CLAIMS

Claim 1 A system for cooling a plurality of segmented battery modules of an electric vehicle using a first coolant, 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, the internal cooling unit configured to generate a cold first coolant from a warm first coolant;

(d) a pair of coolant trunks housed in the electric vehicle,

(i) wherein the pair of coolant trunks includes:

(1) a cool trunk configured to receive the cold first coolant from the ICU outlet and provide the cold first coolant to each HE inlet; and

(2) a warm trunk configured to receive the warm first coolant from each HE outlet and provide the warm first coolant to the ICU inlet;

(ii) wherein the heat exchanger of each energy storage device, the pair of coolant trunks, the internal cooling unit, the ICU outlet, and the ICU inlet form a segmented coolant pathway in which for each energy storage device a HE flow rate for the energy storage device is regulated through the HE flow controller of the energy storage,

(e) a power source configured to charge the plurality of energy storage devices;

(f) an external cooling unit housed in the power source and having a second coolant, the external cooling unit including an ECU inlet configured to receive a warm second coolant, and an ECU outlet configured to provide a cold second coolant, wherein the external cooling unit, the ECU inlet, and the ECU outlet form a second coolant pathway;

(g) an external-to-internal heat exchanger interfacing between the segmented coolant pathway and the second coolant pathway, wherein during a charging session of the plurality of segmented battery modules by the power source, the external cooling unit is configured to provide additional cooling to the cold first coolant through a heat exchange between the cold first coolant and the cold second coolant using the external-to-internal heat exchanger prior to ICU outlet provision of the cold first coolant to the cool trunk, and is configured to receive the warm second coolant from the external-to-internal heat exchanger;

(h) 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 A method for cooling a plurality of segmented battery modules of an electric vehicle, the method comprising:

(a) maintaining a plurality of energy storage devices housed in the electric vehicle, each energy storage device including a heat exchanger having a HE inlet and a HE outlet; a HE flow power; and one of the segmented battery modules,

(i) 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 configured to generate a cold first coolant from a warm first coolant, the internal cooling unit having an ICU inlet for receiving the warm first coolant and an ICU outlet for providing the cold first coolant;

(d) maintaining a pair of coolant trunks housed in the electric vehicle,

(i) wherein the pair of coolant trunks includes:

(1) a cool trunk configured to receive the cold first coolant from the ICU outlet and provide the cold first coolant to each HE inlet; and

(2) a warm trunk configured to receive the warm first coolant from each HE outlet and provide the warm first coolant to 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 the heat exchanger of each energy storage device, the pair of coolant trunks, the internal cooling unit, the ICU outlet, and the ICU inlet form a segmented coolant pathway in which for each energy storage device a HE flow rate for the energy storage device is regulated through the HE flow controller of the energy storage device;

(e) maintaining a power source configured to charge the plurality of energy storage devices;

(f) maintaining an external cooling unit housed in the power source and having a second coolant, the external cooling unit including an ECU inlet configured to receive a warm second coolant, and an ECU outlet configured to provide a cold second coolant, wherein the external cooling unit, the ECU inlet, and the ECU outlet form a second coolant pathway;

(g) maintaining an external-to-internal heat exchanger interfacing between the segmented coolant pathway and the second coolant pathway;

(h) 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;

(i) 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

(j) 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;

(k) providing, during a charging session, an additional cooling to the cold first coolant from the cold second coolant through a heat exchange between the cold first coolant and the cold second coolant using the external-to-internal heat exchanger prior to ICU outlet provision of the cold first coolant to the cool; and

(l) receiving a warm second coolant from the external-to-internal heat exchanger through the ECU inlet in a charging session of the plurality of the segmented battery modules by the power source.

Claim 8 The method of claim 7,

(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 9 The method of claim 7, wherein the coolant is a fluid, water, a gas, or air.

Claim 10 The method of claim 7,

(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 11 The method of claim 7,

(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 12 The method of claim 11, wherein the heat sink of each energy storage device comprises an aluminium shell enclosing the HE passages of the energy storage device.