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SMARTCELL CLUSTER AND BATTERY PACKAGING FOR LOW ELECTROMAGNETIC FIELD EFFECT

Abstract

Various technologies and embodiments are presented to minimize/mitigate electromagnetic field (EMF) effects and electromagnetic interference (EMI) effects generated in a battery module/battery pack when the battery module/battery pack is utilized with alternating current (AC) operation. Respective electrical flowpaths are created throughout a battery module such that EMF/EMI generated in a first portion of a flowpath negates EMF/EMI generated in an adjacent second portion of a flowpath. The battery module operates as a smartcell, wherein battery module comprises a pair of clusterboards located between a first cluster of battery cells and a second cluster of battery cells, wherein the central positioning of the pair of clusterboards functions to isolate the first cluster of battery cells from the second cluster of battery cells.

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Background/Summary

TECHNICAL FIELD

[0001] The subject disclosure relates to electric and/or hybrid electric vehicle drive technologies, and more particularly to a battery configuration for minimizing electromagnetic effects when utilizing the battery with alternating current.

BACKGROUND

[0002] While electric vehicles (EV) are becoming commonplace globally, the adoption of such vehicles is partially dependent upon the charging and use of the onboard batteries. A wealth of technical knowledge exists regarding the development/use of onboard batteries in a direct current (DC) situation, while further research is being conducted regarding EV batteries and alternating current (AC) use. Concerns arise regarding generation of electromagnetic fields (EMFs) and resulting electromagnetic interference (EMI) when utilizing a battery in an AC implementation, whereby EMF and EMI effects can deleteriously affect operation of other electronic devices in sufficient proximity of the battery, as well as being regulated with regard to the health of a person in proximity of the battery. Hence, minimizing EMF and EMI can improve EV battery implementation and according adoption of EV's.

SUMMARY

[0003] The following presents a summary to provide a basic understanding of one or more embodiments described herein. This summary is not intended to identify key or critical elements, or delineate any scope of the different embodiments and/or any scope of the claims. The sole purpose of the Summary is to present some concepts in a simplified form as a prelude to the more detailed description presented herein.

[0004] In one or more embodiments described herein, systems, devices, methods, processes, apparatus, and suchlike are presented to facilitate reduction of EMF and corresponding EMI present in respective battery modules and battery packs.

[0005] In an embodiment, a battery module can comprise a first cluster of battery cells, wherein the first cluster of battery cells are electrically coupled together, a second cluster of battery cells, wherein the second cluster of battery cells are electrically coupled together, and a first clusterboard electrically coupled to the first cluster of battery cells, and a second clusterboard electrically coupled to the second cluster of battery cells, wherein the first clusterboard is co-located with the second clusterboard to form a paired clusterboard, and the paired clusterboard is located between the first cluster of battery cells and the second cluster of battery cells, wherein the battery module is configured to reduce an electromagnetic field (EMF) present in the battery module when electrical energy is flowing through the battery module. In an embodiment, the EMF can be generated when the battery module is utilized with an alternating current (AC) operation.

[0006] In an embodiment, the battery module can be located onboard an electric vehicle and configured to provide energy to a motor located on the electric vehicle. Further, the first cluster of battery cells and the second cluster of battery cells can comprise at least one of prismatic batteries or cylindrical batteries.

[0007] In an embodiment, the paired clusterboard can be located in a dummy cell between the first cluster of battery cells and the second cluster of battery cells. In a further embodiment, the dummy cell has a width such that the distance between the first cluster of battery cells and the second cluster of battery cells is sufficient that a first EMF generated in the first cluster of battery cells cancels a second EMF generated in the second cluster of battery cells.

[0008] In another embodiment, the battery module can further comprise a first set of electrical connectors connecting the respective battery cells in the first cluster of battery cells to each other to create a first electrical circuit, wherein the first electrical circuit connects the first cluster of battery

cells with a first electrical flow path. In an embodiment, the first electrical flow path can be configured such that a first EMF in a first portion of the first electrical flow path cancels a second EMF created in a second portion of the first electrical flow path.

[0009] In a further embodiment, the battery module can further comprise a second set of electrical connectors connecting the respective battery cells in the second cluster of battery cells to each other to create a second electrical circuit, wherein the second electrical circuit connects the second cluster of battery cells with a second electrical flow path. In a further embodiment, the second electrical flow path can be configured such that a third EMF in the first portion of the second electrical flow path cancels a fourth EMF created in a second portion of the second electrical flow path. In a further embodiment, a fifth EMF generated by the first electrical circuit in the first set of battery cells cancels a sixth EMF generated by the second electrical circuit in the second set of battery cells.

[0010] In other embodiments, elements described in connection with the disclosed systems can be embodied in different forms such as a method. For example, in an embodiment, a method can be utilized to reduce EMF and EMI in a battery module, wherein the method comprises positioning a first clusterboard with a second clusterboard to form a pair of clusterboards, and further locating the pair of clusterboards between a first cluster of battery cells and a second cluster of battery cells, wherein pair of clusterboards, the first cluster of battery cells, and the second cluster of battery cells combine to form a battery module, the pair of clusterboards physically separate the first cluster of battery cells from the second cluster of battery cells to reduce electromagnetic interference (EMI) between the first cluster of battery cells and the second cluster of battery cells.

[0011] In an embodiment of the method, the first clusterboard can further comprise a first AC terminal and a second AC terminal, wherein the first AC terminal and second AC terminal respectively connect the first clusterboard to at least one of the second clusterboard, a third clusterboard located in a battery pack that includes the battery module, or a device electrically connected to a battery pack comprising the battery module.

[0012] In a further embodiment of the method, the first clusterboard can comprise a first DC terminal and a second DC terminal, wherein a first busbar connects the first DC terminal and a first battery cell in the first cluster of battery cells, and a second busbar connects the second DC terminal and a second battery cell in the first cluster of battery cells, wherein the respective batteries in the first cluster of battery cells are electrically connected in series.

[0013] In another embodiment of the method, the first DC terminal, the second DC terminal, and battery cells in the first cluster of battery cells can be connected by a set of busbars to form a series circuit, wherein the set of busbars includes the first busbar and the second busbar, the set of busbars are arranged such that a first portion of the series circuit is located proximate to a second portion of the series circuit and a first electromagnetic field (EMF) present in the first portion of the series circuit and a second EMF present in the second portion of the series circuit interact to mutually cancelled out the first EMF and the second EMF. In an embodiment, the first EMF present in the first portion of the series circuit is generated in response to current flow in a first direction relative to the location of the pair of clusterboards, and the second EMF present in the second portion of the series circuit is generated in response to current flow in a second direction relative to the location of the pair of clusterboards, wherein the busbars are arranged such that the first direction and second direction are opposite.

[0014] In another embodiment, a battery module can comprise a first clusterboard electrically coupled to a first cluster of battery cells; and a second clusterboard electrically coupled to a second cluster of battery cells, wherein the first clusterboard can be co-located with the second clusterboard to form a paired clusterboard, and the paired clusterboard can be located between the first cluster of battery cells and the second cluster of battery cells, wherein the battery module is configured to reduce electromagnetic interference (EMI) present in the battery module when electrical energy is flowing through the battery module. In an embodiment, the paired clusterboard can be located in a dummy cell between the first cluster of battery calls and the second cluster of battery cells.

[0015] In a further embodiment, the battery module can further comprise a first alternating current (AC) terminal, a second AC terminal, a first direct current (DC) terminal, and a second DC terminal, wherein, the first AC terminal, the second AC terminal, the first DC terminal, and the second DC terminal are connected to form a first H-bridge. In a further embodiment, the first DC terminal, the second DC terminal, and the first cluster of battery cells can be connected in series to form an electrical circuit, wherein the electrical circuit further comprises, a first connector connecting a first battery cell to a second battery cell to form a first portion of the electrical circuit; and a second connector connecting a third battery cell to a fourth battery cell to form a second portion of the electrical circuit, wherein the first portion of the electrical circuit is aligned relative to the second portion of the electrical circuit such that a first electromagnetic field (EMF) generated in the first portion of the electrical circuit is cancelled by a second EMF present in the second portion of the electrical circuit.

[0016] In another embodiment, the battery module can be located in a battery pack configured to provide AC to a device co-located with the battery pack on a vehicle, and the first EMF and the second EMF are generated when the battery pack generates the AC current.

Description

DESCRIPTION OF THE DRAWINGS

[0017] One or more exemplary embodiments are described below in the Detailed Description section with reference to the following drawings.

[0018] FIG. **1**A illustrates a single clusterboard, in accordance with at least one embodiment.

[0019] FIG. **1**B presents a single clusterboard, with a view of the clusterboard with the external casing removed, as viewed from a first side, in accordance with at least one embodiment.

[0020] FIG. **1**C illustrates a single clusterboard, with a view of the clusterboard with the external casing removed, as viewed from a second side, in accordance with at least one embodiment.

[0021] FIG. **2** illustrates a double/paired clusterboard configuration, in accordance with at least one embodiment.

[0022] FIG. **3** illustrates a battery module comprising a paired clusterboard coupled to prismatic cells with a 6+6 configuration, in accordance with at least one embodiment.

[0023] FIG. **4** illustrates a battery module comprising a paired clusterboard coupled to cylindrical cells in a 2p6s+2p6s configuration, with a busbar configuration for low EMF layout, in accordance with at least one embodiment.

[0024] FIG. **5** illustrates a top view of a paired clusterboard configuration with terminals identified, in accordance with at least one embodiment.

[0025] FIG. **6** illustrates a battery pack configuration having a low EMF configuration for application with both prismatic and cylindrical cells, in accordance with at least one embodiment.

[0026] FIG. **7** illustrates a current path in a left cluster of cells when the cells are connected with a positive current flow path arrangement, in accordance with at least one embodiment.

[0027] FIG. **8** illustrates a current path in a left cluster of cells when the cells are connected with a negative current flow path arrangement, in accordance with at least one embodiment.

[0028] FIG. **9** illustrates a bypass current flow path in a left cluster of cells when the cells are not connected, in a bypass configuration, in accordance with at least one embodiment.

[0029] FIG. **10**A illustrates a battery pack, depicting a current path in a string of cell clusters, in accordance with at least one embodiment.

[0030] FIG. **10**B illustrates a current path flowing through a string of battery clusters, in accordance with an embodiment.

[0031] FIG. **10**C illustrates a current path flowing through a string of battery clusters comprising cylindrical cells, in accordance with an embodiment.
[0032] FIG. **11** illustrates a configuration for a battery module to reduce EMF/EMI, in accordance with an embodiment.
[0033] FIG. **12** illustrates a configuration for a battery module to reduce EMF/EMI, in accordance with an embodiment.
[0034] FIG. **13** illustrates a pair of clusterboards located in a battery module to prevent EMI, in accordance with an embodiment.
[0035] FIG. **14** illustrates a process for manufacturing a battery pack configured to mitigate EMF/EMI, according to one or more embodiments.

DETAILED DESCRIPTION

[0036] The following detailed description is merely illustrative and is not intended to limit embodiments and/or application or uses of embodiments. Furthermore, there is no intention to be bound by any expressed and/or implied information presented in any of the preceding Background section, Summary section, and/or in the Detailed Description section.
[0037] One or more embodiments are now described with reference to the drawings, wherein like referenced numerals are used to refer to like elements throughout. In the following description, for purposes of explanation, numerous specific details are set forth in order to provide a more thorough understanding of the one or more embodiments. It is evident, however, in various cases, that the one or more embodiments can be practiced without these specific details.
[0038] Ranges A-n are utilized herein to indicate a respective plurality of devices, components, statements, attributes, etc., where n is any positive integer.
[0039] While battery cells have conventionally been utilized in DC applications, battery cells, battery modules, battery packs, smartcells, and suchlike, are finding application in AC environments, such as providing AC power to an AC motor located on a vehicle. However, such applications can also give rise to EMF and EMI effects that can negatively affect operation of other electronic devices in sufficient proximity of the battery, as well as being regulated with regard to the health impact on a person in proximity of the battery, as well as potentially affecting lifetime and/or performance of battery cells utilized in the AC application.
[0040] Per the various embodiments presented herein, various battery cell/battery pack configurations and operation are presented, whereby the one or more embodiments address deleterious EMI and EMF effects. The various configurations presented herein utilize one or more designs/configurations such that every string/or phase in the battery cell under AC usage cancels out EMF created respectively within it and in adjacent portions/regions, e.g., EMF present in a first portion of an electrical circuit is cancelled by EMF present in a second portion of the electrical circuit, and vice-versa, thereby eliminating/reducing/negating EMI generated by the various EMFs present in a battery module/battery pack.
[0041] Per the following embodiments, a battery module (e.g., functioning as a smartcell) comprises one or more battery cells connected to, and controlled by, respective clusterboards. To avoid EMI being generated by passage of an electric current through the battery module, it is important that an EMF area present/created by an electric loop in the battery module is as small as possible. In an embodiment, a reduced area EMF can be created by utilizing a counteracting electric current, e.g., in a first busbar/first portion of a current flow path, positioned as close as possible/proximate to an electric current at a second busbar/second portion of the current flow path. In an embodiment, positioning clusterboards (e.g., a pair of clusterboards) in a dummy cell located at a center of two or more clusters of battery cells achieves minimizing the EMF.
[0042] Per the various embodiments presented herein, a battery pack system can be configured to remove large and costly parts from a conventional drivetrain and use the batteries to more efficiently power the vehicle. More particularly, a battery pack system comprises a multilevel inverter concept configured to replace driveline components such as a conventional large inverter

by integrating them into printed circuit boards (PCBs) connected to clusters of battery cells. In an embodiment, utilizing PCBs/components to control operation of a battery pack enables the DC output from a small battery cluster to be converted into AC output to control an electric motor through field-oriented control (FOC). Isolated DC output from a battery pack system/clusterboards can be used for auxiliary (non-propulsive) loads such as onboard lights, infotainment, climate control, and suchlike. The battery pack can be configured in a number of different ways depending on requirements regarding propulsion, utilization by other high and low voltage electrical systems onboard the vehicle, charging, etc.

[0043] It is to be appreciated that the respective configurations presented herein are examples, and any suitable configuration can be utilized. Hence, while configurations mention 2p6s+2p6s configurations of cylindrical cells, 6+6 cell arrangements, and suchlike, any suitable configuration can be utilized. Further, while the various embodiments presented herein are directed towards construction and utilization of battery packs on a vehicle, the various embodiments are equally applicable to battery pack being utilized in any suitable application requiring AC power supply.

[0044] FIGS. **1**A-**1**C, schematics **100**A-C, illustrate a single clusterboard, with, and without, the casing, in accordance with an embodiment. FIGS. **1**A-C present a clusterboard **110**A, with and without a casing **195**A, wherein clusterboard **110**A is an example of a clusterboard in a collection of clusterboards **110**A-n included in a battery pack (e.g., battery pack **602**A, as further described). Each clusterboard **110**A-n can comprise a pair of AC terminals **120**A-n and **121**A-n, identified here for clusterboard **110**A as **120**A and **121**A. Each respective terminal **120**A-n and **121**A-n can comprise of a busbar, wherein a first end, e.g., **120**A-**1** functions as a terminal for connection (e.g., as an input or an output) to another clusterboard **110**A-n to form a series/string of clusterboards in a battery pack, and a second end **120**A-**2** of terminal **120**A forms part of a H-bridge configuration, as further described. First end **121**A-**1** functions as a terminal of busbar **121**A, and second end **121**A-**2** forms part of the H-bridge configuration.

[0045] Further, each clusterboard can include a pair of DC/battery terminals **130**A-n and **131**A-n, (e.g., battery terminals B+ and B−) identified here for clusterboard **110**A as **130**A and **131**A. Each respective battery terminal **130**A-n and **131**A-n can comprise of a busbar, wherein a first end, e.g., **130**A-**1**, functions as a terminal for connection to a first busbar (e.g., busbars **320**A-n/**321**A-n and/or **420**A-n/**421**A-n, as further described) of a battery cluster **310**A-n and/or **410**A-n, and a second end, e.g., **130**A-**2**, forms part of the H-bridge configuration, as further described. Further, wherein a first end, e.g., **131**A-**1**, functions as a terminal for connection to a first busbar (e.g., busbars **320**A-n/**321**A-n and/or **420**A-n/**421**A-n) of a battery cluster **310**A-n and/or **410**A-n, and a second end, e.g., **131**A-**2**, forms part of the H-bridge configuration. An example H-bridge configuration at clusterboard **110**A can comprise AC terminals/busbars **120**A and **121**A in conjunction with battery terminals/busbars **130**A and **131**A, a H-bridge configuration at clusterboard **110**B comprises AC terminals/busbars **120**B and **121**B in conjunction with battery terminals/busbars **130**B and **131**B, a H-bridge configuration at clusterboard **110***n* comprises AC terminals/busbars **120***n* and **121***n* in conjunction with battery terminals/busbars **130***n* and **131***n*, and suchlike for each of the clusterboards **110**A-n included in a battery pack.

[0046] Terminals **140**A-n and **141**A-n respectively present on clusterboards **110**A-n are terminals for microDC isolated outputs for servicing auxiliary loads present on a vehicle, and are separate from the AC circuits of concern herein which can be used for propulsion of the vehicle.

[0047] Clusterboards **110**A-n can respectively include a printed circuit board (PCB) **150**A-n, wherein the respective PCB **150**A-n can include a respective connector **160**A-n enabling a clusterboard **110**A-n to be connected/communicatively coupled to a battery management system, BMS **180**. BMS **180** can be utilized to ensure safety, performance, and reliability of an electric vehicle battery system which includes battery pack **602**A. For example, BMS **180** can control/monitor such functionality as battery temperature, battery voltage, and suchlike, during battery charging operations (e.g., under-charge, over-charge, battery temperature, etc.), battery operation during supplying power to a vehicle's motor, and suchlike. The PCB **150**A-n can include a series of transistors (not shown) e.g., metal-oxide-semiconductor field-effect transistors (MOSFETs) to facilitate formation/operation of the H-bridge configuration formed by terminals **120**A-n, **121**A-n, **130**A-n, and **131**A-n as previously mentioned.

[0048] Operation of the one or more clusterboards **110**A-n can be controlled by a local controller **155**A-n located on PCB **150**A-n, e.g., in conjunction with the BMS **180**, In an embodiment, clusterboards **110**A-n can operate in 3 different respective states: positive current flow, negative current flow, and bypass, as further described, e.g., to enable operation of the battery pack **602** to provide AC power, or be recharged/energy regeneration. Local controller **155**A-n can comprise a microprocessor, a central processing unit (CPU) coupled to memory device, or the like, a wireless communication component, e.g., a radio frequency (RF) transmitter/receiver, transceiver, or the like, and suchlike.

[0049] FIG. **2**, schematic **200**, illustrates a pair of clusterboards arranged together, in accordance with an embodiment. In an embodiment, clusterboards **110**A-n can be combined to form a pair of clusterboards/paired clusterboards **210**A-n. As shown in FIG. **2**, a pair of clusterboards **110**A and **110**B are arranged to form a pair of clusterboards **210**A. As further described, a respective pair of clusterboards **210**A-n can be located between a pair of battery clusters **310**A-n and **410**A-n to enable physical separation of a respective pair of battery clusters **310**A-n and **410**A-n. In an embodiment, the respective pair of clusterboards **110**A-n can be located between a pair of battery clusters **310**A-n/**410**A-n in a dummy cell (per FIG. **13**, dummy cell **1305**). Effectively, a dummy cell is an open slot/structure between, for example, battery cluster **310**A and battery cluster **310**B.

[0050] As shown, clusterboard **110**A comprises AC terminals **120**A and **121**A, battery +/− terminals **130**A and **131**A, microDC terminals **140**A and **141**A, and a connector **160**A for PCB **150**A, further clusterboard **110**B comprises AC terminals **120**B and **121**B, battery terminals **130**B and **131**B, microDC terminals **140**B and **141**B, and a connector **160**B for PCB **150**B. Hence, a clusterboard **110***n* comprises AC terminals **120***n* and **121***n*, battery +/− terminals **130***n* and **131***n*, microDC terminals **140***n* and **141***n*, and a connector **160***n* for PCB **150***n*. As further described, with AC terminals **120**A-n and **121**A-n functioning as input/outputs, the paired clusterboards **210**A-n can be arranged to enable formation of a string comprising battery clusters **310**A-n and **410**A-n separated by paired clusterboards **210**A-n, wherein the string can comprise the respective battery clusters **310**A-n and **410**A-n connected in series in conjunction with the batteries forming each respective battery cluster **310**A-n and **410**A-n.

[0051] FIG. **3**, schematic **300**, illustrates a double cluster configuration comprising paired clusterboards with an arrangement of prismatic cells, in accordance with an embodiment. As shown in FIG. **3**, a pair of clusterboards **210**A is combined with a cluster/collection of prismatic battery cells **310**A and **310**B to form module **305**A. FIG. **3** presents a 6+6 arrangement of battery cells **350**A-n, e.g., **6** prismatic battery cells form the first battery cell cluster **310**A and **6** prismatic battery cells for the second battery cell cluster **310**B, however, any number of battery cells **350**A-n can be utilized, as required to achieve an operational power requirement. The battery cells **350**A-n in battery cluster **310**A are physically separated from the battery cells **350**A-n of battery cluster **310**B by the pair of clusterboards **210**.

[0052] In an embodiment, in the pair of clusterboards **210**, the first clusterboard **110**A can be connected to/control operation of the cluster of battery cells **310**A and the second clusterboard **110**B can be connected to/control operation of the cluster of battery cells **310**B. As further described herein, battery cells on one side of a battery pack, e.g., battery cells on side **1010**A (per FIG. **10**A) can be controlled by the first string of clusterboards positioned/connected to the **1010**A cells, while battery cells on side **1010**B can be controlled by the second string of clusterboards positioned/connected to the **1010**B battery cells.

[0053] As shown the respective battery cells **350**A-n in the battery clusters **310**A-n are interconnected via a first series of busbars **330**A-n (e.g., in battery cluster **310**A) and a second series of busbars **331**A-n (e.g., in battery cluster **310**B). The respective busbars **330**A-n and **331**A-n are connected to the positive/negative terminals of respective battery cells **350**A-n in the battery cell clusters **310**A and **310**B to facilitate connecting the respective cells **350**A-n in series.

[0054] Further, a first pair of busbars **320**A and **320**B connect the end cells, endcell**1** and endcell**2**, to the respective clusterboard **110**A and **110**B via battery terminal **130**A on clusterboard **110**A and battery terminal **130**B on clusterboard **110**B. A second pair of busbars **321**A and **321**B connect the inner cells, innercell**1** and innercell**2** to the respective clusterboard **110**A and **110**B via battery terminal **131**A on clusterboard **110**A and battery terminal **131**B on clusterboard **110**B.

[0055] Busbars **320**A-n, **321**A-n, and **330**A-n connect the battery cells **350**A-n to form clusters **310**A-n and in series. Busbars **320**A-n, **321**A-n, and **330**A-n (and **420**A-n, **421**A-n, **430**A-n, and **431**A-n) can be formed from any suitable conductor, e.g., copper, aluminum, gold, direct metal-to-metal component connections, wired connections, and suchlike. Battery cells **350**A-n (and **450**A-n) can respectively comprise any type of battery cell material, for example, in a non-limiting list, a lithium battery cell material, a lithium ion (Li-Ion) battery cell material, a lithium metal battery cell material, a lithium sulphur (Li—S) battery cell material, a molten salt (Na-niCl2) battery cell material, a nickel metal hydride (Ni-MH) battery cell material, a lead acid battery cell.

[0056] FIG. **4**, schematic **400**, illustrates a double cluster configuration comprising a pair of clusterboards with an arrangement of cylindrical battery cells, in accordance with an embodiment. As shown in FIG. **4**, a pair of clusterboards **210**A is combined with a cluster/collection of cylindrical battery cells **450**A-n to form module **405**A. FIG. **4** presents cylindrical cells **450**A-n in a 2p6s+2p6s configuration, a low EMF configuration, e.g., a first collection of cylindrical battery cells with a 2p6s arrangement form the first battery cell cluster **410**A and a second collection of cylindrical battery cells with a 2p6s arrangement form the second battery cell cluster **410**B. In the example configuration presented in FIG. **4**, first battery cluster **410**A comprises 12 cylindrical cells **450**A-n and second battery cluster **410**B also comprises 12 cylindrical cells **450**A-n. While a 2p6s+2p6s configuration is presented for configuration **400**, any number of battery cells **450**A-n can be utilized, as required to achieve an operational power requirement.

[0057] Similar to battery module **305**A, as previously described, respective battery cells **450**A-n in the battery clusters **410**A and **410**B are interconnected via busbars **420**A-n in conjunction with being connected to the paired clusterboards **210**A, whereby the battery cells **450**A-n in battery cluster **410**A are physically separated from the battery cells **450**A-n of battery cluster **410**B by the pair of clusterboards **210**A.

[0058] With reference to FIGS. **3** and **4**, the paired clusterboards **210**A sits between (e.g., in a dummy cell) a first side of battery cells and a second side of battery cells. Per FIG. **3**, the paired clusterboards **210**A sits between a first cluster of prismatic battery cells **310**A and a second cluster of battery cells **310**B. Per FIG. **4**, the paired clusterboards **210**A sits between a first cluster of cylindrical battery cells **410**A and a second cluster of battery cells **410**B. Effectively the location of the paired clusterboards **210**A functions to isolate the first cluster of battery cells (e.g., clusters **310**A and **410**A) from the second cluster of battery cells (e.g., battery cell clusters **310**B and **410**B), enabling operation/functionality of the respective first cluster of battery cells to be isolated from the second cluster of battery cells. As shown in FIGS. **6** and **10**, the respective clusters of battery cells can be connected via a busbar (e.g., busbar **1020** placed at an end point between a pair of clusterboards in the same battery module, or busbar **1025** connecting an AC terminal **120**A/**121**A in a first battery module with an AC terminal **120**B/**121**B in a second battery module to form a string of battery modules **602**/**1002**).

[0059] FIG. **5**, system **500**, illustrates the respective busbars utilized to connect a series of cylindrical batteries, in accordance with an embodiment. FIG. **5** presents a zoomed image of battery cluster **410**A and illustrates the respective position of busbars **420**A, **421**A, **430**A-n, and **431**A-n. The 12 cylindrical batteries **450**A-n are connected in a 2p6s configuration (2 parallel sets of 6 batteries connected in series) with a clusterboard **110**A-n. As shown, a first busbar **420**A connects battery terminal **130**A (positioned underneath busbar **420**A, as indicated by the hidden detail lines) with a first pair of batteries **450**A/**450**B at terminals **510**A and **510**B. Further, busbar **430**A connects the first pair of batteries **450**A/**450**B to busbar **431**A. Busbar **431**A connects busbar **430**A with terminals **510**C and **510**D of a second pair of batteries **450**C/**450**D. Busbar **430**B connects the second pair of batteries **450**C/**450**D with busbar **431**B, and so on, until busbar **431**E connects to terminals **510**K and **510**L of a sixth pair of batteries **450**K/**450**L, busbar **430**F connects the sixth pair of batteries **450**K/**450**L to busbar **421**A, whereby, busbar **421**A connects busbar **430**F with the terminal **131**A.

[0060] As shown, busbars **431**A-n connect to the terminals **520**A-n (e.g., positive terminals), while busbars **430**A-n connect to the respective cell can of the respective batteries **450**A-n, where the cell can is the outer container of the battery **450**A-n and configured as the negative terminal. Busbars **420**A-n do not touch/connect to the busbars **430**A-n while busbars **421**A-n and **431**A-n connect busbars **430**A-n at a single connection point, e.g., at the stepped connection **550**A, such that the busbars **420**A-n, **421**A-n, and **431**A-n are located above the underlying busbars **430**A-n.

[0061] FIG. **6**, system **600**, illustrates a battery pack configuration, in accordance with at least one embodiment. System **600** presents a low EMF configuration for application with both prismatic and cylindrical cells. As shown in FIG. **6**, system **600** depicts a battery pack **602** comprising 3 strings of cells, strings **605**A, **605**B, and **605**C. The respective neutral wires (N**1**-*n*) and live/hot wires (L**1**-*n*) are depicted, whereby the N-wires can convey current back from an electrical device (e.g., electric motor **680**) to the power source (e.g., battery pack **602**) and the L-wires can convey the current from the power source to the electrical device.

[0062] As further shown, the three strings of cells **605**A-n can be connected to a battery disconnect unit **630** and a motor **680**, whereby the battery disconnect unit **630** can be configured to disconnect/isolate battery pack **602** in the event of a problematic operation.

[0063] In an embodiment, the respective cells/batteries can be configured to create a current path **610**A (e.g., a first current path **610**A in a series of current paths **610**A-n) that cancels electromagnetic interference (EMI) across an entire battery pack **602**. In a further embodiment, by utilizing adjacent current paths **610**A-n (e.g., a first portion of a circuit, second portion of a circuit, etc.) to effectively be flowing in opposite directions, EMI effects can be mitigated/minimized/eradicated. While not shown, current paths can also be present in cell strings **605**B and **605**C functioning to mitigate EMI within the strings of cells and further in adjacent strings, such that a current path **610**A in string **605**A can also function to cancel EMFs and EMI from an adjacent string **605**B (e.g., current path **610**B). To facilitate mitigation of EMI/EMF the current paths **610**A-n should be set up as close/adjacent to as possible to each other, both within a cluster of batteries (e.g., cluster of battery cells **310**A-n/**410**A-n) and also between adjacent clusters of batteries (e.g., in respective strings **605**A-n). As shown in FIG. **6**, current path **610**A initially flows in a first/forward direction X and subsequently in a second/reverse direction Y (e.g., between respective neutral wire inputs N**1**-*n* and respective live wire outputs L**1**-*n*), wherein the current path **610**A in the first direction X cancels EMI effects in the second direction Y of the current path **610**A. The effect of the current path **610**A is enabled by locating the clusterboards **210**A-n in the middle of every cell cluster (whereby, FIG. **6** depicts a 6+6 cells arrangement). Hence, returning to FIGS. **3** and **4**, paired clusterboards **210**A are located in the middle of a first cluster of prismatic battery cells **310**A/**410**A and a second cluster of prismatic battery cells **310**B/**410**B. The separated portions of current path **610** is further described with reference to FIGS. **10**A and **10**B.

[0064] Any number of strings of cells **605**A-n can be utilized, e.g., in an embodiment, the three strings **605**A-C presented in FIG. **6**, can be utilized to generate a 3-phase current from the battery pack **602** (e.g., without use of an inverter). For example, 3 phase currents used to drive one or more motors can comprise Phase A string=string **605**A, Phase B string=string **605**B, and Phase C string=string **605**C.

[0065] FIG. **7**, system **700**, illustrates a current path in a left cluster of cells when the cells are connected with a positive current flow arrangement, in accordance with an embodiment. FIG. **7** depicts a current path **610** passing through the batteries in the left cluster **310**A, with the right cluster **310**B operating independent of the left cluster **310**A. As shown, the current flow path **610** is from terminal **121**A (input), through the battery cell cluster **310**A, to **120**A (output). Battery cells **350**A-n and busbars **320**A, **321**A, and **330**A-n in the left cluster **310**A are arranged/configured to enable the current path **610** to operate in a snakelike/series manner such that a first portion of the current path is flowing in a first direction X and a second portion of the current path is flowing in a second direction Y, wherein the first portion of the current path and the second portion of the current path are adjacent. As further shown in FIG. **7**, first electromagnetic effects arising at a first region **720**A of the collection of cells **310**A are cancelled out by second electromagnetic effects arising at a second region **720**B of the collection of cells **310**A. In an example of operation, motor **680** may be operating at a low level of power such that only energy from the battery cells **350**A-n in battery cluster **310**A are required with the batteries **350**A-n in battery cluster **310**B being in a bypass/de-coupled state.

[0066] FIG. **8**, system **800**, illustrates a current path in a left cluster of cells when the cells are connected with a negative current flow arrangement, in accordance with an embodiment. FIG. **8** depicts a current path **610** passing through the batteries in the left cluster **310**A, with the right cluster **310**B operating independent of the left cluster **310**A. As shown, the current flow path **610** is from AC terminal **120**A (input), through the battery cell cluster **310**A, to AC terminal **121**A (output). Battery cells **350**A-n and busbars **320**A, **321**A, and **330**A-n in the left cluster **310**A are arranged/configured to enable the current path **610** to operate in a snakelike/series manner such that a first portion of the current path is flowing in a first direction X and a second portion of the current path is flowing in a second direction Y, wherein the first portion of the current path and the second portion of the current path are adjacent. As further shown in FIG. **8**, first electromagnetic effects arising at a first region **720**A of the collection of cells **310**A are cancelled out by second electromagnetic effects arising at a second region **720**B of the collection of cells **310**A. In an example of operation, motor **680** may be operating at a low level of power such that only energy from the battery cells **350**A-n in battery cluster **310**A are required with the batteries **350**A-n in battery cluster **310**B being in a bypass/de-coupled state.

[0067] FIG. **9**, system **900**, illustrates a current path in a left cluster of cells when the cells are not connected, in a bypass configuration, in accordance with an embodiment. During a bypass operation, the current flow/path is confined to flow directly between the AC terminals **120**A and **121**A, hence, per FIG. **1**C, the current flow connects AC terminal **120**A with AC terminal **121**A, with no current flow/path occurring in the left cluster **310**A with battery terminals/busbars **130**-A**1** and **130**-A**2** disconnected/de-coupled from the AC terminals/busbars **120**A and **121**A. As shown, current path **610** flows through the clusterboard **110**A of the paired clusterboards **210**A, with the right cluster **310**B isolated from the left cluster **310**A by the paired clusterboards **210**A.

[0068] Accordingly, per the foregoing, FIGS. **7-9** illustrate the current path **610** when respective configurations are applied to the clusterboard **110**A, with current path **610** of FIG. **7** generated with a positive configuration of operation at clusterboard **110**A, current path **610** of FIG. **8** generated with a negative configuration of operation at clusterboard **110**A, a current path **610** of FIG. **9** generated with a bypass configuration of operation at clusterboard **110**A. The respective configuration present/implemented at a clusterboard/cell cluster can be an effect of how the particular cell cluster is being utilized, e.g., energy demand by motor **680** is low, and hence, a few cell clusters are being utilized with the majority of cell clusters in bypass mode, while under high energy demand, e.g., the vehicle is accelerating with high energy draw at motor **680**, the majority/all of the cell clusters are undergoing positive current flow and/or negative current flow. Further, implementation of a particular cluster of cells at a particular time can be a function of load balancing across the battery pack to enable even discharge/charging of respective cell clusters. As previously mentioned, adjustment of operation of the battery pack **602**A-n and respective battery cell clusters **310**A-n/**410**A-n, can be controlled by BMS **180** and/or controller **155**A-n. As shown in FIGS. **7-9**, clusters **310**A and **310**B can function independently about the mirror line, while the configuration on the left side, cluster **310**A, mirrors the configuration on the right side, cluster **310**B.

[0069] FIG. **10**A, illustrates a battery pack **1000**A, depicting a current path in a string of cell clusters, in accordance with at least one embodiment. FIG. **10**A illustrates a current path **610** created in a string of cell clusters included in battery pack **1002**. Battery pack **1002** comprises a string of clusters connected in a sequence of interconnected battery modules **305**A, **305**B, **305**C, a first string comprises a right side cluster **1010**A formed from the battery clusters on the right side of the series of paired clusterboards **210**, and a second string comprises a left side cluster **1010**B formed from the battery clusters on the left side of the series of paired clusterboards **210**, e.g., paired clusterboards **210**A connected to paired clusterboards **210**B, further connected to paired clusterboards **210**C, whereby, as mentioned earlier, the right side cluster **1010**A is operating independently from the left side cluster **1010**B and separated by the series of clusterboards **210**A-n. As shown, a first portion **1030**A of current path **610** is created in the right side cluster **1010**A and a second portion **1030**B of current path **610** is created in the left side cluster **1010**B. The first portion **1030**A of current path **610** connects with the second portion **1030**B of current path **610** via the busbar/interconnect/connector/terminal **1020** located in the top battery module **305**A, and intermediate busbars **1025** connecting adjacent AC terminals **120**A-n and **121**A-n. As shown in FIG. **10**A, apart from the current path **610** passing through the interconnect **1020**, the first portion **1030**A of the current path **610** is confined to the right side cluster **1010**A and the second portion **1030**B of the current path **610** is confined to the left side cluster **1010**B.

[0070] The first portion of current path **610** passes through the right side **1010**A of module **305**C per the negative configuration of FIG. **8**, passes through the right side **1010**A of module **305**B per the bypass configuration presented in FIG. **9**, and further passes through the right side **1010**A of module **305**A per the bypass configuration of FIG. **9**. At connector **1020**, the second portion **1030**B of current path **610** reverses the direction of the first portion **1030**A of the current path **610**, the second portion of current path **610** passes through the left side **1010**B of battery pack **1002**, e.g., fourth cluster in module **305**A per the bypass configuration of FIG. **9**, passes through the left side **1010**B of the fifth cluster **1030**B per the positive configuration of FIG. **7**, and then passes through the left side **1010**B of the sixth cluster in module **305**C in a bypass configuration of FIG. **9**.

[0071] In the example operating scenario presented in FIG. **10**A regarding the **6** battery clusters, the power requirements placed on battery pack **1002** (e.g., by motor **680**) only require energy from 2 clusters of batteries (clusters at **1030**A and **1030**B), while the other 4 clusters of batteries are in bypass mode. Voltage build up generated by the battery pack configurations **602** and **1002**, for example, generates alternating current (AC) which can be utilized for propulsion of a vehicle on which the one or more battery systems presented herein in FIGS. **1**A-**10** can be located.

[0072] FIG. **10**B, schematic **1000**B, illustrates a current path flowing through a string of battery clusters comprising rectangular cells, in accordance with an embodiment. FIG. **10**B illustrates the current path **610** presented in FIG. **10**A being configured such that a distance S between respective portions of the current path **610** is arranged to be at a distance that facilitates cancelling of respective EMFs in the configuration **1000**A, as further described with reference to FIGS. **11** and **12**. Distance S**1** indicates a separation of respective portions of current path **610** between the respective clusterboards **110**A-n in the respective pairs of clusterboards **210**A-n. Distance S**2** indicates a separation of respective portions of current path **610** within a battery cluster **310**A-n.

[0073] FIG. **10**C, schematic **1000**C, illustrates a current path flowing through a string of battery clusters comprising cylindrical cells, in accordance with an embodiment. FIG. **10**C follows the convention presented in FIG. **10**B with a current path **610** representing the current path present when utilizing cylindrical cells, e.g., as previously described with regard to FIGS. **4** and **5**. As shown, the current path **610** has a snake-like configuration resulting from the current path constructed for the cylindrical cells **450**A-n connected with the busbars **430**A-n and **431**A-n. While having a different configuration than the square/rectangular profile presented in FIG. **10**B, the current path **610** is configured such that respective portions of the current path are separated by a distance S to enable cancelling of respective EMFs in the configurations **400** and **500**, as further described with reference to FIGS. **11** and **12**. Distance S**1** indicates a separation of respective portions of current path **610** between the respective clusterboards **110**A-n in the respective pairs of clusterboards **210**A-n. Distance S**2** indicates a separation of respective portions of current path **610** within a battery cluster **410**A-n.

[0074] FIGS. **11** and **12** further illustrate respective busbar configurations to minimize/eliminate EMF and EMI. FIG. **11**, schematic **1100** illustrates a configuration for a battery module to reduce EMF/EMI, in accordance with an embodiment. As shown, a first portion **720**A of a first busbar (e.g., busbar **320**A in busbars **320**A-n, **321**A-n, **330**A-n, **331**A-n, **420**A-n, **421**A-n, **430**A-n, **431**A-n, etc.) is presented proximate/adjacent to a second portion **720**B of a second busbar (e.g., busbar **330**A in busbars **320**A-n, **321**A-n, **330**A-n, **331**A-n, **420**A-n, **421**A-n, **430**A-n, **431**A-n, etc.). Current flow, in direction X through the first busbar causes a first EMF **1110** to be generated and the current flow in direction Y through the second busbar causes second EMF **1120** to be generated. Even though the first busbar and the second busbar are located in the same circuit (e.g., connecting batteries in a battery module **305**A-n, **405**A-n), the first busbar and second busbar are respectively aligned/positioned such that the first EMF **1110** cancels out the second EMF **1120** at region **1130**, thereby reducing the EMI present at region **1130**. In an embodiment, the respective busbars can be positioned in accordance with a distance S, wherein S is the distance that facilitates cancelling of respective EMFs **1110** and **1120** to mitigate EMI in region **1130**.

[0075] FIG. **12**, schematic **1200** illustrates a configuration for a battery module to reduce EMF/EMI, in accordance with an embodiment. As shown, a first portion of a first busbar (e.g., busbar **431**C in busbars **320**A-n, **321**A-n, **330**A-n, **331**A-n, **420**A-n, **421**A-n, **430**A-n, **431**A-n, etc.) is presented in conjunction with a second portion of a second busbar (e.g., busbar **430**D in busbars **320**A-n, **321**A-n, **330**A-n, **331**A-n, **420**A-n, **421**A-n, **430**A-n, **431**A-n, etc.). Current flow, in direction X through the first busbar causes a first EMF **1110** to be generated and the current flow in direction Y through the second busbar causes second EMF **1120** to be generated. Even though the first busbar (e.g., busbar **431**C) and the second busbar (e.g., busbar **430**D are located in the same circuit (e.g., connecting batteries in a module **305**A-n, **405**A-n), the first busbar and second busbar are respectively aligned/positioned such that the first EMF **1110** cancels out the second EMF **1120** at region **1130**, thereby reducing the EMI present at region **1130**. Distance S between respective busbars can be in accordance of mitigating EMI in region **1130**.

[0076] FIG. **13**, schematic **1300**, illustrates a pair of clusterboards located in a battery module to prevent EMI, in accordance with an embodiment. As shown, and previously mentioned, a pair of clusterboards **210**A-n can be located between a first cluster of batteries **310**A/**410**A and a second cluster of batteries **310**B/**410**B. The pair of clusterboards **210**A can be located in a dummy cell **1305**, which is effectively a slot/space between the first cluster of batteries **310**A/**410**A and the second cluster of batteries **310**B/**410**B. The combination of the dummy cell **1305** and the pair of clusterboards **210**A cause a separation between the first cluster of batteries **310**A/**410**A and the second cluster of batteries **310**B/**410**B, wherein the separation can have a width W. W is of sufficient width/distance such that a first EMF **1310** generated at the first cluster of batteries **310**A/**410**A does not interact with a second EMF **1320** generated at the second cluster of batteries **310**B/**410**B. As previously described, per the various embodiments presented herein, the first EMF **1310** and/or the second EMF **1320**, if present, may be of minimal magnitude owing to the respective EMF cancellation being engendered at each of the first cluster of batteries **310**A/**410**A and the second cluster of batteries **310**B/**410**B. Portions **1320** and **1330** of the current path **610** incorporated into to the respective clusterboards **110**A-n (e.g., between terminals **120**A-n and **121**A-n) in the pairs of clusterboards **210**A-n, as shown and as previously mentioned, are configured with a separation of S to enable cancelling of EMF effects present in those respective portions **1320** and **1330**.

[0077] FIG. **14**, process **1400**, presents a configuration to reduce/eliminate EMI in a battery pack, in accordance with one or more embodiments.

[0078] As previously described, by utilizing a combination of clusterboard placement and busbar design and location, electromagnetic fields generated during operation of the battery pack can be utilized against each other to reduce associated EMI effects.

[0079] At **1410**, a first clusterboard (e.g., first clusterboard **110**A) can be paired with a second clusterboard (e.g., a second clusterboard **110**B) to form a pair of clusterboards (e.g., paired clusterboards/pair of clusterboards **210**A), whereby the pair of clusterboards have a width W.

[0080] At **1420**, the pair of clusterboards can be incorporated into a battery module (e.g., battery module **305**A-n/**405**A-n) comprising clusters of battery cells, wherein the battery module can be further included in a battery pack (e.g., battery pack **602**/**1002**). The pair of clusterboards can be located between a first cluster of battery cells (e.g., first cluster of batteries **310**A/**410**A) and a second cluster of battery cells (e.g., second cluster of batteries **310**B/**410**B), wherein the pair of clusterboards, the first cluster of battery cells, and the second cluster of battery cells combine to form a battery module. Given the central/middle positioning of the pair of clusterboards, the pair of clusterboards physically separate (e.g., by distance W) the first cluster of battery cells from the second cluster of battery cells, thereby reducing EMI between the first cluster of battery cells and the second cluster of battery cells. The pair of clusterboards separate the respective first cluster of battery cells from the second cluster of battery cells such that any EMF effects present in the first cluster of battery cells are sufficiently distanced from EMF effects present in the second cluster of battery cells to prevent any EMI effects from being generated.

[0081] At **1430**, the first DC terminal, the second DC terminal, and battery cells (e.g., battery **350**A-n, **450**A-n) in the first cluster of battery cells can be connected by a set of busbars (e.g., busbars **320**A-n, **321**A-n, **420**A-n, **421**A-n) to form a series circuit. The set of busbars are respectively arranged such that a first portion (e.g., portion **720**A) of the series circuit can be located proximate to a second portion (e.g., portion **720**B) of the series circuit and a first EMF (e.g., EMF **1110**A-n) present in the first portion of the series circuit and a second EMF (e.g., EMF **1120**A-n) present in the second portion of the series circuit interact to mutually cancel out the first EMF and the second EMF. In an embodiment, the respective busbars in the set of busbars can be arranged such that a first direction of current flow (e.g., direction X) in the first portion of the series circuit generates the first EMF in a first direction relative to the location of the pair of clusterboards and a second direction of current flow (e.g., direction Y) in the second portion of the series circuit generates a second EMF in a second direction relative to the location of the pair of clusterboards. In a further embodiment, the first EMF and the second EMF can be cancelled by each other, thereby negating the presence of EMI generated during operation of the battery module/battery pack in an AC implementation.

[0082] At **1440**, as previously mentioned, the first clusterboard can include a first AC terminal (e.g., first AC terminal **120**A) and a second AC terminal (e.g., second AC terminal **121**A-n), wherein the first AC terminal and second AC terminal can respectively connect the first clusterboard to at least one of the second clusterboard, a third clusterboard located in another battery module in the battery pack, or a device electrically connected to the battery module/battery pack, such as a motor (e.g., motor **680**), a battery disconnect unit (e.g., battery disconnect unit **630**), a battery regeneration unit, a battery charging unit, a low voltage electrical system, a high voltage electrical system, and suchlike, e.g., co-located on a vehicle with the battery module/battery pack and powered by/controlling operation of the battery module/battery pack. By connecting the respective battery modules together (e.g., via the AC terminals) the battery modules can be combined to form the battery pack.

[0083] At **1450**, operation of any of the first clusterboard, second clusterboard, battery cells, battery modules, battery pack, and suchlike, can be monitored and controlled by any of a controller **155**A-n, a BMS (e.g., BMS **180**), battery disconnect unit (e.g., battery disconnect unit **630**), or other system configured to control operation and interaction of the respective clusterboards, modules, battery packs, and suchlike, in providing power to an onboard device, a motor (e.g., motor **680**) or suchlike, and also charging of the respective modules.

[0084] The description of illustrated embodiments of the subject disclosure as provided herein, including what is described in the Abstract, is not intended to be exhaustive or to limit the disclosed embodiments to the precise forms disclosed. While specific embodiments and examples are described herein for illustrative purposes, various modifications are possible that are considered within the scope of such embodiments and examples, as one skilled in the art can recognize. In this regard, while the subject matter has been described herein in connection with various embodiments and corresponding drawings, where applicable, it is to be understood that other similar embodiments can be used or modifications and additions can be made to the described embodiments for performing the same, similar, alternative, or substitute function of the disclosed subject matter without deviating therefrom. Therefore, the disclosed subject matter should not be limited to any single embodiment described herein, but rather should be construed in breadth and scope in accordance with the appended claims below.

[0085] While not an exhaustive listing, the following provides an overview of various embodiments, but not all embodiments, presented herein:

[0086] Clause 1: A battery module, comprising: a first cluster of battery cells, wherein the first cluster of battery cells are electrically coupled together; a second cluster of battery cells, wherein the second cluster of battery cells are electrically coupled together; a first clusterboard electrically coupled to the first cluster of battery cells; and a second clusterboard electrically coupled to the second cluster of battery cells, wherein the first clusterboard is co-located with the second clusterboard to form a paired clusterboard, and the paired clusterboard is located between the first cluster of battery cells and the second cluster of battery cells, wherein the battery module is configured to reduce an electromagnetic field (EMF) present in the battery module when electrical energy is flowing through the battery module.

[0087] Clause 2: The battery module of any preceding clause, wherein the battery module is located onboard an electric vehicle and configured to provide energy to a motor located on the electric vehicle.

[0088] Clause 3: The battery module of any preceding clause, wherein the paired clusterboard is located in a dummy cell between the first cluster of battery cells and the second cluster of battery cells.

[0089] Clause 4: The battery module of any preceding clause, wherein the dummy cell has a width such that the distance between the first cluster of battery cells and the second cluster of battery cells is sufficient that a first EMF generated in the first cluster of battery cells cancels a second EMF generated in the second cluster of battery cells.

[0090] Clause 5: The battery module of any preceding clause, wherein the first cluster of battery cells and the second cluster of battery cells comprise at least one of prismatic batteries or cylindrical batteries.

[0091] Clause 6: The battery module of any preceding clause, further comprising a first set of electrical connectors connecting the respective battery cells in the first cluster of battery cells to each other to create a first electrical circuit, wherein the first electrical circuit connects the first cluster of battery cells with a first electrical flow path.

[0092] Clause 7: The battery module of any preceding clause, wherein the first electrical flow path is configured such that a first EMF in a first portion of the first electrical flow path cancels a second EMF created in a second portion of the first electrical flow path.

[0093] Clause 8: The battery module of any preceding clause, further comprising a second set of electrical connectors connecting the respective battery cells in the second cluster of battery cells to each other to create a second electrical circuit, wherein the second electrical circuit connects the second cluster of battery cells with a second electrical flow path.

[0094] Clause 9: The battery module of any preceding clause, wherein the second electrical flow path is configured such that a third EMF in the first portion of the second electrical flow path cancels a fourth EMF created in a second portion of the second electrical flow path.

[0095] Clause 10: The battery module of any preceding clause, wherein a fifth EMF generated by the first electrical circuit in the first set of battery cells cancels a sixth EMF generated by the second electrical circuit in the second set of battery cells.

[0096] Clause 11: The battery module of any preceding clause, wherein the EMF is generated when the battery module is utilized with an alternating current (AC) operation.

[0097] Clause 12: A method, comprising: positioning a first clusterboard with a second clusterboard to form a pair of clusterboards; and locating the pair of clusterboards between a first cluster of battery cells and a second cluster of battery cells, wherein pair of clusterboards, the first cluster of battery cells, and the second cluster of battery cells combine to form a battery module, the pair of clusterboards physically separate the first cluster of battery cells from the second cluster of battery cells to reduce electromagnetic interference (EMI) between the first cluster of battery cells and the second cluster of battery cells.

[0098] Clause 13: The method of any preceding clause, wherein the first clusterboard comprises a first AC terminal and a second AC terminal, wherein the first AC terminal and second AC terminal respectively connect the first clusterboard to at least one of the second clusterboard, a third clusterboard located in a battery pack that includes the battery module, or a device electrically connected to a battery pack comprising the battery module.

[0099] Clause 14: The method of any preceding clause, wherein the first clusterboard comprises a first DC terminal and a second DC terminal, wherein a first busbar connects the first DC terminal and a first battery cell in the first cluster of battery cells, and a second busbar connects the second DC terminal and a second battery cell in the first cluster of battery cells, wherein the respective batteries in the first cluster of battery cells are electrically connected in series.

[0100] Clause 15: The method of any preceding clause, wherein the first DC terminal, the second DC terminal, and battery cells in the first cluster of battery cells are connected by a set of busbars to form a series circuit, wherein the set of busbars includes the first busbar and the second busbar, the set of busbars are arranged such that a first portion of the series circuit is located proximate to a second portion of the series circuit and a first electromagnetic field (EMF) present in the first portion of the series circuit and a second EMF present in the second portion of the series circuit interact to mutually cancelled out the first EMF and the second EMF.

[0101] Clause 16: The method of any preceding clause, the first EMF present in the first portion of the series circuit is generated in response to current flow in a first direction relative to the location of the pair of clusterboards, and the second EMF present in the second portion of the series circuit is generated in response to current flow in a second direction relative to the location of the pair of clusterboards, wherein the busbars are arranged such that the first direction and second direction are opposite.

[0102] Clause 17: A battery module comprising: a first clusterboard electrically coupled to a first cluster of battery cells; and a second clusterboard electrically coupled to a second cluster of battery cells, wherein the first clusterboard is co-located with the second clusterboard to form a paired clusterboard, and the paired clusterboard is located between the first cluster of battery cells and the second cluster of battery cells, wherein the battery module is configured to reduce electromagnetic interference (EMI) present in the battery module when electrical energy is flowing through the battery module.

[0103] Clause 18: The battery module of any preceding clause, wherein: the first clusterboard comprises a first alternating current (AC) terminal, a second AC terminal, a first direct current (DC) terminal, and a second DC terminal, wherein: the first AC terminal, the second AC terminal,

the first DC terminal, and the second DC terminal are connected to form a first H-bridge; the first DC terminal, the second DC terminal, and the first cluster of battery cells are connected in series to form an electrical circuit, wherein the electrical circuit further comprises: a first connector connecting a first battery cell to a second battery cell to form a first portion of the electrical circuit; and a second connector connecting a third battery cell to a fourth battery cell to form a second portion of the electrical circuit, wherein the first portion of the electrical circuit is aligned relative to the second portion of the electrical circuit such that a first electromagnetic field (EMF) generated in the first portion of the electrical circuit is cancelled by a second EMF present in the second portion of the electrical circuit.
[0104] Clause 19: The battery module of any preceding clause, wherein battery module is located in a battery pack configured to provide AC to a device co-located with the battery pack on a vehicle, and the first EMF and the second EMF are generated when the battery pack generates the AC current.
[0105] Clause 20: The battery module of any preceding clause, wherein the paired clusterboard is located in a dummy cell between the first cluster of battery calls and the second cluster of battery cells.
[0106] In various cases, any suitable combination of clauses 1-11 can be implemented.
[0107] In various cases, any suitable combination of clauses 12-16 can be implemented.
[0108] In various cases, any suitable combination of clauses 17-20 can be implemented.

Claims

1. A battery module, comprising: a first cluster of battery cells, wherein the first cluster of battery cells are electrically coupled together; a second cluster of battery cells, wherein the second cluster of battery cells are electrically coupled together; a first clusterboard electrically coupled to the first cluster of battery cells; and a second clusterboard electrically coupled to the second cluster of battery cells, wherein the first clusterboard is co-located with the second clusterboard to form a paired clusterboard, and the paired clusterboard is located between the first cluster of battery cells and the second cluster of battery cells, wherein the battery module is configured to reduce an electromagnetic field (EMF) present in the battery module when electrical energy is flowing through the battery module.
2. The battery module of claim 1, wherein the battery module is located onboard an electric vehicle and configured to provide energy to a motor located on the electric vehicle.
3. The battery module of claim 1, wherein the paired clusterboard is located in a dummy cell between the first cluster of battery cells and the second cluster of battery cells.
4. The battery module of claim 3, wherein the dummy cell has a width such that the distance between the first cluster of battery cells and the second cluster of battery cells is sufficient that a first EMF generated in the first cluster of battery cells cancels a second EMF generated in the second cluster of battery cells.
5. The battery module of claim 1, wherein the first cluster of battery cells and the second cluster of battery cells comprise at least one of prismatic batteries or cylindrical batteries.
6. The battery module of claim 1, further comprising a first set of electrical connectors connecting the respective battery cells in the first cluster of battery cells to each other to create a first electrical circuit, wherein the first electrical circuit connects the first cluster of battery cells with a first electrical flow path.
7. The battery module of claim 6, wherein the first electrical flow path is configured such that a first EMF in a first portion of the first electrical flow path cancels a second EMF created in a second portion of the first electrical flow path.
8. The battery module of claim 7, further comprising a second set of electrical connectors connecting the respective battery cells in the second cluster of battery cells to each other to create a

second electrical circuit, wherein the second electrical circuit connects the second cluster of battery cells with a second electrical flow path.

9. The battery module of claim 8, wherein the second electrical flow path is configured such that a third EMF in the first portion of the second electrical flow path cancels a fourth EMF created in a second portion of the second electrical flow path.

10. The battery module of claim 9, wherein a fifth EMF generated by the first electrical circuit in the first set of battery cells cancels a sixth EMF generated by the second electrical circuit in the second set of battery cells.

11. The battery module of claim 1, wherein the EMF is generated when the battery module is utilized with an alternating current (AC) operation.

12. A method, comprising: positioning a first clusterboard with a second clusterboard to form a pair of clusterboards; and locating the pair of clusterboards between a first cluster of battery cells and a second cluster of battery cells, wherein pair of clusterboards, the first cluster of battery cells, and the second cluster of battery cells combine to form a battery module, the pair of clusterboards physically separate the first cluster of battery cells from the second cluster of battery cells to reduce electromagnetic interference (EMI) between the first cluster of battery cells and the second cluster of battery cells.

13. The method of claim 12, wherein the first clusterboard comprises a first AC terminal and a second AC terminal, wherein the first AC terminal and second AC terminal respectively connect the first clusterboard to at least one of the second clusterboard, a third clusterboard located in a battery pack that includes the battery module, or a device electrically connected to a battery pack comprising the battery module.

14. The method of claim 13, wherein the first clusterboard comprises a first DC terminal and a second DC terminal, wherein a first busbar connects the first DC terminal and a first battery cell in the first cluster of battery cells, and a second busbar connects the second DC terminal and a second battery cell in the first cluster of battery cells, wherein the respective batteries in the first cluster of battery cells are electrically connected in series.

15. The method of claim 14, wherein the first DC terminal, the second DC terminal, and battery cells in the first cluster of battery cells are connected by a set of busbars to form a series circuit, wherein the set of busbars includes the first busbar and the second busbar, the set of busbars are arranged such that a first portion of the series circuit is located proximate to a second portion of the series circuit and a first electromagnetic field (EMF) present in the first portion of the series circuit and a second EMF present in the second portion of the series circuit interact to mutually cancelled out the first EMF and the second EMF.

16. The method of claim 15, the first EMF present in the first portion of the series circuit is generated in response to current flow in a first direction relative to the location of the pair of clusterboards, and the second EMF present in the second portion of the series circuit is generated in response to current flow in a second direction relative to the location of the pair of clusterboards, wherein the busbars are arranged such that the first direction and second direction are opposite.

17. A battery module comprising: a first clusterboard electrically coupled to a first cluster of battery cells; and a second clusterboard electrically coupled to a second cluster of battery cells, wherein the first clusterboard is co-located with the second clusterboard to form a paired clusterboard, and the paired clusterboard is located between the first cluster of battery cells and the second cluster of battery cells, wherein the battery module is configured to reduce electromagnetic interference (EMI) present in the battery module when electrical energy is flowing through the battery module.

18. The battery module of claim 17, wherein: the first clusterboard comprises a first alternating current (AC) terminal, a second AC terminal, a first direct current (DC) terminal, and a second DC terminal, wherein: the first AC terminal, the second AC terminal, the first DC terminal, and the second DC terminal are connected to form a first H-bridge; the first DC terminal, the second DC terminal, and the first cluster of battery cells are connected in series to form an electrical circuit, wherein the electrical circuit further comprises: a first connector connecting a first battery cell to a second battery cell to form a first portion of the electrical circuit; and a second connector connecting a third battery cell to a fourth battery cell to form a second portion of the electrical circuit, wherein the first portion of the electrical circuit is aligned relative to the second portion of the electrical circuit such that a first electromagnetic field (EMF) generated in the first portion of the electrical circuit is cancelled by a second EMF present in the second portion of the electrical circuit.

19. The battery module of claim 18, wherein battery module is located in a battery pack configured to provide AC to a device co-located with the battery pack on a vehicle, and the first EMF and the second EMF are generated when the battery pack generates the AC current.

20. The battery module of claim 17, wherein the paired clusterboard is located in a dummy cell between the first cluster of battery calls and the second cluster of battery cells.