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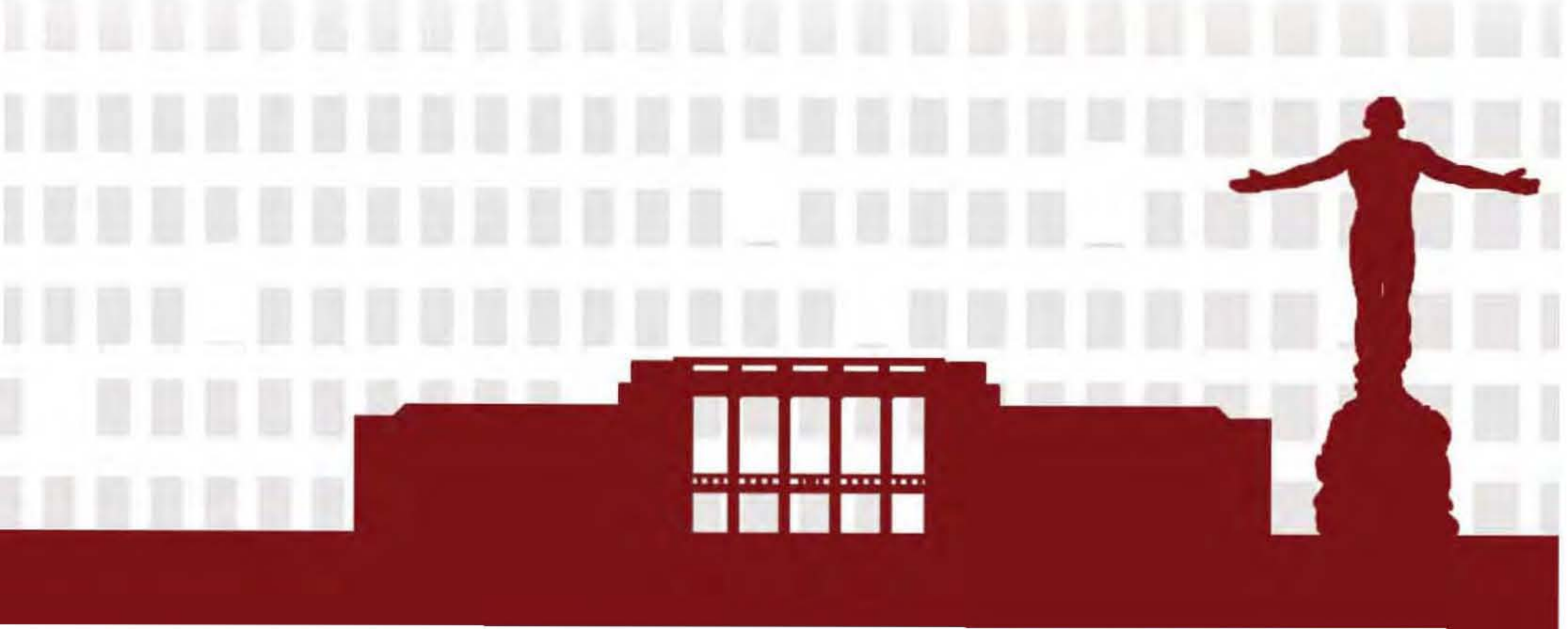

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PERFORMANCE OF THREE-PHASE PERMANENT MAGNET SYNCHRONOUS MACHINES UNDER INFLUENCE OF DIFFERENT MAGNETIZATION PATTERNS

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ABSTRACT

Permanent magnet synchronous machines (PMSMs) are intensively used in industries, home appliances, automotive and aircraft due to their high efficiency, high torque density and good dynamic performance. Rotor magnetic flux is readily available from the magnet materials in the rotor core. Hence, rotor loss is significantly reduced because it does not carry field winding and magnetizing current. PMSMs are normally classified by the manner the permanent magnet materials are placed in the rotor core such as: surface-mounted magnet, surface-inset magnet, bread loaf magnet, interior magnet and spoke magnet [1]. Furthermore, five different magnetization patterns for the surface-mounted PMSMs are possible i.e. radial magnetization, parallel magnetization, sinusoidal amplitude magnetization, ideal Halbach and multi-segment Halbach. Each of these magnetization patterns can be represented in 2D polar coordinate system with the radial and tangential components of magnetic fields as shown in [2]. This paper investigates the influence of different magnetization patterns in the performance of three-phase permanent magnet synchronous motors (PMSMs). In typical surface-mounted PMSM, three magnetization patterns are popularly employed i.e. radial magnetization (RM), parallel magnetization (PaM) and ideal Halbach magnetization (IH). These magnetization patterns are then applied to the 9-slot/10-pole (9s/10p) and 12-slot/10-pole (12s/10p) PMSMs. A 2D finite element method (FEM) is intensively used in this investigation to model and predict the electromagnetic characteristics and performance of the PMSMs such as the air gap flux density distributions, coil flux linkage waveform, phase back-emf, cogging torque, unbalance magnetic pull and output torque. The phase back-emf is further computed into its harmonic components in order to optimize motor performance with minimum ripple in its output torque. As a result, this optimization could potentially provide the cost saving by having smaller magnet volume as being demonstrated in the case of 9s/10p motor in this paper. Figure 1 shows the 2D finite element models and the phase winding allocations for 9s/10p and 12s/10p PMSMs respectively. Figures 2 and 3 show the phase back-emf waveforms induced in both motors at 600rpm rotor speed. As expected, almost sinusoidal waveform with highest magnitude of phase back-emf is induced from motors having ideal Halbach magnetization. Whereas, the phase back-emf is more trapezoidal in shape for the motors having either radial magnetization or parallel magnetization. Contents of higher order harmonics in these trapezoidal phase back-emfs can be extracted using Fast Fourier Transform (FFT). If the motors are excited with sinusoidal currents, the output torque can be predicted as shown in Figures 4 and 5. Table I indicates the predicted average output torque and percentage of torque ripples.

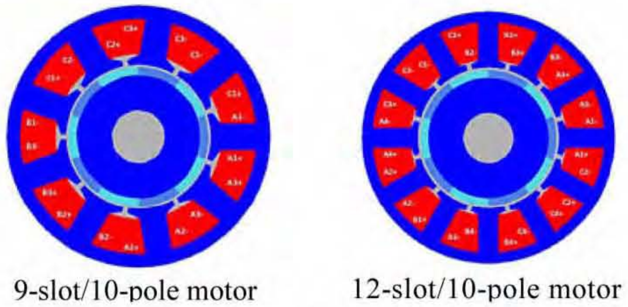

Figure 1. Motor models in 2D FEM

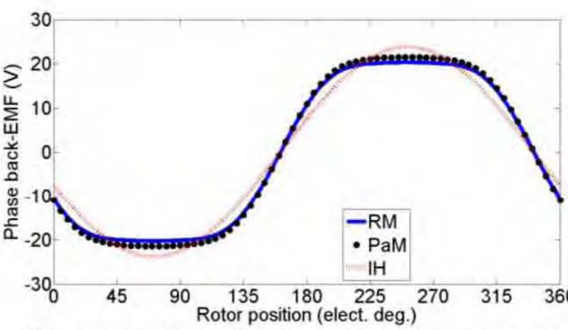

Figure 2. Phase back-emf in 9s/10p motor

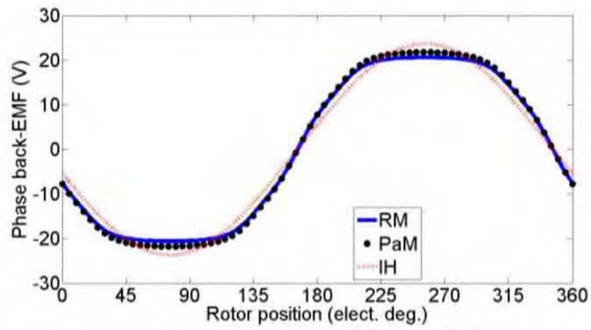

Figure 3. Phase back-emf in 12s/10p motor

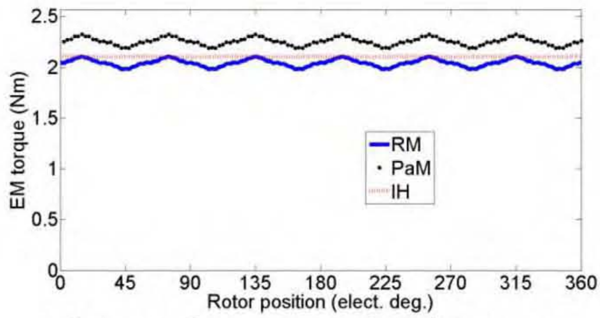

Figure 4. Output torque in 9s/10p motor

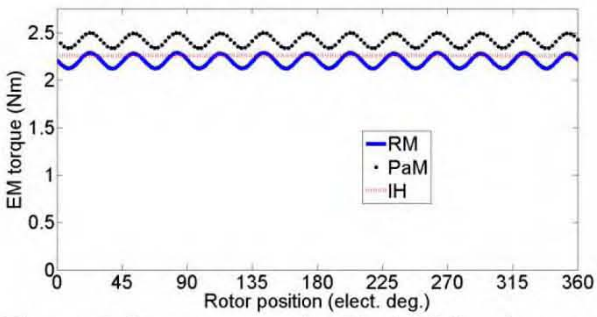

Figure 5. Output torque in 12-slot/10-pole motor

Table I. Electromagnetic Torque

		9s/10p	12s/10p
Average output torque (Nm)	RM	2.04	2.20
	PaM	2.25	2.42
	IH	2.10	2.26
Peak torque ripples (%)	RM	6.76	7.61
	PaM	6.34	6.80
	IH	1.30	0.33

Keywords: permanent magnet, synchronous, radial magnetization, parallel magnetization, ideal halbach.

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