

Spectral Analysis of Signals of Commutator DC Motor

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Summary: Measurement investigations have been carried out for commutator dc motor with internal asymmetries. Construction of considered motor enables to realize the breaking of one rotor coil and shorting of two groups of rotor coils. Each group contains three rotor coils. The basis of study were transients: current and voltage of field winding, current and voltage of armature winding and velocity of the rotor. In paper are presented selected measurement results and corresponding results of spectral analysis.

Key words: commutator dc motor, internal asymmetries, measurement, spectral analysis

1. INTRODUCTION

Study of features of dc machine and presentation of new problems is purpose of this paper. Experimental investigations were carried out for specially designed dc motor. Construction of this motor permits to investigate the internal asymmetries. Authors carried out spectral analysis of field and armature currents as well as field and armature voltages in failure conditions of motor.

2. MATHEMATICAL MODELLING OF COMMUTATOR DC MOTOR

The commutator of dc motor is approximated by resistance circuit. Extremely different values are assigned to parameters of circuits depending on the angular position of the rotor. Mathematical model of dc motor formed in this manner is a set of stiff nonlinear differential equations [5]. This model is competitive in comparison with models presented in literature [1], [4] and [6]. The effective implicit integration method was used for solution of model equations. Measurement investigations were aided with computer simulation [2, 3 and 7]. From simulation implied that field and armature currents, field and armature voltages, electromagnetic torque and rotor velocity may contain diagnostic information.

3. MEASUREMENT INVESTIGATION

This motor enables to realize the breaking of one loop rotor coil and shorting of two groups of rotor coils. Each group of coils contains three loop rotor coils. DC machine operating as a motor in open and closed regulation system was investigated in following cases: faultless state, shorting of first group of coils, shorting of second group of coils, shorting of two groups of coils, breaking of one coil, shorting of first group of coils and breaking of one coil, shorting

of second group of coils and breaking of one coil, shorting of two groups of coils and breaking of one coil. Measurements have been carried out for supplying of armature and field circuits from constant voltage sources (dc generators). The nominal values of dc machine were: $P_N = 13$ kW, $U_N = 75$ V, $I_N = 200$ A, $U_{fN} = 220$ V, $n_N = 700$ rpm. It was assumed that each group of three loop rotor coils is shorted through resistance $R_{bz} = 44$ mW. Measurements have been developed by means of 16-bit a/d converter. The dc generator connected with external resistance produced the load torque. The additional resistances were used in short-circuits to avoid damage of rotor winding. Measurement results of field and armature currents as well as field and armature voltages for dc motor operating in closed regulation system are presented in Figures 1–12.

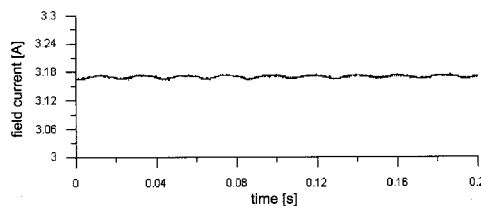


Fig. 1. Field current waveform (faultless state)

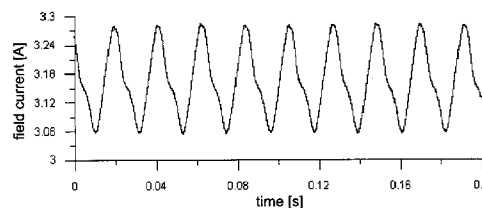


Fig. 2. Field current waveform (shorting of three rotor coils)

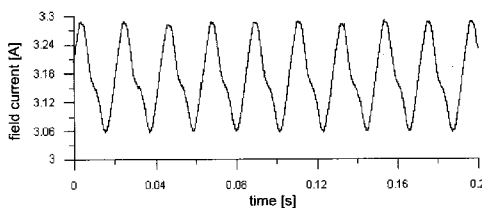


Fig. 3. Field current waveform (shorting of three rotor coils and breaking of one rotor coil)

Fig. 4. Armature current waveform (faultless state)

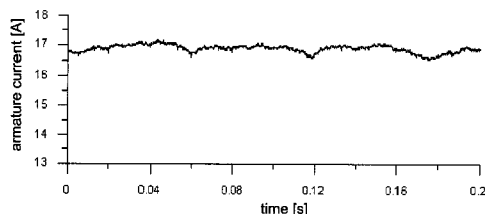


Fig. 5. Armature current waveform (shorting of three rotor coils)

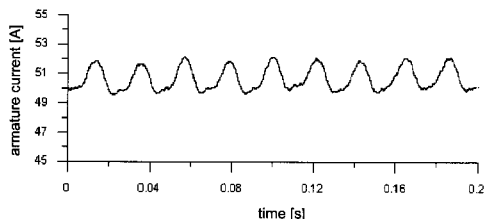


Fig. 6. Armature current waveform (shorting of three rotor coils and breaking of one rotor coil)

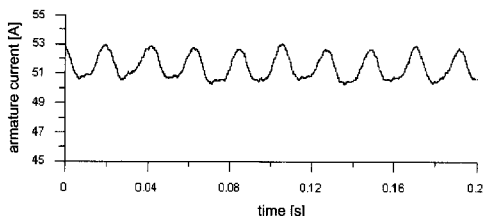


Fig. 7. Field voltage waveform (faultless state)

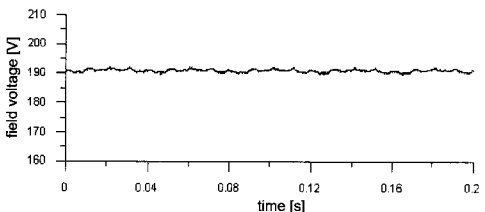


Fig. 8. Field voltage waveform (shorting of three rotor coils)

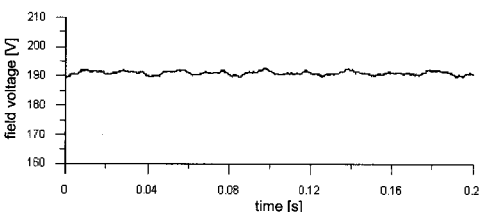


Fig. 9. Field voltage waveform (shorting of three rotor coils and breaking of one rotor coil)

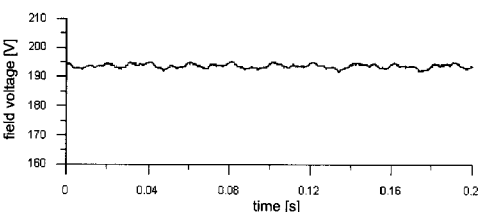


Fig. 10. Armature voltage waveform (faultless state)

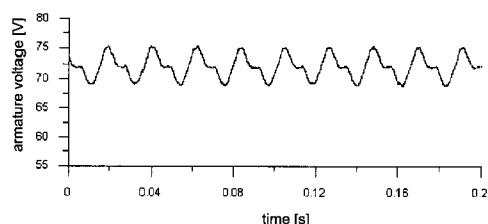
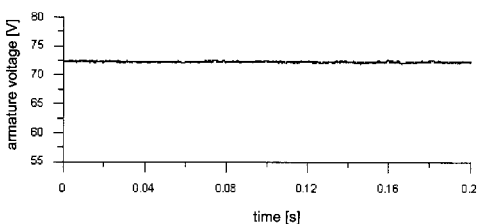


Fig. 11. Armature voltage waveform (shorting of three rotor coils)

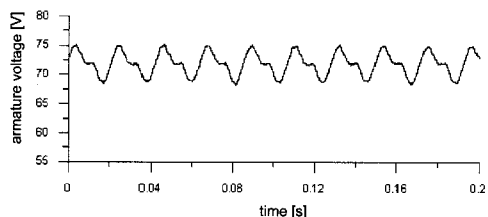


Fig. 12. Armature voltage waveform (shorting of three rotor coils and breaking of one rotor coil)

4. SPECTRAL ANALYSIS

Spectral analysis of signals of commutator dc motor has been carried out using Matlab environment. Example results of spectral analysis are presented in Figures 13–24. Diagnostic harmonic depends on the velocity of rotor. In figures the following notation was assumed: n — rotor velocity, f_{diag} — diagnostic harmonic of field and armature currents as well as field and armature voltages.

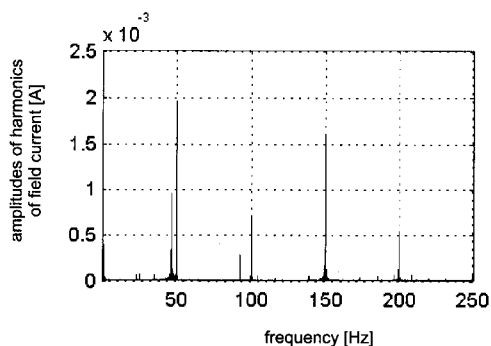


Fig. 13. Spectrum of field current (faultless state), $n = 694.52$ rpm, $f_{diag} = 46.33$ Hz

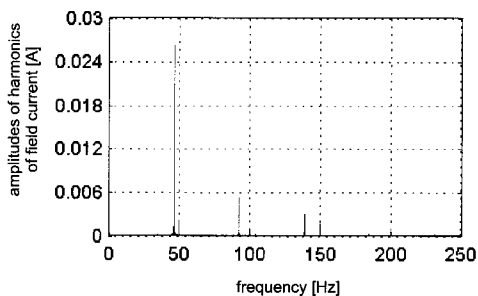


Fig. 14. Spectrum of field current (shorting of three rotor coils), $n = 693.75$ rpm, $f_{diag} = 46.25$ Hz

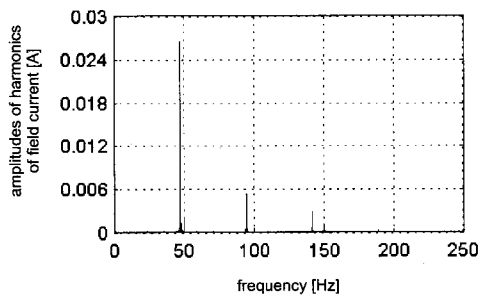


Fig. 15. Spectrum of field current (shorting of three rotor coils and breaking of one rotor coil), $n = 708.05$ rpm, $f_{diag} = 47.20$ Hz

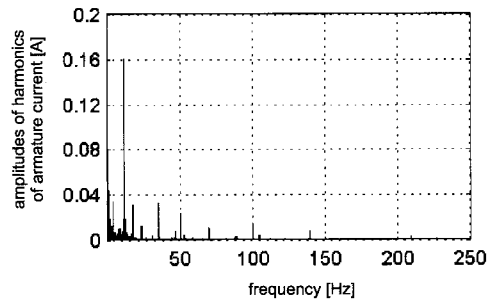


Fig. 16. Spectrum of armature current (faultless state), $n = 694.92$ rpm, $f_{diag} = 46.33$ Hz

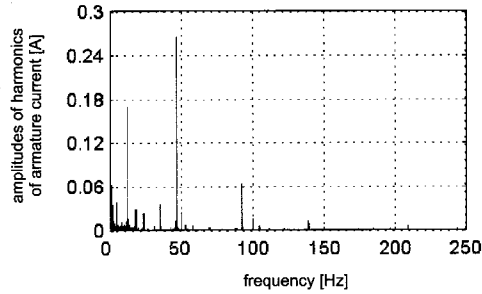


Fig. 17. Spectrum of armature current (shorting of three rotor coils), $n = 693.75$ rpm, $f_{diag} = 46.25$ Hz

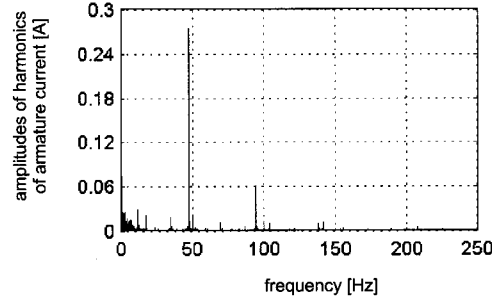


Fig. 18. Spectrum of armature current (shorting of three rotor coils and breaking of one rotor coil), $n = 708.05$ rpm, $f_{diag} = 47.20$ Hz

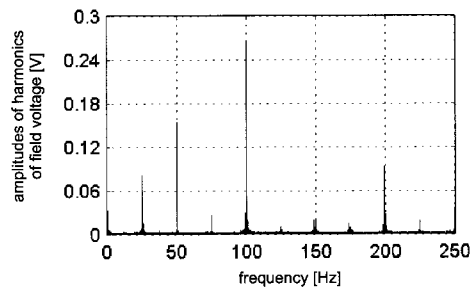


Fig. 19. Spectrum of field voltage (faultless state), $n = 694.92$ rpm, $f_{diag} = 46.33$ Hz

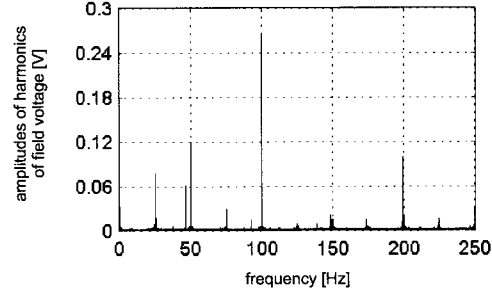


Fig. 20. Spectrum of field voltage (shorting of three rotor coils), $n = 693.75$ rpm, $f_{diag} = 46.25$ Hz

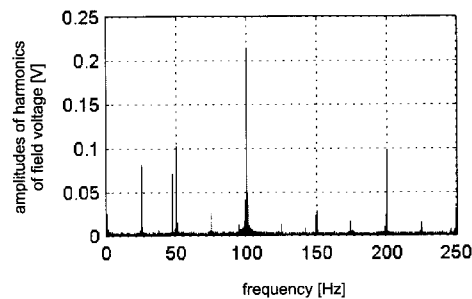


Fig. 21. Spectrum of field voltage (shorting of three rotor coils and breaking of one rotor coil), $n = 708.05$ rpm, $f_{diag} = 47.20$ Hz

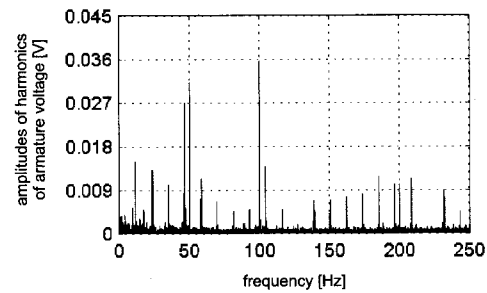


Fig. 22. Spectrum of armature voltage (faultless state), $n = 694.92$ rpm, $f_{diag} = 46.33$ Hz

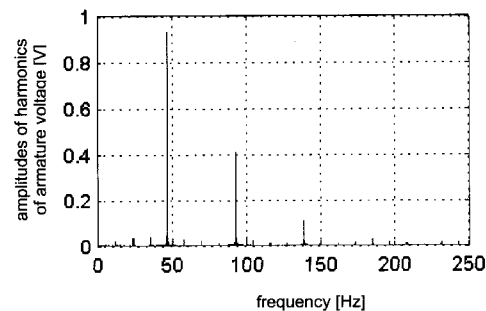


Fig. 23. Spectrum of armature voltage (shorting of three rotor coils), $n = 693.75$ rpm, $f_{diag} = 46.25$ Hz

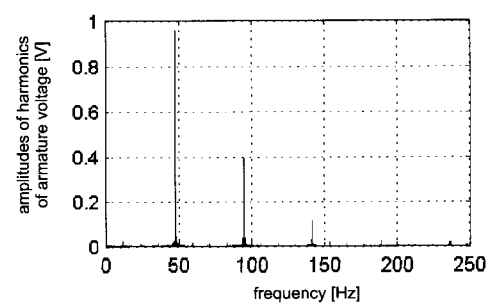


Fig. 24. Spectrum of armature voltage (shorting of three rotor coils and breaking of one rotor coil), $n = 708.05$ rpm, $f_{diag} = 47.20$ Hz

5. CONCLUSIONS

The shorted and broken rotor coils influence on com-mutator dc motor signals: voltages, currents, electromagnetic torque and rotor velocity. In case of shorting of three or six rotor coils occur considerable deformations of field current, armature current, field voltage, armature voltage, electromagnetic torque and rotor velocity. In case of breaking of one coil the deformations of mentioned quantities are also visible. Effects of commutation processes can be found in the wave-forms of signals. Particularly field and armature currents as well as field and armature voltages of dc motor contain deformations which repeatability is closely connected with the velocity of the rotor. Amplitudes of harmonics of field and armature currents as well as field and armature voltages in emergency states are several times greater than those in faultless state. For supply from constant voltage source (from dc generator) in spectrum of signals (particularly in field voltage spectrum) the 50 Hz harmonic and its multiples are visible. Results of spectral analysis indicate that field and armature currents as well as field and armature voltages contain information about the motor state and can be used as diagnostic signals. From investigations implies that in rotor velocity is also included information about motor state according to simulation result. Because of this reason deep assessment of rotor state requires the taking into consideration several measured signals.

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