Characteristic Analysis of Induction Motor with Eccentricity and Broken Rotor bar by Finite Element Method and Motor Current Signal Analysis

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Abstract — This paper deals with fault characteristic analysis of squirrel cage induction motor by Finite Element Method (FEM) and motor current signal analysis (MCSA). Various fault cases of the induction motor are considered, and characteristic analysis of each case is performed by FEM. Based on the FEM results, the motor current signal is analyzed and compared to detect the condition of the induction motor. In addition, the torque and speed characteristic are also dealt with, and they are validated by experimental results.

I. Introduction

The faults of induction motors make torque ripple causing noise and vibration, and although the distorted air-gap flux density can be found using search coil in air-gap, the motor should be unnecessarily opened. Therefore, to overcome the disadvantage, this paper suggests the simpler method applying finite element method (FEM) and motor current signal analysis (MCSA) [1]-[5]. Since the various fault conditions show distinguishable current characteristics, it is possible to predict motor condition analyzing only phase current. In addition, the relationship between torque and speed according to the motor fault are analyzed by FEM and experiment applying speed reference scenario based on DSP (Digital Signal Processor).

II. Electromagnetic Field Analysis by FEM

A. Fault Detecting System

Fig. 1 shows the fault detection system by FEM and MCSA suggested in this paper. In this system, based on the assumed conditions presented in TABLE I, electro-magnetic field analysis by FEM is firstly performed. Here, the faults conditions are broken rotor bar, eccentricity, abnormal input source including harmonics. For example,

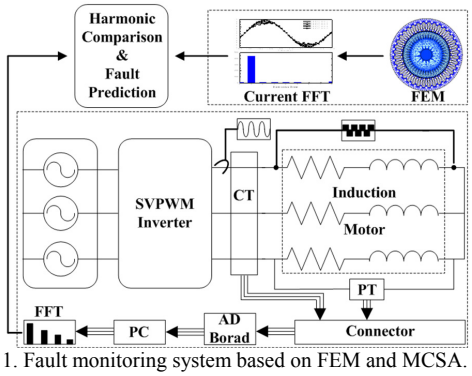

Fig. 1. Fault monitoring system based on FEM and MCSA.

TABLE I
FAULT CONDITIONS (A : BROKEN ROTOR BAR NUMBER, B : ECCENTRICITY, C : HARMONIC ORDER, D : ADDED AMPLITUDE)

B \ A	0	1	2	3	4	B \ A	0	1	2	3	4
0.00	1	2	3	4	5	0.50	15	61	71	81	91
0.05	6	25	34	43	52	0.55	16	62	72	82	92
0.10	7	26	35	44	53	0.60	17	63	73	83	92
0.15	8	27	36	45	54	0.65	18	64	74	84	94
0.20	9	28	37	46	55	0.70	19	65	75	85	95
0.25	10	29	38	47	56	0.75	20	66	76	86	96
0.30	11	30	39	48	57	0.80	21	67	77	87	97
0.35	12	31	40	49	58	0.85	22	68	78	88	98
0.40	13	32	41	50	59	0.90	23	69	79	89	99
0.45	14	33	42	51	60	0.95	24	70	80	90	100

Modulated Input Source Adding Harmonic Component

C \ D	0V	2V	4V	6V	8V	10V	12V	14V	16V	18V	20V
3rd	101	102	103	104	105	106	107	108	109	110	111
5th	112	113	114	115	116	117	118	119	120	121	122
7th	123	124	125	126	127	128	129	130	131	132	133

In the table, condition 1 implies a healthy motor (0 broken rotor bar, 0[mm] eccentricity), and condition 6 presents an unhealthy motor (0 broken rotor bar, 0.05[mm] eccentricity). The obtained phase current results by FEM are then analyzed by FFT (Fast Fourier Transform), and they are compared and analyzed with the real motor current signal.

B. Electromagnetic Field Analysis by FEM

The output power of the analysis model for electro-magnetic field analysis is 2.2[kW] at 1140[rpm], and its current analysis result by FEM is presented in Fig. 2. This result is compared with experimental motor current signal. In addition, this paper also considers various harmonic components of abnormal input source containing harmonic

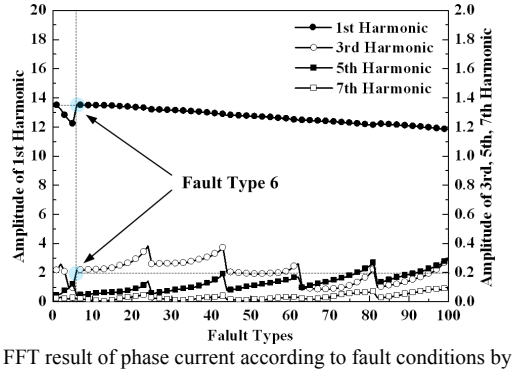

Fig. 2. FFT result of phase current according to fault conditions by FEM.

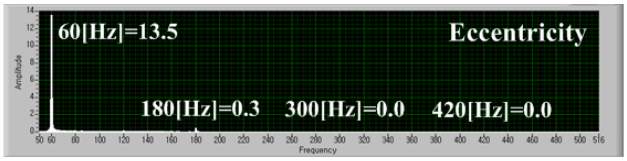

Fig. 3. FFT Result of Induction Motor Phase Current with Eccentricity.

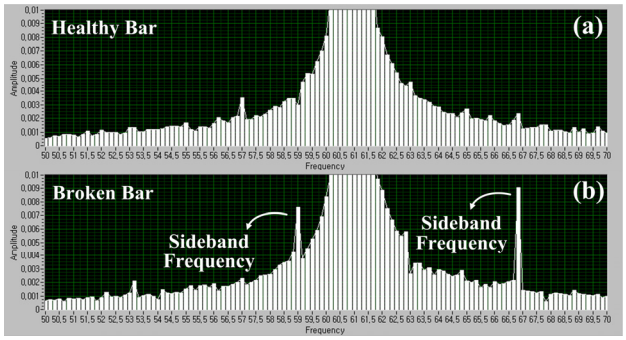

Fig. 4. Sideband frequency detection: (a) healthy, (b) broken rotor bar.

components, and its analysis results will be presented with its related torque characteristics in full paper.

C. Fault Detection by MCSA

Fig.3 shows experimental results, and it is evaluated as fault condition 6 in comparison with the FFT results by FEM. Here, the experimental motor does not have broken bar, and input voltage is sinusoidal. In addition, among the fault conditions, in particular, the broken rotor bar can be found by sideband frequency detection. For the comparison of a healthy motor and an unhealthy motor, this paper employs 0.4[kW] at 1710[rpm] induction motors. When the rotor bar is defected, the sideband frequency emerges, and the sideband frequency can be found as shown in Fig. 4.

D. Speed Characteristic caused by Broken Rotor Bar

The severe operating condition of induction motors can cause the corrosion of rotor bar, and it affects on the conductivity of broken rotor bar directly related to torque characteristics. In Fig.5, the torque characteristics according

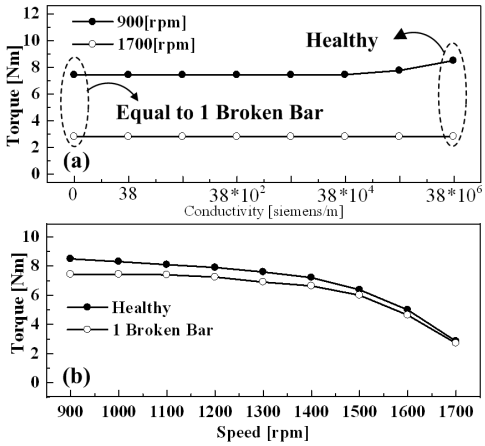

Fig. 5. Torque characteristic according to conductivity and speed : (a) Torque vs. conductivity, (b) Torque vs. speed.

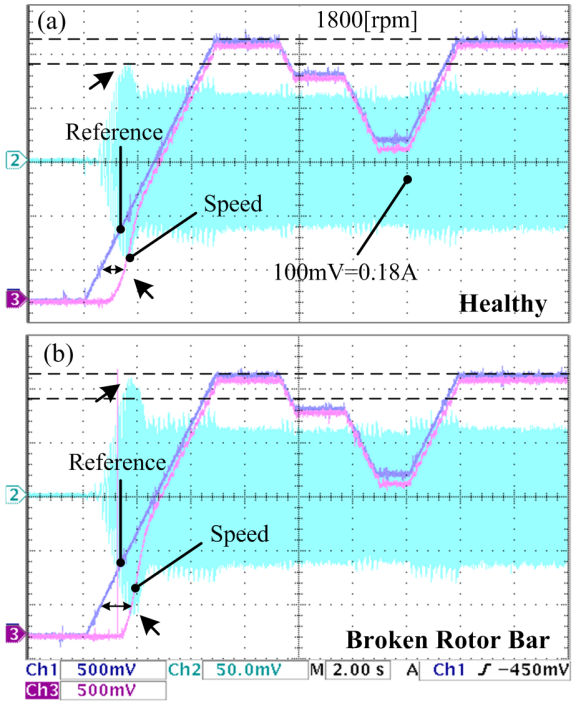

Fig. 6. Experimental current and speed characteristic: (a) healthy, (b) broken rotor bar.

to conductivity of one rotor bar and speed obtained by FEM. Here, it is noticed that the effect of broken rotor bar is not crucial in high speed while it results the decreased torque in low speed. In addition, Fig. 6 compares the experimental speed and current characteristic according to the existence of broken bar. When the speed is low, the difference of speed and current characteristics is visible as shown in the figures. However, in high speed, the difference is minor.

III. Conclusion

In this paper, the fault characteristics of induction motor are dealt with. By showing various results, the faults are detected, and its related characteristics are analyzed. In full paper, motor specific explanation will have been presented.

IV. References

[1] Jawad Faiz, Bashir Mahdi Ebrahimi, Bilal Akin and Hamid A. Toliyat, “Finite-Element Transient Analysis of Induction Motors Under Mixed Eccentricity Fault”, *IEEE Trans. on Magn.*, vol.44, no.1, pp.66-74, 2008.

[2] O. A. Mohammed, N. Y. Abed and S. Ganu, “Modeling and Characterization of Induction motor Internal Faults Using Finite-Element and Discrete Wavelet Transforms”, *IEEE Trans. on Magn.*, vol.42, no.10, pp.3434-3436, 2006.

[3] G.H. Jang, S. J. Park, “Simulation of the Electromechanical Faults in a Single-Phase Squirrel Cage Induction Motor”, *IEEE Trans. on Magn.*, vol.39, no.5, pp.2618-2620, 2003.

[4] Jawad Faiz, Bashir Mahdi Ebrahimi and Hamid A. Toliyat, “Effect of Magnetic Saturation on Static and Mixed Eccentricity Fault Diagnosis in Induction Motor”, *IEEE Trans. on Magn.*, vol.45, no.8, pp.3137-3143, 2009.

[5] Jawad Faiz, Bashir Mahdi Ebrahimi, Bilal Akin and Hamid A. Toliyat, “Comprehensive Eccentricity Fault Diagnosis in Induction Motors Using Finite Element Method”, *IEEE Trans. on Magn.*, vol.45, no.3, pp.1764-1767, 2009.