Development of EV Component – Integrated Motor Drive Unit

Hiroaki Kakei

Keywords Inverter integrated, Efficiency, Downsizing, Flat wire, SiC

Abstract

We developed and manufactured traction motors for Electric Vehicles (EV), such as Mitsubishi i-MiEV and Outlander (PHEV model). In order to meet recent market requirements for a further compact design, lighter weight, and higher efficiency, we are promoting the development of an integrated motor drive system.

We manufactured a prototype model for an integrated motor drive unit on the basis of our conventional model engineering resources. We are currently working on the development of a next-generation model in order to realize a compact design and higher energy efficiency. The energy loss reduction is made through the application of a Silicon Carbide-Metal-Oxide-Semiconductor Field-Effect Transistor (SiC-MOSFET) and the improvement of the slot lamination factor by the use of flat wires.

1 Preface

The recently market of Electric Vehicles (EVs) is rapidly expanding and the development of EV traction motors is urgently required in technological fields. In order to cope with present market requirements for a further compact design and higher efficiency, we are promoting the development of an integrated motor drive system. When this system is developed, the three-phase high-voltage harness wires can be eliminated between the motor and inverter, resulting in the reduction of a dead space when the unit is installed on a vehicle, and the reduction of losses. This paper introduces a prototype of the integrated motor drive unit developed on the basis of current model engineering resources. It also shows a configuration of a next-generation model under development.

2 Configuration of a Prototype of Integrated Motor Drive Unit Utilizing the Current Model Engineering Resources

When the motor and the inverter are integrated, it is unnecessary to use a fixing stay that is conventionally employed for the inverter installed in the vehicle; as a result, space saving can be realized. If an external harness and such devices are reduced, the total number of parts used can be reduced, thus leading to cost reduction. When a three-phase harness is removed, reduction of losses can be effectively accomplished and three-phase power cables can be accommodated in a case. Compared with a former separated system, we confirmed that the shielding performance is improved and radiation noise can be reduced. Fig. 1 shows comparison of the radiation noise spectra.

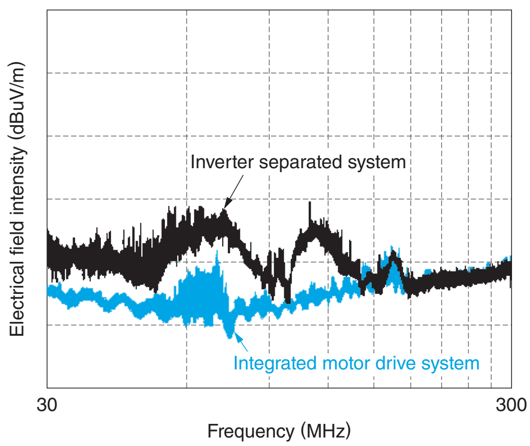


Fig. 1 Comparison of Radiation Noise Spectra

Comparison of the radiation noise spectra between the integrated motor drive system and a separated system is shown. In the case of an integrated motor drive system, no three-phase cables are protruded from the casing, thus securing high shielding performance.

Table 1 Specifications of Prototype of Integrated Motor Drive System

Specifications of the integrated motor drive system using the conventional model engineering resources are shown.

Item	Specification
Category	PM motor of round wire type
Maximum output	60 kW
Temperature under operating environment	−40～105℃
Max. rotational speed	12,000 min^{-1}
Cooling system	Water-cooled
DC voltage	330 V
Power device	Si-IGBT

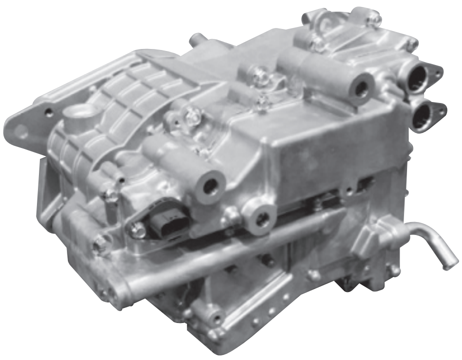


Fig. 2 Prototype of Integrated Motor Drive System

An integrated motor drive system prototype was made using the conventional model engineering resources is shown.

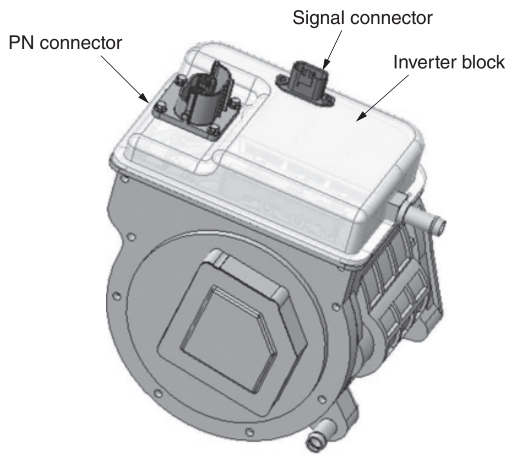


Fig. 3 Configuration of Next-Generation Model of Integrated Motor Drive Unit

Configuration of the next-generation model of an integrated motor drive unit applying the next-generation technologies is shown.

At our company, the mounting position of the inverter is set on the motor shaft. This is because such a setting can contribute to the expansion of the above floor vehicle inside space when the inverter integrated motor unit is loaded on the rear side of the vehicle. Table 1 shows the specifications and Fig. 2 shows an external appearance of the prototype of the integrated motor drive unit.

2.1 Configuration of the Next Generation Model

Fig. 3 shows the configuration of the next-generation model of the integrated motor drive unit. For the next-generation model currently being developed, we are trying to install the inverter block with the motor coupling part in coaxial direction. Using the Silicon Carbide-Metal-Oxide-Semiconductor Field-Effect Transistor (SiC-MOSFET) and next-generation power devices, overall mechanical configuration can be made more compact than ever and the shortest connections to the motor can be established.

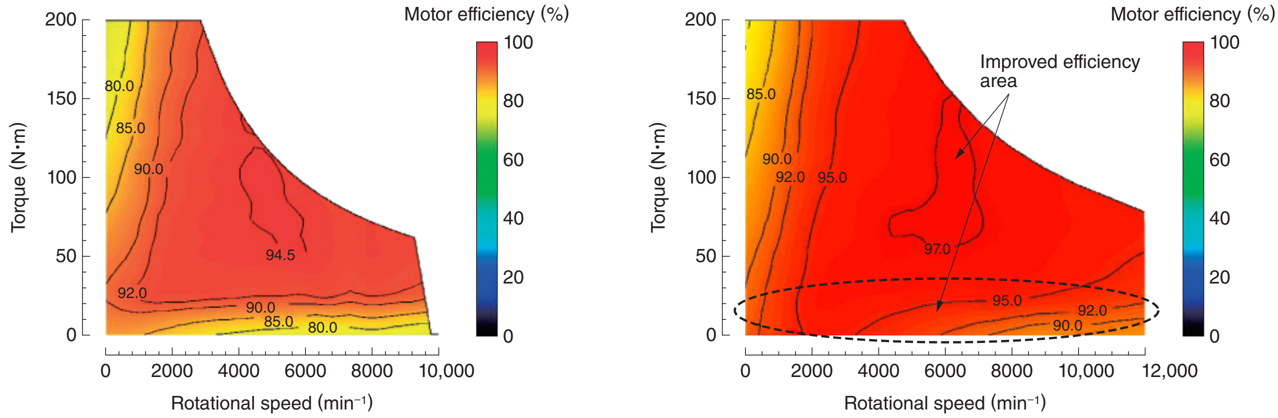
2.1.1 Motor Technologies

For a conventional traction motor, round wires are used for the stator coils. Similarly as shown in Fig. 2, round wires are also used for the mockup motor. In the case of a next-generation model, however, flat wires will be used in order to realize a further compact design and higher efficiency. As a result, the slot lamination factor will be improved by 35% compared with the use of round wires. Compared with the conventional model, the range of high efficiencies is definitely extended by virtue of the adoption of flat wires, a reduction of electromagnetic steel sheet thickness, and an improvement of magnet shapes. Fig. 4 shows a comparison of motor efficiencies. Within the range of the Worldwide-harmonized Light vehicles Test Cycle (WLTC) mode, efficiency improvement around 7% at the maximum can be expected. Thanks to these factors, the resultant output density is estimated to improve by 40%.

2.1.2 Inverter Technologies

For the next-generation model, we are trying to adopt SiC-MOSFET power devices and reduce the film thickness of smoothing capacitors. By changing the Silicon-Insulated Gate Bipolar Transistor (Si-IGBT) to the SiC-MOSFET, the volume of a power device is reduced by 23%. In addition, when the film thickness, thinner by 13% than conventional, is adopted, the volume of a smoothing capacitor can be reduced.

Fig. 5 shows comparison characteristics of power device losses. Regarding losses, a remark-



(a) Basic machine at a current technical level (Round wires applied)

(b) Next-generation model (Flat wires applied; electromagnetic steel sheets and magnets improved)

Fig. 4 Comparison of Motor Efficiencies

A comparison of efficiencies between current and next-generation technical bases is shown. It is clear that for the next-generation model, a high-efficiency area is expanding.

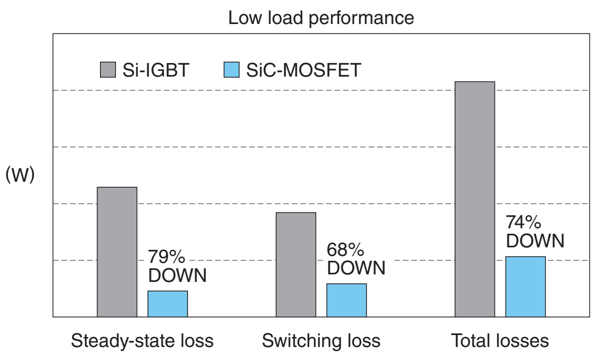


Fig. 5 Comparison Characteristics of Power Device Losses

Comparison of losses (at a low load) between IGBT and SiC is shown. When SiC is used, losses can be remarkably reduced.

Table 2 Specifications of Next-Generation Model

Specifications of the next-generation model are shown.

Item	Specification
Category	PM motor of flat wire type
Maximum output	100 kW
Temperature under operating environment	−40～105℃
Max. rotational speed	12,000 min^{-1}
Cooling system	Water-cooled
DC voltage	330 V
Power device	SiC-MOSFET

able reduction can be expected. As a result, the loss reduction rate at a light load is intensified and this will contribute to the improvement of specific power consumption (Wh/km) in WLTC mode.

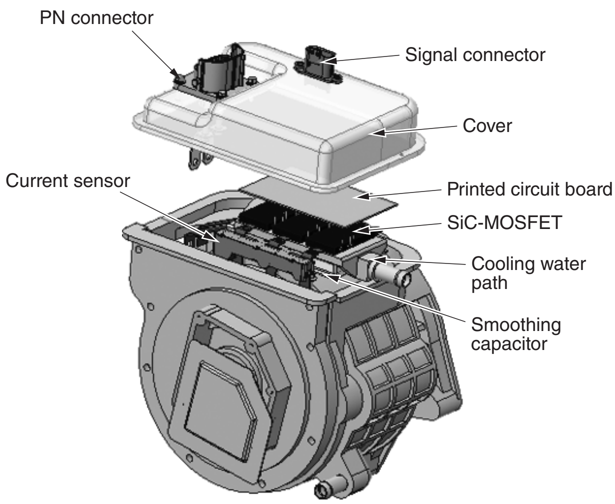


Fig. 6 Inner Configuration of Next-Generation Model of Integrated Motor Drive Unit

The inner configuration of the next generation integrated motor drive unit is shown.

2.1.3 Specifications of the Next-Generation Model

Table 2 shows the specifications of the next-generation model and Fig. 6 shows its inner configuration of an integrated motor drive unit. In order to realize a compact design, the SiC-MOSFET and smoothing capacitor are arranged so that they are wrapped by a water-cooling system. The inverter volume is approximately 1.6 L and the output density amounts to 60 kW/L. In the future, we will make a prototype model and work on its development for mass production.

3 Postscript

In the market, we consider that the development of integrated motor drive units will be continually accelerated well into the future. In this paper, the effectiveness of integrated motor drive units has been examined based on the prototype model utilizing our conventional model engineering resources. Still more, in regard to the next-generation model, we confirmed that the output density will be remarkably improved.

From now on, we will make a prototype of the next-generation model for the verification of performance evaluation and reliability level. We will work on the commercialization of this model.