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BUSBAR ASSEMBLY FOR A PLURALITY OF INVERTERS

Abstract

A busbar assembly for delivering current to a plurality of inverters may include a plurality of busbars, configured to receive current from a current source and to output current to the plurality of inverters, a plurality of spacers positioned between the plurality of busbars, and a plurality of inverter connectors, each inverter connector being coupled to one of the plurality of busbars, wherein each of the plurality of spacers and the plurality of inverter connectors is formed of a conductive material.

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Background/Summary

TECHNICAL FIELD

[0001] The present disclosure relates generally to busbars, and, more particularly, to busbar assemblies having a plurality of busbars.

BACKGROUND

[0002] Machines, such as locomotives, use inverters to convert direct current (DC) from power sources, such as batteries, to alternating current (AC), to power components of the machines, such as a traction motor of a locomotive. Each inverter typically has its own link to the power sources, with each connection requiring conductive material, e.g., copper, which are subject to issues regarding the balance between manufacturing costs and heat management.

[0003] There is a need, therefore, to connect a plurality of traction inverters to a common busbar. However, this type of connection has high current requirements and may cause current recirculation between the inverters due to imbalances in internal capacitors. Further, such a connection may require a relatively large amount of material to form the common busbar and may create thermal inefficiency due to the building up of heat due to current passing through the common busbar.

[0004] U.S. Pat. No. 11,070,036 (“the '036 patent”) discloses multi-phase busbars for conducting alternating electrical current (AC) to different electrical devices. These busbars include a base layer of an insulating material, a first conducting layer of a sheet metal, and a first insulating layer of an insulating material arranged on the first conducting layer. The first and/or second insulating layers comprise spacers. That is, the '036 patent requires insulating material to form the insulating layers and uses multi-phase busbars for AC current.

[0005] The assemblies of the present invention address these and other problems in the art. The scope of the current disclosure, however, is defined by the attached claims, and not by the ability to solve any specific problem.

SUMMARY

[0006] In one aspect of the present disclosure, a busbar assembly for delivering current to a plurality of inverters may include a plurality of busbars, configured to receive current from a current source and to output current to the plurality of inverters, a plurality of spacers positioned between the plurality of busbars, and a plurality of inverter connectors, each inverter connector being coupled to one of the plurality of busbars, wherein each of the plurality of spacers and the plurality of inverter connectors is formed of a conductive material.

[0007] In another aspect of the present disclosure, a busbar assembly may include a plurality of busbars including: a first busbar having a first length, a second busbar having a second length that is greater than the first length, and a third busbar having a third length that is greater than the second length. The busbar assembly may also include a plurality of spacers forming: a first spacer layer, including two or more spacers, of the plurality of spacers, positioned between the first busbar and the second busbar, and a second spacer layer, including a number of spacers that is greater than a number of spacers of the first spacer layer, of the plurality of spacers, positioned between the second busbar and the third busbar. In addition, the busbar assembly may include a plurality of inverter connectors, each inverter connector being coupled to one of the plurality of busbars, wherein each spacer of the first spacer layer and the second spacer layer and the plurality of connectors is formed of a conductive material.

[0008] In still another aspect of the present disclosure, a busbar and inverter assembly may include a busbar assembly that includes a plurality of busbars, configured to receive current from a current source and to output current, a plurality of spacers positioned between the plurality of busbars, and a plurality of inverter connectors, each inverter connector being coupled to one of the plurality of busbars, each of the plurality of spacers and the plurality of connectors being formed of a conductive material. The busbar and inverter assembly may also include a plurality of inverters, arranged in parallel and directly connected to the plurality of inverter connectors and configured to receive the current output by the plurality of busbars.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate various exemplary embodiments and together with the description, serve to explain the principles of the disclosed embodiments.

[0010] FIG. **1** is a schematic drawing of a locomotive, as an example of a machine on which a busbar and inverter assembly according to the present invention may be installed.

[0011] FIG. **2** is a schematic view of a busbar and inverter assembly, including busbar assemblies, in accordance with the present invention.

[0012] FIG. **3** is a schematic detail view of a spacer of the busbar assemblies of FIG. **2**.

[0013] FIG. **4** is a detailed cross-sectional view of a portion of one of the busbar assemblies of FIG. **2**.

[0014] FIG. **5** is a schematic diagram of current flow through the busbar assembly shown in FIG. **2**.

DETAILED DESCRIPTION

[0015] Both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the features, as claimed. As used herein, the terms “comprises,” “comprising,” “having,” including,” or other variations thereof, are intended to cover a non-exclusive inclusion such that a method or apparatus that comprises a list of elements does not include only those elements, but may include other elements not expressly listed or inherent to such a method or apparatus. In this disclosure, relative terms, such as, for example, “about,” “substantially,” “generally,” and “approximately” are used to indicate a possible variation of ±10% in the stated value or characteristic.

[0016] FIG. **1** shows a schematic drawing of a locomotive **100**, as an example of a machine, in which a busbar and inverter assembly **105**, according to the present invention, and shown in FIG. **2**, may be installed. The locomotive has a chassis **110**, a plurality of wheels **115**, an engine compartment **120**, including a motor **125**, and an electronics compartment **130**, among others. The electronics compartment **130** may include a plurality of inverters **140**, such as traction inverters, as part of the busbar and inverter assembly **105**. The electronics compartment **130** may also include at least one current source **145**, such as a direct current (DC) battery, having a positive terminal **150** and a negative terminal **155**.

[0017] FIG. **2** shows the busbar and inverter assembly **105**, according to one embodiment of the invention, including one busbar assembly **160***a* with inverters **140**, and one separate busbar assembly **160***b* without inverters **140**, for simplicity. In the busbar and inverter assembly **105**, the inverters **140** may be arranged in parallel, and each inverter **140** may be directly connected to the busbar assembly **160***a*. In the embodiment shown in FIG. **2**, the busbar and inverter assembly **105** includes four inverters **140**. In some embodiments, three or more inverters **140** are used. However, a lesser number or a greater number of inverters **140** may be used. The number of inverters **140** may be determined based on a number of traction motors provided on the locomotive **100**. The busbar assembly **160***a* delivers current to the plurality of inverters **140**.

[0018] Each busbar assembly **160** includes a current source port **165** for receiving a current from the current source **145** via the positive terminal **150** or the negative terminal **155**. Each busbar assembly **160** also includes a plurality of busbars **170** that are configured to receive current from the current source **145** and to transmit the same amount of current through each of the busbars **170**. The number of busbars **170** may be determined based on the number of inverters **140**. In one embodiment, the busbars **170** may be single-pole busbars. In another embodiment, multi-ole busbars may be used. In the embodiment shown in FIG. **2**, one of the busbar assemblies **160***a* connects to the positive terminal **150** of the current source **145**, and the other of the busbar assemblies **160***a* connects to the negative terminal **155** of the current source **145**. In each busbar assembly **160** shown in FIG. **2**, the busbars **170** include a first busbar **170***a*, a second busbar **170***b*, and a third busbar **170***c*. The first busbar **170***a* may also be referred to as a top busbar, the second busbar **170***b* may also be referred to as a middle busbar, and the third busbar **170***c* may also be referred to as a bottom-most busbar. The busbars **170** may be formed of a conductive material. As one example, the conductive material may be copper.

[0019] The busbars **170** may be in a staggered arrangement, having different lengths, as measured along the x-axis. That is, a length L.sub.170a of the first busbar **170***a* may be less than a length L.sub.170b of the second busbar **170***b*, and the length L.sub.2 of the second busbar **170***b* may be less than a length L.sub.170c of the third busbar **170***c*. The width of the busbars **170** may depend on the current draw of the inverter **140** to which the busbar **170** is connected. In one embodiment, the busbars **170** may have the same width W.sub.170, measured along the x-axis, in a case in which the inverters **140** have the same width. In another embodiment, one or more of the busbars **170** may have a different width than the other busbars **170**, in a case in which one or more of the inverters **140** have different widths than the other inverters **140**. In addition, each of the busbars **170** has the same height H.sub.170, measured along the y-axis. In some embodiments, a proximal end of each of the busbars **170** of a busbar assembly **160** (e.g., busbar assembly **160***a* of FIG. **2**), the proximal end being, nearest the current source **145**, may be bent, for example, to address space constraints. In some embodiments, one or both busbar assemblies **160** may include busbars **170** with bent proximal ends.

[0020] The busbar assembly **160** further includes a plurality of spacers **175**, positioned in between the busbars **170**, in layers **180**. The spacers **175** provided in between the first busbar **170***a* and the second busbar **170***b* may be referred to as a first layer **180***a*, and the spacers **175** provided in between the second busbar **170***b* and the third busbar **170***c* may be referred to as a second layer **180***b*. In the embodiment shown in FIG. **2**, three spacers **175** are provided in the first layer **180***a*, and four spacers **175** are provided in the second layer **180***b*. However, the first layer **180***a* and the second layer **180***b* may include a greater or a lesser number of spacers **175**. For example, each layer **180** may include two or more spacers **175**. In one embodiment, the second layer **180***b* may have a greater number of spacers **175** than a number of spacers in the first layer **180***a*. In addition, although the first layer **180***a* and the second layer **180***b* include a different number of spacers **175** than each other, the first layer **180***a* and the second layer **180***b* may include the same number of spacers **175** as each other.

[0021] FIG. **3** shows a detail view of a spacer **175**, including a length L.sub.175, measured along the x-axis, a height H.sub.175 measured along the y-axis, and a width W.sub.175, measured along the z-axis. These dimensions may be the same for all of the spacers **175**. Alternatively, one or more of the length L.sub.175, the height H.sub.175, and the width W.sub.175 may vary among the spacers **175**. Further, the spacers **175** may be equally spaced apart between the busbars **170**, along the x-axis. Alternatively, the spacing between the spacers **175** along the x-axis may vary. In the embodiment shown in FIG. **2**, as an example, two of the spacers **175** in the first layer **180***a* may be equally spaced apart, with the third, proximal-most spacer **175**, nearest the current source **145**, being at a relatively lesser spacing to an adjacent spacer **175**. Similarly, three of the spacers **175** in the second layer **180***b* may be equally spaced apart, with the fourth, proximal-most spacer **175**, nearest the current source **145**, being at a relatively lesser spacing to an adjacent spacer **175**. The spacers **175** may be formed of a conductive material. As one example, the conductive material may be copper. In between the spacers **175** and the busbars **170**, openings **185** are formed. The openings **185** may be formed by virtue of welding together the busbars **170** and the spacers **175** in the configuration shown in FIG. **2**, or the openings **185** may be formed by removing portions from a block of material. Each of the openings **185** is defined by surfaces of the adjacent busbars **170** and spacers **175**, from which heat, generated by current passing through the busbar assembly **160** to the inverters **140**, dissipates into air within the openings **185**. That is, the openings **185** are not filled with a material and are left empty to promote or allow dissipation of heat from surfaces of the spacers **175** and the busbars **170**.

[0022] The busbar assembly **160** further includes a plurality of connectors **190**, provided on one or more busbars **170**. In the embodiment shown in FIG. **2**, the connectors **190** are provided on all three of the first busbar **170***a*, the second busbar **170***b*, and the third busbar **170***c*. However, in an alternative embodiment, described below with reference to FIG. **5**, the connectors **190** may be provided on only one of the busbars **170**. The connectors **190** may also be considered a third layer **180** of spacers **175**, specifically, a third or bottom layer **180***c*. Each of the connectors **190** is configured to connect the busbars **170** with the inverters **140** of the busbar and inverter assembly **105**. The connectors **190** may be formed of a conductive material. As one example, the conductive material may be copper. A length L.sub.190, measured along the x-axis, a height H.sub.190, measured along the y-axis, and a width W.sub.190, measured along the z-axis, may be the same for all connectors **190**. Alternatively, one or more of the length L.sub.190, the height H.sub.190, and the width W.sub.190 may vary among the connectors **190**.

[0023] The plurality of busbars **170**, the plurality of spacers **175**, and the plurality of connectors **190** may be formed of the same conductive material. As one example, the busbars **170**, the spacers **175**, and the connectors **190** may all be formed of copper. Alternatively, one or more of the busbars **170**, the spacers **175**, and the connectors **190** may be formed of a different conductive material than one or both of the other of the busbars **170**, the spacers **175**, and the connectors **190**. The busbars **170**, the spacers **175**, and the connectors **190** are connected to each other to form the busbar assembly **160**. As one example, the busbars **170**, the spacers **175**, and the connectors **190** may be brazed together. The connections between the busbars **170**, the spacers **175**, and the connectors **190**, and the use of a conductive material to form these components, create electrical connections among them, such that current flowing into the current source port **165**, and through the busbars **170**, the spacers **175**, and the connectors **190**, flows to the inverters **140**.

[0024] FIG. **4** is a detail cross-sectional view of a portion of one of the busbar assemblies **160** shown in FIG. **2**. In particular, FIG. **4** shows the first busbar **170***a*, the second busbar **170***b*, and the third busbar **170***c* of the one busbar assembly **160***a*, and the first busbar **170***a*, the second busbar **170***b*, and the third busbar **170***c* of the other busbar assembly **160***b*, shown in FIG. **2**. FIG. **4** also shows spacers **175** located in between the first busbar **170***a* and the second busbar **170***b* of each busbar assembly **160***a* and **160***b*, and in between the second busbar **170***b* and the third busbar **170***c* of each busbar assembly **160***a* and **160***b*. In addition, FIG. **4** shows connectors **190** on the third busbars **170***c*. The connectors **190** may have a busbar connection portion **200** for connecting to the third busbars **170***c*, and an inverter connection portion **205** for connecting to the inverters **140**. The connectors **190** may be L-shaped, as shown in FIG. **4**, with an approximate **90°** angle in between the busbar connection portion **200** and the inverter connection portion **205**, although the connectors **190** may be formed into other shapes.

INDUSTRIAL APPLICABILITY

[0025] The busbar assembly **160** and the busbar and inverter assembly **105** of the present invention may be used to carry electrical current, such as DC current, from an electrical source to a plurality of inverters **140** of a machine. As one example, the machine may be a locomotive **100**, and the inverters **140** may be a plurality of traction inverters. Other applications for the busbar assembly **160** and busbar and inverter assembly described herein include mining vehicles, solar power arrangements, or any other electrically powered application where several inverters may be needed and can be arranged in parallel.

[0026] In use, the busbar and inverter assembly **105** may include four separate inverters arranged in parallel. FIG. **5** is a schematic diagram of current flowing through one of the busbar assemblies **160**, shown in FIG. **2**. Depiction of the other busbar assembly **160** shown in FIG. **2** is omitted for case of explanation. FIG. **5** shows the busbar assembly **160** from a side view, and shows the current source connection or port **165** for electrical connection to the current source **145**, and the plurality of busbars **170**, which receive current from the current source **145**, such that the same amount of current flows through the busbars **170** to each of the inverters **140**. The busbars **170** include the first busbar **170***a*, the second busbar **170***b*, and the third busbar **170***c*. The busbar assembly **160** further includes the plurality of spacers **175**, positioned in between the busbars **170**, in layers **180**. FIG. **5** also shows the openings **185** in between the spacers **175** and the busbars **170**, which allow dissipation of heat generated by current passing through the busbar assembly **160** to the inverters **140**. Further, FIG. **5** shows the plurality of connectors **190**, provided on the busbars **170**. The connectors **190** provide for direct connection to the inverters **140**, which may be arranged in parallel.

[0027] The amount of heat generated by the busbar assembly **160** is proportional to an amount of current flowing through the busbar assembly **160** and is inversely proportional to the surface area of the busbar assembly **160**. The amount of heat generated by the busbar assembly also depends on the material used to form the busbars **170**. A working temperature of the material used to form the busbar assembly **160** may, therefore, be used to determine the amount of current that the busbar assembly **160** may receive and transfer to the inverters **140**. As a specific example, a busbar assembly **160** formed of copper may have a working temperature of about 120° C., so the dimensions of the busbar assembly **160** and the amount of current supplied to the busbar assembly **160** will be determined in order to avoid the busbar assembly **160** reaching that working temperature.

[0028] Because the plurality of busbars **170**, the plurality of spacers **175**, and the plurality of connectors **235** may be formed of the same conductive material, the current supplied by the current supply **145** via the current connection source **165** may be distributed among the busbars **170** and the spacers **175** evenly, and then flowing to the inverters **140**, as shown by the straight arrows in FIG. **5**. More specifically, the current flows from the current source **145** into the current source connection **165**, through the busbars **170**, from right to left as indicated by the sideward pointing and upward pointing straight arrows in FIG. **5**, and then downward, as indicated by the downward pointing straight arrows in FIG. **5**, toward the inverters **140**. By virtue of the staggered arrangement of the busbars **170**, the arrangement of the inverters **140** in parallel, and the direct connection between each of the inverters **140** and the busbars **170**, each of the inverters **140** may draw about the same amount of current as the other inverters **140** (e.g., about 1000 A), while reducing a path of recirculating current, to that shown by arrows A in FIG. **5** for example.

[0029] By virtue of the busbar assembly **160**, and, in particular, by virtue of the plurality of spacers **175** and the plurality of openings **185** of the busbar assembly **160**, the busbar assemblies **160** have a relatively greater surface area, which facilitates providing greater convection area and dissipation of heat, which is generated when current flows through the plurality of busbars **170**. The dissipation of heat, in turn, facilitates greater the thermal efficiency of the busbar and inverter assembly **105**. In addition, using a plurality of busbars **170** separated by a plurality of spacers **175** provides more heat rejection area without requiring a relatively greater amount of copper. Still further, the busbars assembly **160** is relatively easy to manufacture, considering the staggered arrangement of the busbars **170**, in cases in which only a length of each busbar **170** varies while the cross-sectional shape of the busbars **170** is the same. Further, the staggered arrangement of the busbars **170** combined with the use of the spacers **175** provide for relatively shorter paths for recirculating current, limiting the extent to which recirculating current flows towards the other inverters **140**.

[0030] It will be apparent to those skilled in the art that various modifications and variations can be made to the disclosed busbar assemblies and busbar and inverter assemblies, without departing from the scope of the disclosure. Other embodiments of the busbar assemblies and busbar and inverter assemblies will be apparent to those skilled in the art from consideration of the specification and busbar assemblies and busbar and inverter assemblies disclosed herein. It is intended that the specification and examples be considered as exemplary only, with a true scope of the disclosure being indicated by the following claims and their equivalents.

Claims

1. A busbar assembly for delivering current to a plurality of inverters, the busbar assembly comprising: a plurality of busbars, configured to receive current from a current source and to output current to the plurality of inverters; a plurality of spacers positioned between the plurality of busbars; and a plurality of inverter connectors, each inverter connector being coupled to one of the plurality of busbars, wherein each of the plurality of spacers and the plurality of inverter connectors is formed of a conductive material.
2. The busbar assembly according to claim 1, wherein the plurality of busbars includes a first busbar, a second busbar, and a third busbar, and wherein a length of the third busbar is greater than a length of the second busbar, and the length of the second busbar is greater than a length of the first busbar.
3. The busbar assembly according to claim 2, wherein the plurality of spacers includes a first layer of spacers, including two or more spacers, between the first busbar and the second busbar, and a second layer of spacers, including two or more spacers between the second busbar and the third busbar.
4. The busbar assembly according to claim 2, further comprising a plurality of openings in between adjacent spacers of the plurality of spacers and in between adjacent busbars of the plurality of busbars, the plurality of openings allowing for dissipation of heat generated by current passing through the busbar assembly.
5. The busbar assembly according to claim 1, wherein the plurality of busbars, the plurality of spacers, and each inverter connector are brazed together to form the busbar assembly.
6. The busbar assembly according to claim 1, wherein spacers, of the plurality of spacers, have a same length, a same width, and a same height as each other.
7. The busbar assembly according to claim 1, wherein the conductive material is copper.
8. A busbar assembly comprising: a plurality of busbars including: a first busbar having a first length; a second busbar having a second length that is greater than the first length; and a third busbar having a third length that is greater than the second length; a plurality of spacers forming: a first spacer layer, including two or more spacers, of the plurality of spacers, positioned between the first busbar and the second busbar; and a second spacer layer, including a number of spacers that is greater than a number of spacers of the first spacer layer, of the plurality of spacers, positioned between the second busbar and the third busbar; and a plurality of inverter connectors, each inverter connector being coupled to one of the plurality of busbars, wherein each spacer of the first spacer layer and the second spacer layer and the plurality of connectors is formed of a conductive material.
9. The busbar assembly according to claim 8, further comprising a plurality of openings defined by the spacers of the first spacer layer and the spacers of the second spacer layer, and by the first busbar, the second busbar, and the third busbar, the plurality of openings allowing for dissipation of heat generated by current passing through the busbar assembly.
10. The busbar assembly according to claim 8, wherein the plurality of busbars, the plurality of spacers, and the plurality of connectors are brazed together to form the busbar assembly.
11. The busbar assembly according to claim 8, wherein spacers, of the plurality of spacers, have a same length, a same width, and a same height as each other.
12. The busbar assembly according to claim 8, wherein the spacers of the first spacer layer, the spacers of the second spacer layer, and the plurality of inverter connectors have at least a same width.

13. The busbar assembly according to claim 8, wherein the conductive material is copper.
14. A busbar and inverter assembly, comprising: a busbar assembly comprising: a plurality of busbars, configured to receive current from a current source and to output current; a plurality of spacers positioned between the plurality of busbars; and a plurality of inverter connectors, each inverter connector being coupled to one of the plurality of busbars, each of the plurality of spacers and the plurality of connectors being formed of a conductive material; and a plurality of inverters, arranged in parallel and directly connected to the plurality of inverter connectors and configured to receive the current output by the plurality of busbars.
15. The busbar and inverter assembly of claim 14, wherein the plurality of busbars includes a first busbar, a second busbar, and a third busbar, and wherein a length of the third busbar is greater than a length of the second busbar, and the length of the second busbar is greater than a length of the first busbar.
16. The busbar and inverter assembly of claim 14, wherein the plurality of spacers includes a first layer of spacers, including two or more spacers, between the first busbar and the second busbar, and a second layer of spacers, including two or more spacers between the second busbar and the third busbar.
17. The busbar and inverter assembly according to claim 14, wherein the busbar assembly includes a plurality of openings in between adjacent spacers of the plurality of spacers and in between adjacent busbars of the plurality of busbars, the plurality of openings allowing for dissipation of heat generated by current passing through the busbar assembly.
18. The busbar and inverter assembly according to claim 14, wherein the plurality of busbars, the plurality of spacers, and the plurality of connectors are brazed together to form the busbar assembly that is connected to the plurality of inverters.
19. The busbar and inverter assembly according to claim 14, wherein spacers, of the plurality of spacers, have a same length, a same width, and a same height as each other.
20. The busbar and inverter assembly according to claim 14, wherein the conductive material is copper.