charging the battery packs is disconnected. In case the VCU determines that the difference in SoC

between the plurality of battery packs is greater than the first pre-determined value, the VCU instructs the one or more battery management modules to prohibit the discharge of one or more battery packs with higher SoC to charge the battery packs with lower SoC.

[010] In an embodiment, the one or more battery management modules are instructed by the VCU to discharge the one or more battery packs with higher SoC till the charge of all the battery packs is equal. Such an instruction is provided by the VCU to the one or more battery management modules on satisfaction of the following conditions: (a) the difference in SoC between the plurality of battery packs is greater than a second pre-determined value, (b) the ignition switch of the vehicle is switched ON, and (c) a charger for charging the battery packs is disconnected. In case the VCU determines that the difference in SoC between the plurality of battery packs is less than the second pre-determined value, the VCU instructs the one or more battery management modules to prohibit the discharge of one or more battery packs with higher SoC to charge the battery packs with lower SoC. Instead, the VCU instructs the one or more battery management modules to allow all the battery packs to discharge equally.

[011] In an embodiment, the one or more battery management modules are instructed by the VCU to charge the one or more battery packs with lower SoC prior to the charging of the one or more battery packs with higher SoC. Such an instruction is provided by the VCU to the one or more battery management modules on satisfaction of the following conditions: (a) the difference in SoC between the plurality of battery packs is greater than a third pre-determined value, (b) the ignition switch of the vehicle is switched ON/OFF, and (c) a charger for charging the battery packs is connected to the vehicle. In case the VCU determines that the difference in SoC between the plurality of battery packs is less than the third pre-determined value, the VCU instructs the one or more battery management modules to prohibit the charging of one or more battery packs with lower SoC prior to the charging of

the one or more battery packs with higher SoC. Instead, the VCU instructs the one or more battery management modules to allow all the battery packs to charge equally.

[012] In an embodiment, the discharging of battery packs with higher SoC is performed in descending order of SoC.

[013] In an embodiment, the charging of battery packs with lower SoC is performed in an ascending order of SoC.

[014] In another aspect of the invention, a method for balancing charge between plurality of battery packs in a vehicle is disclosed. The vehicle comprises a plurality of battery packs and a plurality of battery management modules. Each of the battery management modules is operably connected to at least one battery pack. The VCU is operably connected to all the battery management modules.

[015] In a first step, the method comprises receiving a SoC for at least one battery pack by one or more battery management modules and transmitting the SoC of the at least one battery pack to the remaining battery management modules.

[016] In the second step, the method comprises receiving, by the VCU, SoC for each battery pack. The SoC for each battery pack is transmitted to the VCU by the battery management modules.

[017] In the third step, the method comprises determining a difference in SoC between the plurality of battery packs and instructing the one or more battery management modules to allow charge/discharge or prohibit charge/discharge of the one or more battery packs. The third method step is performed by the VCU.

[018] In an embodiment, the one or more battery management modules are instructed by the VCU to discharge the one or more battery packs with higher SoC to charge one or more battery packs with lower SoC. Such an instruction is provided by the VCU to the one or more

battery management modules on satisfaction of the following conditions: (a) the difference in SoC between the plurality of battery packs is less than a first pre-determined value, (b) an ignition switch of the vehicle is switched ON, and (c) a charger for charging the battery packs is disconnected. In case the VCU determines that the difference in SoC between the plurality of battery packs is greater than the first pre-determined value, the VCU instructs the one or more battery management modules to prohibit the discharge of one or more battery packs with higher SoC to charge the battery packs with lower SoC.

[019] In an embodiment, the one or more battery management modules are instructed by the VCU to discharge the one or more battery packs with higher SoC. Such an instruction is provided by the VCU to the one or more battery management modules on determination of the following conditions: (a) the difference in SoC between the plurality of battery packs is greater than a second pre-determined value, (b) the ignition switch of the vehicle is switched ON, and (c) a charger for charging the battery packs is disconnected. In case the VCU determines that the difference in SoC between the plurality of battery packs is less than the second pre-determined value, the VCU instructs the one or more battery management modules to prohibit the discharge of one or more battery packs with higher SoC to charge the battery packs with lower SoC. Instead, the VCU instructs the one or more battery management modules to allow all the battery packs to discharge equally.

[020] In an embodiment, the one or more battery management modules are instructed by the VCU to charge the one or more battery packs with lower SoC prior to the charging the one or more battery packs with higher SoC. Such an instruction is provided by the VCU to the one or more battery management modules on satisfaction of the following conditions: (a) the difference in SoC between the plurality of battery packs is greater than a third pre-determined value, (b) the ignition switch of the vehicle is switched ON/OFF, and (c) a charger

for charging the battery packs is connected to the vehicle. In case the VCU determines that the difference in SoC between the plurality of battery packs is less than the third pre-determined value, the VCU instructs the one or more battery management modules to prohibit the charging of one or more battery packs with lower SoC prior to the charging of the one or more battery packs with higher SoC. Instead, the VCU instructs the one or more battery management modules to allow all the battery packs to charge equally.

[021] In an embodiment, the second pre-determined value and the third pre-determined value are same.

[022] In an embodiment, the second pre-determined value and the third pre-determined value are different.

[023] In an embodiment, the discharging of battery packs with higher SoC is performed in descending order of SoC.

[024] In an embodiment, the charging of battery packs with lower SoC is performed in an ascending order of SoC.

BRIEF DESCRIPTION OF THE DRAWINGS

[025] Reference will be made to embodiments of the invention, examples of which may be illustrated in accompanying figures. These figures are intended to be illustrative, not limiting. Although the invention is generally described in context of these embodiments, it should be understood that it is not intended to limit the scope of the invention to these particular embodiments.

Figure 1 shows a block diagram of a system for balancing charge between plurality of battery packs in a vehicle, in accordance with an embodiment of the present invention.

Figure 2 illustrates a method for balancing charge between the plurality of battery packs, in accordance with an embodiment of the present invention.

Figure 3A, Figure 3B and Figure 3C illustrate a method for balancing charge between a first battery pack and a second battery pack, in accordance with an embodiment of the present invention.

Figure 4A illustrates a graph which plots charging of a first battery pack and a second battery pack, in accordance with the present invention.

Figure 4B illustrates a graph which plots charging of a first battery pack and a second battery pack, in accordance with the conventional methods of charging or the existing art.

Figure 5 illustrates an exploded schematic view of a battery pack 500 in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[026] Various features and embodiments of the present invention here will be discernible from the following further description thereof, set out hereunder.

[027] Figure 1 is a block diagram of a system for balancing charge between plurality of battery packs in a vehicle in accordance with an embodiment of the present invention. The term “vehicle” in the context of the present invention includes both electric vehicle as well as hybrid vehicles using a plurality of battery packs to operate one or more electric motors. The term “vehicle” further include two-wheelers, three-wheelers and four wheelers.

[028] As shown, the system 10 comprises a plurality of battery packs 104a, 104b, 104c, 104d and a plurality of battery management modules 102a, 102b, 102c, 102d. Each battery management module 102a, 102b, 102c, 102d is operatively coupled at least one battery

pack. The plurality of battery management modules 102a, 102b, 102c, 102d are operatively coupled to a vehicle control unit 100.

[029] Each battery management module 102a, 102b, 102c, 102d is configured to receive information on state of one or more battery packs 104a, 104b, 104c, 104d to which it is operatively coupled. The information includes parameters such as State of Charge (SoC), State of Health (SoH), temperature, voltage and current of the battery packs 104a, 104b, 104c, 104d. The information received by each battery management module 102a, 102b, 102c, 102d is communicated to the remaining battery management modules 102a, 102b, 102c, 102d and to the vehicle control unit 100.

[030] In one non-limiting example, the communication between the battery management modules 102a, 102b, 102c, 102d and the VCU is by Controller Area Network (CAN). However, this example should not be construed as limiting and other modes of communication may also be used for communication between the battery management modules and the VCU.

[031] The vehicle control unit 100 receives the information of all the battery packs 104a, 104b, 104c, 104d from the battery management modules 102a, 102b, 102c, 102d. On receiving the information with respect to each battery pack 102a, 102b, 102c, 102d, the vehicle control unit 100 is configured to determine a difference in SoC between the plurality of battery packs 104a, 104b, 104c, 104d. Based on the difference in SoC between the plurality of the battery packs 104a, 104b, 104c, 104d, the vehicle control unit 100 instructs the one or more battery management modules 102a, 102b, 102c, 102d to allow/prohibit charging or discharging of the one or more battery packs 104a, 104b, 104c, 104d.

[032] In an embodiment, the one or more battery management modules 102a, 102b, 102c, 102d are instructed by the VCU 100 to discharge the one or more battery packs with higher

SoC to charge one or more battery packs with lower SoC. Such an instruction is provided by the VCU 100 to the one or more battery management modules 102a, 102b, 102c, 102d on determination of the following conditions: (a) the difference in SoC between the plurality of battery packs 104a, 104b, 104c, 104d is less than a first pre-determined value, (b) an ignition switch of the vehicle is switched ON, and (c) a charger for charging the battery packs 104a, 104b, 104c, 104d is disconnected. In case the VCU 100 determines that the difference in SoC between the plurality of battery packs 104a, 104b, 104c, 104d is greater than the first pre-determined value, the VCU 100 instructs the one or more battery management modules 102a, 102b, 102c, 102d to prohibit the discharge of one or more battery packs with higher SoC to charge the battery packs with lower SoC.

[033] In an embodiment, the one or more battery management modules 102a, 102b, 102c, 102d are instructed by the VCU 100 to discharge the one or more battery packs with higher SoC till charge of all the battery packs 104a, 104b, 104c, 104d is equal. Such an instruction is provided by the VCU 100 to the one or more battery management modules 102a, 102b, 102c, 102d on determination of the following conditions: (a) the difference in SoC between the plurality of battery packs 104a, 104b, 104c, 104d is greater than a second pre-determined value, (b) the ignition switch of the vehicle is switched ON, and (c) a charger for charging the battery packs 104a, 104b, 104c, 104d is disconnected. In case the VCU 100 determines that the difference in SoC between the plurality of battery packs 104a, 104b, 104c, 104d is less than the second pre-determined value, the VCU 100 instructs the one or more battery management modules 102a, 102b, 102c, 102d to prohibit the discharge of one or more battery packs with higher SoC to charge the battery packs with lower SoC. Instead, the VCU 100 instructs the one or more battery management modules 102a, 102b, 102c, 102d to allow all the battery packs 104a, 104b, 104c, 104d to discharge equally.

[034] In an embodiment, the one or more battery management modules 102a, 102b, 102c, 102d are instructed by the VCU 100 to charge one or more battery packs with lower SoC prior to charging one or more battery packs with higher SoC. Such an instruction is provided by the VCU 100 to the one or more battery management modules 102a, 102b, 102c, 102d on determination of the following conditions: (a) the difference in SoC between the plurality of battery packs 104a, 104b, 104c, 104d is greater than a third pre-determined value, (b) the ignition switch of the vehicle is switched ON/OFF, and (c) a charger for charging the battery packs is connected to the vehicle. In case the VCU 100 determines that the difference in SoC between the plurality of battery packs 104a, 104b, 104c, 104d is less than the third pre-determined value, the VCU 100 instructs the one or more battery management modules 102a, 102b, 102c, 102d to prohibit the charging of one or more battery packs with lower SoC prior to the charging of the one or more battery packs with higher SoC. Instead, the VCU 100 instructs the one or more battery management modules 102a, 102b, 102c, 102d to allow all the battery packs 104a, 104b, 104c, 104d to charge equally.

[035] Figure 2 illustrates a method for balancing charge between the plurality of battery packs in accordance with an embodiment of the present invention.

[036] At step 201, the battery management modules 102a, 102b, 102c, 102d receives a State of Charge (SoC) for at least one battery pack 104a, 104b, 104c, 104d and transmitting the SoC of the at least one battery pack 104a, 104b, 104c, 104d to the remaining battery management modules. The information includes parameters such as State of Charge (SoC), State of Health (SoH), temperature, voltage and current of the battery pack.

[037] At step 202, the VCU 100 receives, the SoC for each battery pack 104a, 104b, 104c, 104d from the battery management modules 102a, 102b, 102c, 102d. The VCU 100 and the battery management modules 102a, 102b, 102c, 102d are operatively coupled to each other

by means known in the art. In one non-limiting example, the VCU and the battery management modules are operatively coupled to each other via Controller Area Network (CAN).

[038] At step 203, the VCU 100 determines a difference in the SoC between the plurality of battery packs 104a, 104b, 104c, 104d and instructing, based on the difference in SoC, one or more battery management modules 102a, 102b, 102c, 102d to charge or discharge the one or more battery packs 104a, 104b, 104c, 104d as per method step 204, method step 205 or method step 206.

[039] At step 204, the VCU 100 instructs the one or more battery management modules 102a, 102b, 102c, 102d to allow discharge of one or more battery packs with higher SoC to charge one or more battery packs with lower SoC. In an embodiment, such an instruction is provided by the VCU 100 to the one or more battery management modules 102a, 102b, 102c, 102d on determination of the following conditions: (a) the difference in SoC between the plurality of battery packs 104a, 104b, 104c, 104d is less than a first pre-determined value, (b) an ignition switch of the vehicle is switched ON, and (c) a charger for charging the battery packs 104a, 104b, 104c, 104d is disconnected. In case the VCU 100 determines that the difference in SoC between the plurality of battery packs 104a, 104b, 104c, 104d is greater than the first pre-determined value, the VCU 100 instructs the one or more battery management modules 102a, 102b, 102c, 102d to prohibit the discharge of one or more battery packs with higher SoC to charge the battery packs with lower SoC.

[040] At step 205, the VCU 100 instructs the one or more battery management modules 102a, 102b, 102c, 102d to allow discharge of one or more battery packs with higher SoC till charge of all battery packs is equal. In an embodiment, such an instruction is provided by the VCU 100 to the one or more battery management modules 102a, 102b, 102c, 102d on

determination of the following conditions: (a) the difference in SoC between the plurality of battery packs 104a, 104b, 104c, 104d is greater than a second pre-determined value, (b) the ignition switch of the vehicle is switched ON, and (c) a charger for charging the battery packs 104a, 104b, 104c, 104d is disconnected. In case the VCU 100 determines that the difference in SoC between the plurality of battery packs 104a, 104b, 104c, 104d is less than the second pre-determined value, the VCU 100 instructs the one or more battery management modules 102a, 102b, 102c, 102d to prohibit the discharge of one or more battery packs with higher SoC to charge the battery packs with lower SoC. Instead, the VCU 100 instructs the one or more battery management modules 102a, 102b, 102c, 102d to allow all the battery packs 104a, 104b, 104c, 104d to discharge equally.

[041] At step 206, the VCU 100 instructs the one or more battery management modules 102a, 102b, 102c, 102d to allow charging of one or more battery packs with lower SoC prior to charging one or more battery packs with higher SoC. In an embodiment, such an instruction is provided by the VCU 100 to the one or more battery management modules 102a, 102b, 102c, 102d on determination of the following conditions: (a) the difference in SoC between the plurality of battery packs 104a, 104b, 104c, 104d is greater than a third pre-determined value, (b) the ignition switch of the vehicle is switched ON/OFF, and (c) a charger for charging the battery packs is connected to the vehicle. In case the VCU 100 determines that the difference in SoC between the plurality of battery packs 104a, 104b, 104c, 104d is less than the third pre-determined value, the VCU 100 instructs the one or more battery management modules 102a, 102b, 102c, 102d to prohibit the charging of one or more battery packs with lower SoC prior to the charging of the one or more battery packs with higher SoC. Instead, the VCU 100 instructs the one or more battery management

modules 102a, 102b, 102c, 102d to allow all the battery packs 104a, 104b, 104c, 104d to charge equally.

[042] Figure 3A, Figure 3B and Figure 3C illustrate a method for balancing charge between a first battery pack and a second battery pack in accordance with an embodiment of the present invention.

[043] As shown, step 301 indicates that an ignition switch of a vehicle is switched ON. On switching ON the ignition switch of the vehicle, a first battery management module (BMM1) 402a, a second battery management module (BMM2) 402b and a Vehicle Control Unit (VCU) 400 are also switched on. The first battery management module (BMM1) 402a is operatively coupled to the first battery pack 402a and the second battery management module (BMM2) 402b is operatively coupled to the second battery pack 404b. Both the first battery management module (BMM1) 402a and the second battery management module (BMM2) 402b are operatively coupled to the VCU 400.

[044] At step 302, a first battery management module (BMM1) 402a receives State of Charge (SoC1) of the first battery pack 404a and transmits it to the second battery management module (BMM2) 402b and the VCU 400.

[045] At step 303, the second battery management module (BMM2) 402b receives State of Charge (SoC2) of second battery pack 404b and transmits it first battery management module (BMM1) 402a and the VCU 400.

[046] On receiving the SoC1 of the first battery pack 404a and the SoC2 of the second battery pack 404b, the VCU 400 determines if there is a difference between SoC1 and SoC2 as shown in step 304.

[047] In an event of no difference in SoC between the first battery pack 404a and the second battery pack 404b i.e. the SoC1 for first battery pack 404a is equal to the SoC2 for the second battery pack 404b, the BMM 1 and BMM 2 will await charge/discharge input from the VCU.

[048] In an event of difference in SoC between the first battery pack and the second battery pack, the VCU will determine whether the difference in the SoC between the first battery pack 404a and the second battery pack 404b is greater than a first pre-determined value as shown in step 305. The first pre-determined value is allowable range of difference in SoC which is generally set by the manufacturer.

[049] In an event, when the difference in SoC between the first battery pack 404a and the second battery pack 404b is less than the first pre-determined value, the VCU 400 instructs the battery management module operatively coupled to the battery pack with higher SoC to charge the battery pack with lower SoC as shown in step 306. For example, the first battery pack 404a has 80 percent SoC and the second battery pack 404b has 60 percent SoC and the first pre-determined value/allowable range is set as 40. In such a scenario, the BMM1 will allow the first battery pack 404a to charge the second battery pack 404b. The first battery pack 404a may charge the second battery pack 404b till the charge of both the battery packs is equal.

[050] In an event, when the difference in SoC between the first battery pack 404a and the second battery pack 404b is greater than the first pre-determined value, the VCU 400 instructs the battery management module operatively coupled to the battery pack with lower SoC to prohibit the charging of the battery pack with lower SoC till a charge input is received by the VCU 400 as shown in step 307. This is a safety measure to avoid high current from the battery pack with higher SoC. In an embodiment, the charge port of the battery pack with lower SoC is switched off to avoid charging of the battery pack with lower SoC.

[051] For example, the first battery pack 404a has 80 percent SoC and the second battery pack 404b has 10 percent SoC and the first pre-determined value is set as 40. In such a scenario, the BMM2 402b will prohibit the charging of the second battery pack 404b by the first battery pack 404a. The charging of second battery pack shall take place only upon charge input from the VCU 400.

[052] At step 308, both BMM1 402a and BMM2 402b awaits charge/discharge input from the VCU. At step 309, the VCU 400 awaits input from a charger for charging the battery packs. At step 310, the VCU 400 detects if the charger for charging the first battery pack 404a and second battery pack 404b is connected.

[053] In an event that the charger is connected, the VCU sends charging signals to the BMM1 402a and BMM2 402b as shown in step 311. At step 312, the VCU 400 again determines a difference in SoC between the first battery pack 404a and the second battery pack 404b and determines whether the difference in SoC is greater than a second pre-determined value. In an event that the difference in SoC between the first battery pack 404a and the second battery pack 404b is greater than the second pre-determined value, the VCU 400 will instruct the battery management module with lower SoC to charge prior to the battery management module with higher SoC as shown in step 313. For example, the first battery pack 404a has 80 percent SoC and the second battery pack 404b has 30 percent SoC and the second pre-determined value is set as 40. In such a scenario, the VCU 400 will instruct the BMM2 to charge the second battery pack 404b prior to instructing the BMM1 to charge the first battery pack 404a. In an event that the difference in SoC between the first battery pack 404a and the second battery pack 404b is less than the second pre-determined value, the VCU 400 will instruct both the battery management modules BMM1 and BMM2 to charge equally as shown in step 314. For example, the first battery pack has 80 percent SoC and

the second battery pack has 60 percent SoC and the first pre-determined value range is set as 40. In such a scenario, the VCU 400 will instruct BMM1 and BMM2 to charge the battery pack 1 and battery pack 2 equally.

[054] In an event that the charger is disconnected, the VCU sends discharging signals to the BMM1 and BMM2 as shown in step 315. At step 316, the VCU 400 again determines a difference in SoC between the first battery pack 404a and the second battery pack 404b and determines whether the difference in SoC is greater than a third pre-determined value. In an event that the difference in SoC between the first battery pack 404a and the second battery pack 404b is greater than the third pre-determined value, the VCU 400 will instruct the battery management module with higher SoC to discharge till charge of both the battery packs is equal as shown in step 317. In one non-limiting example, BMM1 will enter into a discharge mode and BMM2 will be on sleep mode till the charge of both the battery packs is equal. For example, the first battery pack 404a has 80 percent SoC and the second battery pack 404b has 30 percent SoC and the third pre-determined value is set as 40, the VCU 400 will instruct the BMM2 to discharge the first battery pack 404a till the charge of the first battery pack 404a and the second battery pack 404b is equal. In an event that the difference in SoC between the first battery pack 404a and the second battery pack 404b is less than the third pre-determined value, the VCU 400 will instruct both the battery management modules BMM1 and BMM2 to equally discharge the first battery pack 404a and the second battery pack 404b as shown in step 318. For example, the first battery pack has 80 percent SoC and the second battery pack has 60 percent SoC and the third pre-determined value range is set as 40, the VCU will instruct BMM1 and BMM2 to discharge the battery pack 1 and battery pack 2 equally.

[055] In an embodiment, the second pre-determined value and third pre-determined value are same. In another embodiment, the second pre-determined value and third pre-determined value are different.

[056] In an embodiment having three or more battery packs, the discharging of battery packs with higher SoC is performed in descending order of SoC. In an embodiment having three or more battery packs, the charging of battery packs with lower SoC is performed in an ascending order of SoC.

[057] Figure 4A illustrates a graph which plots charging of a first battery pack and a second battery pack in accordance with the present invention. As shown, within a time span of 6 hours both the battery packs are equally charged and thus eliminates pack to pack imbalance and maintains vehicle performance and range.

[058] Figure 4B illustrates a graph which plots charging of a first battery pack and a second battery pack in accordance with the conventional methods of charging or the existing art. As shown, within a time span of 6 hours both the battery packs have different SoC's and the imbalance increases over the period of time which is undesirable and negatively affects the performance and range of the vehicle.

[059] Figure 5 illustrates an exploded schematic view of a battery pack 500 in accordance with an embodiment of the present invention.

[060] The battery pack 500 consists of one or more battery units 502 and each of the battery unit 502 has plurality of battery cells in it. The battery cells in each battery unit 502 are connected in series and parallel using a plurality of interconnectors 504.The battery pack 500 comprises top cover 506, bottom cover 508 and side covers 510 to secure the battery pack 500. The battery pack 500 has a Battery Management Module 512 to protect and control the battery parameters. The Battery Management Module 512 monitors each battery

cell and protect it from over voltage, over current and over charge/discharge conditions. The battery pack also comprises a signal Printed Circuit Board 514 connected to the Battery management module 512 via connector (not shown). It is to be understood that the battery pack illustrated in Figure 5 comprises other components which are already known to a person skilled in the art and therefore a detailed explanation with respect to the same has not been provided. It is also to be understood that battery packs discussed in Figure 1-4 have similar construction as disclosed in Figure 5.

[061] Advantageously, the present invention avoids pack to pack imbalance between plurality of battery packs in the vehicle thereby improving the performance of the vehicle. The life of the battery packs is also increased as overcharging or deep discharging of battery packs is avoided.

[062] While the present invention has been described with respect to certain embodiments, it will be apparent to those skilled in the art that various changes and modification may be made without departing from the scope of the invention as defined in the following claims.

CLAIMS:

1. A system for balancing charge between plurality of battery packs (104a, 104b, 104c, 104d) in a vehicle, the system comprising:
   - a plurality of battery management modules (102a, 102b, 102c, 102d) wherein each battery management module is configured to receive a State of Charge (SoC) for at least one battery pack and transmit the SoC of the at least one battery pack to the remaining battery management modules;
   - a vehicle control unit (100) in communication with the plurality of battery management modules (102a, 102b, 102c, 102d) and configured to:
     - receive the SoC for each battery pack from the battery management modules (102a, 102b, 102c, 102d);
     - determine a difference in the SoC between the plurality of battery packs (104a, 104b, 104c, 104d); and
     - instruct, based on the difference in SoC, one or more battery management modules (102a, 102b, 102c, 102d) to:
       - discharge (206) one or more battery packs with higher SoC to charge one or more battery packs with lower SoC; or
       - discharge (208) one or more battery packs with higher SoC till charge of all battery packs is equal; or
       - charge (210) one or more battery packs with lower SoC prior to charging one or more battery packs with higher SoC.

2. The system for balancing charge as claimed in claim 1, wherein the one or more battery management modules (102a, 102b, 102c, 102d) allows the discharge of one or more battery packs with higher SoC to charge the one or more battery packs with lower SoC upon satisfaction of the following conditions:
   - the difference in SoC between the plurality of battery packs is less than a first pre-determined value; and
   - an ignition switch of the vehicle is switched ON; and
   - a charger for charging the battery packs is disconnected.

3. The system for balancing charge as claimed in claim 2, wherein the one or more battery management modules (102a, 102b, 102c, 102d) prohibits the discharge of battery packs with higher SoC to charge the battery packs with lower SoC when the difference in SoC between the plurality of battery packs is greater than a first pre-determined value.

4. The system for balancing charge as claimed in claim 1, wherein the one or more battery management modules (102a, 102b, 102c, 102d) allows the discharge of one or more battery packs with higher SoC upon satisfaction of the following conditions:
   - the difference in State of Charge between the plurality of battery packs is greater than a second pre-determined value; and
   - an ignition switch of the vehicle is switched ON; and
   - a charger for charging the battery packs is disconnected.

5. The system for balancing charge as claimed in claim 4, wherein the one or more battery management modules (102a, 102b, 102c, 102d) prohibits the discharge of one or more

battery packs with higher SoC when the difference in SoC between plurality of battery packs is less than a second pre-determined value and allows all the battery packs to discharge equally.

6. The system for balancing charge as claimed in claim 1, wherein the one or more battery management modules (102a, 102b, 102c, 102d) allows the charging of one or more battery pack with lower SoC prior to charging of the one or more battery packs with higher SoC upon satisfaction of the following conditions:
   - the difference in SoC between the plurality of battery packs is greater than a third pre-determined value; and
   - an ignition switch of the vehicle is switched ON/OFF; and
   - a charger for charging the battery packs is connected.

7. The system for balancing charge as claimed in claim 6, wherein the one or more battery management modules (102a, 102b, 102c, 102d) prohibits the charging of one or more battery pack with lower SoC prior to charging of the one or more battery packs with higher SoC when the difference in SoC between the plurality of battery packs is less than a third pre-determined value and allows all the battery packs to charge equally.

8. The system as claimed in claim 1, wherein discharging of battery packs with higher SoC is performed in descending order of State of Charge (SoC).

9. The system as claimed in claim 1, wherein charging of battery packs with lower SoC is performed in an ascending order of State of Charge (SoC).

10. A method for balancing charge between plurality of battery packs (104a, 104b, 104c, 104d) in a vehicle wherein the vehicle comprises a plurality of battery management modules (102a, 102b, 102c, 102d) and a vehicle control unit (100) in communication with the plurality of the battery management modules (102a, 102b, 102c, 102d), the method comprising:

- receiving (200), by the battery management module, a State of Charge (SoC) for at least one battery pack and transmit the SoC of the at least one battery pack to remaining battery management modules;
- receiving (202), by the control unit, the SoC for each battery pack from the battery management modules;
- determining (204), by the control unit, a difference in the SoC between the plurality of battery packs and instructing, based on the difference in SoC, one or more battery management modules to:
    - discharge (206) one or more battery packs with higher SoC to charge one or more battery packs with lower SoC; or
    - discharge (208) one or more battery packs with higher SoC till charge of all battery packs is equal; or
    - charge (210) one or more battery packs with lower SoC prior to charging one or more battery packs with higher SoC.

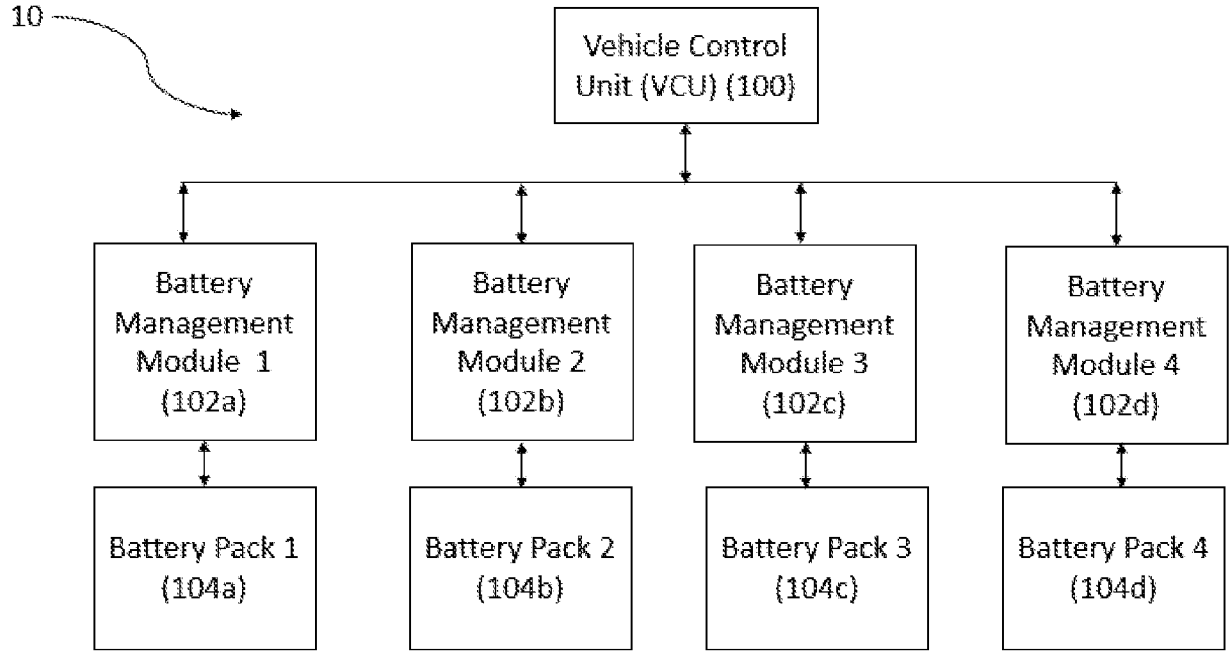

10
Vehicle Control Unit (VCU) (100)
Battery Management Module 1 (102a)
Battery Management Module 2 (102b)
Battery Management Module 3 (102c)
Battery Management Module 4 (102d)
Battery Pack 1 (104a)
Battery Pack 2 (104b)
Battery Pack 3 (104c)
Battery Pack 4 (104d)

Figure 1

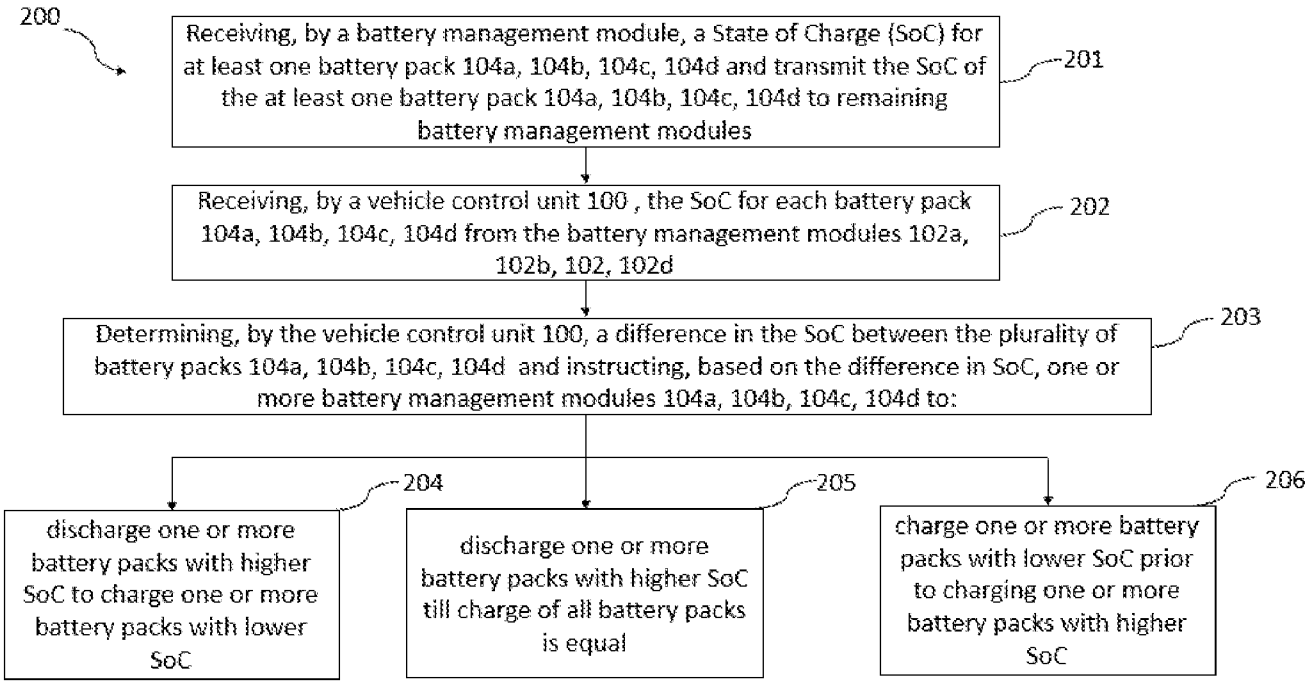

200
Receiving, by a battery management module, a State of Charge (SoC) for at least one battery pack 104a, 104b, 104c, 104d and transmit the SoC of the at least one battery pack 104a, 104b, 104c, 104d to remaining battery management modules
201
Receiving, by a vehicle control unit 100 , the SoC for each battery pack 104a, 104b, 104c, 104d from the battery management modules 102a, 102b, 102, 102d
202
Determining, by the vehicle control unit 100, a difference in the SoC between the plurality of battery packs 104a, 104b, 104c, 104d and instructing, based on the difference in SoC, one or more battery management modules 104a, 104b, 104c, 104d to:
203
discharge one or more battery packs with higher SoC to charge one or more battery packs with lower SoC
204
discharge one or more battery packs with higher SoC till charge of all battery packs is equal
205
charge one or more battery packs with lower SoC prior to charging one or more battery packs with higher SoC
206

Figure 2

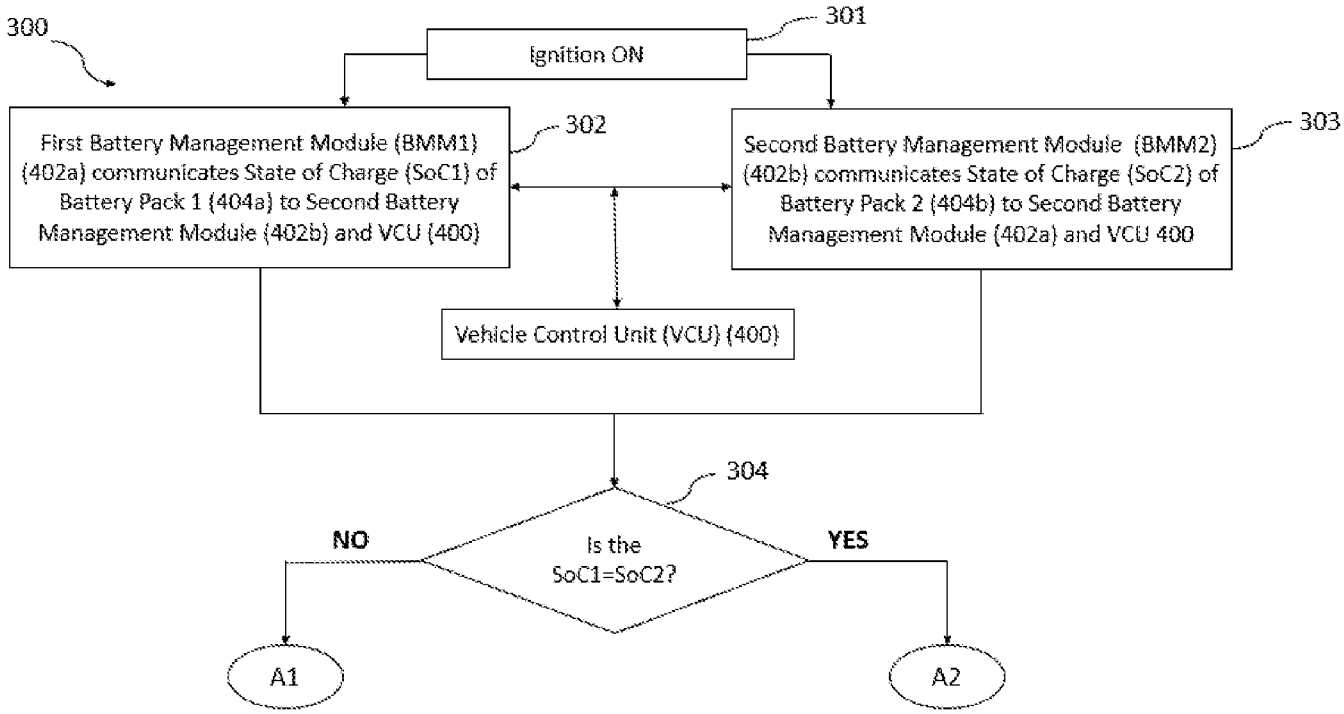

300
301
Ignition ON
First Battery Management Module (BMM1) (402a) communicates State of Charge (SoC1) of Battery Pack 1 (404a) to Second Battery Management Module (402b) and VCU (400)
302
Second Battery Management Module (BMM2) (402b) communicates State of Charge (SoC2) of Battery Pack 2 (404b) to Second Battery Management Module (402a) and VCU 400
303
Vehicle Control Unit (VCU) (400)
304
Is the SoC1=SoC2?
NO
YES
A1
A2

Figure 3A

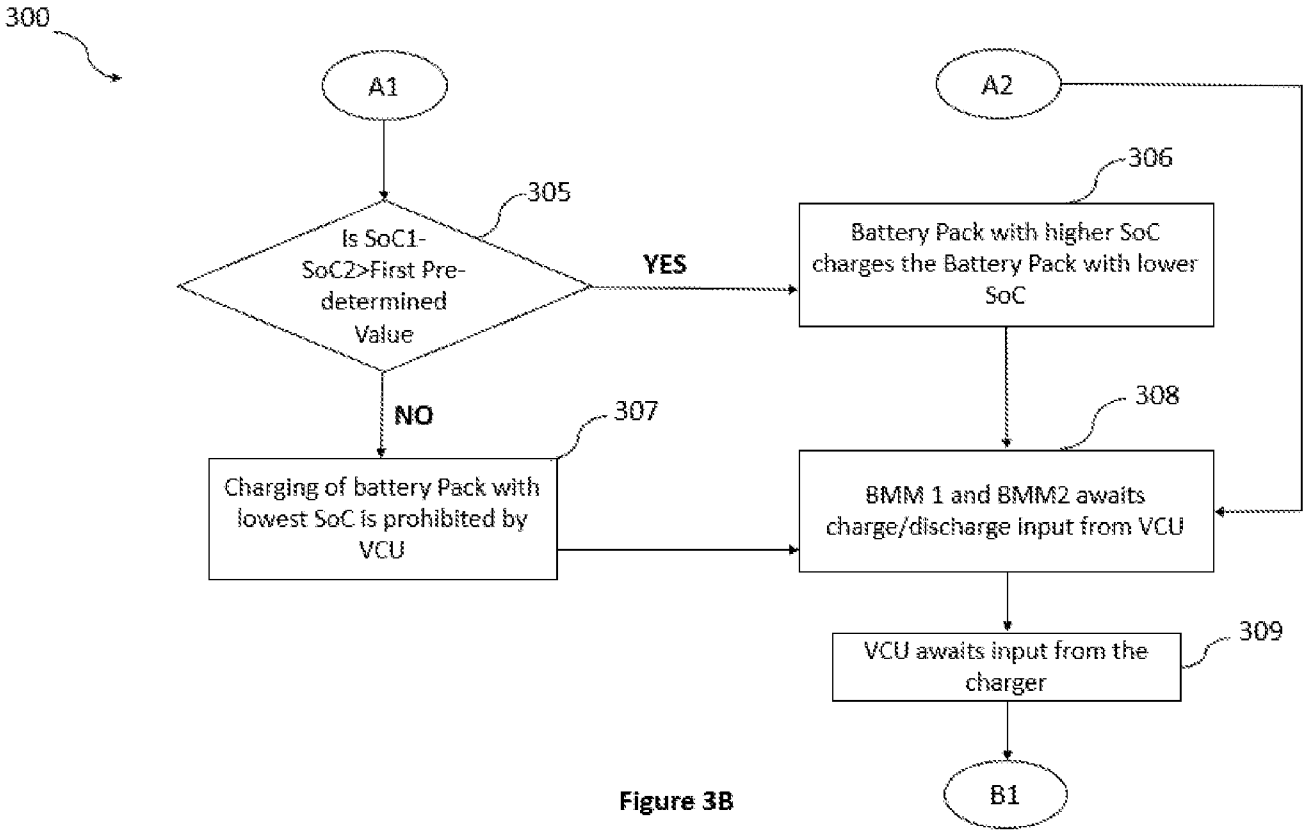

300
A1
A2
305
Is SoC1-SoC2>First Pre-determined Value
YES
NO
306
Battery Pack with higher SoC charges the Battery Pack with lower SoC
307
Charging of battery Pack with lowest SoC is prohibited by VCU
308
BMM 1 and BMM2 awaits charge/discharge input from VCU
309
VCU awaits input from the charger
B1

Figure 3B

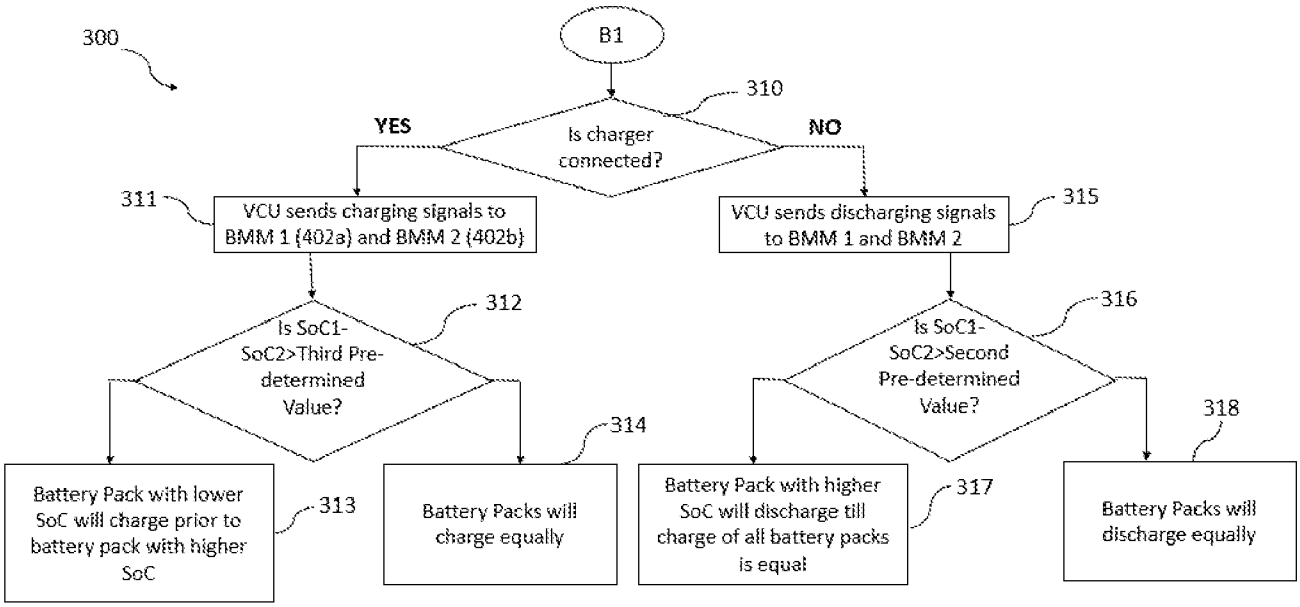

300
B1
310
Is charger connected?
YES
NO
311
VCU sends charging signals to BMM 1 (402a) and BMM 2 (402b)
315
VCU sends discharging signals to BMM 1 and BMM 2
312
Is SoC1-SoC2>Third Pre-determined Value?
316
Is SoC1-SoC2>Second Pre-determined Value?
313
Battery Pack with lower SoC will charge prior to battery pack with higher SoC
314
Battery Packs will charge equally
317
Battery Pack with higher SoC will discharge till charge of all battery packs is equal
318
Battery Packs will discharge equally

Figure 3C

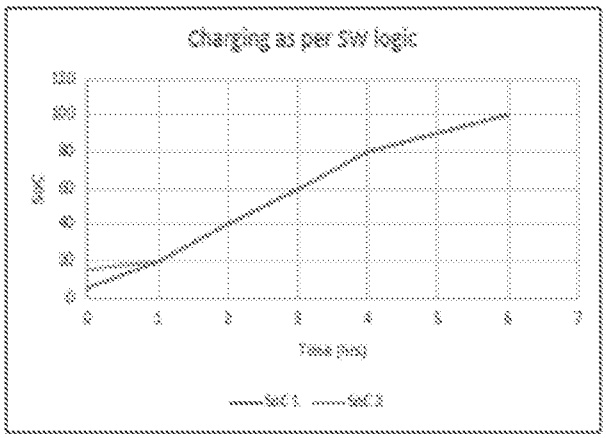


Figure 4A

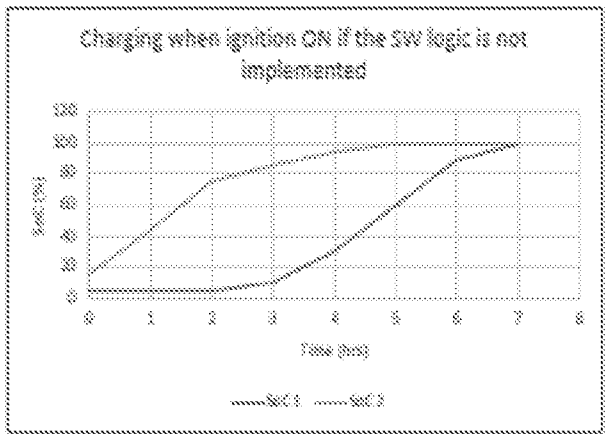


Figure 4B

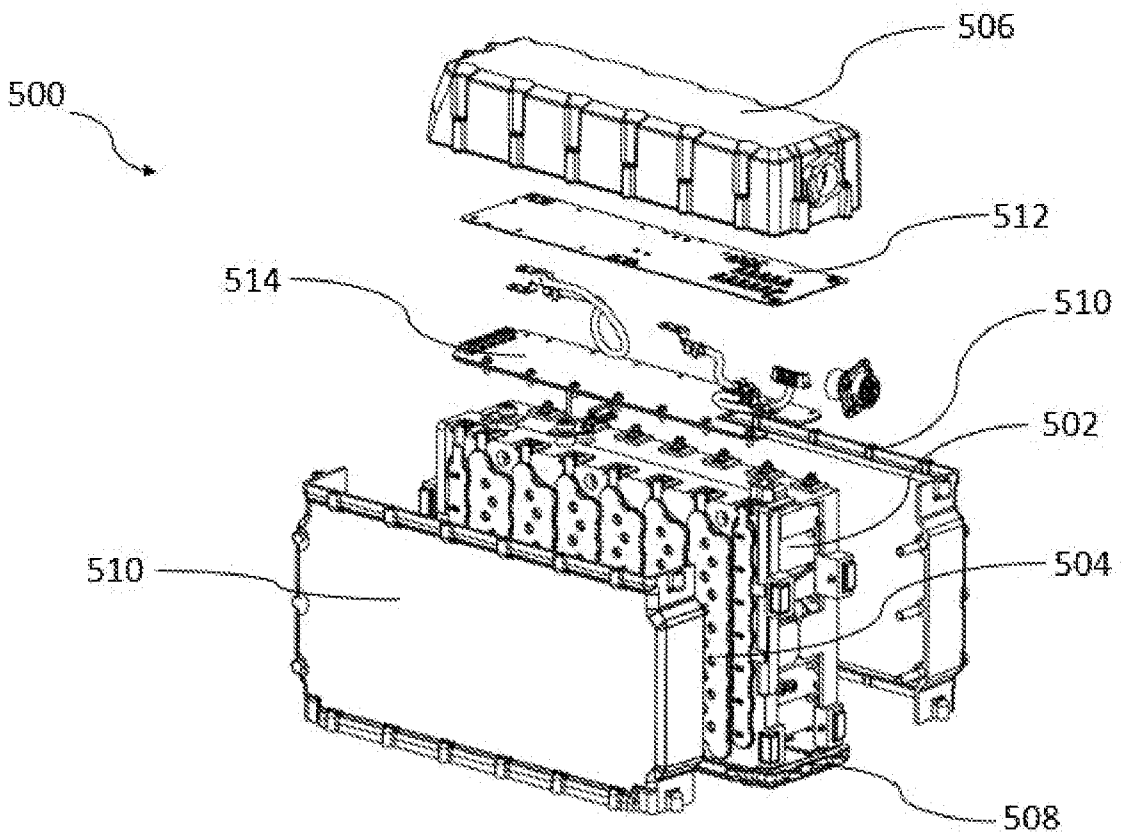


Figure 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IN2022/051069

A. CLASSIFICATION OF SUBJECT MATTER
B60L58/22,B60L58/13,H01M10/44 Version=2023.01

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)

B60L, H01M

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

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

DATABASES: PatSeer, IPO Internal Database, WIPO Patentscope
KEYWORDS: Battery, charge, balance, management, transmit, control

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US20190356025A1(LG Energy Solution Ltd) 21 November 2019(21-11-2019) [abstract, paragraphs [0011]-[0028],[0040]-[0206], claims 1-14, figures 1-10]	1-10
A	US20190168632A1(BYD Co Ltd) 06 June 2019 (06-06-2019) [abstract, paragraphs [0010]-[0019],[0030]-[0139], claims 1-20, figures 1-10]	1-10

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"D" document cited by the applicant in the international application
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"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

Date of the actual completion of the international search	Date of mailing of the international search report
31-01-2023	31-01-2023

Name and mailing address of the ISA/	Authorized officer
Indian Patent Office Plot No.32, Sector 14,Dwarka,New Delhi-110075 Facsimile No.	Vipin Kumar Telephone No. +91-1125300200

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IN2022/051069

Citation	Pub.Date	Family	Pub.Date
US 20190356025 A1	21-11-2019	KR 20190036242 A	04-04-2019
		CN 110249475 A	17-09-2019
		EP 3579327 A1	11-12-2019
		JP 2020508027 A	12-03-2020
		WO 2019066214 A1	04-04-2019
US 20190168632 A1	06-06-2019	CN 107696863 A	16-02-2018
		WO 2018028518 A1	15-02-2018
		JP 2019525711 A	05-09-2019
		EP 3498521 A1	19-06-2019