Future Trend of Electrical Motor Drive System

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Electrical motors are used more than one-hundred years ago. At first DC motor was used because of battery power source [1]. After electrical power network was distributed as AC, AC electrical motors were driven by constant frequency and constant voltage such as 50 Hz or 60 Hz. So they were mainly used in fan, blower and compressor to give some force to water or air in water and sewage plant or so. They are considered to support the industrial revolution in modern society. However, the applications were limited in almost constant force or constant rotation speed condition, and the rotational speed control is difficult to be realized in high efficiency because of electrical power source problem.
Power electronics technology [2] solves the problem. It makes it possible to realize the variable rotational speed efficiently [3, 4]. The variable speed requires the change of voltage and frequency of supplied electrical power source because of the electrical motor theory. The rotating speed should be controlled to be the same as the traveling speed of magnetic field in the stator core, which is decided by supplied frequency. When the frequency increases, supplied voltage should increase because of the Faraday's law of induction. By means of the power electronics technology, variable voltage and frequency are possible to be realized efficiently, and then electrical energy is used widely [5].
Power device is used in it as a switching operation, which makes a high efficient electrical power conversion because voltage or current becomes zero and then the power loss becomes almost zero. Figure 1 shows the inverter circuit, a kind of power electronics technology, and IPM motor. The variable voltage is realized by changing the pulse-width and the variable frequency is realized by changing the pulse-timing in the output voltage as shown in Fig. 2. Then the electrical motor drive system is realized in transportation system such as electrical vehicle, hybrid ship or electrical airplane. Now is considered to be the second stage of electrical motor application. The closed connection between the electrical motor and the power electronics technology is indispensable. So their total system design is required as shown in Fig. 3 because each technology in the motor drive system is usually based on the different background [6-8].

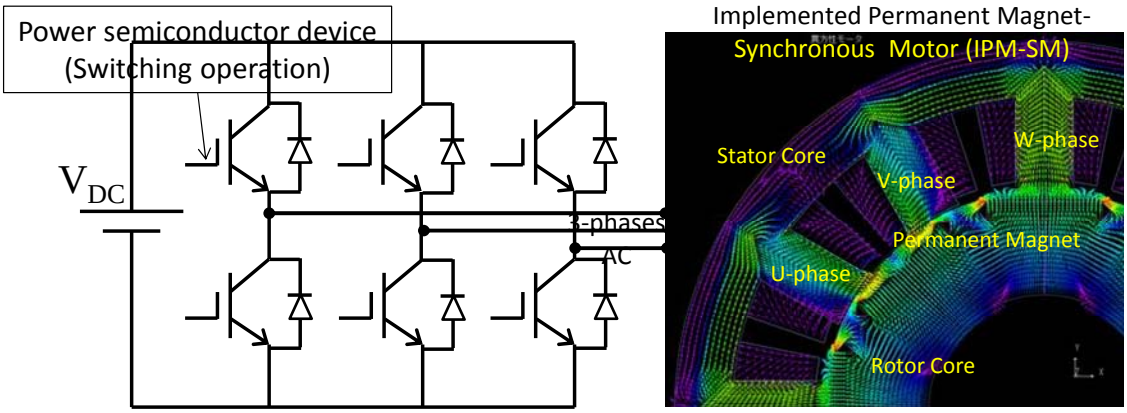

Fig. 1 Electrical motor drive system for speed control of electrical motor by power electronics technology.

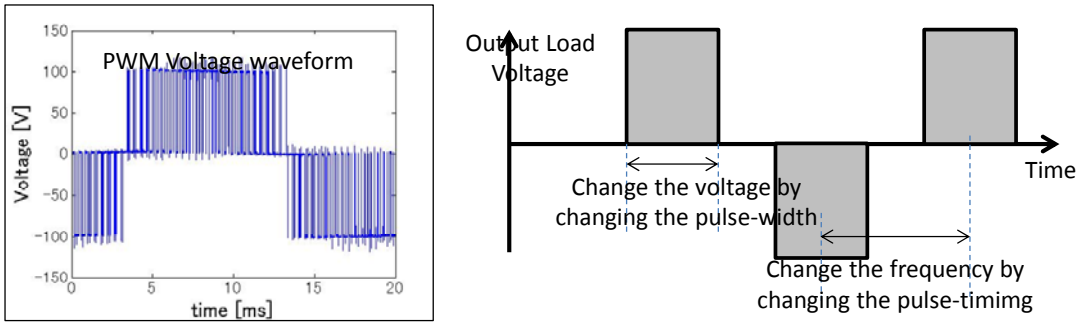

Fig. 2 Variable voltage and variable frequency realization by switching operation of power semiconductor device.

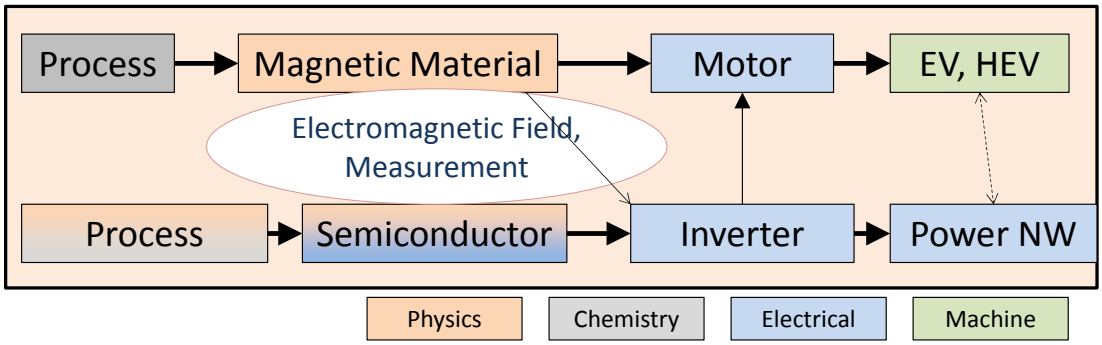

Fig. 3. Elementary technologies of motor drive system in electrical motor and power electronics.

The motor drive system usually moves with the vehicle in the transportation system. So there is a requirement for the downsizing and weight reduction of drive system. Because of electrical motor theory, the high rotational speed and then the high frequency operation are demanded in motor drive system as well as magnetic material [8]. Usually electrical power of motor (P) is shown as

$$P=\omega T$$

Here, ω is rotational angle velocity, and T is electrical torque. Since magnetic saturation of magnetic material is usually limited as 2 [T] or so, the torque per unit volume is said to be almost constant. Maxwell stress's law shows that electrical force is proportion to the square of magnetic flux density. So in order to increase the electrical power, the increase of rotational speed is required.

However, the high frequency demand derives some new problems to be solved; 1.Increase of supplied voltage (extra step-up converter is required), 2. Increase of mechanical gear, 3.Bearing problem for high rotation, 4.Increase of iron loss of the motor, 5. Increase of centrifugal force of the rotor (high tensile strength steel superior to magnetic property is required).

Direct drive system is considered to be another trend for high rotational speed and high frequency. Electrical motor directly rotates the wheels. So it has superior characteristics as; 1.Low voltage, 2.Gear less or so, 3.No bearing problem, 4.Iron loss reduction, 5.Centrifugal force reduction. Vehicle weight is reported to deduce more than 30 %. Which system is better is not now decided. But magnetic material is considered to be a key technology for future vehicle, because it is used not only in electrical motor but also in power electronics circuit [9].

Table 1 EV comparison of high speed and direct drive

	High Speed	Direct Drive
Electrical motor size	Small	Large
Supplied voltage	Large	Small
Mechanical gear	Large	Small
Mechanical bearing	Difficult	Easy
Iron loss	Large	Small
Centrifugal force	Large	Small
Drive shaft	Large	Small

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