

A POWER UNIT ASSEMBLY

The present invention relates to a power unit assembly of semiconductor modules.

5 A power unit assembly utilizing semiconductor elements usually has a cooling device for diffusing the heat generated during operation of the power unit assembly to cool the semiconductor elements. In order to attain sufficient cooling, such a cooling device requires a
10 considerable degree of mass. This fact makes the power unit assembly bulky. In particular, if such a power unit assembly is composed of a plurality of power units, e.g. a converter and an inverter, each power unit is usually formed as a semiconductor device stack, having its own
15 cooling device, and therefore the power unit assembly necessarily becomes bulky.

Also, when the power unit assembly is viewed as a whole, it is difficult to determine when the total cooling performance of the power unit assembly is effectively
20 exhausted. For example, it is possible for the cooling device of one power unit to be fully loaded whilst the cooling device of another power unit still has sufficient margin in its cooling ability.

The present invention seeks to provide a compact
25 power unit assembly, in which a plurality of power units, each of which is formed by semiconductor modules, are effectively assembled by improving the arrangement and

structure of the semiconductor modules and the cooling device therefor. It does this by providing a power unit assembly for use in an elevator motor drive comprising a converter for receiving AC power and for converting the AC power into DC power, and an inverter for inverting the converted DC power into AC power and supplying it for a driving motor of an elevator, which converter and inverter are formed by semiconductor modules provided on a pair of cooling devices, each cooling device being electrically isolated from, but thermally connected to, associated semiconductor modules, wherein each of the cooling devices has a plane, on one side of which are the associated semiconductor modules of the cooling device, and on the other side of which plane is a heat exchange unit, and the cooling devices are positioned such that their heat exchange units are in thermal contact with each other.

Preferably, an insulating board is fixed to the semiconductor modules attached on the cooling device, the insulating board having a plate-like conductor of a predetermined pattern on the side of the insulating board which opposes the semiconductor modules, whereby when the insulating board is fixed to the semiconductor modules, terminals of the semiconductor modules are electrically coupled by the plate-like conductor to form a circuit for a desired power unit.

In this way it becomes possible to improve the wiring of the semiconductor modules, and so further improve the

compactness of the assembly.

Embodiments of the invention will now be described in detail, by way of example, with reference to the accompanying drawings, in which:

Fig. 1 shows a schematic example of an elevator

driving system which includes power units to which the present invention may be applied;

Figs. 2A and 2B show the structure and the circuit of an insulation-type semiconductor module which is
5 utilized to form the power units shown in Fig. 1;

Fig. 3 illustrates the appearance of a power unit constructed for assembling a power unit assembly of the present invention;

Fig. 4 is an explanatory drawing showing a cooling
10 device utilized in the power unit of Fig. 3;

Fig. 5 shows the appearance of another example of a power unit constructed for assembling a power unit assembly of the present invention;

Fig. 6 illustrates the appearance of a power unit
15 assembly according to a first embodiment of the present invention;

Fig. 7 is a drawing showing a modification of the first embodiment of the present invention;

Fig. 8 is a drawing for explaining the transient
20 thermal resistance characteristics during the operation of the power units shown in Fig. 1;

Fig. 9 shows an insulating board employed for further improving the compactness of the power unit assembly; and

25 Fig. 10 shows a side view of a power unit to which the insulating board shown in Fig. 9 is attached.

The following description is concerned with

embodiments of the invention in which the present invention is applied to a power unit assembly for use in an elevator driving system. Therefore, referring first to Fig. 1, an elevator driving system will be described.

5 In the circuit of Fig. 1, alternating current (AC) power from a power source 1 is converted into direct current (DC) power by a converter 3 consisting of power transistors TR1 to TR6 and diodes D1 to D6. The converted DC power is supplied through a DC reactor 5 for an inverter 10 7 consisting of power transistors TR7 to TR12 and diodes D7 to D12, in which the DC power is inverted into AC power of the desired frequency and voltage. The inverted AC power is fed to a driving motor 9. A sheave 11 is connected to the motor 9 through an appropriate reduction mechanism (not 15 shown). A rope 13 is hung, on the sheave 11, to respective ends of which rope 13 are coupled an elevator cage 15 and a counterweight 17. Reference numerals 19 and 21 denote capacitors.

As is apparent from the presence of the DC reactor 20 5, the power unit shown has a current source inverter. It is of course possible to apply the present invention to a power unit having a voltage source inverter, in which a converter and an inverter are directly coupled without a DC reactor and a capacitor is connected across the output 25 terminals of the converter 3, i.e. across the input terminals of the inverter 7.

The various kinds of control methods for the

converter 3 and inverter 7 are well known. By way of example, the converter 3 may function as a simple rectifier to output the DC power of the constant voltage, and the voltage and the frequency of the AC power as the output of the power unit are controlled by the inverter 7. Alternatively, the voltage of the output AC power may be adjusted by the converter 3 and the frequency thereof controlled by the inverter 7. Other kinds of control methods are also well known.

10 Since the present invention is not concerned with the structure and method of control of the power unit, they will not be discussed further.

15 Referring next to Figs. 2A and 2B, a typical example of an insulation-type semiconductor module which is utilized to form the power unit as shown in Fig. 1 will be discussed. Fig. 2A shows the appearance of a module 22, which is partially sectioned. As is apparent from the figure, an insulating plate 25 is located on a copper base-plate 23. The insulating plate 25 is made of a material such as alumina which is electrically an insulator, but has good thermal conductivity. On the insulating plate 25 there is provided a thermal diffusion and buffer plate 27, 20 which is usually formed by the combination of a molybdenum layer and a copper layer. The plate 27 has semiconductor elements 29 thereon.

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The semiconductor elements 29 are electrically connected within the module 22 in a suitable circuit arrangement. In the module 22 of the present embodiment, the semiconductor elements 29 included therein are two
5 pairs of transistors and diodes and are connected in the circuit shown in Fig. 2B. Electrodes of the semiconductor elements 29, which are to be connected to an external circuit, are coupled to hollow terminals 31 and 33 by appropriate leads. The inner surface of each hollow
10 terminals 31 and 33 is provided with a female screw, and connecting leads of the external circuit can be screwed to the terminals 31,33. The whole of the structure described above is covered by moulding resin 35. Reference numeral 39 denotes a hole through which a bolt is inserted to fix
15 the module 22 on a cooling device to be described later.

As is apparent from the circuit arrangement of the module 22 shown in Fig. 2B, a single module includes a pair of arms connected in series among six arms of a three phase bridge circuit which functions as the converter 3 or the
20 inverter 7; for example, an arm pair composed of the transistors TR1 and TR4 and the diodes D1 and D4. Therefore, the converter 3 or the inverter 7 can be formed by three modules 22.

As shown in Fig. 3, the three modules 22 are
25 arranged on a cooling device 41 and fixed thereto by bolts 43 to form a power unit 40. The modules 22 of the power unit 40 are wired in a predetermined manner to function as

the converter 3 or the inverter 7. The heat generated by operation of the power unit 40 is diffused through the cooling device 41 so that the modules 22 are cooled.

Fig. 3 shows the case where the semiconductor modules are directly attached to the cooling device 41. This results in an insulation-type semiconductor module, in which the semiconductor elements in one module can be electrically isolated from those of other modules attached on the same cooling device by insulating plates included in the respective modules. However, any type of the semiconductor modules can be also utilized by attaching them on the cooling device electrically isolatedly from, but thermally connected to the cooling device, so that semiconductor elements included in those modules are electrically insulated from one another.

Referring to Fig. 4, the cooling device 41 will be explained more in detail. The cooling device 41 has a base plate 45 made of material having a good heat transfer characteristic, such as aluminium, on one side of which the modules 22 are attached. To the other side of the base plate 45 there are fixed a plurality of heat exchange units 47, which are also made of material having a good heat transfer characteristic, such as aluminium. Each heat exchange unit 47 has a multiplicity of through holes 49 each functioning as a duct through which cooling air may flow. The unit 47 having such ducts 49 can be formed by various kinds of known working methods. It may be made by

drawing, for example. The cross-section of each duct 49 in this embodiment has a rectangular form, however it is not limited to such form. The cross-section thereof may be circular or honeycomb.

5 The cooling device 41 of this embodiment is assembled from several parts but, depending on its size, it may be manufactured as a unitary body including the base plate 45.

When many modules 22 are utilized, these modules can
10 be arranged in a zigzag pattern on the cooling device 41, as shown in Fig. 5. With such an arrangement of the modules, a better cooling effect can be attained, for the module 22' is cooled by air flow different from that cooling the module 22. Thus, the air flowing under the
15 module 22' is not significantly warmed by the heat generated by the module 22. Certainly, the cooling effect of the module 22" is not improved so much, because the air flowing thereunder is warmed by the heat generated by the module 22. Nevertheless, the total cooling effect can be
20 improved to a considerable extent.

In this way, there is constructed the power unit 40, which functions as the converter 3 or the inverter 7 of Fig. 1. Two of the thus constructed power unit 40, 40', one i.e. the power unit 40, being utilized for the converter 3
25 and the other, e.g. the power unit 40', for the inverter 7, are assembled as a single body as shown in Fig. 6. In this way, both power units 40, 40' are so integrated that the

heat exchange units of the cooling devices 41,41' thereof are opposed (adjacent), and they are fixed by side plates 51 in both sides of the power units 40,40'. In the underside of a thus formed power unit assembly 53, a wind channel 55 and, thereunder, a fan device 57 are provided so that the cooling air is sent into the air ducts 49 of the cooling devices 41,41' as shown by arrows in the figure.

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The power unit assembly 53 for use in the elevator driving system as shown in Fig. 1 is usually accommodated in a cubicle having a very limited space, together with other devices or equipment. Therefore, it is desirable that the power unit assembly 53 be as compact as possible.

Where the power unit assembly 53 is installed in such a cubicle, the following modification may be considered. As shown in Fig. 7, there is usually provided within a cubicle 59 a partition panel 61, on which various devices and equipment including the power unit assembly 53 are attached so that the limited space of the cubicle 59 can be effectively utilized. In this case, two power units 40,40' are coupled from opposite sides of the partition

panel 61 to form the power unit assembly 53. With this arrangement, a considerable saving can be made in the area on the panel 61 which is occupied by the assembly 53, compared with the case where both units 40,40' are juxtaposed on the same side of the panel 61.

The embodiments discussed above have a further effect, in addition to achieving a compact power unit assembly. That effect will be explained hereinafter with reference to Fig. 8. This figure shows an example of the transient thermal resistance characteristics of the cooling device 41,41'. In Fig. 8, the curve r_1 (solid line) shows the characteristics of the transient thermal resistance exhibited by a single power unit as shown in Fig. 3, and when it is operated as the converter. The curve r_2 (two dot chain line) shows the characteristics of the transient thermal resistance exhibited when two power units are assembled as shown in Fig. 6 to form the power unit assembly comprising the converter and the inverter and only the power unit as the converter is operated. The ordinate of Fig. 8 represents the temperature rise per power loss ($^{\circ}\text{C}/\text{watt}$) and the abscissa the lapse of time from the start of operation of the power unit. It is apparent from both characteristics r_1 and r_2 that the time constant T_2 of the transient thermal resistance in the latter case is twice times that T_1 in the former case and the thermal resistance in the latter case is reduced to about $1/2$. As is easily understood, these facts are caused by the effective mass of

the cooling device being doubled in the latter case by integrating the cooling devices of the converter and the inverter, although only the converter is operated.

An elevator is not always operated at its rated speed, but in most cases operated at a speed which is lower than the rated speed. Accordingly, in the power units for use in the elevator driving system as shown in Fig. 1, the operating conditions of the converter 3 are different from that of the inverter 7; the converter 3 is always actuated by the supply voltage of the power source 1, while the inverter 7 is actuated by the lower voltage. When a pulse width modulation (PWM) control method is used, in which the switching operation is conducted at a high frequency, the inverter 7 is in most cases operated in a low voltage range so that the switching loss is small and hence the amount of the heat generation is also small. Thus, the two power units are different in their duty of operation in the system shown in Fig. 1. However, the difference in the duty of operation is not limited to the system for driving the elevator. There can exist more or less such difference in the system which has a converter for converting an AC power to a DC power and an inverter connected thereto for reconvertng the converted DC power to an AC power. The present invention has advantage in application to all of such systems.

Under these circumstances, even if the converter and the inverter assembled as the power unit assembly 53 shown

in Fig. 6 are simultaneously operated, the transient thermal resistance characteristics generally follows the curve r_3 (broken line) in Fig. 8. Viewed from the loss for very short time (t_1), the cooling device operates at a thermal resistance of R_3 , which is smaller than R_1 ; in other words, the cooling efficiency is enhanced.

Accordingly, in the power unit assembly composed of power units which are different in operating duty and loss from each other, such as the power unit assembly for use in the elevator driving system as mentioned above, the cooling efficiency is equivalently improved by effectively utilizing integrated cooling devices.

Referring next to Figs. 9 and 10, there is described another embodiment, according to which a power unit assembly including wiring conductors and peripheral or auxiliary devices, such as a control device, a protection device and so on, may be made compact. In this embodiment, an insulating board as shown in Fig. 9 is attached on to the modules 22 which are fixedly arranged on the cooling device 41. As shown in Fig. 9, through the insulating board 63 there are bored a plurality of holes 65, 67. Of these holes, the holes 65 are bored at the positions corresponding to the terminals 31 of the modules 22 which are arranged under the board 63 as indicated by two dot chain line in the figure. The holes 67 are utilized for connection with other devices or equipment and can be provided in arbitrary positions within the insulating board

63. These holes 65, 67 are coupled by a plate-like conductor 69 in a predetermined circuit pattern. As is described later, the conductor 69 functions as conductors electrically connecting the modules 22. Further, such a
 5 predetermined circuit pattern can be also realized by known printed-circuit technology.

The holes 65, bored such as to correspond with the terminals 31, are also used to attach the insulating board 63 to the modules 22. As shown in Fig. 10, the insulating
 10 board 63 is secured on the modules 22 by bolts 71 which are screwed into the hollow terminals 31, the inner surfaces of which are provided with the female screws. As a result, the electrical connection is achieved between the terminals 31 of the modules 22 and between the terminals 31 and the
 15 holes 67 for connection with the external devices or equipments. With this, the space for wiring among the modules 22 can be considerably saved. Peripheral or auxiliary devices 73 can be provided on the insulating board 63, for example, a protection device for the tran-
 20 sistors of the modules 22 such as a surge killer circuit, a control device for controlling the switching operation of the transistors, and so on. These devices are preferably arranged close to the modules 22 as much as possible. The insulating board 63 makes such a desirable arrangement
 25 possible, so that the wiring conductors between the modules 22 and the protection and control devices can be shortened and therefore the control operation is not susceptible to

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higher harmonics and the noise caused by the switching operation of the transistors. Accordingly, stable operation of the power units can be achieved.

In Fig. 9, reference numeral 74 denotes rectangular holes bored through the insulating board 63. The fixing of the modules 22 to the cooling device 41 by means of the bolts 43 is achieved using the holes 74. The power unit constructed in this manner is a complete power unit having the protection and control devices, as shown in Fig. 10.

10 The completed power unit is assembled with another power unit similarly completed in such a manner that the cooling devices of both the power units are opposed as shown in Fig. 6. The thus assembled power unit assembly is not only compact as a complete assembly having peripheral or

15 auxiliary devices, but also very convenient for maintenance.

Although we have herein shown and described only limited forms of assembly embodying our invention, it is understood that various changes and modifications may be

20 made therein within the scope of the appended claims without departing from the spirit and scope of our invention.

CLAIMS

1. A power unit assembly for use in an elevator motor drive comprising a converter for receiving AC power and for converting the AC power into DC power, and an inverter for inverting the converted DC power into AC power and supplying it for a driving motor of an elevator, which converter and inverter are formed by semiconductor modules provided on a pair of cooling devices, each cooling device being electrically isolated from, but thermally connected to, associated semiconductor modules, wherein each of the cooling devices has a plane, on one side of which are the associated semiconductor modules of the cooling device, and on the other side of which plane is a heat exchange unit, and the cooling devices are positioned such that their heat exchange units are in thermal contact with each other.
2. An assembly according to claim 1, wherein the heat exchanging unit has a plurality of air ducts for the passage therethrough of cooling air.
3. An assembly according to claim 2, having a fan device for sending air into the air ducts from one end thereof.
4. An assembly according to any one of claims 1 to 3, wherein each cooling device has a base plate made of material having a good heat transfer characteristic, one of the surfaces of the plate serving as the plane on which the semiconductor modules are attached and the other surface of which supports the heat exchange unit.
5. An assembly according to any one of the preceding



claims, wherein the heat exchanging unit is divided into a plurality of sectioned units, adjacent ones of which are fixedly contacted to each other.

6. An assembly according to any one of the preceding claims, wherein the semiconductor modules are arranged in a zig-zag pattern on the corresponding cooling device.

7. An assembly according to any one of the preceding claims, wherein each semiconductor module has terminals only on the side opposite to the side on which the semiconductor module is connected to the cooling device, and

wherein there is further provided an insulating board on the semiconductor modules which has a plate-like conductor of a predetermined pattern on the side of the insulating board which opposes the side of the semiconductor modules having the terminals, so that when the insulating board is fixed on the semiconductor modules, the terminals of the semiconductor modules are coupled by the plate-like conductor to form a circuit for a power unit.

8. An assembly according to claim 7, wherein the plate-like conductor is formed by a printed-circuit technology.

9. An assembly according to claim 7 or claim 8, wherein peripheral or auxiliary devices for the power units are attached on the side of the insulating board opposite to the side on which the plate-like conductor is provided.

10. A power unit assembly substantially as herein



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described with reference to and as illustrated in Figs. to 6 or Fig. 7, or Figs. 9 and 10 of the accompanying drawings.
