Partial Discharge Testing of Motor Stators Using an Impulse Tester and Oscilloscope

It's possible to check for insulation defects in motor stators by observing current waveforms during impulse testing. If there are insulation defects between coils, partial discharges will occur at a lower voltage.

Target

EV motors, motors in inverter-equipped household appliances, air-conditioner compressors, industrial motors, industrial pumps, etc.

Market Movements

Inverters and motors are transitioning to high drive (switching) voltages. EVs use drive voltages of up to 800 V, while the drive voltages used by some inverter-equipped household appliances such as washing machines, air conditioners, and refrigerators range from 400 V to in excess of 600 V. Generally speaking, partial discharges occur when there is a voltage difference of greater than 350 V to 400 V. With general-purpose inverters, the problem of partial discharges becomes particularly conspicuous for motors when the primary-side voltage reaches 400 VAC.

Additionally, increasingly high-speed switching operation of inverters produces surge voltages of up to two to three times the switching voltage at the motor's terminals, making discharges more likely to occur (Fig. 1).

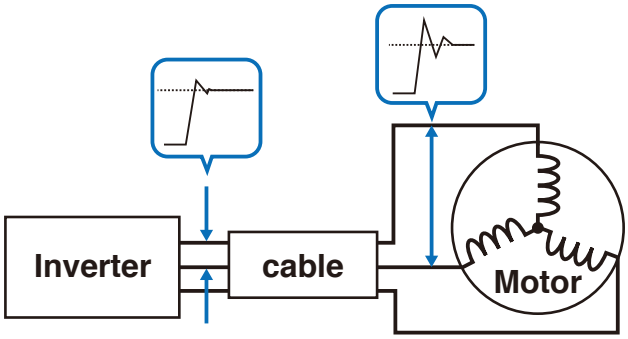

Fig.1 Surge voltage at the edge of a motor

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Problem

Fig. 2 illustrates the locations where there is a risk of partial discharge in a stator. When testing these at-risk locations while the stator is connected to the neutral point (Fig. 3), testing between shorted coils on the same phase can only be performed by applying an impulse voltage. By contrast, testing between coils and the core (ground), which are mostly isolated, can be carried out at a high AC voltage such as that used by a withstand voltage tester, rather than at an impulse voltage.

Impulse testers are designed to detect layer shorts (shorts occurring across multiple turns caused by coil damage). These instruments have not provided functionality for detecting partial discharges. Demand for the ability to detect partial discharges at impulse voltages is rising due to the trend towards higher-voltage inverters.

Fig.2 Locations with a high risk of partial discharge

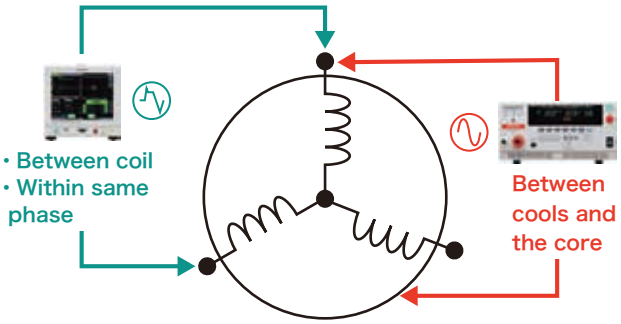

Fig.3 Test voltage when connected to the neutral point

Solutions

An impulse tester is connected between the coils of a stator that is connected to the neutral point (Figs. 4 and 5). Two CT probes are attached to the ground side. CT1 measures from DC to 120 MHz, while CT2 measures from 4.8 kHz to 400 MHz. The current waveforms from these two CTs are observed using an MR6000.

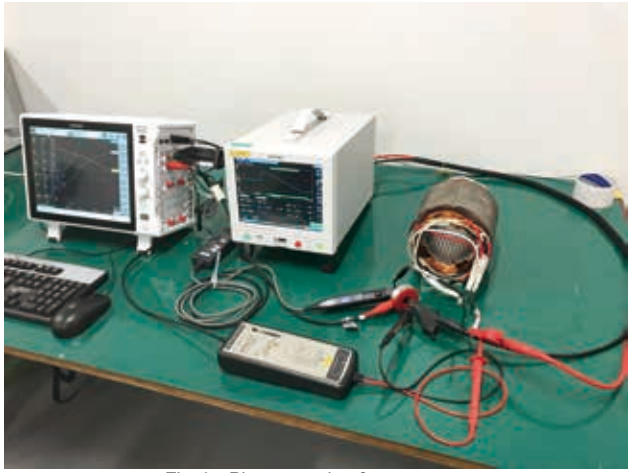

Fig.4 Photograph of test setup

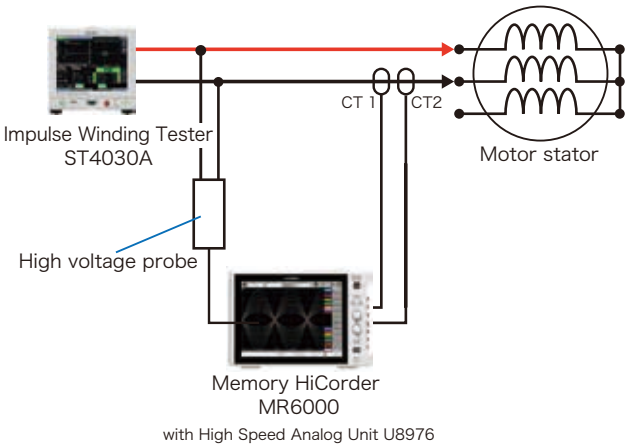

Fig.5 Partial discharge measurement circuit diagram

Equipment used

IMPULSE WINDING TESTER	ST4030A	HIOKI
MEMORY HiCORDER	MR6000	HIOKI
CURRENT PROBE (CT1)	CT6711	HIOKI
HFCT Current Transformer Broad Frequency Response (CT2)	CT-B5.0	MAGNELAB
High-Voltage Differential Probe	TA044	Pico Technology

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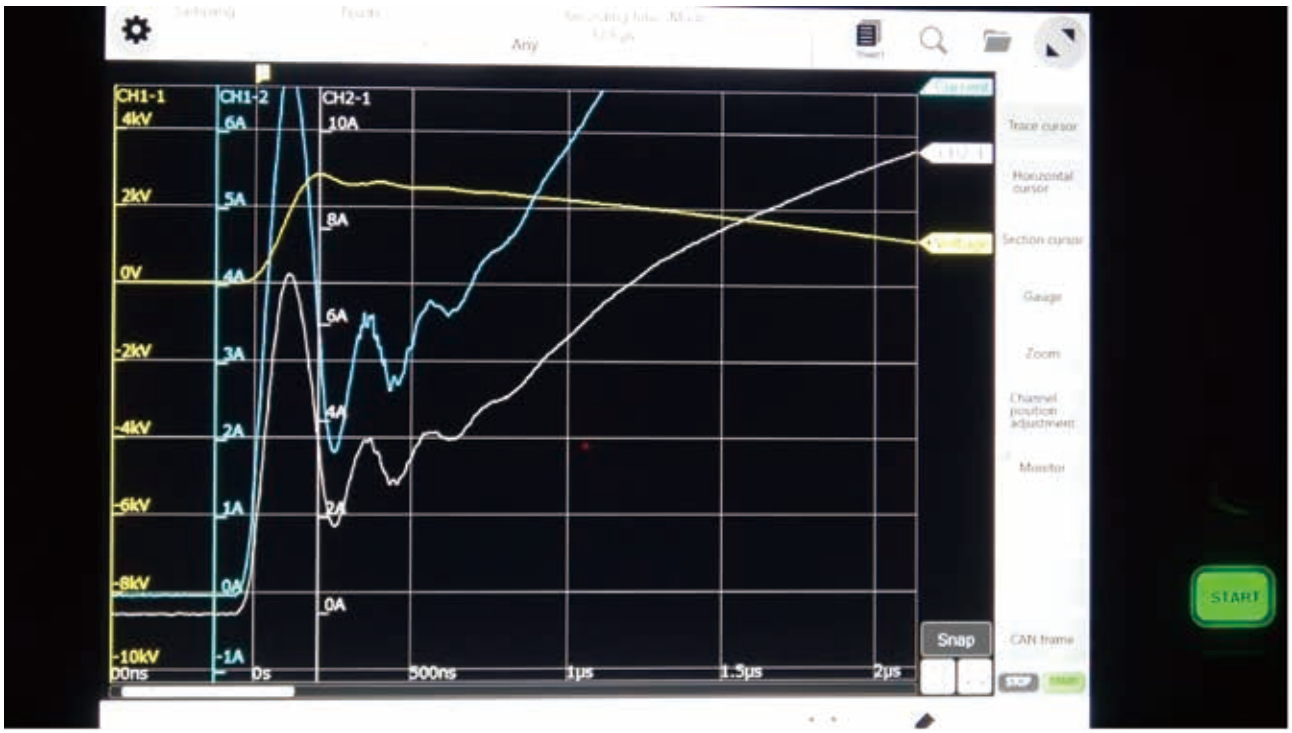
Measured data

- The current waveforms did not exhibit significant disturbances at a test voltage of 2000 Vpeak.
- A significant disturbance resembling a pulsating current was observed at a test voltage of 2600 Vpeak. That disturbance indicates a partial discharge.

Video URL:
https://www.youtube.com/watch?v=r0dAgxWSvUk



Summary

- Partial discharges can be detected by observing current waveforms during impulse testing.
- If there is a low level of insulation, the discharge starting voltage will decrease.
- It may be possible to automate testing using the oscilloscope's trigger or spectrum analyzer function.
- However, it will be necessary to exercise caution concerning grounding and the noise environment.

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