Train-draft-cooling Power Converters for Bullet Trains : A Blowerless Converter/inverter

Takafumi Fukushima (born in 1972)[*1], Katsuya Umeda (born in 1962), [*2] Takeshi Tanaka (born in 1970)[*3],
Takashi Kameda (born in 1952)[*4], Jun Kanda (born in 1967)[*5]

1. Overview

A power converter (called a "converter/inverter" or "CI") is a power conversion device that controls the powering and energy-regeneration processes of a train. It combines a converter for converting AC power from the overhead wire to DC power with an inverter for converting DC power into three-phase AC power for driving the traction motors.

The converter/inverter for bullet trains has a large electrical capacity; therefore, it is important to efficiently dissipate the heat generated by switching of semiconductor devices. On the other hand, since there are major restrictions on the equipment weight and mounting space under the floor of a train, a forced-air cooling system - which directly cools cooling fins with a motor-operated blower mounted in the equipment - has been the most effective means up until now for reducing equipment size while ensuring reliability.

To reduce the weight and improve the reliability of the converter/inverter, Central Japan Railway Company (JR Central) has conducted, jointly with four converter/inverter manufacturers, research and development on a converter/inverter for a bullet train with train-draft-cooling system (called a "blowerless CI"). This blowerless CI is implemented in the mass-produced N700-series bullet trains, which started commercial operation in July 2007.

2. Outline of technology

The converter/inverter used for conventional bullet trains has a cooling arrangement with large-capacity semiconductor devices mounted on a cooler, which is filled with a CFC-substitute refrigerant in the vacuum state, as shown in Figure 1. The heat generated by the semiconductor devices is transmitted by vaporization of this refrigerant in the cooler. The vaporized refrigerant migrates to the top of the cooler mounted in an air channel in the converter/inverter, is liquefied again as a result of heat exchange in the cooler condensing unit with the cooling air that is stably fed to the air channel from a motor-operated blower mounted in the converter/inverter. The liquefied refrigerant then returns to the heat-receiving section of the cooler. In this forced-air cooling system, components such as the motor-operated blower and air channel take up a large portion of the equipment (see Figures 2 and 3), thereby making it difficult to downsize the system. Nevertheless, this system is considered to be the optimum one for reducing the size and the weight of the main circuit equipment in bullet trains, since the converter/inverter faces major restrictions on the equipment weight and mounting space under the floor. In addition, owing to the large electrical capacity required, the train-draft cooling that is applied in railcars on conventional lines cannot practically be used for bullet trains.

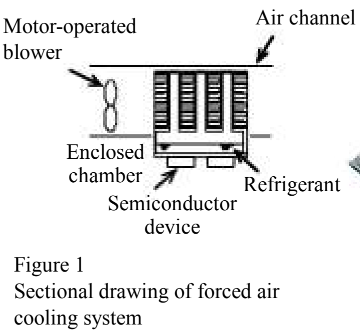

Figure 1
Sectional drawing of forced air cooling system

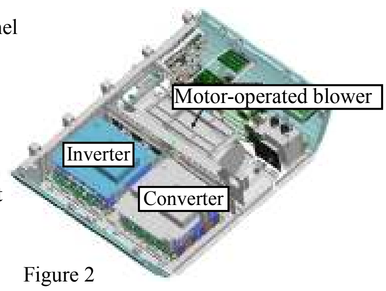

Figure 2
Schematic view of converter/inverter with forced air cooling system

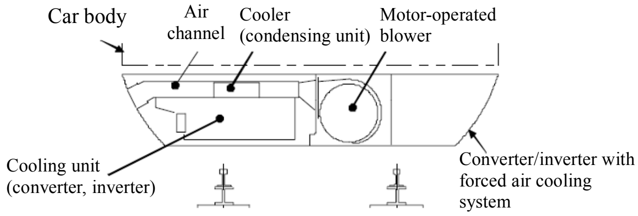

Figure 3: Sectional view of converter/inverter with forced-air-cooling system

In the blowerless CI described in this paper, the heat generated by the semiconductor devices is exchanged directly by the exposing aluminum cooling fins, on which semiconductor devices are mounted and which are located outside of the converter/inverter, to traveling air that hits the bullet train (see Figure 4). If the cooling fins are merely mounted on the bottom face, they protrude the underfloor clearance envelope, and cooling equipment cannot be arranged owing to the configuration of other components. A cooling-fin configuration with the bottom face of the converter/inverter angled so that the traveling air of the train can be fully utilized and the cooling equipment height is not affected (see Figures 5, 6 and 7) is therefore chosen.

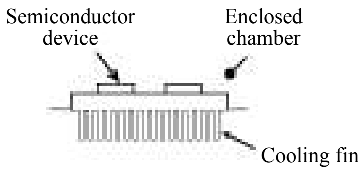

Figure 4
Sectional drawing of train-draft-cooling system

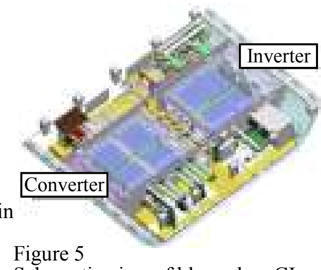

Figure 5
Schematic view of blowerless CI

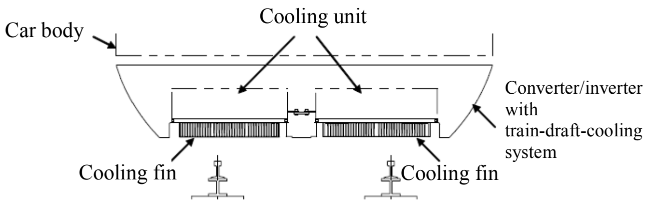

Figure 6 Sectional view of blowerless CI

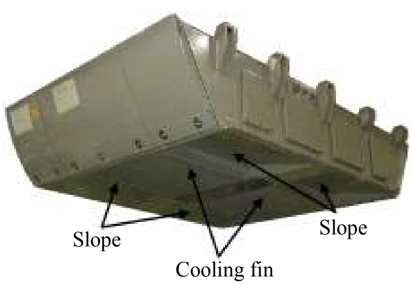

Figure 7 External appearance of blowerless CI

3. Summary

Compared to a converter/inverter (CI) of a forced-air-cooling system, a blowerless CI weighs about 220 kg (14%) less per unit. Furthermore, the blowerless CI is expected to exhibit additional effects such as better reliability thanks to its simpler structure and reduced environmental impact thanks to the refrigerantless system that does not use a CFC substitute.

*1 Affiliate, Central Japan Railway Company (Marunouchi 1-9-1, Chiyoda-ku, Tokyo 100-0005)
*2 Affiliate, Toshiba Corporation (Toshiba-cho 1, Fuchu City, Tokyo 183-8511)
*3 Hitachi, Ltd. (Ichige 1070, Hitachinaka City, Ibaraki 312-8506)
*4 Mitsubishi Electric Corporation (Tsukaguchi-honcho 8-1-1, Amagasaki City, Hyogo 661-8661)
*5 Fuji Electric Systems Co., Ltd. (Takatsukadai 4-1-1, Nishi-ku, Kobe City, Hyogo 651-2271)