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POWER CONVERSION DEVICE

Abstract

A power conversion device includes a power conversion unit that converts three phase alternating-current power supplied from a three phase alternating-current power source into direct-current power, a first busbar connected to a first phase terminal of the power conversion unit and provided to an insulating substrate, a second busbar connected to second phase terminal of the power conversion unit and provided to the insulating substrate, and a third busbar connected to third phase terminal of the power conversion unit and provided to the insulating substrate, a first insulating layer is positioned on the second busbar, and the first busbar and the third busbar are positioned on the first insulating layer.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS
[0001] This application is based upon and claims the benefit of priority from Japanese Patent Application No. 2024-017561 filed on Feb. 8, 2024, the contents of which are incorporated herein by reference.
BACKGROUND OF THE INVENTION
Field of the Invention
[0002] The present disclosure relates to a power conversion device.
Description of the Related Art
[0003] In recent years, efforts toward realization of low-carbon or decarbonized society have been activated, and research and development have been conducted on power conversion devices for reducing CO.sub.2 emission and improving energy efficiencies also in moving objects including aircrafts.
[0004] JP 2021-129406 A discloses a power conversion device interposed between a battery and an alternating-current motor. The power conversion unit converts the direct-current power supplied from the battery into three-phase alternating-current power and outputs the three-phase alternating-current power to the three-phase alternating-current motor. The power conversion device includes a plurality of power cards (switching elements), a plurality of output busbars, and a plurality of external connection terminals. The U-phase power card is connected to the U-phase external connection terminal via the U-phase output busbar. Similarly, the V-phase power card is connected to the V-phase external connection terminal via the V-phase output busbar, and the W-phase power card is connected to the W-phase external connection terminal via the W-phase output busbar. Adjacent two output busbars are spaced from each other for insulation.
SUMMARY OF THE INVENTION
[0005] A better power conversion device is desired.
[0006] The present invention has the object of solving the aforementioned problem.
[0007] An aspect of the present disclosure is to provide a power conversion device including a power conversion unit configured to convert three-phase alternating-current power, which is supplied from a three-phase alternating-current power source, into direct-current power; an insulating substrate formed of an insulating material; a first busbar connected to a first phase terminal of the power conversion unit, the insulating substrate being provided with the first busbar; a second busbar connected to a second phase terminal of the power conversion unit, the insulating substrate being provided with the second busbar; and a third busbar connected to a third phase terminal of the power conversion unit, the insulating substrate being provided with the third busbar, wherein the insulating substrate includes a plurality of insulating layers, a first insulating layer of the plurality of insulating layers is positioned on the second busbar, the first busbar and the third busbar are positioned on the first insulating layer, and the first busbar, the second busbar, and the third busbar are mutually insulated by the insulating material forming the insulating substrate.
[0008] According to the present invention, a favorable power conversion device can be provided.
[0009] The above and other objects, features and advantages of the present invention will become more apparent from the following description when taken in conjunction with the accompanying drawings in which a preferred embodiment of the present invention is shown by way of illustrative example.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. **1** is a schematic diagram of an aircraft;

[0011] FIG. **2** is a circuit diagram of the power supply device;

[0012] FIG. **3** is a perspective view of a Power Control Unit (PCU);

[0013] FIG. **4** is a perspective view of a power conversion unit;

[0014] FIG. **5** is a perspective view of the power conversion unit and a cooler;

[0015] FIG. **6** is a perspective view of five busbars and the power conversion unit;

[0016] FIG. **7** is a side view of the five busbars and the power conversion unit;

[0017] FIG. **8** is a plan view of a first conductive layer; and

[0018] FIG. **9** is a plan view of a second conductive layer.

DETAILED DESCRIPTION OF THE INVENTION

[0019] It is desirable that a power conversion device provided, for example, in a moving object be small. Therefore, it is preferable that two busbars are disposed as close as possible in the power conversion device. The power conversion device according to the embodiment described below can reliably insulate a plurality of busbars from each other while shortening the distance therebetween.

[0020] A power conversion device **10** according to one embodiment will be described with reference to the drawings. In the present embodiment, a case where the power conversion device **10** is a power control unit will be described as an example, but the present invention is not limited thereto. The power control unit **10** is mounted on a moving object. In the present embodiment, a case where the moving object is an aircraft **12** will be described as an example, but the present invention is not limited thereto.

1 Configuration of Aircraft **12**

[0021] FIG. **1** is a schematic diagram of an aircraft **12**. The aircraft **12** according to the present embodiment is an electric vertical take-off and landing (eVTOL) aircraft. In the aircraft **12**, electric motors drive rotors. The aircraft **12** generates a vertical thrust and a horizontal thrust by the rotors.

[0022] The aircraft **12** has an airframe **14**. The aircraft **12** has eight VTOL rotors **16**. The VTOL rotors **16** generate an upwardly directed thrust with respect to the airframe **14**. The aircraft **12** includes two cruise rotors **18**. The cruise rotors **18** generate a forwardly directed thrust with respect to the airframe **14**.

[0023] The VTOL rotors **16** and the cruise rotors **18** are driven by electric motors (not shown). The aircraft **12** includes a generator **20** and a battery (not shown) as power sources of the electric motors. The electrical power supplied by the generator **20** is supplied to electric motors. The electrical power supplied by the generator **20** is stored in a battery (capacitor). In the case that the electrical power generated by the generator **20** is insufficient with respect to the required amount of electrical power, the electrical power stored in the battery is supplied to the electric motors.

2 Configuration of Power Supply Device **22**

[0024] The aircraft **12** includes a power supply device **22**. The power supply device **22** includes the generator **20**, a power control unit **10**, and a main junction box **24**. Hereinafter, the power control unit **10** may be referred to as a PCU **10**. The main junction box **24** may be referred to as an MJB **24**.

[0025] Two generators **20** are provided for the power supply device **22**. One of the two generators **20** is a first power generator **20***a*, and the other of the two generators **20** is a second power generator **20***b*. The first power generator **20***a* is disposed on the right side of the center line L in the lateral direction of the airframe **14** of the aircraft **12**, and the second power generator **20***b* is disposed on the left side of the center line L.

[0026] The power supply device **22** has two PCUs **10**. One of the two PCUs **10** is a first PCU **10***a*, and the other of the two PCUs **10** is a second PCU **10***b*. The MJB **24** is disposed about the center line L of the airframe **14**. The first PCU **10***a* is attached to the right side surface of the MJB **24**, and the second PCU **10***b* is attached to the left side surface of the MJB **24**.

[0027] The three-phase alternating-current electrical power generated by the first power generator **20***a* is supplied to the first PCU **10***a*. The first PCU **10***a* converts the three-phase alternating-current electrical power supplied from the first power generator **20***a* into direct-current electrical power. The converted direct-current electrical power is supplied to the MJB **24**.
[0028] The three-phase alternating-current electrical power generated by the second power generator **20***b* is supplied to the second PCU **10***b*. The second PCU **10***b* converts the three-phase alternating-current electrical power supplied from the second power generator **20***b* into direct-current electrical power. The converted direct-current electrical power is supplied to the MJB **24**.
3 Configuration of Power Supply Device **22**
[0029] FIG. **2** is a circuit diagram of the power supply device **22**. FIG. **2** illustrates a circuit including the power generator **20** disposed on one of the left and right sides, the PCU **10** disposed on one of the left and right sides, and a MJB **24**. The circuit of the PCU **10** will be described below.
[0030] The PCU **10** includes three external connection terminals **26***u*, **26***v*, **26***w*, and two external connection terminals **28***p*, **28***n*. The three external connection terminals **26***u*, **26***v*, **26***w*, and the two external connection terminals **28***p*, **28***n* are attached to a casing (not shown).
[0031] The external connection terminal **26***u* is connected to the power generator **20** via a U-phase wire **32***u*. The external connection terminal **26***v* is connected to the power generator **20** via a V-phase wire **32***v*. The external connection terminal **26***w* is connected to the power generator **20** via a W-phase wire **32***w*. The external connection terminal **28***p* is connected to the MJB **24** via a positive electrode line **34***p*. The external connection terminal **28***n* is connected to the MJB **24** via the negative electrode line **34***n*.
[0032] The PCU **10** includes a U-phase power module **38***u*, a V-phase power module **38***v*, a W-phase power module **38***w*, and a smoothing capacitor **40**. As shown in FIG. **4**, the three power modules (**38***u*, **38***v*, **38***w*) are also collectively referred to as a power conversion unit **36**. The U-phase power module **38***u* includes two power devices **42**, the U-phase terminal (first phase terminal) **44***u*, the positive terminal (first direct-current terminal) **46***u*, and the negative terminal (second direct-current terminal) **48***u*. The V-phase power module **38***v* includes two power devices **42**, the V-phase terminal (second phase terminal) **44***v*, the positive terminal (first direct-current terminal) **46***v*, and the negative terminal (second direct-current terminal) **48***v*. The W-phase power module **38***w* includes two power devices **42**, the W-phase terminal (third phase terminal) **44***w*, the positive terminal (first direct-current terminal) **46***w*, and the negative terminal (second direct-current terminal) **48***w*. Each power device **42** includes a switching element such as a MOSFET and a diode. The smoothing capacitor **40** includes a positive terminal **50***p* and a negative terminal **52***n*.
[0033] In the U-phase power module **38***u*, one of the two power devices **42** is connected to the positive terminal **46***u* and the U-phase terminal **44***u*. In the U-phase power module **38***u*, the other of the two power devices **42** is connected to the negative terminal **48***u* and the U-phase terminal **44***u*.
[0034] In the V-phase power module **38***v*, one of the two power devices **42** is connected to the positive terminal **46***v* and the V-phase terminal **44***v*. In the V-phase power module **38***v*, the other of the two power devices **42** is connected to the negative terminal **48***v* and the V-phase terminal **44***v*.
[0035] In the W-phase power module **38***w*, one of the two power devices **42** is connected to the positive terminal **46***w* and the W-phase terminal **44***w*. In the W-phase power module **38***w*, the other of the two power devices **42** is connected to the negative terminal **48***w* and the W-phase terminal **44***w*.
[0036] The U-phase terminal **44***u* of the U-phase power module **38***u* is connected to the external connection terminal **26***u* of the PCU **10** via the U-phase busbar (first busbar) **54***u*. The V-phase terminal **44***v* of the V-phase power module **38***v* is connected to the external connection terminal **26***v* of the PCU **10** via the V-phase busbar (second busbar) **54***v*. The W-phase terminals **44***w* of the W-phase power module **38***w* is connected to the external connection terminal **26***w* of the PCU **10** via the W-phase busbar (third busbar) **54***w*.
[0037] The positive terminal **46***u* of the U-phase power module **38***u*, the positive terminal **46***v* of

the V-phase power module **38***v*, and the positive terminal **46***w* of the W-phase power module **38***w* are connected respectively to the external connection terminal **28***p* of the PCU **10** via the first positive busbar (fourth busbar) **56***p* and the second positive busbar **58***p*. The positive terminal **50***p* of the smoothing capacitor **40** is connected to the external connection terminal **28***p* of the PCU **10** via the second positive busbar **58***p*.

[0038] The negative terminal **48***u* of the U-phase power module **38***u*, the negative terminal **48***v* of the V-phase power module **38***v*, and the negative terminal **48***w* of the W-phase power module **38***w* are respectively connected to the external connection terminal **28***n* of the PCU **10** via the first negative busbar (fifth busbar) **56***n* and the second negative busbar **58***n*. The negative electrode terminal **52***n* of the smoothing capacitor **40** is connected to the external connection terminal **28***n* of the PCU **10** via the second negative busbar **58***n*.

4 Configuration of PCU **10**

[0039] FIG. **3** is a perspective view of the PCU **10**. FIG. **3** shows the PCU **10** with the external connection terminals **26***u*, **26***v*, **26***w*, **28***p*, **28***n* and the casing removed. In FIG. **3**, arrows indicating the X direction, the Y direction, and the Z direction are shown. The X direction, the Y direction, and the Z direction are orthogonal to each other. One of the X directions is defined as a +X direction, and the other is defined as a −X direction. The same applies to the Y direction and the Z direction.

[0040] As described above, the PCU **10** includes the plurality of power modules (**38***u*, **38***v*, **38***w*), the smoothing capacitor **40**, and the plurality of busbars (**54***u*, **54***v*, **54***w*, **56***p*, **56***n*, **58***p*, **58***n*). The PCU **10** further comprises a cooler **64**.

[0041] FIG. **4** is a perspective view of the power conversion unit **36**. Each of the U-phase power module **38***u*, the V-phase power module **38***v*, and the W-phase power module **38***w* has a shape of a flat plate extending in the X direction and the Z direction. The U-phase power module **38***u*, the V-phase power module **38***v*, and the W-phase power module **38***w* are arranged along the Y direction.

[0042] As described above, the U-phase power module **38***u* includes the two power devices **42** (FIG. **2**). The two power devices **42** are sealed with an insulating material containing resin or the like. Thus, the two power devices **42** are integrated. The U-phase power module **38***u* includes the U-phase terminal **44***u*, the positive terminal **46***u*, the negative terminal **48***u*, and a plurality of signal terminals **62**. Each of the U-phase terminal **44***u*, the positive terminal **46***u*, and the negative terminal **48***u* extends from the U-phase power module **38***u* in the +Z direction. The plurality of signal terminals **62** extend from the U-phase power module **38***u* in the −Z direction. Each of the signal terminals **62** is connected to an unillustrated driver circuit. The driver circuit amplifies signals output from an unillustrated controller. The driver circuit supplies amplified drive signals to the signal terminals **62**. The V-phase power module **38***v* and the W-phase power module **38***w* are configured in the same manner as the U-phase power module **38***u*. Therefore, the descriptions thereof are omitted here.

[0043] FIG. **5** is a perspective view of the power conversion unit **36** and the cooler **64**. The cooler **64** includes two pipe sections **66** and four pipe sections **68**. The two pipe sections **66** extend along the Y direction. The four pipe sections **68** extend along the X direction. The four pipe sections **68** extend between the two pipe sections **66**. One end of each pipe section **68** is connected to one pipe section **66***a* of the two pipe sections **66**. The other end of each pipe section **68** is connected to the other pipe section **66***b* of the two pipe sections **66**. Thus, the two pipe sections **66** communicate with each other via the four pipe sections **68**. Each of the two pipe sections **66** communicates with a pump (not shown).

[0044] The pipe section **68***a* of the four pipe sections **68** is in contact with an outer wall surface of the U-phase power module **38***u* facing in the −Y direction. The pipe section **68***b* of the four pipe sections **68** is in contact with an outer wall surface of the U-phase power module **38***u* facing in the +Y direction and also with an outer wall surface of the V-phase power module **38***v* facing in the −Y direction. The pipe section **68***c* of the four pipe sections **68** is in contact with an outer wall surface of the V-phase power module **38***v* facing in the +Y direction and also with an outer wall surface of the W-phase power module **38***w* facing in the −Y direction. The pipe section **68***d* of the four pipe sections **68** is in contact with the outer wall surface of the W-phase power module **38***w* facing in the +Y direction.

[0045] A cooling medium is caused to flow inside the cooler **64**. For example, the cooling medium is discharged from the pump to the pipe section **66***a*, and is supplied from the pipe section **66***a* to each of the four pipe sections **68**. Further, the cooling medium is discharged from the four pipe sections **68** to the pipe section **66***b* and is cooled by an unillustrated radiator or the like. The cooling medium having been cooled returns to the pump. The cooling medium absorbs heat of the plurality of power modules (**38***u*, **38***v*, **38***w*) and radiates heat in the radiator. Thus, the plurality of power modules (**38***u*, **38***v*, **38***w*) are cooled.

[0046] FIG. **6** is a perspective view of five busbars (**54***u*, **54***v*, **54***w*, **56***p*, **56***n*) and the power conversion unit **36**. FIG. **7** is a side view of the five busbars (**54***u*, **54***v*, **54***w*, **56***p*, **56***n*) and the power conversion unit **36**. In FIG. **7**, the V-phase power module **38***v* and the W-phase power module **38***w* are hidden behind the U-phase power module **38***u*. Therefore, in FIG. **7**, the reference numerals relating to the V-phase power module **38***v* and the W-phase power module **38***w* are shown in parentheses. Similarly, in FIG. **7**, the W-phase busbar **54***w* is hidden behind the U-phase busbar **54***u*. Therefore, in FIG. **7**, the reference numeral relating to the W-phase busbar **54***w* is shown in parentheses.

[0047] As shown in FIG. **6**, the U-phase busbar **54***u*, the V-phase busbar **54***v*, the W-phase busbar **54***w*, the first positive busbar **56***p*, and the first negative busbar **56***n* are disposed on a common insulating substrate **74**. The U-phase busbar **54***u* is partially sealed by the insulating material forming the insulating substrate **74**. Each of the V-phase busbar **54***v*, the W-phase busbar **54***w*, the first positive busbar **56***p*, and the first negative busbar **56***n* is also partially sealed in the same manner as the U-phase busbar **54***u*. The five busbars (**54***u*, **54***v*, **54***w*, **56***p*, **56***n*) and the insulating substrate **74** form an integrated busbar board **72**.

[0048] The busbar board **72** includes a plurality of insulating layers stacked along the Z direction. For example, as shown in FIG. **7**, the busbar board **72** includes a first insulating layer **76**, a second insulating layer **78**, and a third insulating layer **80**. The first insulating layer **76** is arranged between the second insulating layer **78** and the third insulating layer **80**. In addition, the busbar board **72** includes a first conductive layer **82** and a second conductive layer **84**. The first conductive layer **82** includes the V-phase busbar **54***v* and the first negative busbar **56***n*. The second conductive layer **84** includes the U-phase busbar **54***u*, the W-phase busbar **54***w*, the first positive busbar **56***p*, and a supplementary negative busbar **56***na*. The first negative busbar **56***n* of the first conductive layer **82** and the supplementary negative busbar **56***na* of the second conductive layer **84** are electrically connected to each other by a through hole or the like (not shown).

[0049] Each of the busbars (**54***u*, **54***v*, **54***w*, **56***p*, **56***n*, **56***na*) may be formed of a metallic film (e.g., a copper film). In this case, the insulating substrate **74** may be a printed circuit board. Each of the busbars (**54***u*, **54***v*, **54***w*, **56***p*, **56***n*, **56***na*) may be made of rolled metal (such as rolled copper). In this case, the metal is embedded in the insulating material.

[0050] The first conductive layer **82** is formed between the second insulating layer **78** and the first insulating layer **76**. The second conductive layer **84** is formed between the first insulating layer **76** and the third insulating layer **80**. In other words, the first insulating layer **76** is formed on the V-phase busbar **54***v* and the first negative busbar **56***n*. In addition, the U-phase busbar **54***u*, the W-phase busbar **54***w*, the first positive busbar **56***p*, and the supplementary negative busbar **56***na* are positioned on the first insulating layer **76**. In other words, the first insulating layer **76** is interposed between the first conductive layer **82** and the second conductive layer **84**.

[0051] FIG. **8** is a plan view of a first conductive layer **82**. As shown in FIG. **8**, in the first conductive layer **82**, the V-phase busbar **54***v* and the first negative busbar **56***n* are arranged along the X direction. The V-phase busbar **54***v* and the first negative busbar **56***n* are separated from each

other. An insulating material forming the insulating substrate **74** is interposed between the V-phase busbar **54***v* and the first negative busbar **56***n*.
[0052] FIG. **9** is a plan view of the second conductive layer **84**. As shown in FIG. **9**, in the second conductive layer **84**, the U-phase busbar **54***u* and the W-phase busbar **54***w* are arranged along the Y direction. The U-phase busbar **54***u*, the supplementary negative busbar **56***na*, and the first positive busbar **56***p* are arranged along the X direction. The W-phase busbar **54***w*, the supplementary negative busbar **56***na*, and the first positive busbar **56***p* are arranged along the X direction. The U-phase busbar **54***u*, the W-phase busbar **54***w*, the supplementary negative busbar **56***na*, and the first positive busbar **56***p* are separated from each other. The insulating material forming the insulating substrate **74** is interposed between each of the U-phase busbar **54***u*, the W-phase busbar **54***w*, the supplementary negative busbar **56***na*, and the first positive busbar **56***p*.
[0053] When viewed in the stacking direction, the U-phase busbar **54***u* and the V-phase busbar **54***v* overlap each other at least partially. In the present embodiment, as shown in FIG. **9**, the U-phase busbar **54***u* and the V-phase busbar **54***v* overlap each other at least partially when viewed in the Z direction.
[0054] When viewed in the stacking direction, the W-phase busbar **54***w* and the V-phase busbar **54***v* overlap each other at least partially. In the present embodiment, as shown in FIG. **9**, the W-phase busbar **54***w* and the V-phase busbar **54***v* overlap each other at least partially when viewed in the Z direction.
[0055] When viewed in the stacking direction, the first positive busbar **56***p* and the first negative busbar **56***n* overlap each other at least partially. In the present embodiment, as shown in FIG. **9**, the first positive busbar **56***p* and the first negative busbar **56***n* overlap each other at least partially when viewed in the Z direction.
[0056] As shown in FIG. **3**, each of the U-phase terminal **44***u*, the positive terminal **46***u*, and the negative terminal **48***u* of the U-phase power module **38***u* extends through the busbar board **72** and protrudes in the +Z direction. At the protruded portion, the U-phase terminal **44***u* is joined, by soldering or the like, to a portion of the U-phase busbar **54***u* exposed in the +Z direction. At the protruding portion, the positive terminal **46***u* is joined, by soldering or the like, to a portion of the first positive busbar **56***p* exposed in the +Z direction. At the protruding portion, the negative terminal **48***u* is joined, by soldering or the like, to a portion of the supplementary negative busbars **56***na* exposed in the +Z direction.
[0057] Similarly to the U-phase power module **38***u*, each of the V-phase terminal **44***v*, the positive terminal **46***v*, and the negative terminal **48***v* of the V-phase power module **38***v* extends through the busbar board **72** and protrudes in the +Z direction. At the protruded portion, the V-phase terminal **44***v* is joined, by soldering or the like, to a portion of the V-phase busbar **54***v* exposed in the +Z direction. At the protruding portion, the positive terminal **46***v* is joined, by soldering or the like, to a portion of the first positive busbar **56***p* exposed in the +Z direction. At the protruding portion, the negative terminal **48***v* is joined, by soldering or the like, to a portion of the supplementary negative busbars **56***na* exposed in the +Z direction.
[0058] Similarly to the U-phase power module **38***u*, each of the W-phase terminal **44***w*, the positive terminal **46***w*, and the negative terminal **48***w* of the W-phase power module **38***w* extends through the busbar board **72** and protrudes in the +Z direction. At the protruded portion, the W-phase terminal **44***w* is joined, by soldering or the like, to a portion of the W-phase busbar **54***w* exposed in the +Z direction. At the protruding portion, the positive terminal **46***w* is joined, by soldering or the like, to a portion of the first positive busbar **56***p* exposed in the +Z direction. At the protruding portion, the negative terminal **48***w* is joined, by soldering or the like, to a portion of the supplementary negative busbars **56***na* exposed in the +Z direction.
[0059] The end of the U-phase busbar **54***u* on the +X direction side is connected to the external connection terminal **26***u* (FIG. **2**). The end of the V-phase busbar **54***v* on the +X direction side is connected to the external connection terminals **26***v* (FIG. **2**). The end of the W-phase busbar **54***w*

on the +X direction side is connected to the external connection terminals **26***w* (FIG. **2**). The end of the first positive busbar **56***p* on the −X direction side is connected to the second positive busbar **58***p*. The end of the first negative busbar **56***n* on the −X direction side is connected to the second negative busbar **58***n*.

[0060] As shown in FIG. **3**, the PCU **10** includes a snubber capacitor **88**. The snubber capacitor **88** is disposed on the outer wall surface of the busbar board **72** on the +Z direction side. One end of the snubber capacitor **88** is joined, by soldering or the like, to a portion of the first positive busbar **56***p* exposed in the +Z direction. The other end of the snubber capacitor **88** is joined, by soldering or the like, to a portion of the supplementary negative busbar **56***na* exposed in the +Z direction.

[0061] As shown in FIG. **3**, the second positive busbar **58***p* and the second negative busbar **58***n* are stacked along the Z direction. The insulating body **90** is interposed between the second positive busbar **58***p* and the second negative busbar **58***n*. The second positive busbar **58***p* is connected to the positive electrode terminal **50***p* (FIG. **2**) of the smoothing capacitor **40**. The second positive busbar **58***p* is connected to the external connection terminal **28***p* (FIG. **2**). The second negative busbar **58***n* is connected to the negative electrode terminal **52***n* (FIG. **2**) of the smoothing capacitor **40**. The second negative busbar **58***n* is connected to the external connection terminal **28***n* (FIG. **2**).

[0062] In the present embodiment, the first insulating layer **76** is positioned on the V-phase busbar **54***v*, and the U-phase busbar **54***u* and the W-phase busbar **54***w* are positioned on the first insulating layer **76**. Instead, the first insulating layer **76** may be positioned on the U-phase busbar **54***u*, and the V-phase busbar **54***v* and the W-phase busbar **54***w* may be positioned on the first insulating layer **76**. Further, the first insulating layer **76** may be positioned on the W-phase busbar **54***w*, and the U-phase busbar **54***u* and the V-phase busbar **54***v* may be positioned on the first insulating layer **76**. In these embodiments, two of the three busbars (the U-phase busbar **54***u*, the V-phase busbar **54***v*, and the W-phase busbar **54***w*) are arranged in the +Z direction, and one of the three busbars is arranged in the −Z direction. Instead, one of the three busbars (the U-phase busbar **54***u*, the V-phase busbar **54***v*, and the W-phase busbar **54***w*) may be arranged in the +Z direction, and two of the three busbars may be arranged in the −Z direction.

[0063] In the present embodiment, the first insulating layer **76** is formed on the first negative busbar **56***n*, and the first positive busbar **56***p* is positioned on the first insulating layer **76**. Instead, the first insulating layer **76** may be formed on the first positive busbar **56***p*, and the first negative busbar **56***n* may be positioned on the first insulating layer **76**.

[0064] According to the present embodiment, the busbars (**54***u*, **54***v*, **54***w*, **56***p*, **56***n*) are insulated from each other by the insulating material forming the insulating substrate **74**, and thus the distances between the busbars can be made shorter than in the case where spaces are provided between the busbars. Therefore, the power conversion device **10** can be downsized.

[0065] According to the present embodiment, the busbars (**54***u*, **54***v*, **54***w*, **56***p*, **56***n*) disposed in the different layers overlap each other when viewed in the stacking direction. In the case of arranging two busbars in an area, the size of each busbar can be larger if the two busbars overlap each other than if the two busbars do not overlap each other. That is, according to the present embodiment, since each busbar can be increased in size, the heat dissipation of the busbars can be improved. On the other hand, in the case of arranging two busbars of the same size on one substrate, the size of the substrate can be smaller if the two busbars overlap each other than if the two busbars do not overlap each other. That is, according to the present embodiment, the substrate can be made small, and thus the space around the substrate can be effectively used.

[0066] According to the present embodiment, the three busbars (**54***u*, **54***v*, **54***w*) and the two busbars (**56***p*, **56***n*) are integrated. Therefore, easy assembling of the PCU **10** can be achieved.

[0067] Since the snubber capacitor **88** is disposed in the vicinity of the power conversion unit **36**, the present embodiment can elicit high switching performance of the power conversion unit **36**.

5 Supplementary Note

[0068] In relation to the above-described embodiment, the following Supplementary Notes are further disclosed.

Supplementary Note 1

[0069] The power conversion device (**10**) according to the present disclosure includes the power conversion unit (**36**) configured to convert three-phase alternating-current power, which is supplied from a three-phase alternating-current power source (**20**), into direct-current power; the insulating substrate (**74**) formed of an insulating material; the first busbar (**54***u*) connected to the first phase terminal (**44***u*) of the power conversion unit, the insulating substrate being provided with the first busbar; the second busbar (**54***v*) connected to the second phase terminal (**44***v*) of the power conversion unit, the insulating substrate being provided with the second busbar; and the third busbar (**54***w*) connected to the third phase terminal (**44***w*) of the power conversion unit, the insulating substrate being provided with the third busbar, wherein the insulating substrate includes the plurality of insulating layers (**76**, **78**, **80**), the first insulating layer (**76**) of the plurality of insulating layers is positioned on the second busbar, the first busbar and the third busbar are positioned on the first insulating layer, and the first busbar, the second busbar, and the third busbar are mutually insulated by the insulating material forming the insulating substrate.

[0070] In accordance with such a configuration of Supplementary Note 1, since the busbars are insulated from each other by the insulating material forming the insulating substrate, the distances between the busbars can be made shorter than in the case where the busbars are insulated by being spaced from each other. Therefore, the power conversion device can be downsized.

Supplementary Note 2

[0071] In the power conversion device according to Supplementary Note 1, the first busbar and the second busbar may overlap each other at least partially when viewed in the stacking direction of the insulating layers.

Supplementary Note 3

[0072] In the power conversion device according to Supplementary Note 2, the third busbar and the second busbar may overlap each other at least partially when viewed in the stacking direction of the insulating layers.

[0073] According to the configurations of Supplementary Notes 2 and 3, the busbars in different layers overlap each other when viewed in the stacking direction. In the case of arranging two busbars in one area, the size of each busbar can be larger if the two busbars overlap each other than if the two busbars do not overlap each other. That is, according to the present embodiment, since each busbar can be increased in size, the heat dissipation of the busbars can be improved. On the other hand, in the case of arranging two busbars of the same size in one substrate, the size of the substrate can be smaller if the two busbars overlap each other than if the two busbars do not overlap each other. That is, according to the present embodiment, the substrate can be made small, and thus the space around the substrate can be effectively used.

Supplementary Note 4

[0074] In the power conversion device according to any one of Supplementary Notes 1 to 3, each of the first phase terminal, the second phase terminal, and the third phase terminal may extend in the stacking direction of the insulating layers and pass through the insulating substrate.

Supplementary Note 5

[0075] The power conversion device according to Supplementary Note **1** may further include the fourth busbar (**56***p*) connected to the first direct-current terminal (**46***u*, **46***v*, **46***w*) of the power conversion unit, the insulating substrate being provided with the fourth busbar, and the fifth busbar (**56***n*) connected to the second direct-current terminal (**48***u*, **48***v*, **48***w*) of the power conversion unit, the insulating substrate being provided with the fifth busbar, wherein the first insulating layer may be positioned on the second busbar and the fifth busbar, the first busbar, the third busbar and the fourth busbar are positioned on the first insulating layer, and the first busbar, the second busbar, the third busbar, the fourth busbar, and the fifth busbar are mutually insulated by the insulating material forming the insulating substrate.

[0076] According to the configuration of Supplementary Note 5, the first to third busbars and the fourth and fifth busbars are integrated. Therefore, the assemblability of the power conversion device can be improved.

Supplementary Note 6

[0077] In the power conversion device according to Supplementary Note 5, each of the first phase terminal, the second phase terminal, the third phase terminal, the first direct-current terminal, and the second direct-current terminal may extend in a stacking direction of the insulating layers and pass through the insulating substrate.

Supplementary Note 7

[0078] The power conversion device according to Supplementary Note 5 or 6 may further include the snubber capacitor (**88**) having one end connected to the fourth busbar and the other end connected to the fifth busbar.

[0079] In accordance with the configuration of Supplementary Note 7, since the snubber capacitor is arranged in the vicinity of the power conversion unit, the present embodiment can elicit high switching performance of the power conversion unit.

Supplementary Note 8

[0080] In the power conversion device according to any one of Supplementary Notes 1 to 7, the insulating substrate may be a printed substrate.

[0081] According to the configuration of Supplementary Note 8, such the busbars are thinned, and thus the power conversion device can be further downsized.

[0082] Although concerning the present disclosure, a detailed description thereof has been presented above, the present disclosure is not necessarily limited to the individual embodiments described above. These embodiments may be subjected to various additions, substitutions, modifications, partial deletions and the like, within a range that does not deviate from the essence and gist of the present disclosure, or the spirit of the present disclosure as derived from the contents described in the claims and equivalents thereof. Further, the embodiments can also be implemented together in combination. For example, in the above-described embodiments, the order of each of the operations and the order of each of the processes are illustrated as examples, and the present invention is not necessarily limited to these features. The same also applies to cases in which numerical values or mathematical expressions are used in the description of the aforementioned embodiments.

Claims

1. A power conversion device comprising: a power conversion unit configured to convert three-phase alternating-current power, which is supplied from a three-phase alternating-current power source, into direct-current power; an insulating substrate formed of an insulating material; a first busbar connected to a first phase terminal of the power conversion unit, the insulating substrate being provided with the first busbar; a second busbar connected to a second phase terminal of the power conversion unit, the insulating substrate being provided with the second busbar; and a third busbar connected to a third phase terminal of the power conversion unit, the insulating substrate being provided with the third busbar, wherein the insulating substrate includes a plurality of insulating layers, a first insulating layer of the plurality of insulating layers is positioned on the second busbar, the first busbar and the third busbar are positioned on the first insulating layer, and the first busbar, the second busbar, and the third busbar are mutually insulated by the insulating material forming the insulating substrate.

2. The power conversion device according to claim 1, wherein the first busbar and the second busbar overlap each other at least partially when viewed in a stacking direction of the insulating layers.

3. The power conversion device according to claim 2, wherein the third busbar and the second busbar overlap each other at least partially when viewed in the stacking direction of the insulating layers.

4. The power conversion device according to claim 1, wherein each of the first phase terminal, the second phase terminal, and the third phase terminal extends in a stacking direction of the insulating layers and passes through the insulating substrate.

5. The power conversion device according to claim 1, further comprising: a fourth busbar connected to a first direct-current terminal of the power conversion unit, the insulating substrate being provided with the fourth busbar, and the fifth busbar connected to a second direct-current terminal of the power conversion unit, the insulating substrate being provided with the fifth busbar, wherein the first insulating layer is positioned on the second busbar and the fifth busbar, the first busbar, the third busbar and the fourth busbar are positioned on the first insulating layer, and the first busbar, the second busbar, the third busbar, the fourth busbar, and the fifth busbar are mutually insulated by the insulating material forming the insulating substrate.

6. The power conversion device according to claim 5, wherein each of the first phase terminal, the second phase terminal, the third phase terminal, the first direct-current terminal, and the second direct-current terminal extends in a stacking direction of the insulating layers and passes through the insulating substrate.

7. The power conversion device according to claim 5, further comprising: a snubber capacitor having one end connected to the fourth busbar and another end connected to the fifth busbar.

8. The power conversion device according to claim 1, wherein the insulating substrate is a printed substrate.