Development of a System Simulation Model for Estimating Short-Circuit Discharge Energy of an Automotive Electric Compressor

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▪ Background and Objectives

In recent years, the operating voltage of automotive electric compressors has been increasing. On the other hand, if a short-circuit fault, such as a phase-to-phase short circuit, occurs inside the compressor, the refrigerant may undergo self-decomposition. Accordingly, this study aims to develop a system simulation model for estimating the discharge energy generated during phase-to-phase short circuits in automotive electric compressors and to verify its validity through comparison with experimental results.

▪ System Model Construction and Experimental Validation

In the experimental setup shown in Fig. 1, an actuator was operated to generate a discharge between the v- and w-phases. In addition, a teardown analysis of the target compressor was conducted to identify circuit parameters, including the capacitance and switching device characteristics. Based on these parameters, the motor drive circuit shown in Fig. 2, an overcurrent protection (OCP) model for stopping PWM, and the short-circuit model connected between the v- and w-phases shown in Fig. 3 were developed. Validation was carried out using both the actual hardware and simulations under no-load conditions while varying the input voltage and motor speed. As shown in Fig. 4, the voltage and current waveforms obtained from the measurements and simulations were in good agreement. These results confirmed that the discharge energy depends on the input voltage rather than the motor speed, and that the discharge energy can be estimated by simulation at the same order of magnitude as that obtained experimentally.

▪ Simulation Results under Maximum Output Conditions and Summary conclusion

This study combined the short-circuit and OCP models with a maximum-power control model for an IPMSM. Under maximum-power operation, the simulated discharge of energy remained within the range of 33.49 to 34.44mJ over the speed range of 1000 to 8500 rpm. These results indicate that the discharge of energy depends strongly on the OCP response time. In contrast, the influence of the battery voltage was limited, and no significant dependence on the motor torque or rotational speed was observed.

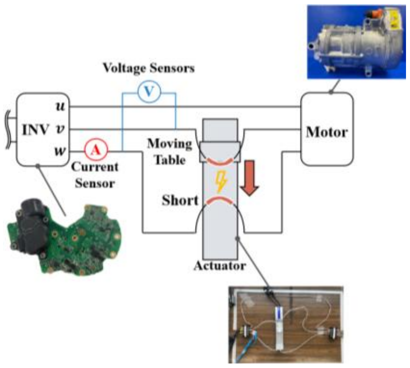

Fig.1 Experimental environment

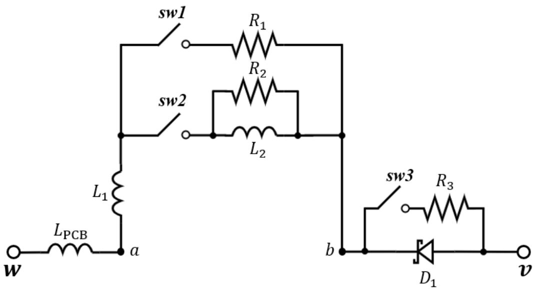

Fig.3 Short circuit model

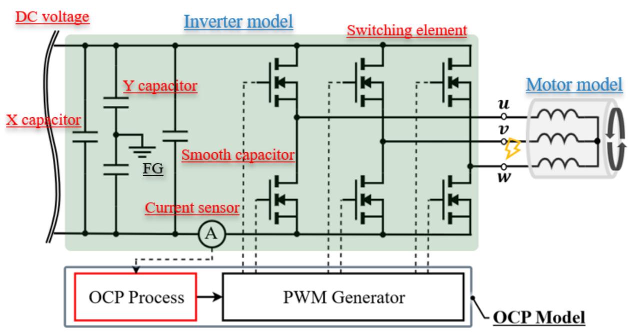

Fig.2 Simulation circuit configuration for a compressor

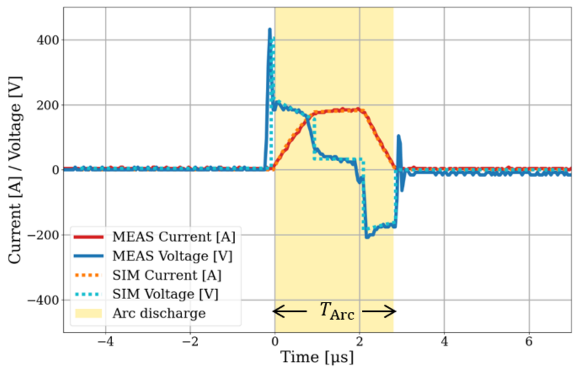

Fig.4 Phase-to-phase short-circuit discharge
(Input voltage: 400V, Rotational speed: 4000rpm)