

“Battery swapping systems and methods”**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 a swapping systems and methods for 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] Several systems exist for energy storage for both transport and stationary applications. Most of these systems 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
25 and adversely effect product design and implementation time.

[005] One of the other important issues with battery powered systems is a tradeoff between the amount of batteries employed and the cost. In an electric vehicle, this translates as a tradeoff between driving range and vehicle price – both of which can affect electric vehicle adaptation. Long charging time is required in case of ‘large on board’ batteries also affects vehicle ‘availability’. Such ‘availability’ issues adversely affect adaptation of electric vehicles in ‘public’ commuting applications.

[006] Several solutions have proposed and implemented ‘battery swapping’ systems to circumvent the issues associated with large on board storage and charging times. Most of these swap systems suffer issues such as being ‘platform specific’ and lack portability across platforms and applications.

OBJECTS

[007] The principal object of embodiments disclosed herein is to disclose methods and systems to enable swapping of a battery module at a swapping station, wherein the swapping station can provide a battery module to a user based on a plurality of factors comprising of weather parameters, battery module application, user behaviour, and so on.

[008] Another object of the invention is to disclose an application present on a user device that enables a user to connect to the swapping station, wherein the application provides information to the swapping station, which will enable the swapping station to determine at least one suitable battery module for the user.

[009] Another object of the invention is to disclose methods and systems for managing a second life application for the battery module.

[0010] 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 embodiments herein include all such modifications.

BRIEF DESCRIPTION OF FIGURES

[0011] Embodiments herein are illustrated in the accompanying drawings, through out which like reference letters indicate corresponding parts in the various figures. The embodiments herein will be better understood from the following description with reference
5 to the drawings, in which:

[0012] FIG. 1a depicts a swapping station connected to at least one energy source, the power grid, at least one user, at least one battery module, at least one user device, and an application server, according to embodiments as disclosed herein;

[0013] FIG. 1b depicts the swapping station, according to embodiments as disclosed
10 herein;

[0014] FIGs. 1c and 1d depict the swapping station managing the feed of power to and from the batteries present in the docking bay, according to embodiments as disclosed herein;

[0015] FIG. 2a depicts the docking bay, according to embodiments as disclosed
15 herein;

[0016] FIG. 2b depicts a system where a DCU is connected to a plurality of chargers and docks, according to embodiments as disclosed herein;

[0017] FIG. 2c depicts a plurality of chargers and docks connected to the DCU, according to embodiments as disclosed herein;

[0018] FIGs. 3a and 3b depict the AS, according to embodiments as disclosed herein;
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[0019] FIG. 4 depicts an example scenario where the battery module is used in a vehicle, according to embodiments as disclosed herein;

[0020] FIG. 5 is an example flow diagram depicting the process of matching a vehicle with a battery, according to embodiments as disclosed herein;

[0021] FIG. 6 is a flow chart depicting the process of performing battery conditioning, according to embodiments as disclosed herein; and
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[0022] FIG. 7 depicts an example scenario of a second life application for a battery module, according to embodiments as disclosed herein, according to embodiments as disclosed herein.

DETAILED DESCRIPTION

[0023] 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.

[0024] The embodiments herein disclose methods and systems to enable swapping of a battery module at a swapping station, wherein the swapping station can provide a battery module to a user based on a plurality of factors comprising of weather parameters, battery module application, user behaviour, and so on. Referring now to the drawings, and more
15 particularly to FIGS. 1 through 7, where similar reference characters denote corresponding features consistently throughout the figures, there are shown embodiments.

[0025] Vehicle as disclosed herein can be any vehicle that uses at least one battery for propulsion, such as a pure electric vehicle, a hybrid vehicle, and so on. Examples of the vehicles can be, but not limited to, cars, bikes, scooters, vans, trucks, buses, and so on.

20 [0026] Embodiments herein disclose methods and systems to enable swapping of the battery module at a swapping station, wherein the swapping station can provide a battery module to a user based on a plurality of factors comprising of weather parameters, battery module application, user behaviour, and so on.

[0027] Embodiments herein disclose an application present on a user device that
25 enables a user to connect to the swapping station, wherein the application provides information to the swapping station, which will enable the swapping station to determine at least one suitable battery module for the user and determine specific conditioning required for the module.

[0028] Embodiments herein disclose methods and systems for managing a second life application for the battery module.

[0029] FIG. 1 depicts a swapping station connected to at least one energy source, the power grid, at least one user, at least one battery module, at least one user device, and an application server. The swapping station 101 can comprise of a plurality of docking bays 103, wherein the battery modules 102 can be docked for charging and/or conditioning into the docking bays 103. The docking bays 103 can accept battery modules with different usage histories and provide electrical conditioning (charging) and thermal conditioning specific to each usage demand. Embodiments herein use the terms 'docking bays' and 'docks' interchangeably and both the terms herein refer to the docking bays 103. The battery module 102 can be configured for use in a variety of transport and non-transport applications of energy storage. The battery module 102 can comprise of a mechanism for easy swapping between the application and the swapping station 101. In an embodiment herein, the swapping station 101 can provide energy back to the power grid.

[0030] The user device 104 can communicate with the swapping station 101. The user device 104 can be at least one of a mobile phone, a smart phone, a tablet, a wearable computing device, an on-board console, a computer, a laptop, or any other device capable of performing functionalities as disclosed herein. The swapping station 101 and the user device 104 can communicate using a suitable wireless communication means such as Wi-Fi, cellular networks, Bluetooth, BLE (Bluetooth Low Energy), and so on. The communication between the user device 104 and the swapping station 101 can comprise of at least one of information related to at least one battery module 102, information related to the battery module application, information related to the environment where the application is being used (for example, if the battery module 101 is being used in a vehicle, the vehicle data), usage pattern (if the battery module 101 is being used in a vehicle, the usage pattern can be of the vehicle), state of the battery module 101 (wherein the state can comprise of information such as temperature, SOC, SOH, imbalances (if any), and so on), information related to authentication, and so on. The user device 104 can also communicate with the application server (AS) 105. The communication between the user device 104 and the AS 105 can comprise of at least one of information related to at least one battery module 102, information related to the battery module application, information related to the environment where the

application is being used, and so on. The user device 104 can also perform authentication functions. In an embodiment herein, the user device 104 can comprise of an application that performs the communication and other functions, as disclosed above.

[0031] The user device 104 can gather data about the host device and the application.

5 The user device 104 can provide the user with alerts such as impending charging, error codes, and other conditioning requirements. The user device 104 can communicate with the network of swapping stations 101 and advising the user on location of nearby stations, status/availability of suitable replacement modules in each of the stations, and capacity available in vehicle to reach each of these stations (if the host device is a vehicle). If required,

10 the user device 104 can guide the user to the most appropriate swap station for his requirements and conditions. Once at the station, the user device 104, on input from the user can initiate a conversation with the specific station, communicate request for swap/conditioning and also authenticate the request. The user device 104 can also facilitate billing and payment transaction with due authentication.

15 [0032] In an embodiment herein, the user using the user device 104 can pre-book a battery module 102, providing a location for the swapping station 101 from where the user can swap the battery module 102 and a time for the swap the battery module 102. In an embodiment herein, the user using the user device 104 can pre-book a battery module 102, wherein the user device 104 can determine a location for the swapping station 101 from

20 where the user can swap the battery module 102 and a time for the swap the battery module 102, based on a plurality of factors such as the application requirements, route taken by the user (if the application is for a vehicle), SOC of the battery module 102, and so on. In an embodiment herein, the user device 104 can pre-book a battery module 102 automatically, wherein the user device 104 can determine a location for the swapping station 101 from

25 where the user can swap the battery module 102 and a time for the swap the battery module 102, based on a plurality of factors such as the application requirements, route taken by the user (if the application is for a vehicle), SOC of the battery module 102, and so on.

[0033] FIG. 1b depicts the swapping station. The swapping station 101 can receive power from at least one energy source such as a distribution grid, a solar array, a diesel

30 generator, a battery bank or other renewable energy sources. The swapping station 101, as

depicted, comprises of an analysis engine 106, a plurality of docking bays 103, a memory 107, and at least one communication interface 108.

[0034] The communication interface 108 enables the swapping station 101 to interface with at least one external entity, such as a host system, the battery module 102, the docking bay 103, and the user device 104 and perform bi-directional communication with the at least one external entity. 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 also incorporate authentication means to ensure information security such as two-way authentication mechanisms.

[0035] The memory 108 can be a local memory such as at least one of a RAM (Random Access Memory) or a ROM (Read Only Memory). The memory 108 can be at least one of a file server, a data server, the cloud, or a database.

[0036] The analysis engine 106 can keep track of the state readiness of battery modules in each docking bay 103 and the suitability of the battery module(s) to individual application/platform needs. The analysis engine 106 can collect data. The analysis engine 106 can analyze the data in real time. From the analysis, the analysis engine 106 can determine usage patterns for each vehicle and energy storage device, history of each of the battery modules, suitability of specific battery modules for each host device, and specific conditioning each module has to undergo as decided by immediate data and historical data.

[0037] Using the determined information, the analysis engine 106 can identify a specific conditioned battery module to be picked up by a user after depositing the used battery module, on receiving an intimation from the user and/or user device that the user is coming to the swapping station for a swap. The analysis engine 106 can suggest alternate modules suitable for the application, with different performance parameters and differential pricing. The analysis engine 106 can inform this to the user using the user device 104. The analysis engine 106 can unlock specific modules automatically and made available to the user, on performing successful authentication.

[0038] On detecting that a battery module 102 is approaching the station 101, the analysis engine 101 establishes communication between the battery module 102 and the station 101. The station 101 automatically validates the request by initiating a handshake with the battery module 102 through the user device or directly. The station 101 collects the
5 information (either from the memory 107 or the AS 105) such as type and configuration of the battery module 102, charging profile for the specific battery (such as limits of voltage, current, temperature), history of host device usage (comprising of parameters such as patterns of usage, stress profiles, and so on), and weather information (temperature, humidity, information from environment sensors, and so on). As the battery module is loaded onto the
10 docking bay 103, the station 101 also communicates with the module 103 to gather information about current set of parameters (such as state of charge, temperature, state of function, internal resistance), stored data for the entire usage cycle with corresponding time stamps (comprising of temperatures, voltages, currents, SOC (State of Charge), SOH (State of Health), drive cycle pattern, and so on). Using all these data, the analysis engine 106
15 computes conditioning outputs required such as voltage, state of charge, temperature, and so on. The analysis engine 106 can determine this based on reference data already available for the specific type of battery and optimized for optimum performance and life. The analysis engine 106 can also balance the amount of energy to be drawn from at least one energy source, based on prediction of energy available from renewable energy sources during the
20 duration of charge (wherever applicable). The analysis engine 106 can further compute the limits of voltage, current and heating/cooling to be applied to the module 103.

[0039] The analysis engine 106 can also use the information collected to suggest an already conditioned battery module for replacement, based on suitability of specific conditioning the battery module has undergone, to the host device, suitability of the
25 characteristics of the battery (for example, energy content, power delivery capability) to the application.

[0040] The analysis engine 106 can provide information received from at least one of the docking bay 103, the battery module 102 and the user device 104 to the AS 105. The analysis engine 106 can provide the determined factors to the AS 105. The analysis engine
30 106 can receive information from the AS 105 and store the received information in the

memory 107. The analysis engine 106 can use the stored information for the determination process.

[0041] In an embodiment herein, the swapping station 101 can exchange information with other swapping stations, either directly or through the AS 105.

5 [0042] In an embodiment herein, the swapping station 101 can provide power to at least one load connected to the swapping station 101 from energy stored in at least one battery module 102 present in a docking bay 103. In an embodiment herein, the swapping station 101 can provide power to the electrical grid, from energy stored in a battery module 102. The analysis engine 106 can manage the direction of power transfer based on factors
10 such as time of day, time of use, tariff structure (if any) and availability of excess power.

[0043] The analysis engine 106 can perform power management functions, such as managing the bi-directional flow of power to and from the swapping station 101 (as depicted in FIGs. 1c and 1d). FIG. 1c depicts a plurality of energy sources (such as, but not limited to, the power grid, alternative energy sources, and so on) supplying power to an inverter 111,
15 which can be connected to a plurality of battery modules 102 through a switch 110 (which is controlled by the charger 109) and the docking stations 103.

[0044] The analysis engine 106 can provide stored energy to the power grid from the battery module(s), based on a plurality of factors such as date/time, power availability in the grid, power stored in battery modules present in the station 101, availability of power from
20 alternate sources (such as solar power, wind energy, and so on), the demand for battery modules, and so on. FIG. 1d depicts the power being supplied to the power grid, through a bi-direction converter 112.

[0045] The analysis engine 106 can also manage each docking bay, in terms of the charging rate, discharge rate, and so on. This can be based on factors such as demand for the
25 battery modules, availability of power, date and time, and so on. The analysis engine 106 can perform testing and diagnostic functions to test at least one of the docking bay, battery, charger, inverter, the grid, the other energy sources, and so on. The diagnostics can comprise of performing high discharge of the pack to check for degradation in performance (such as internal resistance, temperature rise, and so on). The analysis engine 106 can also perform

battery discharge to check capacity, wherein the discharge unit can be at least one of resistive, electronic or bi-directional to the grid.

[0046] In an embodiment herein, the swapping station 101 can comprise of at least one thermal element. The thermal elements can heat or cool the batteries to the required level as directed by the analysis engine 106. The thermal elements can be at least one of heater(s), thermoelectric, air cooled system, thermal jackets, and so on. The thermal elements can be used to cool/heat the external surface of the module(s) and/or the swapping station 101, which in turns cools/heats the cells to maintain the right temperature, or via direct contact (conduction).

[0047] In case of a loss of power to the station, the analysis engine 106 can channel energy for the batteries to charge one or multiple units. For example, if most of the batteries are 50% charged, half the batteries can provide energy to the other half of the batteries, to ensure that at least 50% of the batteries are fully charged.

[0048] In an embodiment herein, the swapping station 101 can be stationary at a certain location. In an embodiment herein, the swapping station 101 can be a mobile station, wherein the swapping station 101 is located in a vehicle.

[0049] FIG. 2a depicts the docking bay. The docking bay 103, as depicted, comprises of a Docking Control Unit (DCU) 201, a docking mechanism 202, a charger(s) 203, at least one communication interface 204, a memory 205, a Thermal Management Unit (TMU) 206 and thermal elements 207.

[0050] The docking mechanism 202 ensures a connection to the battery module 102. The docking mechanism 202 can be at least one of a mechanical, an electrical, or an electro-mechanical mechanism. The docking mechanism 202 can be at least one of a manual system (wherein a user manually removes a battery from the docking bay 103), a semi-automatic system, or an automatic system. The docking mechanism 202 can be a universally useable interface that works across applications and platforms. In an embodiment herein, the docking mechanism 202 can comprise of a lock to ensure secure connection, wherein the lock can be operated through an authentication mechanism operated either manually or remotely (based on instructions from the swapping station 101 and/or from the user and/or the user device 104).

[0051] The communication interface 204 enables the docking bay 103 to interface with at least one external entity, such as a host system, the battery module 102, the swapping station 101, and the user device 104 and perform bi-directional communication with the at least one external entity. The communication interface 204 can comprise of at least one of
5 wired communication interfaces or wireless communication interfaces. The communication interface 204 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 204 can be flexible, so as to accommodate different data structures required by different battery modules
10 102. The communication interface 204 can also incorporate authentication means to ensure information security such as two-way authentication mechanisms.

[0052] The memory 205 can be at least one of a RAM (Random Access Memory) or a ROM (Read Only Memory). The memory 205 can comprise of information received from the battery module(s) 102. The information can comprise of the usage life of the batteries such as
15 number of full/partial cycles of usage, temperature, current and voltage conditions during usage depth of discharge and level of charge during discharge/charge cycles as also DC (Direct Current) resistance and impedance values of the battery. The memory 205 can comprise of information received from the swapping station 101, such as type of conditioning required for the specific module, and so on.

20 [0053] The DCU 201 can perform an onboarding process for each new battery that is added to a swap station 101. This can involve steps such as preparing the battery, assign a unique identification means (ID) to the battery, assigning security keys to the battery, mapping the batteries to specific entities, and so on.

[0054] The DCU 201 can assign each battery in a swap station with a dynamic key,
25 wherein the dynamic key can comprise of identifiers that identify the battery, the swap station, the vehicle in which the battery is going to be used, and so on. Each time the battery is being assigned to a vehicle, the DCU 201 can assign a new dynamic key to the battery 102. The dynamic key can be used by the AS 105 for authentication, before charging the battery in the swap station or enabling the battery 102 to supply power to a vehicle.

[0055] The DCU 201 can determine the state of the battery module 102 present in the docking bay 103 and the usage, to set up a specific charging profile and a thermal conditioning profile. The DCU 201 can control the charger(s) 203, to enable the charger(s) 203 to provide a customized charge profile to the battery module 102. The charger(s) 203 can receive power from at least one energy source such as a distribution grid, a solar array, a diesel generator, a battery bank or other renewable energy sources. The charge profile can comprise of type of charging, charging current/voltage values, limits of charging voltage/temperature, heating/cooling required, and so on. The charge profile can be based on factors such as temperature of the battery, remaining SOC of the battery, SOH of the battery, demand for batteries/energy, time required for charging the battery, customized conditioning, and so on. The charging profile can comprise of a modifiable rate of charging. If it is known that demand is low, the DCU 201 can charge batteries slowly as they last longer. If it is known that energy cost is low for 1 hour, the DCU 201 can do a fast charge. The charging profile can consider balancing requirements to correct any imbalances that may have developed between individual cells of the module during usage. The DCU 201 can determine the charge profile based on factors such as the specific condition of the battery, the host device, the user of the host device, the usage pattern in each specific application, weather condition, historical behavior of the specific module/pack, and power available (depends on time, unit cost, and so on). The DCU 201 can charge the battery using at least one power source based on the determined charge profile, either one at a time or simultaneously, using one or more power connectors 207. Examples of the power sources that can be used for charging the battery can be, but not limited to, the power grid, alternative energy sources (such as solar, wind, and so on), other batteries present in the swapping station 101, and so on.

[0056] The DCU 201 can run diagnostics on the battery module 102. The diagnostics can comprise of performing high discharge of the pack to check for degradation in performance (such as internal resistance, temperature rise, and so on). The DCU 201 can also perform battery discharge to check capacity, wherein the discharge unit can be at least one of resistive, electronic or bi-directional to the grid.

[0057] The DCU 201 can perform security and authentication functions. The DCU 201 can authenticate the user using the user device. The DCU 201 can authenticate the

battery module and can also check if the battery module 201 and the user match with each other.

[0058] In an embodiment herein, the docking bay 103 can have a temperature control means comprising of the TMU 206 and the thermal elements 207. The temperature control
5 means can comprise of a heating and cooling mechanism made of heaters, phase change material(s), and/or thermoelectric devices or external liquid or air cooling and heating with settable temperature profile(s).

[0059] The DCU 201 can determine the thermal conditioning required for each module/pack by a combination of factors such as vehicle usage pattern, climatic conditions
10 and optimum temperature of operation to ensure maximum throughput. In an example, if a vehicle is expected to heat up the battery during a run, and the weather conditions are already hot, the DCU 201 will 'precool' the batteries to a level to optimize performance. In another example, in case of extreme cold conditions, the batteries can be preheated to an appropriate level considering the weather and the temperature changes imposed by the driving cycle. The
15 thermal conditioning mechanism would include cooling/heating by air, fluid or use of thermoelectric devices. In cases where it is desirable to maintain temperature at in a close range, phase change materials would be used to maintain the temperature. The host device could also be equipped with insulating enclosures that prevent heat exchange between the ambient and the battery pack. Such cases would be factored into the customization of the
20 thermal conditioning of each battery module/pack.

[0060] The TMU 206 can be a heating/cooling/air conditioning unit used to condition the temperature of the batteries before and during charging process. The TMU 206 can be designed to bring the batteries to a predefined target temperature levels at the start of charge and the end of charge. In an embodiment herein, the TMU 206 can be a centralized unit,
25 which can control the temperature of the entire station. Here, each dock can further comprise a mechanism to manage it's own temperature independently. This mechanism could be one or more fans or ducts or special thermal elements 207, with individual control to achieve differential cooling as required by different batteries. In an embodiment herein, the TMU 206 can comprise of individual units associated with individual docks. The TMU 206 can also
30 perform preemptive thermal conditioning routine.

[0061] The thermal elements 207 can be at least one of heater(s), thermoelectric, air cooled system, thermal jackets, and so on. The thermal elements 207 can be used to cool/heat the external surface of the module, which in turns cools/heats the cells to maintain the right temperature, or via direct contact (conduction). The thermal jacket for the batteries can
5 ensure proper thermal management of the batteries.

[0062] The DCU 201 can recognize specific protocols used by each application and battery module. The DCU 201 can then adapt the protocol used by the docking bay 103 to match with the requirements of the battery module 102. The DCU 201 can add new protocols to the vocabulary of the docking bay 103, as required.

10 [0063] In an embodiment herein, the docking bay 103 can be constructed with a flexible architecture, which enables the docking bay 103 to be 'configured' for different sizes of battery modules and packs/groups of battery modules. The docking bay 103 can also comprise of adaptation components to accommodate different physical sizes and types of modules based on requirements of the host device.

15 [0064] In an embodiment herein, the docking bay 103 can comprise of a visual interface. The visual interface can enable a user and/or any authorized person to identify a specific docking bay 103. The visual interface can also provide information related to the battery module 102, currently present in the docking bay 103, such as the SOC, time that the battery module has been charging, the rate of charging, the thermal conditioning, the host
20 device, and so on.

[0065] In an embodiment herein, the docking bay 103 can provide power to at least one load connected to the swapping station 101 or the docking bay 103. In an embodiment herein, the docking bay 103 can provide power to the electrical grid, from energy stored in a battery module 102. In an embodiment herein, power exchange between modules can also be
25 based on exigencies (such as one specific module requiring priority service).

[0066] In an embodiment herein, the docking bay 103 can have bidirectional power flow capabilities. The DCU 201 can manage power flow from one module to another in times of such requirement. The DCU 201 can also manage the flow of power from the module to grid. The station will also incorporate inverters/multidirectional power converters to enable
30 routing of energy between the station, grid and any other renewable energy source.

[0067] The DCU 201 can perform testing and diagnostic functions to test the docking bay, battery, and so on. The DCU 201 can run diagnostics on the battery module 102. The diagnostics can comprise of performing high discharge of the pack to check for degradation in performance (such as internal resistance, temperature rise, and so on). The DCU 201 can also perform battery discharge to check capacity, wherein the discharge unit can be at least one of resistive, electronic or bi-directional to the grid. These tests can measure parameters like the actual capacity, state of charge variation, state of function variation, impedance build up and temperature changes with usage/ageing, and so on. Using these tests, the DCU 201 can re-characterize the battery at usage intervals. The DCU 201 can write the respective values into the battery pack as new set of parameters that characterize the battery pack in it's current state. These will be used by the battery pack to apply corrections to on board algorithms of state of charge (SOC), state of health (SOH) and function.

[0068] In an embodiment herein, there may be different types of docking bays, such a docking bay in the host device (such as a docking bay in the vehicle), a docking bay in the swapping station 101, and a third docking bay in a second life application (such as at home, at an industrial premises, and so on). The docking bays can also have intelligence and based on the application communication with the external entities, such as the host device, the swapping station, a second life host, and so on.

[0069] FIG. 2b depicts a system where a DCU 201 is connected to a plurality of chargers 203 and docks 202. The chargers 203 can be connected to at least one power connector 207, which can further be provided power from at least one power source. The DCU 201 can be connected to at least one locking means for securing the battery modules 102 and the docks 202. The DCU 201 can also monitor the conditions inside the swapping station and using a HVAC system, the DCU 201 can maintain the conditions inside the swapping station at a desired level.

[0070] FIG. 2c depicts a plurality of chargers and docks connected to the DCU 201. Data can be exchanged between the various modules 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 DCU 201 can receive inputs from the docks 202 and the chargers 203.

[0071] FIGs. 3a and 3b depict the AS. The AS 105 can comprise of usage data, specific vehicle related data and analysis algorithms. The AS 105 can connect with entities such as swap stations, user devices, batteries, and so on, to collect data from them continually, process the collected data and issue commands to ensure that the overall battery swap process functions optimally. The AS 105 can monitor the entities connected to it in a live manner via the communication interface 303. In an embodiment herein, the AS 105 can have a centralized structure. In an embodiment herein, the AS 105 can be of a distributed structure, wherein one or more entities such as batteries, swap stations, a server and so on, can perform on or more parts of the required processing.

[0072] As depicted in FIG. 3a, the AS 105 can comprise of an analytics engine 301, at least one database 302, and at least one communication interface 303.

[0073] The communication interface 303 enables the AS 105 to interface with at least one external entity, such as at least one swapping station 101, the user device, the battery module, and so on. The communication interface 303 can perform bi-directional communication with the at least one external entity. The communication interface 303 can comprise of at least one of wired communication interfaces or wireless communication interfaces. The communication interface 303 can use protocols such as GPRS (General Packet Radio Service) using cellular networks, LTE (Long Term Evolution), LORA WAN (Low Power Wide Area Network using radio), Wi-Fi (IEEE 802.1.x standard), MQTT (Message Queuing Telemetry Transport), HTTP (Hyper Text Transfer Protocol) over TCP/IP (Transfer Control Protocol/Internet Protocol) network protocol, 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 303 can also comprise an Application Programming Interface (API) for enabling the AS 105 to communicate with other entities/applications.

[0074] The communication interface 303 can collect information from the battery 102, related to the battery, and the vehicle. The collected information can comprise of a unique identifier for the vehicle, the battery, the dock, and so on.

[0075] The analytics engine 301 can operate on the data received from external entities such as the swapping stations, the user devices, and so on, via the communication interface 303. In an example, the battery can transmit data to the AS 105 continually during scenarios such as when charging at the swap station, when attached to an electric vehicle and
5 powering the vehicle by discharging current.

[0076] The analytics engine 301 can analyze the received data to obtain information regarding generic usage patterns, usage classes, user behaviour related information and patterns related to terrain, demographic variations, seasonal distributions and so on. The analytics engine 301 can operate on specific individual module data and can calculate
10 parameters such as SOH, SOF of specific modules/batteries. The analytics engine 301 can estimate second life for each specific battery module. The analytics engine 301 can perform details diagnostics and prognostics to predict performance. The analytics engine 301 can communicate these values to the swap stations and the user devices, using the communication interface 303.

[0077] The analytics engine 301 can determine an estimated range for each driver
15 based on factors such as past driving behavior, current vehicle and battery information. This can involve identifying the vehicle, the driver to which the battery would be assigned during the battery swap process at the swap station, and the battery information that is currently present in the vehicle or is being swapped into the vehicle.

[0078] The analytics engine 301 can further collect historical drive pattern data from
20 the network system via an Application Programming Interface (API) function call and can arrive at an estimate of Distance to empty and/or Range for the specific battery being attached to the vehicle for discharge. This is helpful in estimating the range at the beginning and during the discharge cycle.

[0079] The analytics engine 301 can build predictive models based on the received
25 data. The analytics engine 301 can predict the battery usage and range, based on factors such as the vehicle in which the battery is currently being used, the driver of the vehicle, the route that the vehicle is being driven on, current SOC, SOH, current weather conditions, and so on. The analytics engine 301 can also compute the SOH of the battery, based on information
30 received from the battery. The analytics engine 301 can detect anomalies in the swap station

and batteries using information received from the swap station and the batteries. Examples of the anomalies can be, but not limited to, power fluctuations, malfunctioning docks, issues with input power supplies, and so on.

[0080] The analytics engine 301 can factor in past vehicle behavior in terms of power utilization per unit distance traveled. The analytics engine 301 can model vehicle performance and predict system level or unit level failures in the vehicle on the basis of vehicle data obtained from the vehicle control unit. This can involve identifying the vehicle, the driver to which the battery would be assigned during the battery swap process at the swap station, and the battery information that is currently present in the vehicle or is being swapped into the vehicle. The analytics engine 301 can further collect historical drive pattern data from the network system via an API function call and can arrive at an estimate of vehicle health and generate alerts that predict potential system and sub-system failures.

[0081] The analytics engine 301 can forecast energy requirements for a pre-defined period of time at various levels (such as station level city level, regional level, and so on). The analytics engine 301 can consider parameters such as consumption pattern at each swap station 101, characteristics of batteries present at each swap station 101, number of vehicle using the batteries currently, forecasted number of vehicles which will use the batteries in the pre-defined period of time, weather conditions, seasonality, and so on. The forecasted energy requirements can be in terms of number of batteries required at one or more levels, times that the batteries would be required, and so on. In an embodiment herein, based on the forecasted energy requirements, the analytics engine 301 can determine an optimal time of charging (which can depend on electricity charges, which can vary with day and time). In an embodiment herein, based on the forecasted energy requirements, the analytics engine 301 can determine the rate of charging for each battery. In an example scenario, when energy demand is forecasted as slow, batteries in the swap station can be charged at a slow rate of charging, which improves battery life. In an example scenario, when energy demand is forecasted as high, batteries in the swap station can be charged at a high rate of charging.

[0082] The analytics engine 301 can configure a variable depth of discharge for each battery. Here, the battery is allowed to discharge only to a pre-determined level, wherein the level can depend on factors such as nature of the driver of the vehicle, user preferences, safety (restricting to a certain range), and so on.

[0083] The analytics engine 301 can re-configure the batteries, as required using over the air updates. The updates can be customized for the battery based on factors such as population, terrain, season, weather, specific user patterns, user preferences, and so on.

[0084] The database 302 comprises of the received information. This information
5 includes specific details of each swap stations, their ids, capacities and utilization data; details of all the battery modules coming up for conditioning in each of the swap stations including types of battery, host application (vehicle/energy storage), usage patterns encountered, usage history, life related information, latest SOH, SOF, history of previous conditioning sessions and so on. The database 302 can comprise of battery telematics data while attached to a
10 vehicle (such as location of the vehicle/battery, direction of travel of the battery/vehicle, altitude of the battery/vehicle, acceleration of the battery/vehicle, Speed of the battery/vehicle, vibration data from sensors present in the battery, current, Voltages and temperature from battery cells in the battery, vehicle information (as fetched from the vehicle by the battery), status data from the battery, and so on. The database 302 also collates system
15 level data collected from the individual battery modules related to the other systems of the host application (for example, the drive system data in vehicles, information from environment sensors, and so on). The database 302 can also contain data from charging and swapping stations (such as number of active dock units and their ID and current status including but not limited to lock status, dock unit temperature, connection status,
20 identification of batteries connected to the docks, rate of charging in amperes set per docking unit, charging information on batteries at the station, rate of charge current state of charge, and so on).

[0085] FIG. 3b depicts the modules of the AS 105. The transaction database 302a is where all incoming data from the entities are stored. The data is not processed data, but
25 merely structured data as per pre-defined schema. The transaction database 302a can be used for live monitoring of data, performing stream analytics, and executing one or more rules for one or more alerts.

[0086] In the data warehouse 302b, structured data is further aggregated as data cubes across pre-defined dimensions such as day, day part, device, location, swap station etc., for
30 easy retrieval, analytics and data mining operations.

[0087] The alerts and messaging service 304 manages all rule-based alerts that are defined based on specific parameters breaching thresholds, and patterns of sequence. The alerts and messaging service 304 could provide alerts in the form of alarms, SMS sent to designated mobile numbers, push notifications sent to client applications via the API, and so on. All commands issued to user devices, swap stations and vehicles can be transmitted via appropriate communication interfaces (communication interface 303).

[0088] The wallet module 305 is a virtual wallet and manages credits and debits of a virtual currency. It is used to add credit balance and to pay for services received by a user.

[0089] The telematics module 306 can manage the interfacing with all types of batteries with the AS 105. The telematics module 306 can receive data and transmit commands from the alerts and messaging service 304 via the communication interface 303.

[0090] The data modelling engine 307 can analyze data using techniques such as segmentation, clustering, collaborative filtering, and so on.

[0091] The data processing module 308 can process the received data. The processing performed by the data processing module 308 can include parsing, normalization and storing data for each source as per pre-defines data schema.

[0092] The analytics engine 301 can provide insights on battery utilization, quality and performance over a pre-defined time period. The analytics engine 310 can perform predictive services such as, but not limited to, user device performance, failure prediction, energy utilization at swapping station, predict swap event frequency at a swap station, and so on.

[0093] The asset manager 310 can comprise and manage definitions of batteries, swap stations and their subsystems, such as, but not limited to, identifiers, capacity, date of manufacture and production details like brand, batch ID, the location of pickup of the battery, the customer to which the battery has been assigned, and so on.

[0094] The customer manager 311 can comprise and manage definitions of all types of customer with attributes of the customers such as, but not limited to, name, address, company ID, unique ID, billing relationship type, preferred billing options, wallet details, customer type (such as end user, fleet operator, dealer, franchise, and so on), and so on.

[0095] The station manager 312 provides the ability to monitor status of swap stations including all the sub-systems remotely. The station manager 312 can also issue commands to the swap station to configure, upgrade software running at the station and perform specific actions such as, but not limited to, charge profile specific to each battery, run diagnostics on
5 specific user devices in station, download updated configuration per user device, perform data transfer from the battery to the data processing module 308, and so on.

[0096] The OEM (Original Equipment Manufacturer) manager 313 can comprise and manage definitions of the vehicle OEMs and devices OEMs. This allows the security layer to provide access for authorized users for a specific OEM entity.

10 [0097] The security module 314 provides security access control to access programmatic services available on the AS 105. The security module 314 also authorizes usage of user device based on vehicle and driver identification and can remotely disable operation when unauthorized usage or theft is detected.

[0098] FIG. 4 depicts an example scenario where the battery module is used in a
15 vehicle. An electric vehicle with a discharged battery approaches a swapping station 101. The user device (a user mobile, in the example herein) initiates a conversation with the station 101 by requesting a swap. The station 101 communicates with the vehicle by wireless means to automatically authenticate the request. It also gathers information about the vehicle, state of the battery and usage pattern. In the background, the station also communicates with the AS
20 105 to access additional information about the vehicle usage, history of the particular battery pack and specific conditioning requirements. Combining this information with climatic information, the station works out a custom conditioning program for the specific battery, even as the battery is getting disconnected from the vehicle. Using this data, the station 101 also identifies one of the conditioned batteries already available in the system for replacing
25 the removed battery. On due authentication for both the transactions, the station allows swapping of the used battery with an already conditioned battery. The system also incorporates automatic billing and payment mechanisms.

[0099] FIG. 5 is an example flow diagram depicting the process of matching a vehicle with a battery. During the example swapping process herein, consider that there are 2 battery
30 packs that have to be placed inside the vehicle. The swapping station 101 assigns a master

role to one of the battery packs 102 and a slave role to the other battery pack 102. The swapping station 101 can assign the master and slave roles based upon the history and performance parameters of the battery packs 102. In an embodiment herein, the swapping station 101 can assign the master role to the battery with the better performance. The swapping station 101 will provision the master with information about the slave(s). Once inside the vehicle, as first level of authentication, the master battery pack will first check for the slave battery packs and setup communication with them. Then the master will perform a first level of authentication of the slaves. After the completion of the first level authentication and when the vehicle key is on, the master will initiate a second level of authentication, where the vehicle is authenticated. After the completion of the second authentication, the master battery pack will notify the swapping station 101 and the AS 101 and will enable power out of the battery.

[00100] FIG. 6 is a flow chart depicting the process of performing battery conditioning. In step 601, the battery is received at the swap station 101. The battery can be received from a vehicle, or a second life application. This can involve the battery being plugged into the dock. On the battery being placed in the dock, in step 602, the battery exchanges data with the swap station. The data can comprise of current state of charge, the battery temperature, battery usage, and other associated parameters. In step 603, the DCU 201 performs backend processing, which can comprise of analyzing the data received from the battery, validate the battery/users, updates of the battery software (if required), and so on. In step 604, the DCU 201 checks if a test is required. This can involve the DCU 201 checking if the DCU 201 needs to be re-characterized at pre-defined intervals. The pre-defined intervals can depend on the battery characteristics and usage. In step 605, the DCU 201 can perform re-characterization tests. The tests are facilitated by discharge and measurement set up built into the station. The tests can measure parameters like the actual capacity, state of charge variation, state of function variation, impedance build up, temperature changes with usage/ageing, and so on. If tests are not required, in step 606, a customized conditioning schedule is determined. This can depend on the usage of the battery, the history of the battery, the predicted future usage of the battery, and so on. In step 607, the battery is conditioned, according to the determined customized conditioning schedule. In step 608, the battery is updated according to the battery conditioning, the characterized tests, the backend processing, and so on. The various actions in method 600 may be performed in the order

presented, in a different order or simultaneously. Further, in some embodiments, some actions listed in FIG. 6 may be omitted.

[00101] In an embodiment herein, the battery module 102 can have second life applications. As the battery system in a demanding application like vehicular usage causes progressive degradation of battery characteristics, the batteries become unusable in the same application. The typical parameters indicating this degradation are reduction in energy storage capacity below a threshold, increased temperature rise under conditions of higher stress (current, power) encountered in vehicle usage, increase in internal resistance/impedance of the battery, and reduction in power delivery capacity to a level below demands of the host device. Such batteries, however, continue to be useful in other applications like domestic UPS, rural energy storage and other backup power systems including large scale grid back up. The algorithms built into the swapping station 101 and the AS 105 keep track of such health parameters of each battery module and intimate the primary user of any impending end of service life for the first application. Once the battery/module is taken out of service from the first application, the station 101 also maps the battery's current level of specification to possible second life application requirements and makes suitable suggestions. The residual value of the battery can be computed and a commercial value can be fixed for the same. During the second life usage, the process of usage/conditioning cycle continues.

[00102] Consider an example wherein the second life application is providing power to a residence. The battery modules can be used as energy sources for providing power to a residence. The battery power module can directly dock to a home inverter and supply. The communication interface 207 can communicate with the AS 105 and/or the user device 104 to obtain authentication and release power to the inverter system.

[00103] Depending on the requirements of the new host system, the battery modules communicate with each other and share the load in proportion to their own capacity and state of function (as illustrated in FIG. 7). Modules with different capacities x, y and z are combined to supply an energy system requirement. The modules communicate and arbitrate with each other to share their outputs in proportion of their capacities. FIG. 7 illustrates an example where only capacity is taken into account. However, modules have different parameters like voltage, state of charge, state of function and temperature which all will

influence the exact sharing to be worked out. This feature enables ‘hot swap’ of individual modules. In case any module needs to be replaced or a new module is to be added, it can be carried out with all other modules working. The modules/packs can also predict performance and life in the new host system by accessing information from the AS 105.

5 [00104] Embodiments herein use the terms “swapping station” and “swap station” interchangeably and both the terms herein refer to the swapping station 101.

 [00105] Embodiments herein use the terms “battery pack” and “battery” interchangeably and both the terms herein refer to the battery 102.

 [00106] The embodiments disclosed herein can be implemented through at least one
10 software program running on at least one hardware device and performing network management functions to control the network elements. The network elements shown in FIG. 1 include blocks which can be at least one of a hardware device, or a combination of hardware device and software module.

 [00107] The embodiments disclosed herein enable swapping of a battery module at a
15 swapping station, wherein the swapping station can provide a battery module to a user based on a plurality of factors comprising of weather parameters, battery module application, user behaviour, and so on. 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
20 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
25 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.

[00108] 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 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.