CLAIMS

[Claim 1] An internal cooling system for a plurality of segmented battery modules, the system comprising:

(a) a plurality of energy storage devices, each energy storage device including a heat exchanger and one of the segmented battery modules,

(i) wherein the heat exchanger of each energy storage device includes:

(1) an HE flow controller for controlling flow of coolant through the heat exchanger;

(2) an HE inlet for receiving the coolant into a plurality of HE passages within the heat exchanger; and

(3) an HE outlet for discharging coolant from the HE passages of the heat exchanger; and

(ii) wherein the segmented battery module of each energy storage device includes:

(1) a plurality of battery cells in electrical connection with an electrical connection connector;

(2) a battery management module (BMU) in data communication with a plurality of sensors, the sensors including at least one temperature sensor located within the segmented battery module and the BMU configured to collect sensor information from the sensors; and

(3) a BMU connector in wired or wireless data communication with the BMU;

(b) an electrical connection,

(i) wherein the electrical connection is in electrical connection to the battery connector of each of the energy storage devices;

(ii) wherein the electrical connection is in electrical connection with one or more electrical connection connectors; and

(iii) wherein each of the one or more electrical connection connectors are connectable to one of one or more power supplies of a power source during a charging session for one or more of the energy storage devices;

(c) an internal cooling unit with an ICU inlet and an ICU outlet;

(d) a pair of coolant trunks,

(i) wherein the pair of coolant trunks includes:

(1) a cool trunk with cooled coolant received from the internal cooling unit via the ICU outlet; and

(2) a warm trunk with warmed coolant directed into the internal cooling unit via the ICU inlet;

(ii) wherein the cool trunk is in fluid connection with each of the HE inlets of the energy storage devices;

(iii) wherein the warm trunk is in fluid connection with each of the HE outlets of the energy storage devices;

(iv) wherein a segmented coolant pathway between the internal cooling unit and each heat exchanger is established for each energy storage device,

(1) the segmented coolant pathway exiting from the internal cooling unit via the ICU outlet, through the cool trunk, through the HE inlet of the energy storage device, through the HE passages of the energy storage device, through the HE outlet of the energy storage device, through the warm trunk, and back into the internal cooling unit via the ICU inlet;

(2) the segmented coolant pathway passing through the HE flow controller of the energy storage device; and

(3) the segmented coolant pathway having an HE flow rate through the HE flow controller of the energy storage device; and

(v) wherein the segmented coolant pathway established for each energy storage device has an HE flow rate regulated by the HE flow controller; and

(e) an internal segmented cooling controller (SCC) configured to control based on a set of parameters,

(i) wherein the internal SCC is in direct or indirect data communication by wire or wirelessly with:

(1) the internal cooling unit;

(2) the HE flow controller of each energy storage device; and

(3) the BMU of the segmented battery module of each energy storage device via the BMU connector of the energy storage device;

(ii) wherein the internal SCC is configured to directly or indirectly receive the sensor information collected by the BMU of each energy storage device wirelessly or by wire via the BMU connector of the energy storage device, the sensor information including at least temperature information measured by the at least one temperature sensor located within the segmented battery module of the energy storage device;

(iii) wherein the set of parameters include at least a preferred temperature range for the segmented battery module of each energy storage device; and

(iv) wherein the internal SCC is configured to periodically:

(1) calculate or recalculate an optimal range for the HE flow rate of the heat exchanger of each energy storage device, the optimal range a function of:

(a) the sensor information received by the internal SCC from the sensors of the energy storage device via the BMU of the energy storage device; and

(b) the preferred temperature range for the energy storage device; and

(2) control by wire or wirelessly the HE flow rate of each energy storage device, via the direct or indirect data communication between the internal SCC and the HE flow controller of the energy storage device, to maintain the HE flow rate within the optimal range; and

(v) wherein the internal SCC employs a control loop to:

(1) adjust a power rating delivered to the internal cooling unit;

(2) according to the temperature information from the temperature sensor of the segmented battery module of each of the energy storage devices, prioritize delivery of coolant to at least one of the energy storage devices; and

(3) adjust the HE flow rate of coolant through one or more of the HE flow controllers.

[Claim 2] The system of claim 1,

(a) wherein the plurality of sensors in the segmented battery module of each energy storage device further include a current sensor configured to measure and transmit current information of the battery cells of the segmented battery module to the internal SCC via the BMU of the energy storage device;

(b) wherein the set of parameters includes a thermal model for each energy storage device; and

(c) wherein the internal SCC is further configured to calculate or recalculate for each energy storage device:

(i) a heat generation estimate for the energy storage device from:

(1) the thermal model of the energy storage device;

(2) the current information for the energy storage device; and

(3) the preferred temperature range for the energy storage device; and

(ii) the optimal range for the HE flow rate of the energy storage device to counteract the heat generation estimate for the energy storage device.

[Claim 3] The system of claim 1, wherein the coolant is a fluid, water, a gas, or air.

[Claim 4] The system of claim 1,

(a) wherein the system further includes a master battery management system (MBMS); and

(b) wherein wired or wireless data communication between the internal SCC and the BMU connector of each energy storage device is routed through the MBMS.

[Claim 5] The system of claim 1,

(a) wherein the heat exchanger and the segmented battery module of each energy storage device are paired in thermal conductivity via a thermal interface;

(b) wherein the heat exchanger for each energy storage device includes a heat sink conforming to at least one outer surface area of the segmented battery module of the energy storage device; and

(c) wherein the thermal interface between the heat sink and the segmented battery module of each energy storage device is a compressible thermally conductive material or a thermally conductive paste.

[Claim 6] The system of claim 5, wherein the heat sink of each energy storage device comprises an aluminium shell enclosing the HE passages of the energy storage device.

[Claim 7] An electric vehicle comprising the system of any one of claims 1 to 6 housed in the electric vehicle.

[Claim 8] The electric vehicle of claim 7,

(a) wherein the electric vehicle is a motorized electric vehicle including a vehicle control system and at least one traction motor in electrical connection with the electrical connection;

(b) wherein operation of the at least one traction motor is controlled by the vehicle control system;

(c) wherein the internal SCC is in data communication with the vehicle control system; and

(d) wherein the internal SCC is configured to download or link to at least one of:

(i) an itinerary map detailing at least one of a speed map, an incline grade map, a travel distance, and a travel time; and

(ii) a vehicle dashboard detailing at least one of a present speed of the motorized electric vehicle, a present electrical current load of the at least one traction motor of the motorized electric vehicle, and a present incline of the motorized electric vehicle.

[Claim 9] The electric vehicle of claim 7,

(a) wherein the electric vehicle is a power car including one or more power outlets in electrical connection to the electrical connection of the system; and

(b) wherein the one or more power outlets are connectable to one or more power inlets of a motorized electric vehicle.

[Claim 10] A computer-implemented internal cooling method for a plurality of segmented battery modules, the method comprising:

(a) maintaining a plurality of energy storage devices, each energy storage device including a heat exchanger and one of the segmented battery modules,

(i) wherein the heat exchanger of each energy storage device includes:

(1) an HE flow controller for controlling flow of coolant through the heat exchanger;

(2) an HE inlet for receiving the coolant into a plurality of HE passages within the heat exchanger; and

(3) an HE outlet for discharging coolant from the HE passages of the heat exchanger; and

(ii) wherein the segmented battery module of each energy storage device includes:

(1) a plurality of battery cells in electrical connection with an electrical connection connector;

(2) a battery management module (BMU) in data communication with a plurality of sensors, the sensors including at least one temperature sensor located within the segmented battery module and the BMU configured to collect sensor information from the sensors; and

(3) a BMU connector in wired or wireless data communication with the BMU;

(b) maintaining an electrical connection,

(i) wherein the electrical connection is in electrical connection to the battery connector of each of the energy storage devices;

(ii) wherein the electrical connection is in electrical connection with one or more electrical connection connectors; and

(iii) wherein each of the one or more electrical connection connectors are connectable to one of one or more power supplies of a power source during a charging session for one or more of the energy storage devices;

(c) maintaining an internal cooling unit with an ICU inlet and an ICU outlet;

(d) maintaining a pair of coolant trunks,

(i) wherein the pair of coolant trunks includes:

(1) a cool trunk with cooled coolant received from the internal cooling unit via the ICU outlet; and

(2) a warm trunk with warmed coolant directed into the internal cooling unit via the ICU inlet;

(ii) wherein the cool trunk is in fluid connection with each of the HE inlets of the energy storage devices;

(iii) wherein the warm trunk is in fluid connection with each of the HE outlets of the energy storage devices;

(iv) wherein a segmented coolant pathway between the internal cooling unit and each heat exchanger is established for each energy storage device,

(1) the segmented coolant pathway exiting from the internal cooling unit via the ICU outlet, through the cool trunk, through the HE inlet of the energy storage

device, through the HE passages of the energy storage device, through the HE outlet of the energy storage device, through the warm trunk, and back into the internal cooling unit via the ICU inlet;

(2) the segmented coolant pathway passing through the HE flow controller of the energy storage device; and

(3) the segmented coolant pathway having an HE flow rate through the HE flow controller of the energy storage device; and

(v) wherein the segmented coolant pathway established for each energy storage device has an HE flow rate regulated by the HE flow controller;

(e) maintaining an internal segmented cooling controller (SCC) configured to control based on a set of parameters,

(i) wherein the internal SCC is in direct or indirect data communication by wire or wirelessly with:

(1) the internal cooling unit;

(2) the HE flow controller of each energy storage device; and

(3) the BMU of the segmented battery module of each energy storage device via the BMU connector of the energy storage device;

(ii) wherein the internal SCC is configured to directly or indirectly receive the sensor information collected by the BMU of each energy storage device wirelessly or by wire via the BMU connector of the energy storage device, the sensor information including at least temperature information measured by the at least one temperature sensor located within the segmented battery module of the energy storage device; and

(iii) wherein the set of parameters include at least a preferred temperature range for the segmented battery module of each energy storage device;

(f) periodically employing the internal SCC to calculate or recalculate an optimal range for the HE flow rate of the heat exchanger of each energy storage device, the optimal range a function of:

(i) the sensor information received by the internal SCC from the sensors of the energy storage device via the BMU of the energy storage device; and

(ii) the preferred temperature range for the energy storage device; and

(g) controlling by wire or wirelessly the HE flow rate of each energy storage device, via the direct or indirect data communication between the internal SCC and the HE flow controller of the energy storage device, to maintain the HE flow rate within the optimal range, wherein the internal SCC employs a control loop to:

(i) adjust a power rating delivered to the internal cooling unit;

(ii) according to the temperature information from the temperature sensor of the segmented battery module of each of the energy storage devices, prioritize delivery of coolant to at least one of the energy storage devices; and

(iii) adjust the HE flow rate of coolant through one or more of the HE flow controllers.

[Claim 11] The method of claim 10,

(a) wherein the plurality of sensors in the segmented battery module of each energy storage device further include a current sensor configured to measure and transmit current information of the battery cells of the segmented battery module to the internal SCC via the BMU of the energy storage device;

(b) wherein the set of parameters includes a thermal model for each energy storage device; and

(c) wherein the step of periodically employing the internal SCC to calculate or recalculate the optimal range includes calculating or recalculating for each energy storage device:

(i) a heat generation estimate for the energy storage device from:

(1) the thermal model of the energy storage device;

(2) the current information for the energy storage device; and

(3) the preferred temperature range for the energy storage device; and

(ii) the optimal range for the HE flow rate of the energy storage device to counteract the heat generation estimate for the energy storage device.

[Claim 12] The method of claim 10, wherein the coolant is a fluid, water, a gas, or air.

[Claim 13] The method of claim 10,

(a) wherein the system further includes a master battery management system (MBMS); and

(b) wherein wired or wireless data communication between the internal SCC and the BMU connector of each energy storage device is routed through the MBMS.

[Claim 14] The method of claim 10,

(a) wherein the heat exchanger and the segmented battery module of each energy storage device are paired in thermal conductivity via a thermal interface;

(b) wherein the heat exchanger for each energy storage device includes a heat sink conforming to at least one outer surface area of the segmented battery module of the energy storage device; and

(c) wherein the thermal interface between the heat sink and the segmented battery module of each energy storage device is a compressible thermally conductive material or a thermally conductive paste.

[Claim 15] The method of claim 14, wherein the heat sink of each energy storage device comprises an aluminium shell enclosing the HE passages of the energy storage device.