**Fault Signature of a Flux-Switching DC-Field Generator**

F. LIN, K. CHAU, C. LEE, C. LIU
*The University of Hong Kong, Hong Kong*

## I. INTRODUCTION

Flux-switching DC-field (FSDC) machine has the merits of low-cost and flux control ability. Furthermore, this type of machine also possesses the advantage of fault-tolerant capability [1]. However, a few studies have been done on the analyses of fault signatures of this type of machine even though it has two sets of windings [2].

This paper investigates the fault signatures of a magnetless FSDC generator under armature winding faults. It focuses on the study of short circuit faults and open circuit faults. The prototyped machine is operated with 10% to 50% turn shorts in one of phase windings. Open circuit fault is tested in one of the phases. The rectified generator output current and torque are utilized as the fault indicators. Both simulation and experiment results are studied for the verification.

## II. FAULT SIGNATURE APPROACH

The proposed magnetless FSDC machine is implemented by using software JMAG as shown in Figure 1(a). By using time-stepping finite element method (TS-FEM), the magnetic field distribution of the proposed machine under normal condition and half-phase A short circuit fault are showed in Figure 1(b) and 1(c) respectively. It can be found that the magnetic field is evenly and symmetrically distributed under normal operation, while it turns out to be asymmetrical under faulty operation (especially the circled areas). In this study, motor current signature analysis (MCSA) is used as the main fault detection method. It aims to sampling the harmonics components in the stator current spectra via fast Fourier transform (FFT). The corresponding frequency spectrum is given by:

$f_a = [(1-s)* n/p \pm k ]*f_1$ (1)

Where $k$ = 1, 2, 3, 4…, $n$ is the number of rotor bars, $p$ the number of pole pairs, $s$ the motor slip, and $f_1$ the fundamental frequency.

## IV. VERIFICATION RESULTS

Except for the model simulation, the FSDC generator is also prototyped for the experimentation. In the tests, both short circuit faults and open circuit faults are investigated on the prototype machine. Figure 2 is the measured rectified generator output current (light green) and the corresponding FFT outputs (dark green) of the prototyped machine. It demonstrates the machine's performance under normal operation (a) and 50% turns shorts in phase *A* (b). As expected, the current is periodical and regular under normal operation. Under short circuit condition, the current waveform becomes irregular and the peak-to-peak magnitude becomes larger. This is due to the fact that the 3-phase windings become imbalanced after short-circuit fault occurs. It can also be observed that the FFT output under short circuit operation has more glitches than the one under normal operation. Table I summarizes the machine performance under normal and faulty conditions. As expected, under short circuit operation, the average torque value is smaller than the normal one, and its torque ripple is larger than the normal condition.

This work was supported by a Grant (RGC GRF 17200614) from the Research Grants Council, Hong Kong Special Administrator Region.

## REFERENCES

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2) S. Cheng, T. G. Habetler, "Using only the DC current information to detect stator turn faults in automotive claw-pole generator" IEEE Trans. Ind. Electron, 60(8) 3462-3471, (2013)

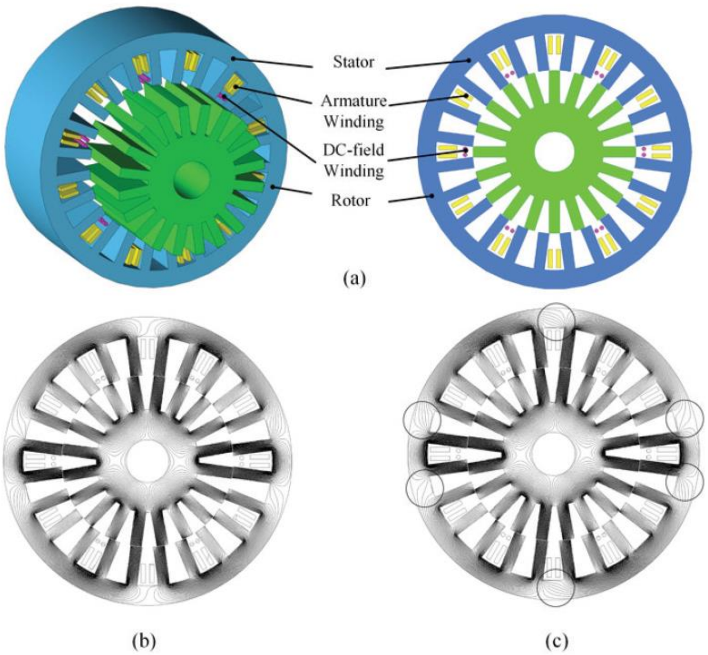


Fig. 1 (a) Exploded diagram of the proposed machine. (b) Magnetic field distribution under normal operation. (c) Magnetic field distribution under faulty operation.

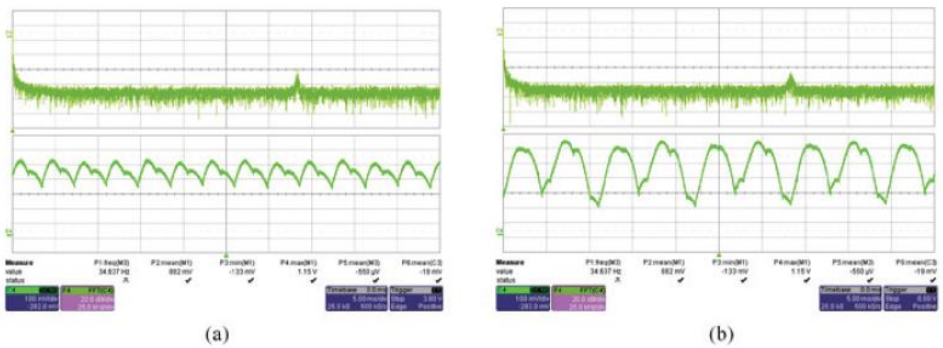


Table I Machine performance under normal and faulty conitions

| Operation mode | Average Torque | Torque ripple | Rectified output current | Phase A current(RMS) |
|---|---|---|---|---|
| Normal Operation | -1.37 Nm | -9.61 % | 1.71 A | 1.23 A |
| 50% turns shorts in Phase A | -1.71 Nm | -9.12 % | 1.95 A | 1.57 A |

Fig. 2 Measured rectified output current (light green) and the corresponding FFT outputs (dark green). (a) Normal. (b) Faulty