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(54) PACKAGED POWER INVERTER

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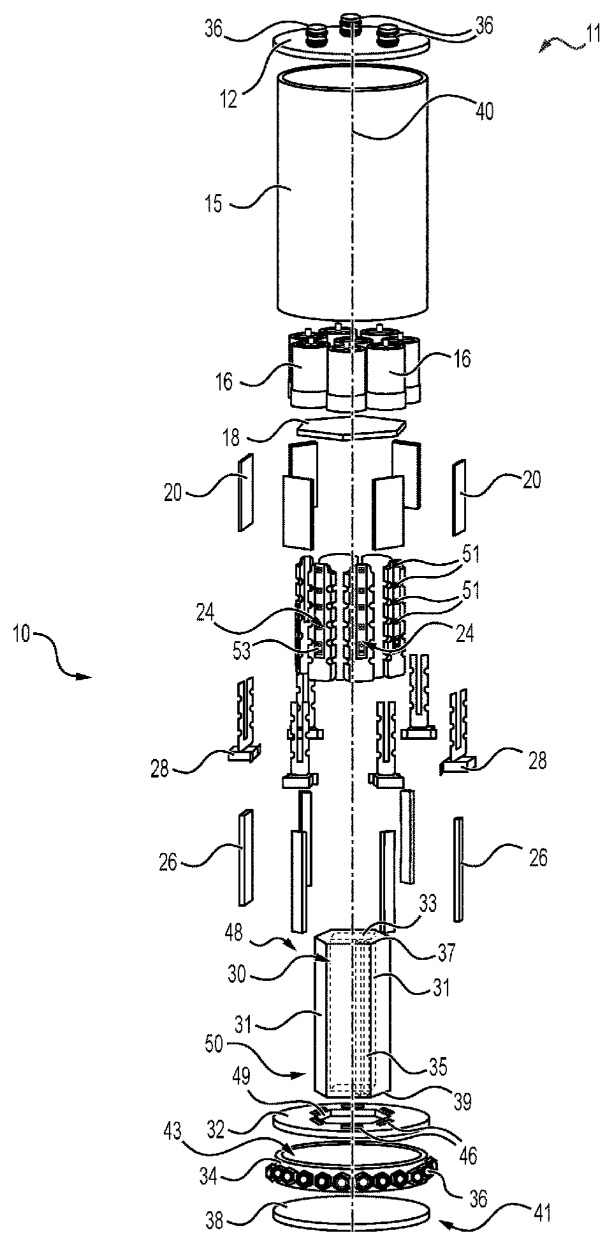
CPC ***H05K 7/209*** (2013.01); ***H02M 7/003*** (2013.01); ***H05K 7/20927*** (2013.01)

(57) **ABSTRACT**

A packaged power inverter including a cylindrical outer housing having a central longitudinal axis, a heatsink core located within the housing and having a longitudinal axis aligned with the longitudinal axis of the outer housing and a plurality of outer planar surface portions. The packaged power inverter further includes a plurality of electronic modules each being coupled to one of the plurality of planar surface portions. A plurality of AC bus bars are coupled to one of the plurality of planar surface portions. A plurality of capacitors and DC bus bars located within the outer housing.



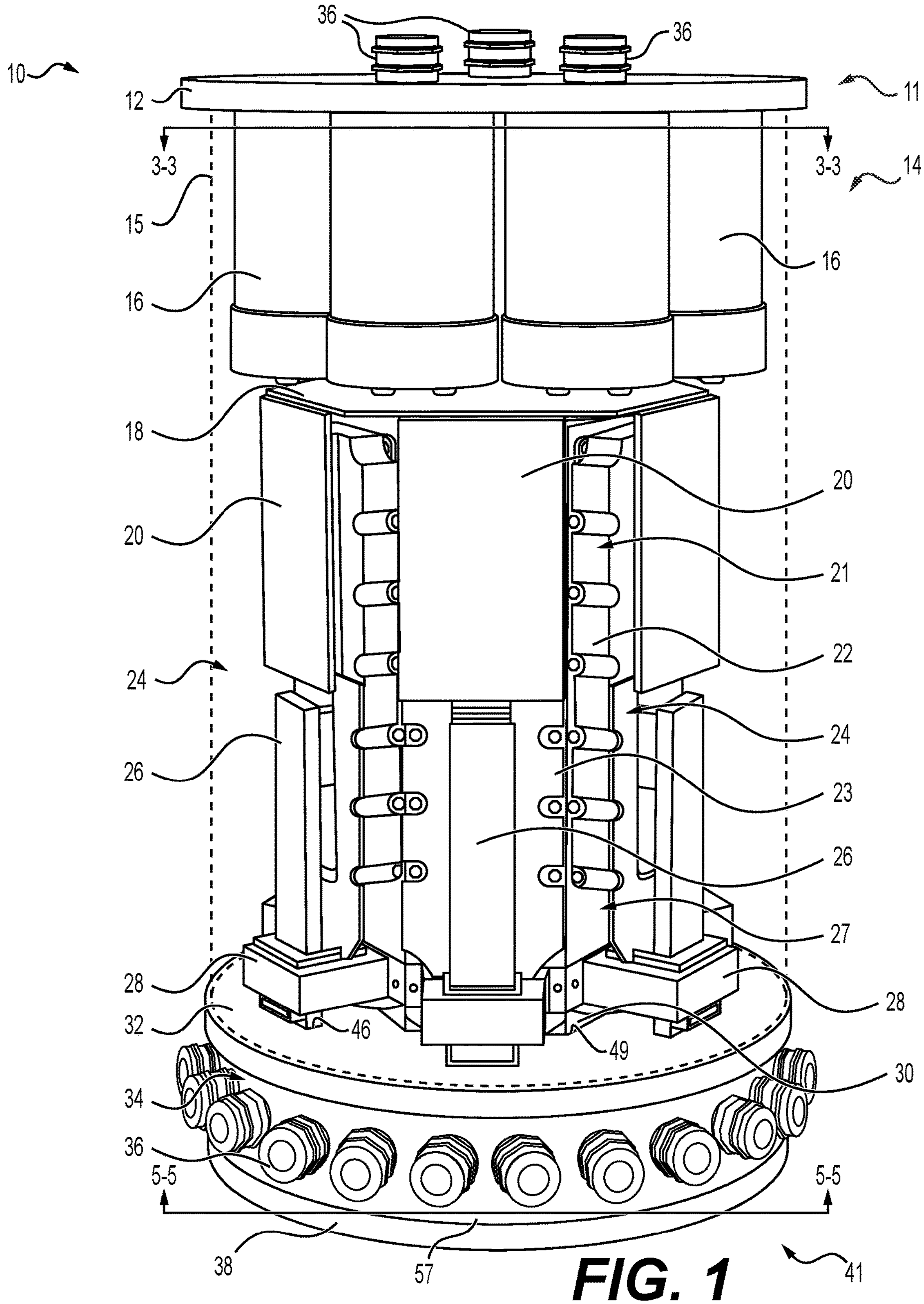

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FIG. 1

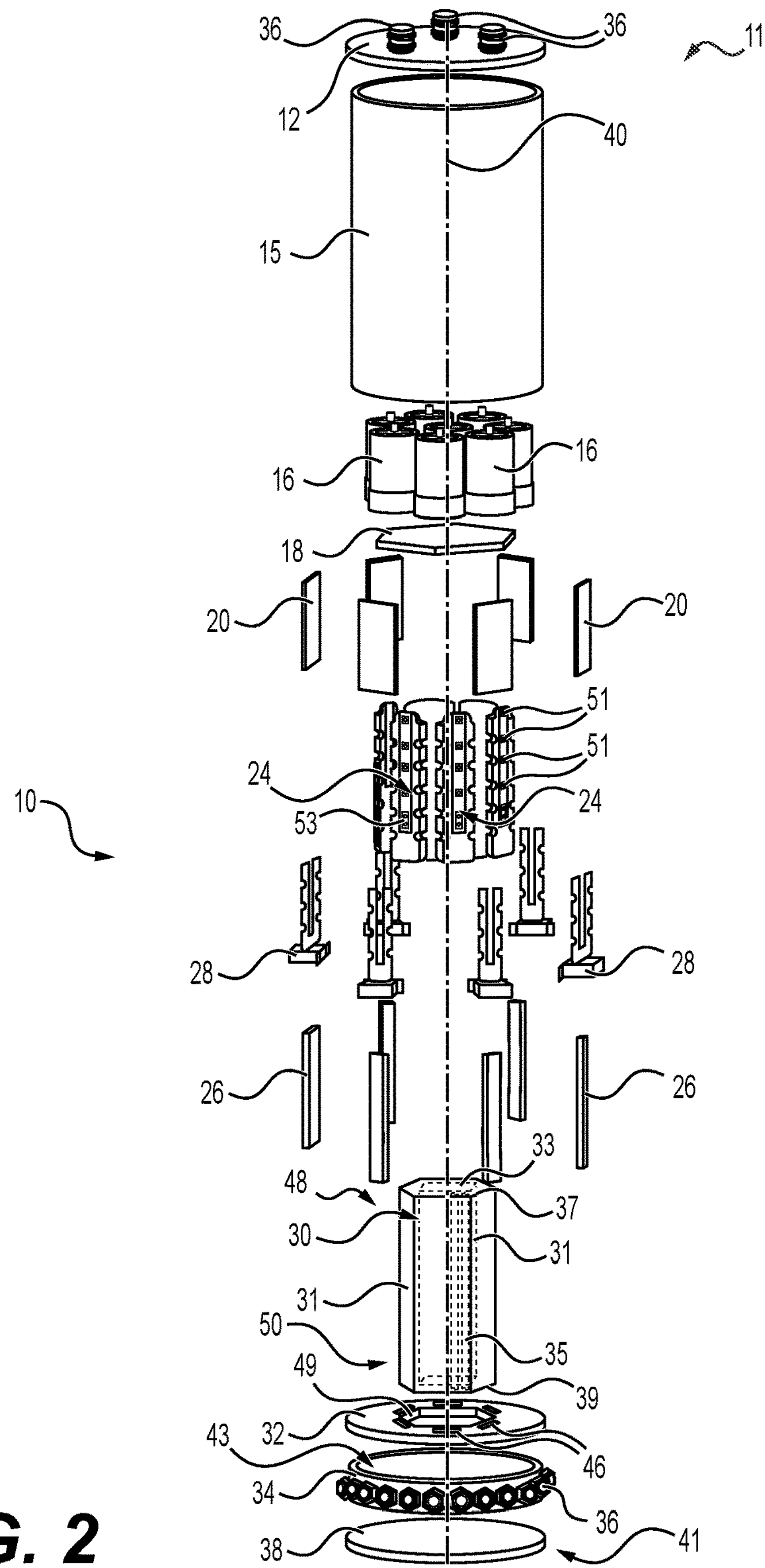
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FIG. 2

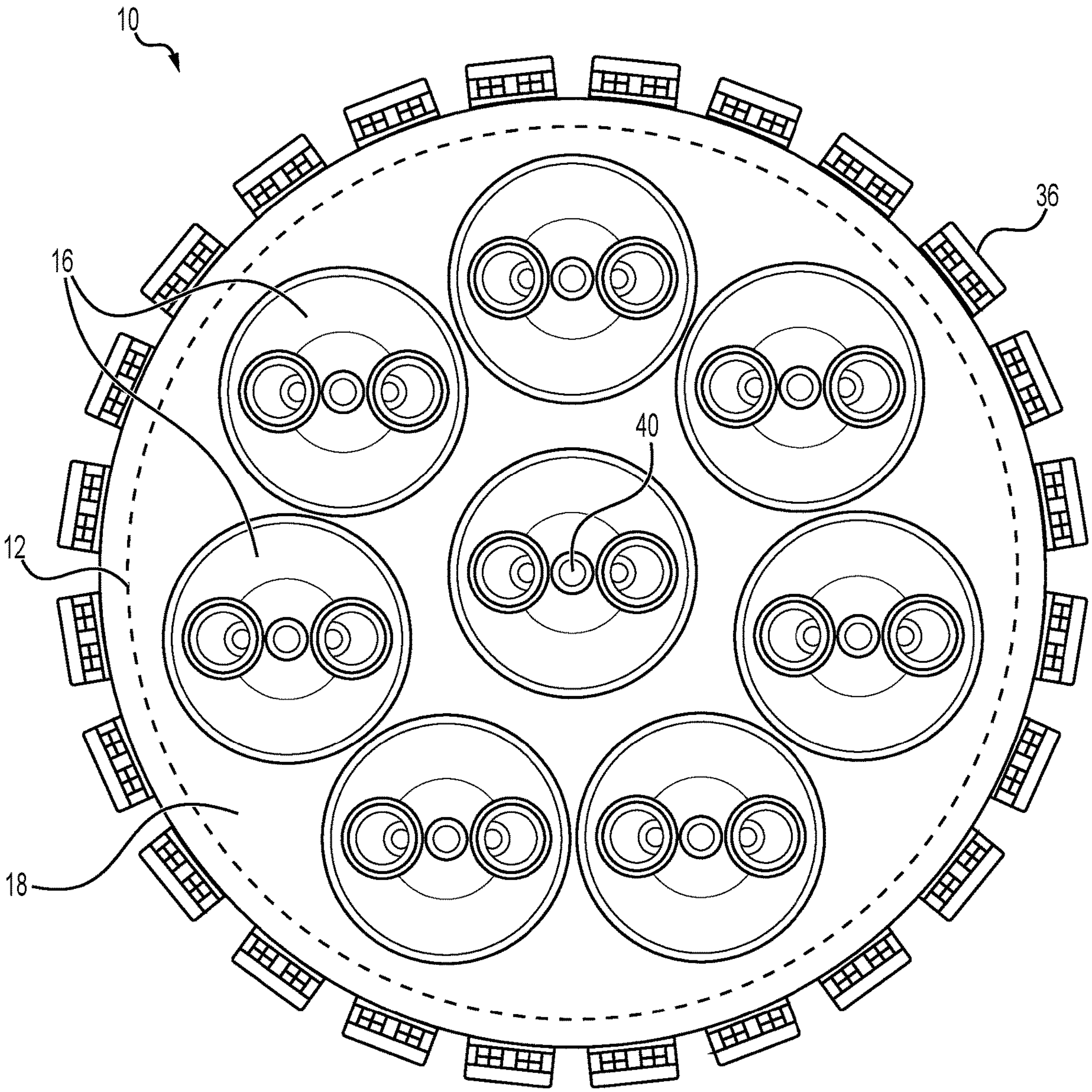


FIG. 3

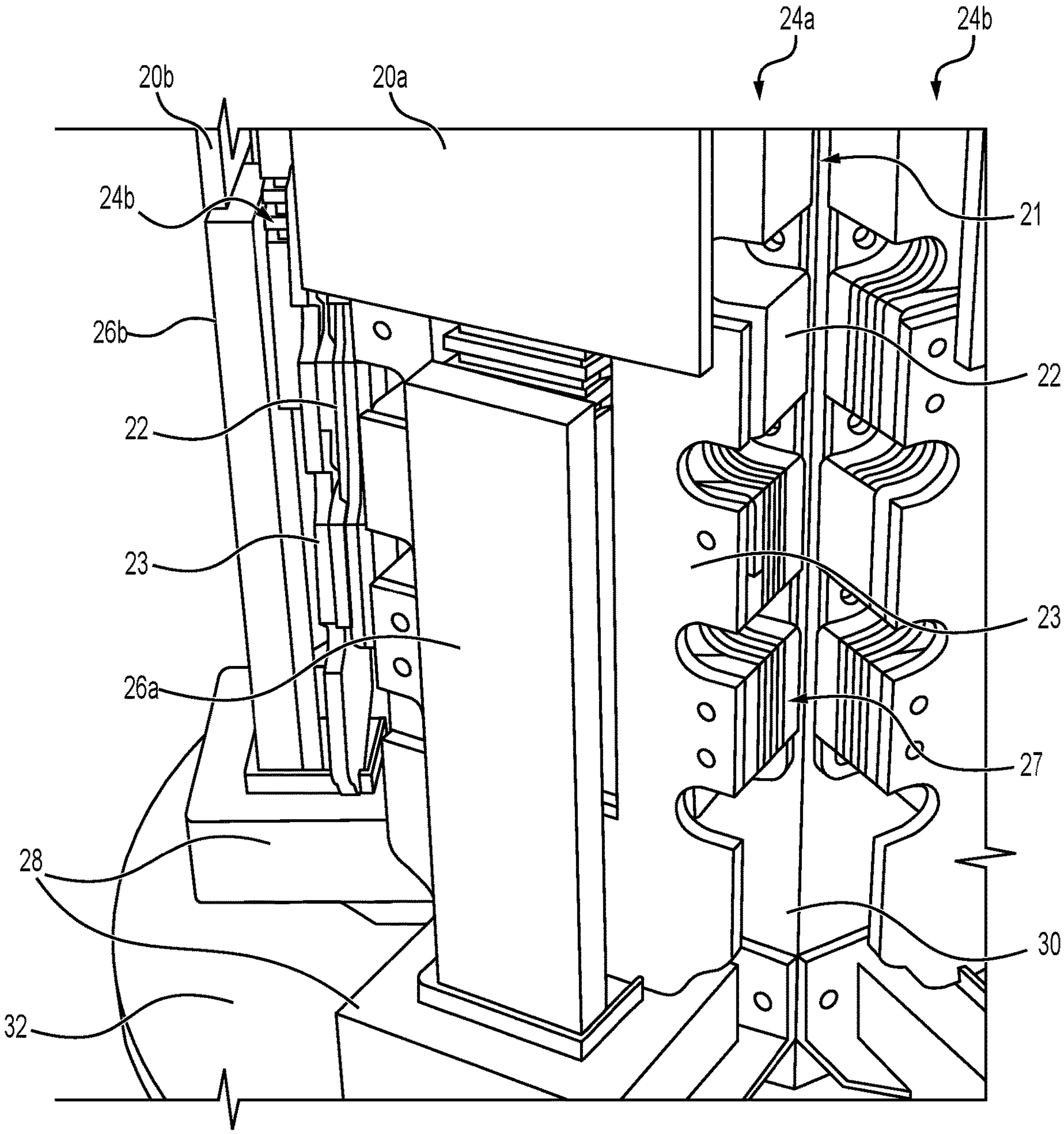


FIG. 4

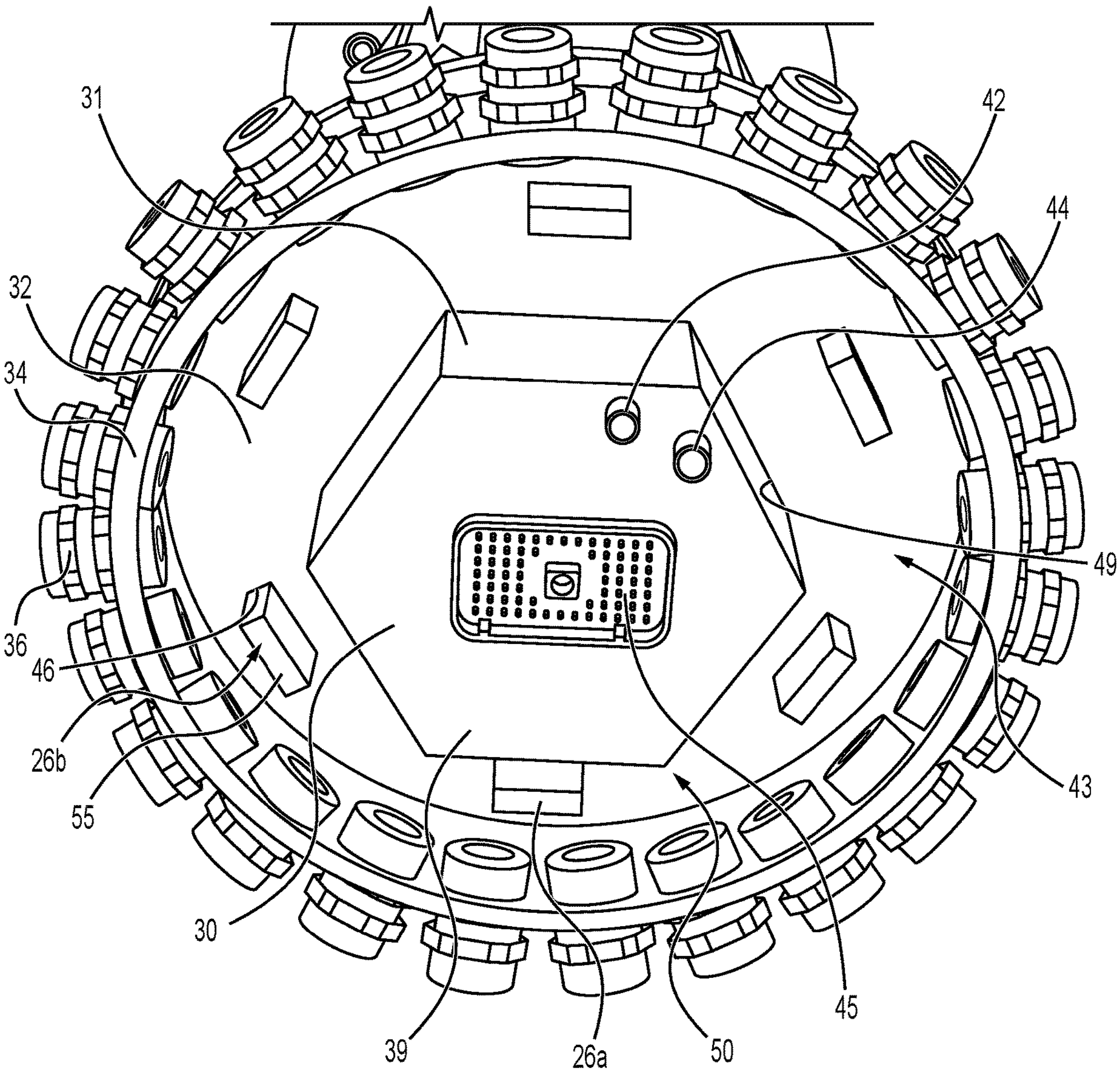
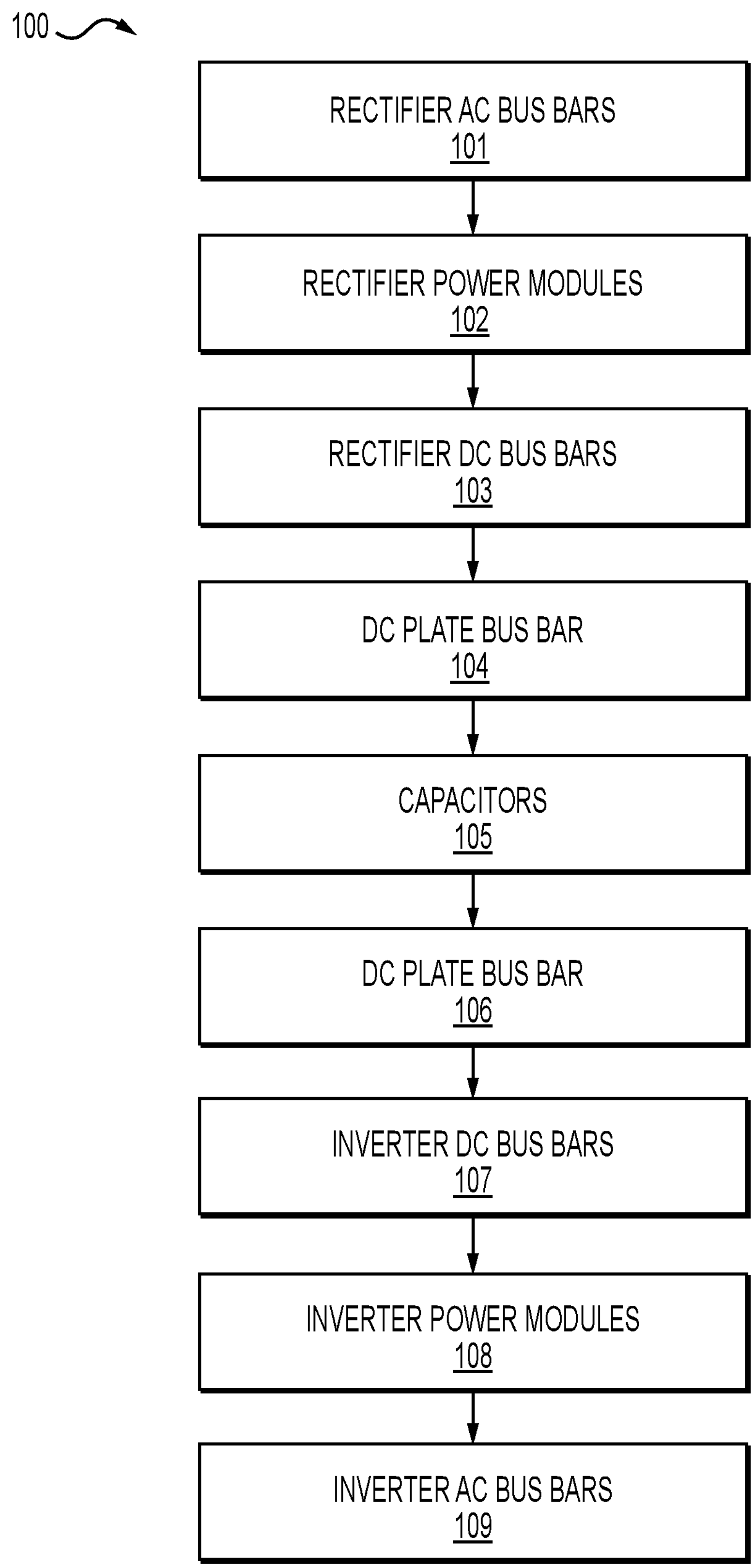


FIG. 5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RECTIFIER AC BUS BARS
101
RECTIFIER POWER MODULES
102
RECTIFIER DC BUS BARS
103
DC PLATE BUS BAR
104
CAPACITORS
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DC PLATE BUS BAR
106
INVERTER DC BUS BARS
107
INVERTER POWER MODULES
108
INVERTER AC BUS BARS
109

FIG. 6

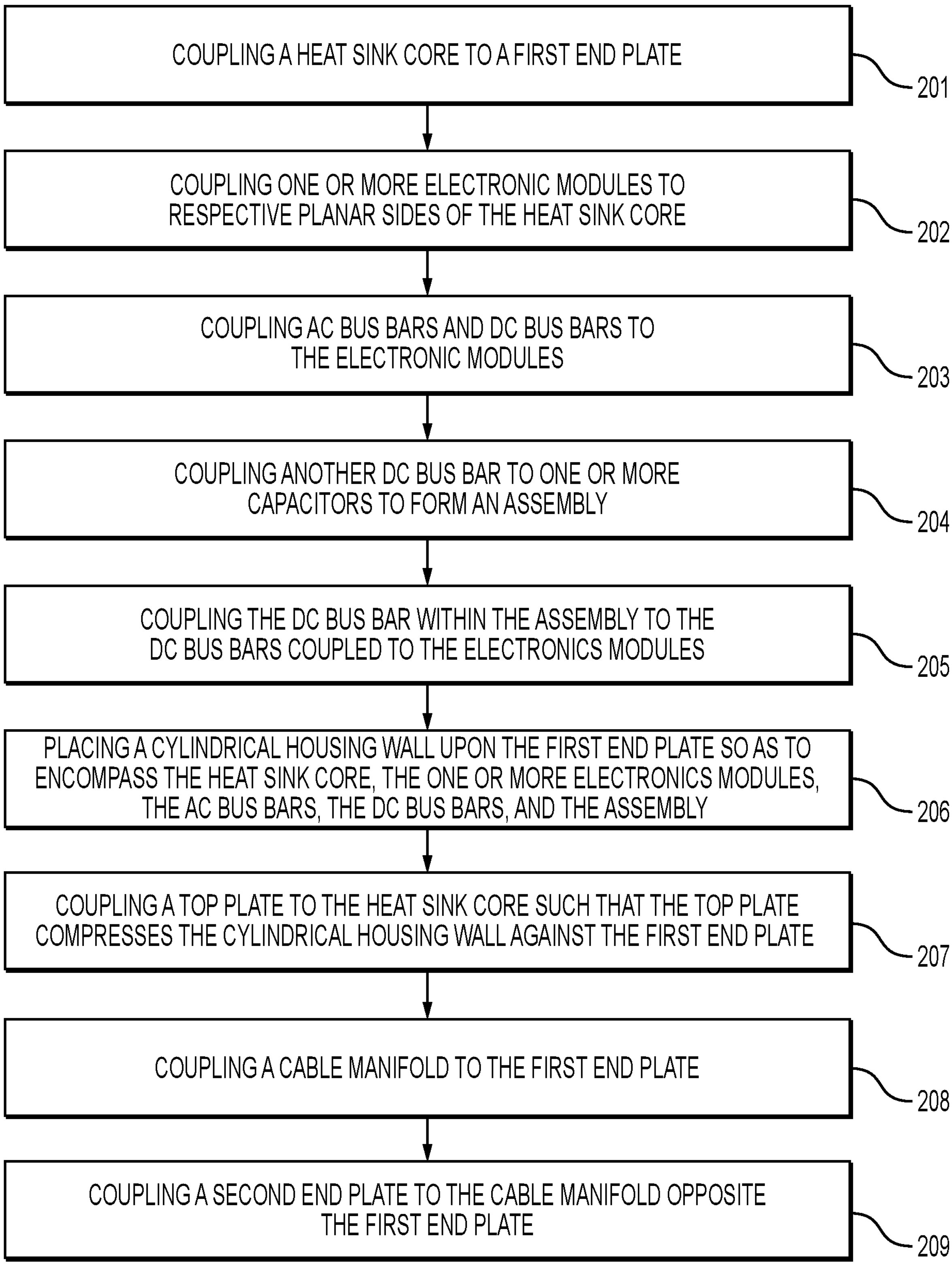
COUPLING A HEAT SINK CORE TO A FIRST END PLATE
201
COUPLING ONE OR MORE ELECTRONIC MODULES TO RESPECTIVE PLANAR SIDES OF THE HEAT SINK CORE
202
COUPLING AC BUS BARS AND DC BUS BARS TO THE ELECTRONIC MODULES
203
COUPLING ANOTHER DC BUS BAR TO ONE OR MORE CAPACITORS TO FORM AN ASSEMBLY
204
COUPLING THE DC BUS BAR WITHIN THE ASSEMBLY TO THE DC BUS BARS COUPLED TO THE ELECTRONICS MODULES
205
PLACING A CYLINDRICAL HOUSING WALL UPON THE FIRST END PLATE SO AS TO ENCOMPASS THE HEAT SINK CORE, THE ONE OR MORE ELECTRONICS MODULES, THE AC BUS BARS, THE DC BUS BARS, AND THE ASSEMBLY
206
COUPLING A TOP PLATE TO THE HEAT SINK CORE SUCH THAT THE TOP PLATE COMPRESSES THE CYLINDRICAL HOUSING WALL AGAINST THE FIRST END PLATE
207
COUPLING A CABLE MANIFOLD TO THE FIRST END PLATE
208
COUPLING A SECOND END PLATE TO THE CABLE MANIFOLD OPPOSITE THE FIRST END PLATE
209

FIG. 7

PACKAGED POWER INVERTER

TECHNICAL FIELD

[0001] The present disclosure relates generally to a power inverter, and more particularly, to a packaged power inverter.

BACKGROUND

[0002] A large driver of cost in power inverters systems is the packaging of the system. Often the packaging requires a complex and difficult assembly process requiring specialized parts. The packaging may also drive the layout of the internal components, which may lead to non-uniform power and heat distribution that may interfere with performance and make accessing the internal components difficult.

[0003] Commonly, power inverter system packaging is non-modular, which may limit a system's ability to readily combine with multiple different power systems, such as electric motors, power generators, and other packaged power inverters. The non-modular designs may also limit the scalability of power inverter systems by limiting access and preventing the internal components from being interchanged.

[0004] U.S. Pat. No. 6,501,653 B1 (the '653 reference) describes a multiphase converter which contains semiconductor power components and a capacitor on a support containing cooling devices. The components of the multiphase converter are arranged in a compact configuration, in which the support containing the cooling device is configured as a hollow body, the capacitor is insertable in its interior, and the semiconductor power components are arranged on its outer side, where the height of the hollow body corresponds substantially to the height of the necessary capacitor. For a three-phase converter, the hollow body may be in the shape of a hexagon on the outer side, so that an overall shape approximating a cylinder is created, and a cylindrical cover protects everything and makes a compact component available. The '653reference does not appreciate the need for variably sized capacitors, nor does the '653 reference recognize the use of an enclosure to secure an inner heatsink. The '653 is also silent as to sealed compartments that can accept a number of connections at a multitude of directions.

[0005] The modular packaged power inverter of the present disclosure may solve one or more of the problems set forth above and/or 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, the disclosure relates to a packaged power inverter including a cylindrical outer housing having a central longitudinal axis, and a heatsink core located within the housing and having a longitudinal axis aligned with the longitudinal axis of the outer housing and a plurality of outer planar surface portions. The packaged power inverter further includes a plurality of electronic modules, each being coupled to one of the plurality of planar surface portions. The packaged power inverter further includes a plurality of AC bus bars, each being coupled to one of the plurality of planar surface portions. The packaged power inverter further includes a plurality of capacitors located within the outer housing, and a plurality of DC bus bars located within the outer housing.

[0007] In another aspect, the disclosure described herein relates to a packaged power inverter, including a cylindrical outer housing having a central longitudinal axis, and a heatsink core located within the housing and having a longitudinal axis aligned with the longitudinal axis of the outer housing and a plurality of outer planar surface portions. The packaged power inverter further includes a plurality of electronic modules, each being coupled to one of the plurality of planar surface portions. The packaged power inverter further includes a plurality of AC bus bars, each associated with one of the plurality of electronic modules, and located radially outside a respective electronic module. The packaged power inverter further includes a plurality of capacitors located within the outer housing, a plurality of DC bus bars located within the outer housing, and a DC bus bar located axially between the heatsink core and the plurality of capacitors.

[0008] In another aspect, the techniques described herein relate to a method of assembling a packaged power inverter, the method including: coupling a heat sink core to a first endplate; coupling one or more electronic modules to respective planar sides of the heat sink core; coupling AC bus bars and DC bus bars to the electronic modules; coupling another DC bus bar to one or more capacitors to form an assembly; coupling the DC bus bar within the assembly to the DC bus bars coupled to the electronics modules; placing a cylindrical housing wall upon the first endplate so as to encompass the heat sink core, the one or more electronics modules, the AC bus bars, the DC bus bars, and the assembly; and coupling a top plate to the heat sink core such that the top plate compresses the cylindrical housing wall against the first endplate.

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 front perspective view of a packaged power inverter according to aspects of the disclosure.

[0011] FIG. **2** is an exploded view of the packaged power inverter of FIG. **1**.

[0012] FIG. **3** is a cross sectional view of the packaged power inverter of FIG. **1**.

[0013] FIG. **4** is a close up side view of the packaged power inverter of FIG. **1**.

[0014] FIG. **5** is a cross sectional view of the packaged power inverter of FIG. **1**

[0015] FIG. **6** provides a flowchart depicting current transfer through a packaged power inverter, according to aspects of the present disclosure.

[0016] FIG. **7** provides a flowchart depicting a method of assembling a packaged power inverter, according to aspects of the present disclosure

DETAILED DESCRIPTION

[0017] 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," "has," "having," "includes," "including," or other variations thereof, are intended to cover a non-exclusive inclusion such that a process, method, article, 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 process, method, article, or apparatus. In this disclosure, unless stated otherwise, relative terms, such as, for example, "about," "substantially," and "approximately" are used to indicate a possible variation of ±10% in the stated value.

[0018] FIG. **1** and FIG. **2** are a front perspective view and an exploded view, respectively, of a packaged power inverter **10**, according to an example embodiment. As will be explained in more detail below, components of the packaged power inverter **10** may transform an input alternating current (AC current) having an input waveform to an output AC current having an output waveform. Within the packaged power inverter **10**, the input AC current may be transformed to a direct current (DC current) by power electronic devices acting as power rectifiers before being transformed to the output AC current having a desired output waveform by power electronic components acting as power inverters. Although referenced as a power inverter, those in the art will understand that the packaged power inverter **10** may function as both an inverter and a rectifier.

[0019] Referring to FIG. **1** and FIG. **2**, the packaged power inverter **10**, forms a generally cylindrical shape including a central longitudinal axis **40** extending between a first, top end **11** and a second, bottom end **41**. The packaged power inverter **10** may further include a cylindrical outer housing **14**, a centrally-located heatsink core **30**, a plurality of electronic modules **24** coupled radially outside the heatsink core **30**, a plurality of AC bus bars **26** coupled radially outside the electronic modules **24**, and a plurality of DC bus bars, which may include vertical DC bus bars **20** also located radially outside the electronic modules and a horizontal DC bus bar **18** above the heatsink core **30**. The packaged power inverter **10** further includes a plurality of capacitors **16** above the horizontal DC bus bar **18**, and a cable manifold **34** located below the heatsink core **30**. As shown in FIGS. **1** and **2**, a plurality of similar components may additionally be disposed circumferentially about the central longitudinal axis **40** as well, and it is to be understood that the description of one component herein equally applies to the other similar components.

[0020] The cylindrical outer housing **14** may further comprise a cylindrical housing wall **15** (shown in dashed lines in FIG. **1**), a first, or top endplate **12** at the top end **11** of the packaged power inverter **10**, and a second, or bottom endplate **32** at the bottom end **41** of the packaged power inverter **10**. The top endplate **12** may be bolted to the heat sink core **30**, or attached in any other appropriate manner, so as to compress the cylindrical outer housing wall **15** onto the bottom endplate **32**. The top endplate **12** may be may optionally include one or more cable glands **36**. The cylindrical housing wall **15** may be made from a single Aluminum tube, and formed by an extrusion process. In other embodiments, the cylindrical housing wall **15** may be formed by a different process or a different material. The top endplate **12** and the bottom endplate **32** may also be made from aluminum, or another suitable material, and may be formed by any appropriate process.

[0021] The dimensions of the cylindrical housing wall **15** may vary based on the desired size or capacity of the packaged power inverter **10**. The size or capacity of the packaged power inverter **10** may dictate the size of the heatsink core **30**, as well as the number and size of the plurality of electronic modules **24**, the plurality of capacitors **16**, or other components of the packaged power inverter **10**. In embodiments shown in FIG. **1**. and FIG. **2**, the cylindrical housing wall **15** may be, for example, between **8** inches and **16** inches in outer diameter. In particular embodiments, the cylindrical housing wall **15** may be 8 inches in diameter, 12 inches in diameter, or 16 inches in diameter. In other embodiments, the housing wall **15** may have a different diameter. The length of the cylindrical housing wall **15** may be between 12 and 36 inches. In particular embodiments, the cylindrical housing wall **15** may be 12 inches in length or 24 inches in length. In other embodiments cylindrical housing wall **15** may have a different length. The cylindrical housing wall **15** may have a thickness between 1 millimeter and 10 millimeters. In particular embodiments, the cylindrical housing wall **15** may have a thickness of 6 millimeters. In other embodiments the cylindrical housing wall **15** may have different wall thickness values.

[0022] The heatsink core **30** may have a bottom end **50** connected to the bottom endplate **32** and a top end **48** opposite the bottom end **50**. The bottom end **50** may comprise a bottom face **39**, and the top end **48** may comprise a top face **37**. The bottom face **39** and the top face **37** may be oriented normal to a longitudinal axis aligned with the central longitudinal axis **40**. As best shown in FIG. **5**, the bottom end **50** may extend beyond the bottom endplate **32** in a direction opposite the top end **48** through an opening **49** in bottom plate **32**. In other embodiments, the bottom face **39** may be aligned or flush with the bottom plate **32**. The heatsink core **30** may be rigidly attached to endplate **32** using bolts, screws, pins, or other fasteners. In other embodiments, the heatsink core **30** may be welded or glued to the bottom endplate **32**. The heatsink core **30** may be a monolithic (i.e., single) component formed of extruded aluminum. In other embodiments, the heatsink may be formed by a different process or a different material, and may be made from multiple pieces.

[0023] As best seen in FIG. **2**, the heatsink core **30** may have a length extending along the central longitudinal axis **40** and have a horizontal cross-section (normal to the central longitudinal axis **40**) forming a hexagon (six straight sides). Outer planar surface portions, or outer planar sides **31** extend along the length between the bottom face **39** and the top face **37**, and may be radially oriented about a longitudinal axis aligned with the central longitudinal axis **40**. Thus, as best shown in FIG. **2**, heatsink core **30** forms six planar sides **31**. In further embodiments, the heatsink core **30** may have a triangular cross-section forming three planar sides **31**, an octagonal cross-section forming eight planar sides **31**, or an enneagonal cross-section forming nine planar sides **31**. In other embodiments, the heatsink core **30** may have a different number of planar sides **31** that form a different shape.

[0024] The heatsink core **30** may be hollow, so as to form a central opening **33** radially interior to the planar sides **31**. The central opening **33** in heatsink core **30** may extend along the central longitudinal axis **40** and may extend completely through heatsink core **30**. A partial central opening **33**, not extending completely through the heatsink core **30** is also contemplated. The walls of the heatsink core **30** may include internal longitudinal passages **35** circumferentially around heatsink core **30** (only two shown in dashed lines in FIG. **2**) for conveying cooling fluid, such as liquid coolant in the form of water. Control electronics, such as controllers, sensors, and wiring for controlling and communicating with the electronics modules **24** may also be placed within the central opening **33**.

[0025] The electronics modules **24**, AC bus bars **26**, and vertical DC bus bars **20** may be symmetrically organized about the heat sink core **30** and aligned with a respective one of the planar sides **31**. The electronic modules **24** may comprise insulated-gate bipolar transistor modules (IGBT modules) **22** and a gate drivers **23**. The IGBT modules **22** may be directly coupled to the one of the plurality of planar sides **31** of the heatsink core **30** such that IGBT modules contact the planar sides **31**, and the gate drivers **23** may be coupled to the IGBT modules **22** at a radially outer surface of the IGBT modules **22**. In some embodiments, the IGBT modules **22** may be coupled to the planar sides **31** of the heatsink core **30** using bolts (as shown), screws, pins or other fasteners. In other embodiments, the IGBT modules **22** may be welded or glued to the planar sides **31** of the heatsink core **30**. In further embodiments, the IGBT modules **22** may be coupled to planar sides **31** of the heatsink core **30** using another suitable means, and the IGBT modules **22** may be indirectly coupled to the planar sides **31** such that there is a gap or other component between the IGBT modules **22** and the planar sides **31**.

[0026] IGBT modules **22** may have a first set of terminals, or AC terminals **53**, located on the radially outer surface at a first, AC end **27** of the electronic modules **24** nearest the bottom end **41** of the of the packaged power inverter **10**, and a second set of terminals, or DC terminals **51**, located on the radially outer surface at a second DC end **21** of the electronic modules **24** nearest the top end **11** of the packaged power inverter **10**.

[0027] Each of the plurality of AC bus bars **26** may be rectangular in shape, with a lengthwise dimension extending parallel to the central longitudinal axis **40** of the packaged power inverter **10**. The AC bus bars **26** may overlap and directly couple to a radially outer portion of the AC end **27** of the electronic modules **24** so as to engage the AC terminals **53**, and may extend through holes **46** in the bottom plate **32** of the cylindrical housing **14**. As shown in FIG. **5**, a bottom end portion **55** of the AC bus bars extend into the cable manifold **34**.

[0028] Each of the plurality of the vertical DC bus bars **20** may be rectangular in shape with a lengthwise dimension extending parallel to the central longitudinal axis **40** of the packaged power inverter **10**. The vertical DC bus bars **20** may overlap and couple to a radially outer portion of the DC end **21** of the electronic modules **24** and extend towards the top endplate **12** until reaching and connecting to the horizontal DC bus bar **18**.

[0029] The horizontal DC bus bar **18** may be a plate within the cylindrical outer housing **14** connected to the vertical DC bus bars **20**, and oriented normal to the central longitudinal axis **40**. The horizontal DC bus bar **18** may be flat or plate-shaped and have a geometric outer shape, such as a circular shape or a hexagon shape. In some embodiments, the horizontal DC bus bar may be shaped so as to match the number of sides of the heat sink **30**. For example, as shown in FIGS. **1-2**, both the horizontal DC bus bar **18** and the heat sink core **30** may be hexagonal to match the number of sides of the heatsink core **30**. The horizontal DC bus bar **18** may be electrically coupled to the vertical DC bus bars **20** via, for example, bolts, clamps, or welds. In some embodiments, conductive tape may be used to electrically connect the horizontal DC bus bar **18** to the vertical DC bus bars **20**. In particular embodiments, the horizontal DC bus bar **18** and the vertical DC bus bar **20** may be integrally formed. Additional horizontal bus bars **18** may be added so as to provide parallel connections to the positive and negative terminals of the capacitors **16**.

[0030] The plurality of capacitors **16** are located axially between the horizontal DC bus bar **18** and the top endplate **12**, such that the horizontal DC bus bar **18** may axially separate the heatsink core **30** from the plurality of capacitors **16**. The capacitors **16** may be cylindrical film capacitors with a longitudinal axis oriented parallel to the central longitudinal axis **40**. In other embodiments, different shapes and types of capacitors may be used. The top endplate **12** may fix the capacitors **16** on to the horizontal DC bus bar **18** so as to restrain the motion of the capacitors **16** along the central longitudinal axis **40**. The capacitors **16** may be coupled to the horizontal DC bus bar **18** by screwing the terminals of the capacitors **16** into corresponding holes (not shown) within the horizontal DC bus bar **18**, or in any other appropriate manner.

[0031] The cable manifold **34** may include an outer cylindrical wall **57** extending from the bottom endplate **32** in a direction away from the heatsink core **30**. The cable manifold **34** may further comprise a plurality of cable glands **36** circumferentially disposed about all or a portion of the outer cylindrical wall **57**. A third endplate, or manifold endplate **38**, may be attached to an end of the cable manifold **34** opposite the bottom endplate **32**. The manifold endplate **38** may be circular in shape and oriented normal to the central longitudinal axis **40**. The manifold endplate **38** may be attached to the bottom of the cable manifold **34** using bolts, screws, threading, welding, or another attachment means.

[0032] A cylindrical cable chamber **43** is formed within the cable manifold **34** between the bottom endplate **32** and the manifold endplate **38**. As noted above, and as best shown in FIG. **5**, bottom end **50** of the heatsink core **30** and bottom end portions **55** of the AC bus bars **26** extending through the bottom endplate **32**. Inlets **42** and outlets **44** to the internal coolant passages **35** of the heatsink core **30** may also extend into the cable chamber **43** from the heat sink core **30**.

[0033] A cable manifold **34** may additionally or alternatively be placed on the top end **11** of the packaged power inverter **10**, and attached to the top endplate **12**. In such embodiments, additional bus bars may be added that connect to horizontal DC bus bar **18** and extend into the cable manifold **34**. In other embodiments, the additional bus bars may connect directly to the capacitors **16**.

[0034] FIG. **3** is a cross sectional view of a packaged power inverter **10** at section **3-3** of FIG. **1**, according to an example embodiment. The capacitors **16** may be positioned axially above the heatsink core **30** and between the top endplate **12** and the horizontal DC bus bar **18**. Accordingly, the horizontal DC bus bar **18** axially separates the heatsink core **30** from the plurality of capacitors **16**. Further, capacitors **16** may be organized radially symmetrically about the central longitudinal axis **40** (extending out of the page in FIG. **3**). The capacitors **16** may be further organized in radial layers, such that each radially outer layer encompasses radially inner layers. For example, as shown in FIG. **3**, one capacitor **16** forms a radially inner layer, and six capacitors **16** form a radially outer layer. The capacitors **16** may have terminals that connect the capacitors **16** to the horizontal DC bus bar **18** and allow electricity to flow between the horizontal DC bus bar **18** and the capacitors **16**.

[0035] FIG. **4** is a close up side view of a packaged power inverter **10**, according to an example embodiment. The gate drivers **23** may be form a "U" shape around the AC end **27** of the electronic modules **24**, and connect to both the AC end **27** and the DC end **21** of the electronic modules **24**. The gate drivers **23** control the flow of electricity through the IGBT modules **22** according to an input from the external controller (not show). In other embodiments, the gate drivers **23** may have a different shape, and may connect to the electronic modules **24** at different positions.

[0036] Depending on the inputs from the controller, the electronic modules **24** function as either power rectifiers or power inverters. In the example embodiment shown in FIG. **4**, half of the electronic modules **24** of packaged power inverter **10** may function as power rectifiers (rectifier electronic modules **24***a*), and the other half of the electronic modules **24** of packaged power inverter **10** may function as power inverters (inverter electronic modules **24***b*). In such embodiments, the rectifier electronic modules **24***a* may be on every other planar side **31** of the heat sink **30**, and the inverter electronic modules **24***b* may be on the remaining planar sides **31**. In other embodiments, different numbers and sequences of rectifier electronic modules **24***a* and inverter electronic modules **24***b* may be used.

[0037] The AC bus bars **26** may transfer AC current to or from the AC end **27** of the electronic modules **24** depending on the function of the electronic modules **24**, as determined by the controller and gate drivers **23**. The AC bus bars **26** attached to rectifier electronic modules **24***a* may be referred to as rectifier AC bus bars **26***a,* and AC bus bars attached to inverter electronic modules **24***b* may be referred to as inverter AC bus bars **26***b.* A current sensor **28** may be attached to or encircle the AC bus bars **26** longitudinally between the electronic modules **24** and the bottom endplate **32**, and may measure the amount of current passing through the AC bus bars **26** and communicate that information to the controller.

[0038] The vertical DC bus bars **20** may transfer DC current to or from the DC end **21** of the electronic modules **24** and the horizontal DC bus bar **18** depending on the function of the electronic modules **24** as determined by the controller and gate drivers **23**. The vertical DC bus bars **20** attached to the rectifier electronic modules **24***a* may be referred to as rectifier vertical DC bus bars **20***a,* and the vertical DC bus bars attached to the inverter electronic modules **24***b* may be referred to as inverter vertical DC bus bars **20***b.*

[0039] FIG. **5** is a cross sectional view of a packaged power inverter **10** at section **5-5** of FIG. **1**, according to an example embodiment. Within the cylindrical cable chamber **43**, a control port **45** may be attached to the bottom face **39** of the heat sink **30**. The control port **45** may couple the external controller to the electronics of packaged power inverter **10** (e.g., electronic modules **24** and current sensors **28**). For example, control port may be connected to the electronic modules **24** and current sensor **28** by wires running through the central opening **33** of the heatsink core **30** and exiting through the planar sides **31** of the heatsink core. The control port **45** may also be connected to control electronics within the central opening **33** of the heatsink core **30**. In example embodiments, the control port **45** may be bolted, screwed, welded, glued, or otherwise attached to the bottom face **39**. The control port may be a **70** pin connector, or any other suitable port.

[0040] External power components may be connected to the packaged inverter **10** by inserting cables (not shown) through the cable glands **36**. For example, a controller cable (not shown) can extend through a cable gland **36** and connect to control port **45**. Further, power cables (not shown) may extend through cable glands **36** and connect to the bottom end portions **55** of AC bus bars **26** within the cylindrical cable chamber **43**. A first set of power cables or wires may connect an input source of AC current to the rectifier AC bus bars **26***a*. A second set of wires may connect a load to the inverter AC bus bars **26***b*. The plurality of cable glands **36** allows cables to be inserted into the cable manifold **34** at a multitude of desired trajectories. In some embodiments, the external components connected to the packaged power inverter may connect to every cable gland **36** and AC bus bar **26**. In other embodiments, the external components may connect to a subset of the cable glands **36** and the AC bus bars **26**.

[0041] In some embodiments, an AC source, such as a generator (not shown), may be electrically connected to the packaged power inverter **10** through the cable glands **36** on the cable manifold **34**. The AC source may be electrically connected to some or all of the rectifier AC bus bars **26***a*. An AC load, such as an electric motor, may be connected to one or more of the inverter AC bus bars **26***b* through the cable glands **36** in the cable manifold **34**. In further embodiments, a DC source or load, such as a battery, may be electrically connected to the packaged power inverter **10**. In some embodiments, the DC source or load may be electrically connected to one or more of the vertical DC bus bars **20** or the horizontal DC bus bar **18** using cables or additional bus bars. The DC source or load may be electrically connected to the packaged power inverter **10** through the cable manifold **34** at the bottom end **41**, a cable manifold at the top end **11**, or cable glands **36** on the top endplate **12**. In some embodiments, an AC source and a DC load may be connected to the packaged power inverter. In other embodiments, a DC source and an AC load may be electrically connected to the packaged power inverter **10**. The sources and loads may be coupled to the packaged power inverter **10**, such that they are mounted on either end **11**, **41** of the packaged power inverter **10** along the central longitudinal axis **40**.

INDUSTRIAL APPLICABILITY

[0042] The disclosed aspects of the packaged power inverter **10** of the present disclosure may be used to isolate and/or provide desirable AC current to a load. The packaged power inverter **10** provides a system by which an input AC voltage or current having an input frequency is transformed into a desired output AC voltages or current having a desired output frequency for use in an electrically powered device.

[0043] The modular design may also allow components to be easily accessed and swapped. For example, the capacitance may be increase by simply switching to a longer cylindrical outer housing **14** and switching to longer capacitors **16**. The internal components are scalable such that a variable number of internal components may be used within a given cylindrical outer housing **14**. Moreover, the packaged power inverter **10** provides flexible mounting options, such that it may be joined with other packaged power inventers or attached to an electric motor or generator. The symmetrical layout of the packaged power inverter **10** aides in distributing the thermal gradient and provides electrical symmetry, which may aide in dynamic current sharing and loss distribution.

[0044] FIG. **6** provides a flowchart **100** depicting the flow of power through the system, according to an example embodiment. Although those skilled in the art will understand AC current to have a bi-directional flow, for explanatory purposes, AC currents will be described as moving in a single direction from input to output. In step **101**, an input AC current enters the rectifier AC bus bars **26***a* from a power cable or wire extending through the cable manifold **34** from an outside power source. In step **102**, the input AC current transfers from the rectifier AC bus bars **26***a* to the rectifier electronic modules **24***a,* wherein the input AC current is transformed into a DC current that may have ripples. In step **103**, the DC current with ripples exits the rectifier electronic modules **24***a* and enters the rectifier vertical DC bus bars **20***a.* In step **104**, the current transfers from the rectifier vertical DC bus bars **20***a* to the horizontal DC bus bar **18**. From the horizontal DC bus bars **18**, a portion of the current may enter the capacitors **16** at step **105**. The capacitors **16** provide a stiff DC source for the inverter or rectifier operations. At step **107**, a stiff DC current is transferred to the inverter vertical DC bus bars **20***b.* At step **108**, the stiff DC current enters the inverter electronic modules **24***b,* wherein the smoothed DC current is transformed into an output AC current having a desired waveform. At step **109**, the output AC current is transferred to the inverter AC bus bars **26***b,* which are connected to output cables or wires in cable manifold **34** that carry the output AC current to the load.

[0045] FIG. **7** is a flowchart depicting an example method for assembling the packaged power inverter **10**. At step **201**, the heat sink core **30** may be coupled to the bottom endplate **32**. At step **202**, the electronic modules **24** may be coupled to the respective planar sides **31** of the heat sink core **30**. At step **203**, the AC bus bars **26** and vertical DC bus bars **20** are coupled to the electronic modules **24**. At step **204**, the horizontal DC bus bar **18** is coupled to one or more capacitors **16** to form an assembly. At step **205**, the horizontal DC bus bar **18** within the assembly is coupled to the vertical DC bus bars **20** coupled to the electronics modules **24**. Additional supports may also be added between the top face **37** of the heat sink core **30** and the horizontal DC bus bar **18** within the assembly. At step **206**, the cylindrical housing wall **15** is placed upon the bottom endplate **32** so as to encompass the heat sink core **30**, the one or more electronics modules **24**, the AC bus bars, the vertical DC bus bars **20**, and the assembly. O-rings may be placed between the cylindrical housing wall **15** and the bottom endplate **32** to provide a seal between the two. At step **207** the top endplate **12** may be coupled to the top face **37** of the heat sink core **30**, for example, by using a bolt extending between the two through gaps and passages within the capacitors **16** and horizontal DC bus bar **18**. The coupling of the top endplate **12** to the heat sink core **30** may compresses the top endplate **12** against the cylindrical housing wall **15**, securing the cylindrical housing wall **15** against the bottom endplate **32**. In some embodiments, as shown at step **208**, the cable manifold **34** may then be coupled to the bottom endplate **32**, and then, as shown in step **209**, the cable manifold endplate **38** may be coupled to the cable manifold opposite the bottom endplate **32**.

[0046] The packaged power inverter **10** may provide a simplified and scalable packaging means for power inverters. For example, the capacitance of the packaged power inverter **10** may be increased by replacing a first set of capacitors **16** with a second set of longer capacitors **16**, and replacing the cylindrical outer housing **15** with a longer cylindrical outer housing **15**. The modular design also allows for the packaged power inverter to be easily integrated with a similarly-shaped electric motor, as well as an electric generator. Moreover, multiple packaged power inverters **10** may be stacked end to end in order to transform the power produced by a motor and stored by a generator. In particular embodiments, multiple heat sink cores **30** may be joined to a shared capacitor assembly.

[0047] The packaged power inverter **10** may also provide desirable performance characteristics and operational aspects. For example, the geometric shape of the heat sink core **30** combined with the geometric arrangement of the electronic modules **24** may assist in providing desirable uniform power density. The geometric shape combined with the placement of the electronic modules **24** on a radially outer surface of the heat sink core **30** may aid in evenly distributing thermal energy while maintaining electrical symmetry and a compact packaging. The placement of the capacitors **16** above the heatsink may allow for a variety of size, types, and arrangements of capacitors **16**, and may allow the capacitors **16** to be easily accessed for repairs or replacement. Further, the packaged power inverter **10** allows for a sealed cable manifold **34** that can accommodate cable connections in a multitude of directions.

[0048] It will be apparent to those skilled in the art that various modifications and variations can be made to the disclosed system without departing from the scope of the disclosure. Other embodiments of the system will be apparent to those skilled in the art from consideration of the specification and practice of the system 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.

What is claimed is:

1. A packaged power inverter, comprising:
- a cylindrical outer housing having a central longitudinal axis;
- a heatsink core located within the housing and having a longitudinal axis aligned with the longitudinal axis of the outer housing, the heatsink core including a plurality of outer planar surface portions;
- a plurality of electronic modules, each being coupled to one of the plurality of planar surface portions;
- a plurality of AC bus bars, each being coupled to one of the plurality of planar surface portions;
- a plurality of capacitors located within the outer housing; and
- a plurality of DC bus bars located within the outer housing.

2. The packaged power inverter of claim **1**, wherein the capacitors are spaced axially from the heatsink core.

3. The packaged power inverter of claim **2**, wherein at least one of the DC bus bars is plate-shaped and located axially between the heatsink core and the plurality of capacitors.

4. The packaged power inverter of claim **1**, wherein the plurality of electronic modules, the plurality of AC bus bars, and the plurality of DC bus bars are symmetrically organized about the heatsink core and aligned with a respective one of the plurality of planar surface portions.

5. The packaged power inverter of claim **1**, further including a cable manifold having a portion that is axially spaced from the heatsink core.

6. The packaged power inverter of claim **5**, wherein the cable manifold forms a cylindrical cable chamber between a first endplate and a second, manifold endplate opposite the first endplate, and a plurality of cable glands are radially orientated about an outer wall of the cylindrical cable chamber.

7. The packaged power inverter of claim **6**, wherein the plurality of AC bus bars extend through openings in the first endplate and into the cylindrical cable chamber.

8. The packaged power inverter of claim **1**, wherein the heatsink core is formed of extruded aluminum and includes coolant passages.

9. The packaged power inverter of claim **1**, wherein control electronics are located within a central opening in the heatsink core.

10. The packaged power inverter of claim **1**, wherein the planar surface portions form one of a octagon, hexagon, or triangle outer shape of the heatsink core.

11. The packaged power inverter of claim **1**, wherein the electronic modules are directly coupled to the plurality of planar surface portions of the heatsink core.

12. The packaged power inverter of claim **1**, wherein the plurality of AC bars are directly coupled to a radially outer surface of a corresponding electronic module, and the electronic modules include an insulated-gate bipolar transistor (IGBT) module and a gate driver.

13. The packaged power inverter of claim **1**, wherein the capacitors are located axially between an endplate of the cylindrical outer housing, and a DC bus bar.

14. The packaged power inverter of claim **1**, wherein a cylindrical housing wall of the cylindrical outer housing is a single aluminum tube.

15. The packaged power inverter of claim **1**, further including a current sensor attached to the AC bus bars.

16. A packaged power inverter, comprising:

a cylindrical outer housing having a central longitudinal axis;

a heatsink core located within the housing and having a longitudinal axis aligned with the longitudinal axis of the outer housing, the heatsink core including a plurality of outer planar surface portions;

a plurality of electronic modules, each being coupled to one of the plurality of planar surface portions;

a plurality of AC bus bars, each associated with one of the plurality of electronic modules, and located radially outside a respective electronic module;

a plurality of capacitors located within the outer housing;

a plurality of DC bus bars located within the outer housing; and

a DC bus bar located axially between the heatsink core and the plurality of capacitors.

17. The packaged power inverter of claim **16**, further including a plurality of DC bus bars, each associated with one of the plurality of electronic modules, and located radially outside a respective electronic module.

18. The packaged power inverter of claim **16**, wherein the capacitors are spaced axially from the heatsink core.

19. A method of assembling a packaged power inverter, the method comprising:

coupling a heat sink core to a first endplate;

coupling one or more electronic modules to respective planar sides of the heat sink core;

coupling AC bus bars and DC bus bars to the electronic modules;

coupling another DC bus bar to one or more capacitors to form an assembly;

coupling the DC bus bar within the assembly to the DC bus bars coupled to the electronics modules;

placing a cylindrical housing wall upon the first endplate so as to encompass the heat sink core, the one or more electronics modules, the AC bus bars, the DC bus bars, and the assembly; and

coupling a top plate to the heat sink core such that the top plate compresses the cylindrical housing wall against the first endplate.

20. The method of assembling a packaged power inverter of claim **19**, the method further comprising:

coupling a cable manifold to the first endplate, and

coupling a second endplate to the cable manifold opposite the first endplate.

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