

A RECHARGEABLE BATTERY MANAGEMENT SYSTEM

CROSS REFERENCE TO RELATED APPLICATION

This application is based on and derives the benefit of Indian Provisional Application 201641041860 filed on December 7, 2016, the contents of which are incorporated herein by reference.

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TECHNICAL FIELD

[001] Embodiments disclosed herein relate to rechargeable batteries, and more particularly to swappable rechargeable batteries.

BACKGROUND

10 [002] With increasing need for reliable and dependable energy sources in various applications, storage and usage of electrical energy is assuming an ever increasing importance. This has resulted in an increasing usage of batteries in a variety of transportation and stationary applications.

15 [003] Designers of transportation and energy storage systems alike are often required to choose from a variety of batteries. With no industry wide standards, this often results in very long periods of selection, evaluation, detailed design and validation, specific to each application. Intense and custom specific efforts are also required to conceptualize, build and prove electronic management systems for these batteries for each application. This customized development requirement often results in unaffordable delays in product introduction and further large delays if further changes are required.

20 [004] Most of the batteries available today, are custom designed for a specific application and a platform. Such custom implementations involve intense and focused efforts at design, proving and deployment stages and form a significant part of the overall product design and implementation cycle. Any changes required will result in significant redevelopment efforts and adversely effect product design and implementation time.

[005] With rapid improvements in battery formulations and chemistries, such custom designs also result in significant new effort requirements to upgrade batteries and related infrastructures. Such an approach results in a constant race to ‘catch up’ with latest developments in the field.

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OBJECTS

[006] The principal object of embodiments herein is to disclose a standardized modular battery module, wherein the battery module can be used for a plurality of applications and comprises of a system for collating and communicating parameters related to the application and the battery.

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[007] These and other aspects of the embodiments herein will be better appreciated and understood when considered in conjunction with the following description and the accompanying drawings. It should be understood, however, that the following descriptions, while indicating at least one embodiment and numerous specific details thereof, are given by way of illustration and not of limitation. Many changes and modifications may be made within the scope of the embodiments herein without departing from the spirit thereof, and the
15 embodiments herein include all such modifications.

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BRIEF DESCRIPTION OF FIGURES

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[008] Embodiments herein are illustrated in the accompanying drawings, through out which like reference letters indicate corresponding parts in the various figures. The
20 embodiments herein will be better understood from the following description with reference to the drawings, in which:

[009] FIGs. 1a and 1b depict a battery, according to embodiments as disclosed herein;

[0010] FIGs. 2a, 2b and 2c depict example arrangements of cells in battery module, according to embodiments as disclosed herein;

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[0011] FIGs. 3a and 3b depict example designs of batteries with connectors, wherein the batteries can engage with a corresponding contact, according to embodiments as disclosed herein;

[0012] FIG. 4 depicts an example scenario where the batteries of differing capacity provide power to a host device, according to embodiments as disclosed herein, according to embodiments as disclosed herein; and

[0013] FIGs. 5a, 5b and 5c depict a plurality of batteries and docks in a host device,
5 according to embodiments as disclosed herein.

DETAILED DESCRIPTION

[0014] The embodiments herein and the various features and advantageous details thereof are explained more fully with reference to the non-limiting embodiments that are illustrated in the accompanying drawings and detailed in the following description.

5 Descriptions of well-known components and processing techniques are omitted so as to not unnecessarily obscure the embodiments herein. The examples used herein are intended merely to facilitate an understanding of ways in which the embodiments herein may be practiced and to further enable those of skill in the art to practice the embodiments herein. Accordingly, the examples should not be construed as limiting the scope of the embodiments
10 herein.

[0015] The embodiments herein disclose a standardized modular battery module, wherein the battery module can be used for a plurality of applications and comprises of a system for collating and communicating parameters related to the application and the battery. Referring now to the drawings, and more particularly to FIGS. 1a through 5c, where similar
15 reference characters denote corresponding features consistently throughout the figures, there are shown embodiments.

[0016] FIGs. 1a and 1b depict a battery module. The battery modules have a flexible architecture, so as to enable creation of groups, each group comprising of a plurality of battery modules. Each group can be configured to behave like a single contiguous unit in both
20 mechanical and electronic interface terms. This would facilitate swapping of an entire group for specifications as required.

[0017] The battery 100, as depicted, comprises of a battery management module (BMM) 101, at least one cell 102, a Telematics control unit (TCU) 103, a switching control unit (SCU) 104, at least one sensor 105, at least one thermal element 106, a memory 107, at
25 least one communication interface 108, a docking mechanism 109, and at least one power interface 110.

[0018] The BMM 101 and the TCU 103 can perform functions related to the State of Charge (SOC) of the battery 100, state of health of the battery 100, charging/balancing functions related to the battery 100, diagnostic/prognostic functions related to the battery 100,

data generation, data transmission and on-board analysis. The BMM 101 is responsible for performing functions including those listed above. The TCU 103 can perform tuning of the functions and can structure data for transmission (using the communication interface 108) and storage (such as the memory 107).

5 [0019] The battery 100 can comprise of one or more cells 102. A plurality of cells 102 can be connected together to store energy. In an embodiment herein, the cells 102 can be connected in a parallel combination (as depicted in FIG. 2a). In an embodiment herein, the cells 102 can be connected in a series combination (as depicted in FIG. 2b). In an embodiment herein, the cells 102 can be connected in a hybrid combination, wherein at least
10 one of the cells 102 is connected in series and at least one of the cells is connected in parallel (as depicted in FIG. 2c). The cells and cell formats can be standardized for adaptability to any required battery chemistry and also upgradation to newer formulations. The cells 102 can use at least one of different chemical formulations (such as Lithium cobalt oxide, NMC (nickel manganese cobalt oxide), Lithium Sulphur, titanate and other existing combinations), fuel
15 cells, and super capacitors. The cells 102 can be modular, scalable and adaptable to different configurations and future upgradeability.

 [0020] The sensor(s) 105 can comprise of sensors such as temperature sensors, current sensors, voltage sensors, location sensors (such as GPS (Global Positioning System) sensors), external environment sensors (such as pollution monitoring sensors),
20 accelerometers, gyroscopes, and so on. In an embodiment herein, the sensors 105 can measure parameters for each cell separately. Considering an example scenario, where the battery 100 is located in a vehicle, the sensor(s) 105 can also measure vehicle parameters such as acceleration, deceleration, velocity, distance traveled, and so on.

 [0021] The sensor(s) 105 can comprise of sensors that can measure any sudden
25 movement or drops, which can cause damage to the battery 100. The sensor(s) 105 can use sensors such as accelerometers, shock sensors and so on for this measurement. The sensor(s) 105 can also comprise of at least one biometric sensor, which can collect biometric data from a user. Examples of the biometric sensor can be, but not limited to, fingerprint readers, palm scanners, iris scanners, face scanners, voice recorders, and so on. In an example herein, the

biometric sensor can be incorporated into a handle of the battery 100. The sensor(s) 105 can also comprise of a pressure sensor, which can measure the pressure inside the battery 100.

[0022] The thermal element(s) 106 can be configured to maintain the battery 100 at a pre-defined temperature level. The thermal element(s) 106 can be at least one of electric
5 heaters, thermoelectric devices, thermal insulators, heat pipe(s), fans, mechanical heat conduction means or any other means that can be used for external heat transfer. The thermal element(s) 106 can also comprise of heat storage elements like phase change material. The thermal element(s) 106 can also comprise of elements, which will help in managing the temperature, such as heat sinks, thermal blankets, thermal enclosures, and so on. In an
10 embodiment herein, at least one portion of the body of the battery 100 can also act as a thermal element 106.

[0023] The memory 107 can be at least one of a RAM (Random Access Memory) or a ROM (Read Only Memory). The memory 107 can comprise of information on the usage life of the batteries such as number of full/partial cycles of usage, temperature, current and
15 voltage conditions during usage depth of discharge and level of charge during discharge/charge cycles, DC (Direct Current) resistance and impedance values of the battery, and so on. The memory 107 can comprise of information measured by the sensor 105. The memory 107 can comprise of information received by the battery 100 from external modules, such as a host device, a user device, and so on. The host device can be a device, where the
20 battery 100 has been installed. Examples of the host device can be, but not limited to, an electric vehicle, a UPS (Uninterruptible power supply), an inverter, an energy storage unit, a swapping station, and so on.

[0024] The memory 107 can further comprise of a means to identify itself to external entities, the type of battery module/cell being used, limits of operating parameters for the
25 specific battery 100, state of charge at any given moment (either by 'local calculation' by the BMM 101 or 'value received' from external devices over the communication interface), ageing information of the battery 100 in real time terms (comprising of information such as dates of installation and commissioning, current date, and so on), cyclic ageing information (such as number of full and partial cycles of charging and discharging the module has been
30 subjected to since commissioning/previous charging and so on), salient usage parameters

(such as average and peak stresses of voltages, currents, temperatures, depth of discharge), external sensors (such as environmental sensors), battery performance parameters (such as State of Health, State of Function, Internal resistance and so on, which can be computed by the BMM 101 or received from external devices over the communication interface 108). The memory 107 can comprise of a dynamic key, which is changed every time that battery is being inserted into a host device from a swap station. The memory 107 can also comprise of additional information such as information related to warranty, second life, and so on.

[0025] The memory 107, in conjunction with the BMM 101 can also function as an aggregator of information received from different subsystems of the host system/application.

Considering an example scenario, where the battery 100 is being used in a vehicle, the memory 107 can comprise of information received from the vehicle and systems/subsystems associated with the vehicle, wherein the information can be measured by the sensor(s) 105 or can be received from the vehicle. Examples of the vehicle parameters can comprise of, but not limited to, acceleration, deceleration, velocity, distance traveled, information received from the drive unit such as speed, acceleration, braking patterns, terrain information, and so on.

[0026] The communication interface 108 enables the battery 100 to interface with at least one external entity, such as the host device, a remote server (such as data server, the Cloud, and so on), vehicle systems, and so on. The communication interface 108 can comprise of at least one of wired communication interfaces or wireless communication interfaces. The communication interface 108 can use protocols such as CAN (Controller Area Network), Zigbee, Wi-Fi, Bluetooth, NFC (Near Field Communication), cellular, satellite, powerline, or any other suitable standards, which can be passive or active. The communication interface 108 can be flexible, so as to accommodate different data structures required by different users/applications/host devices. The communication interface 108 can also incorporate authentication means to ensure information security such as two-way authentication mechanisms. The communication interface 108 can communicate the received information to the TCU 103 and can receive information to be transmitted from the TCU 103.

[0027] The TCU 103 can control the communication interface 108 and can manage the transmission and receiving of data over the communication interface 108. The TCU 103

can aggregate data received by the battery 100. Based on information related to the vehicle and the battery 100 (such as the current usage, the current SOC, the driver of the vehicle and so on), the TCU 103 can compute parameters such as distance to empty (DTE), which can then be relayed to an external entity such as the vehicle or a user, using the communication interface 108. The TCU 103 can compute the DTE using the State of Charge (SOC), State of Health (SOH), State of Function (SOF) of the battery 100, vehicle information (such as current speed, nature of driving/road, vehicle load and so on), and user information (such as type of driver, and so on)

[0028] The docking mechanism 109 ensures quick and easy connection to the host device, for example, the vehicle. FIGs. 3a and 3b depict example ways in which the battery 100 can connect to the vehicle. The docking mechanism 109 can be at least one of a mechanical, an electrical, or an electro-mechanical mechanism. The docking mechanism 109 can be a universally useable interface that works across applications and platforms including the docking bays 105 and/or host devices. In an embodiment herein, the docking mechanism 109 can comprise of a lock to ensure secure connection, wherein the lock can be operated through an authentication mechanism operated either manually or remotely.

[0029] The power interface 110 can be used for connecting the battery 100 and/or the cells 102 to an external entity, such as an energy source, a load, and so on. The power interface 110 can be bi-directional. In an example herein, the load can be an electric vehicle. In an embodiment herein, the power interface 110 can be an electronic/electromechanical switch.

[0030] The SCU 104 enables connection and disconnection of the battery 100 to the host device using the docking mechanism 109 and the power interface 110. The SCU 104 can also control the power output to/from the battery 100. This can be used in cases where power to the vehicle has to be reduced, either due to the state of the battery or on a command from the vehicle. Consider an example scenario, wherein multiple batteries 100 are used, the SCU 104 can manage the sharing of power from the batteries. In another example, the SCU 104 can facilitate unequal sharing of power of batteries 100 as may be required because of unequal states of the battery 100 (as depicted in the example in FIG. 4).

[0031] The SCU 104 can also enable batteries 100 to share energy among themselves based on a command structure. Example applications of this can be battery-to-battery charging inside vehicles, jump charging of one vehicles battery by another vehicle after exchange of authentication information, on the road charging of vehicles by mobile battery packs, and so on.

[0032] The BMM 101 can receive data from other modules and from the host device. The BMM 101 can read these values during charge, discharge and idle conditions. The BMM 101 can monitor parameters, and ensure operation within safe operating region by generating early warnings and initiating cutoff mechanisms. The BMM 101 can manage the memory 107 and organization of information in the memory 107.

[0033] The BMM 101 can manage communication protocols through the communication interface 108 with built in authentication mechanisms. This can comprise checking if the user is authorized to use the battery 100, if the battery 100 can be used by the user, if the battery 100 can be used in this host device, and so on. The BMM 101 can check this using a suitable means such as a biometric means, or a user name password, a user database (such as Aadhar, SSN (Social Security Number), license number, and so on), the dynamic key, and so on. For example, if the battery 100 is being used in a vehicle, the BMM 101 can check if the battery 100 can be used in the vehicle by checking a unique identification means for the vehicle (such as the VIN (Vehicle Identification Number), chassis number, engine number, RFID (Radio Frequency Identification), vehicle registration number, and so on), which can be received from the vehicle using the communication interface 108. The BMM 101 can authenticate at least one of the host device, the application, the user device, a dock into which the battery 100 is being inserted, and so on. The BMM 101 can perform the security and authentication functions with the assistance of external entities (such as the user device, a remote server, and so on). If the BMM 101 has performed successful authentication, the BMM 101 enables tasks such as enabling the user to remove the battery 101 by unlocking the docking mechanism 109, providing power to the host device, charging, and so on.

[0034] The BMM 101 can compute state of charge, state of health and state of function of the battery using sensor readings, stored parameters and information received

from outside sources through the communication interface 108. The BMM 101 can perform several operations related to safety and proper usage of the battery 100. The BMM 101 ensures operation of the battery 100 under defined operating conditions during charging and discharge. The BMM 101 can compute parameters of the battery 100 such as SOC (State of Charge), SOH (State of Health) and SOF (State of function). The BMM 101 can store the
5 received information and the computed parameters in the memory 107.

[0035] The BMM 101 enables the battery 100 into a self-aware energy system which always contains information about it's own state, usage conditions, ageing and abuses it has undergone. The information stored in the battery can include the following a unique
10 identification means for the battery (hereinafter referred to as a battery id), manufacturing batch information, usage duration in calendar time, usage in cycles, initial capacity, capacity at specific intervals, peak and average temperature stresses encountered, peak and average current stresses encountered, internal resistance value trends over usage, temperature rise patterns during usage, usage patterns in terms of charge/discharge SOC, SOH pattern with
15 calendar time and cyclic usage, physical stresses encountered such as vibration and impact, abuse conditions encountered and so on.

[0036] Based on inputs from the sensor(s) 105, the BMM 101 can determine if the battery 100 has suffered any undesired variations in the battery 100, such as damage, falls, tampering, accidents, and so on. The BMM 101 can use data from sensor(s) 105, such as the
20 accelerometer, shock sensor to determine any sudden changes in height, orientation, acceleration, deceleration, and so on. The BMM 101 can check if the changes exceed one or more pre-defined thresholds. If the BMM 101 determines that the one or more thresholds are exceeded, the BMM 101 can provide an alert to at least one external entity (such as the user device, a remote server, and so on), about potential damage to the battery 100 and data
25 related to the damage, using the communication interface 108.

[0037] In an embodiment herein, the BMM 101 can check for tampering with the battery 100 by monitoring for a mechanical and/or electronic lock being disabled and/or broken, communication being lost with the dock in the host device without proper authentication, or any other pre-defined scenarios. On detecting at least one of the pre-

defined scenarios, the BMM 101 can disable power and enable a tracking system for the battery 100.

[0038] The BMM 101 can use inputs from the pressure sensor to determine the health of the battery 100. Over time and use, the cells in the battery 100 will expand. The BMM 101
5 can determine the level of expansion using inputs from the pressure sensor. On the BMM 101 determining that the expansion has crossed a pre-determined threshold, the BMM 101 can perform at least one action, such raising an alert, disabling the battery 100, and so on.

[0039] The BMM 101 can collect and aggregate information about the host device using the communication interface. Examples of this information can be, but not limited to,
10 energy usage of the host device, the loads present in the host device, usage patterns of the host device, type of usage of the host device, a unique identifier for the host device, and so on.

[0040] The BMM 101 can receive updates using the communication interface 108 and configure one or more modules in the battery 100 using the received updates. In an
15 embodiment herein, the updates can be over the air updates. The updates can be customized for the battery 100.

[0041] In an embodiment herein, one or more batteries 100 can be combined to form a battery pack. The BMM 101 of each battery 100 in such cases can interact with each other, consolidate information from different batteries in the pack and provide consolidated
20 information to external entities, such as the user device, a remote server, and so on.

[0042] The battery 101 can also comprise of additional modules such as a Real time clock (RTC) 111 to perform timestamping of all the readings and events, and a DC/DC converter 112 (to provide power to the various modules present in the battery 100 and which draws power from the cell(s) 102). The battery 101 can also comprise of other sensors and
25 communication management units as required, including an isolated CAN (CAN-IR) communication (not shown).

[0043] FIGs. 5a, 5b and 5c depict a plurality of batteries and docks in a host device. Data can be exchanged between the battery 100 and the dock 501 using a suitable means such

as a CAN bus. The locks can be at least one of a digital lock and/or a physical lock, using a suitable means such as a magnetic means to secure the battery. The locks can be activated/deactivated based on authentication and identification during the process of swap. The locks can also comprise of manual overrides. The docks 501 can be further connected to the host device using a suitable means such as a CAN bus. The host device may comprise a single dock with a battery (as depicted in FIG. 5a). The host device may comprise a plurality of docks connected in series with each dock connected to a battery (as depicted in Fig. 5b). The host device may comprise a dock connected to a plurality of batteries (as depicted in Fig. 5c).

[0044] The embodiment disclosed herein describes a standardized modular battery module, wherein the battery module can be used for a plurality of applications and comprises of a system for collating and communicating parameters related to the application and the battery. Therefore, it is understood that the scope of the protection is extended to such a program and in addition to a computer readable means having a message therein, such computer readable storage means contain program code means for implementation of one or more steps of the method, when the program runs on a server or mobile device or any suitable programmable device. The method is implemented in at least one embodiment through or together with a software program written in e.g. Very high speed integrated circuit Hardware Description Language (VHDL) another programming language, or implemented by one or more VHDL or several software modules being executed on at least one hardware device. The hardware device can be any kind of portable device that can be programmed. The device may also include means which could be e.g. hardware means like e.g. an ASIC, or a combination of hardware and software means, e.g. an ASIC and an FPGA, or at least one microprocessor and at least one memory with software modules located therein. The method embodiments described herein could be implemented partly in hardware and partly in software. Alternatively, the invention may be implemented on different hardware devices, e.g. using a plurality of CPUs.

[0045] The foregoing description of the specific embodiments will so fully reveal the general nature of the embodiments herein that others can, by applying current knowledge, readily modify and/or adapt for various applications such specific embodiments without departing from the generic concept, and, therefore, such adaptations and modifications should

and are intended to be comprehended within the meaning and range of equivalents of the disclosed embodiments. It is to be understood that the phraseology or terminology employed herein is for the purpose of description and not of limitation. Therefore, while the embodiments herein have been described in terms of embodiments and examples, those
5 skilled in the art will recognize that the embodiments and examples disclosed herein can be practiced with modification within the spirit and scope of the embodiments as described herein.

CLAIMS

I/We claim:

1. A battery (100) comprising:

a battery management module (BMM) (101) configured for:

authenticating a user of the battery (100) and a host device where the battery (100) is being used;

computing State of Charge (SOC), State of Health (SOH) and State of Function (SOF) of the battery (100), wherein the BMM (101) is configured to determine SOH of the battery (100) using a pressure sensor, wherein the BMM (101) determines level of expansion of a plurality of cells (102) using inputs from the pressure sensor;

ensuring operation of the battery (100) under defined operating conditions during charging of the battery (100) and discharging of the battery (100);

checking for tampering with the battery (100) by checking if a docking mechanism (109) is at least one of disabled; and broken;

checking for an undesired variation in the battery (100) using inputs from at least one sensor (105); and

providing an alert if the battery (100) has been tampered or there is an undesired variation in the battery (100), wherein the BMM (101) checks for the undesired variation by checking for a

sudden change in at least one height, orientation, acceleration, and deceleration, of the battery (100) using inputs from the at least one sensor (105), wherein the BMM (101) provides the alert if the sudden change exceeds at least one pre-defined threshold;

the plurality of cells (102) for storing energy, wherein the plurality of cells (101) are arranged modularly in at least one of a series, parallel or hybrid manner;

a Telematics control unit (TCU) (103) configured for:

managing transmission and receiving of data over a communication interface (108); and

computing a distance to Empty (DTE) using the State of Charge (SOC), State of Health (SOH), State of Function (SOF) of the battery (100), vehicle information, and user information;

a switching control unit (SCU) (104) configured for controlling connection and disconnection to the host device using the docking mechanism (109) and a power interface (110), wherein the SCU (104) is configured for enabling the battery (100) to share energy with at least one other battery based on a command structure; and

at least one thermal element (106) configured for maintaining the battery (100) at a pre-defined temperature.

2. The battery, as claimed in claim 1, wherein the BMM (101) is configured to authenticate the user of the battery (100) and the host device by performing a plurality of security and authentication functions by using external entities.

3. The battery, as claimed in claim 1, wherein the at least one sensor (105) comprises at least one of a temperature sensor, a current sensor, a voltage sensor, a location sensor, an external environment sensor, an accelerometer, a gyroscope, a shock sensor, the pressure sensor and at least one biometric sensor.

4. The battery, as claimed in claim 1, wherein the at least one thermal element (106) comprises at least one of electric heaters, thermoelectric devices, thermal insulators, heat pipe(s), fans, mechanical heat conduction means, phase change material, heat sinks, thermal blankets, thermal enclosures, and at least one portion of a body of the battery (100).

5. The battery, as claimed in claim 1, wherein the BMM (101) is configured for checking for tampering by checking for at least one of a mechanical and/or electronic lock being disabled and/or broken, and communication being lost with the host device without proper authentication.
6. The battery, as claimed in claim 1, wherein the battery (100) further comprises a Real time clock (RTC) (111) to perform timestamping of readings and events related to the battery (100).
7. The battery, as claimed in claim 1, wherein the battery (100) further comprises a DC/DC converter (112).
8. The battery, as claimed in claim 1, wherein the battery (100) is further configured for connecting at least one other battery (100) to form a battery pack.
9. The battery, as claimed in claim 1, wherein the BMM (101) is further configured for collecting and aggregating information about the host device.
10. The battery, as claimed in claim 1, wherein the battery (100) is configured using over the air updates.
11. The battery, as claimed in claim 10, wherein the updates are customized for the battery (100).