

Experimental Verification of Winding Switching and AC Charging in a Power Unit with Integrated Charging and Power Supply

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In recent years, growing interest in the global environment has accelerated the development of electric vehicles (EVs) for carbon neutrality. For it to become widely adopted, there are obstacles regarding the increased weight and cost of the power converters required for connection to diverse power infrastructures. As a solution, we are developing a power unit that integrates the drive motor, inverter, and converter. This unit also incorporates a winding switching function to improve drive performance. However, switching the winding connection may cause torque fluctuation, and using the motor coils for AC charging requires control that accounts for the motor inductance. This paper presents verification tests of the performance improvement by winding switching during motor drive, and of an AC charging function realized with the motor coils and inverter.

Fig.1 shows the power unit that integrates the charging and power-supply functions into the drive motor and inverter. The motor is a two-phase motor with an α -phase ($\alpha 1$, $\alpha 2$) and a β -phase ($\beta 1$, $\beta 2$), each consisting of two coils, and the α -phase is electrically positioned at 90 degrees to the β -phase. Each of the four coils is connected to an H-bridge inverter, and a semiconductor bidirectional switch placed between the H-bridges of each phase changes the winding connection between series and parallel during motor drive.

Fig.2 shows the output characteristics of the motor. Since the number of turns in the parallel winding is halved relative to the series winding, the parallel winding has one-quarter the inductance and resistance and half the winding voltage, resulting in a higher output. By using the high-efficiency series mode during mode driving and the parallel mode for high output at high speed, both high efficiency and high output are achieved. Fig.3 shows the measured torque when the winding connection is switched from series to parallel mode. With the motor torque fixed at 64 N·m and the speed increased, each phase was switched at its zero-crossing current by a seamless switching control, so that the winding connection was changed without any torque fluctuation.

Fig.4 shows the results of the AC charging test, in which the α -phase operates as an isolated DC-DC (DAB) converter and the β -phase as a PFC. The figure shows the current and voltage waveforms of the PFC, the DAB, and the battery terminal. At a source voltage of 230 Vrms, an output of 681 V and -13.3 A was obtained at the battery terminal, confirming that AC charging is achieved using only the motor coils and inverter, without a dedicated on-board charger.

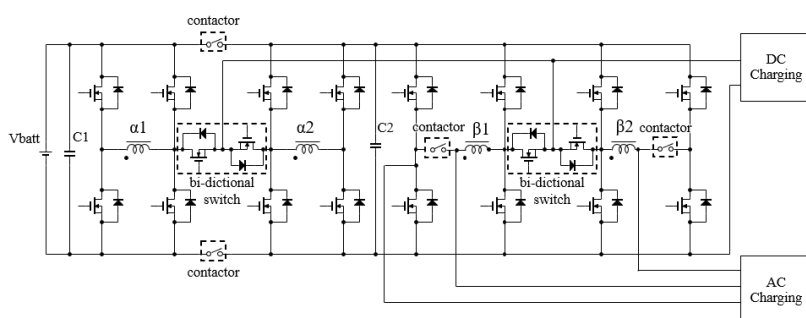


Fig.1 the power unit that integrates the charging and power-supply functions into the drive motor and inverter

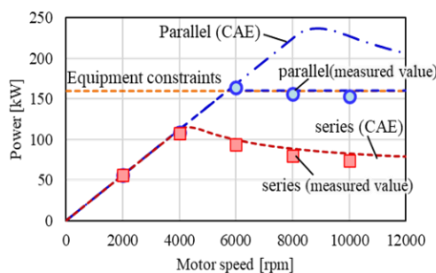


Fig.2 Motor power characteristics

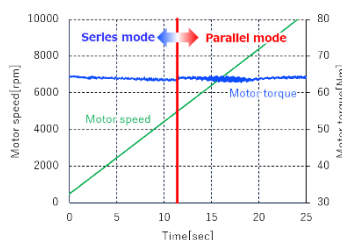


Fig.3 Measured torque during winding switching

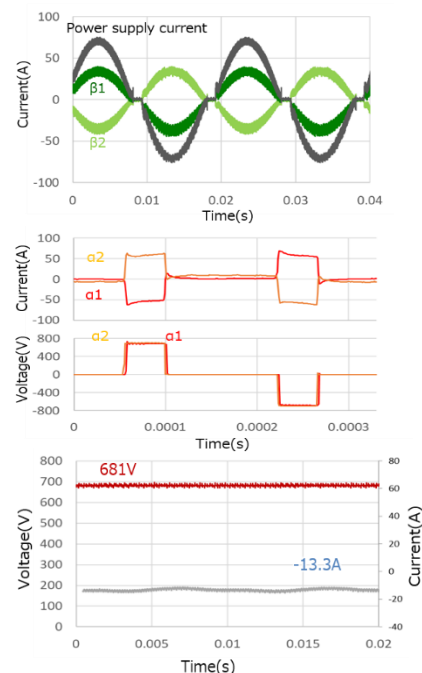


Fig.4 Results of the AC charging test