L-Università ta' Malta

Research Expo 2026

Dr. Javed Ali
Research Support officer - III
Department of Electrical Engineering

Rotor Saliency Impact in Inductance Variation during PMSM Sensorless Control

Project Brief

This research work presents an in depth analysis of the impact of rotor saliency on inductance variation during PMSM sensorless control. The study examines both geometric and magnetic sources of saliency and evaluates how these characteristics shape the machine inductance profile under various load and excitation conditions. By combining analytical modelling, finite element simulations, and experimental validation, the work highlights the direct correlation between saliency magnitude and observability of rotor position. Results demonstrate that higher saliency enhances the detectability of rotor position through inductance modulation but may also introduce nonlinear magnetic effects and distortions that require careful compensation within the control algorithm.

Virtual Prototyping & Analysis

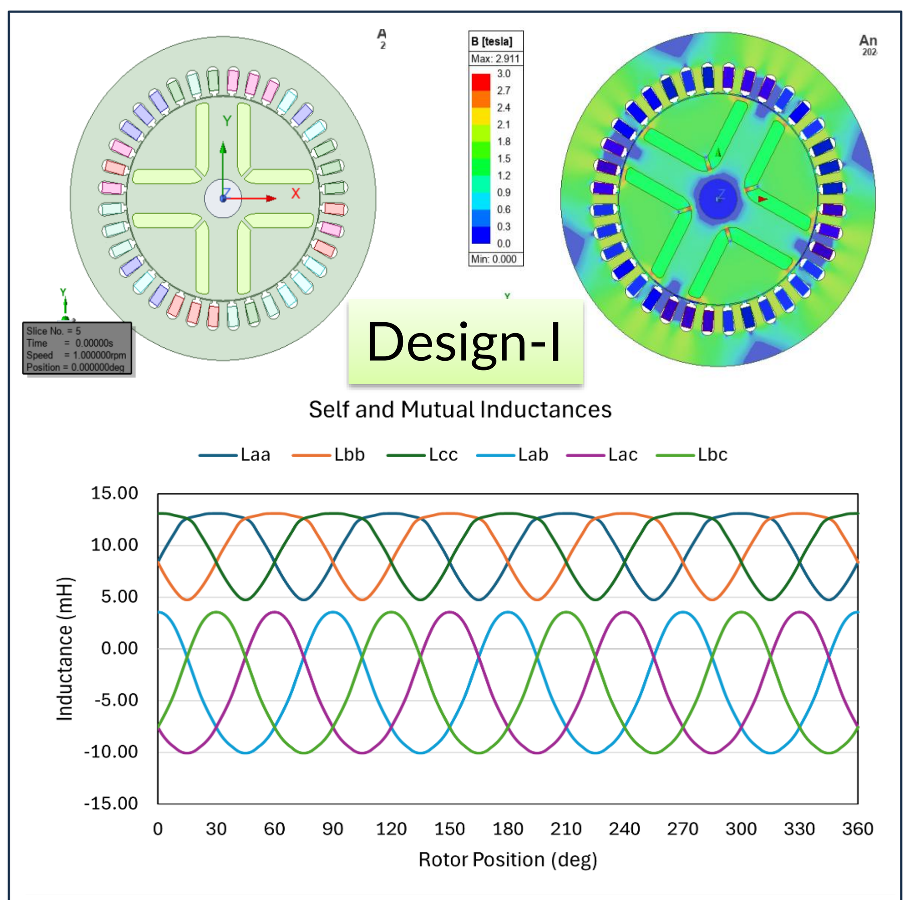
- The stator winding inductance L is proportional to the flux linkage per unit current, and flux linkage depends on the air gap magnetic permeance as given by: $L \propto \Lambda(\theta)$
- Therefore, the inductance seen by the stator phase winding varies with rotor position θ_r (electrical angle), hence, the inductance variation with rotor position can be written as: $L(\theta_r) = L_s + \sum_{k=1}^{\infty} L_k \cos(k2\theta + \delta_k)$
- where L_s represents the average inductance independent of rotor position. L_k represents inductance harmonics magnitude, and the factor 2 inside the cosine arises because inductance depends on the square of the flux, making it periodic at twice the electrical rotor angle (fundamental spatial frequency of permeance).
- The inductance variation corresponds to the second harmonic spatial permeance variation because the flux linkage of a winding varies roughly as $\cos(\theta_r)$. Now, the self-inductance of stator winding phases can be written using equation (3) as follows-

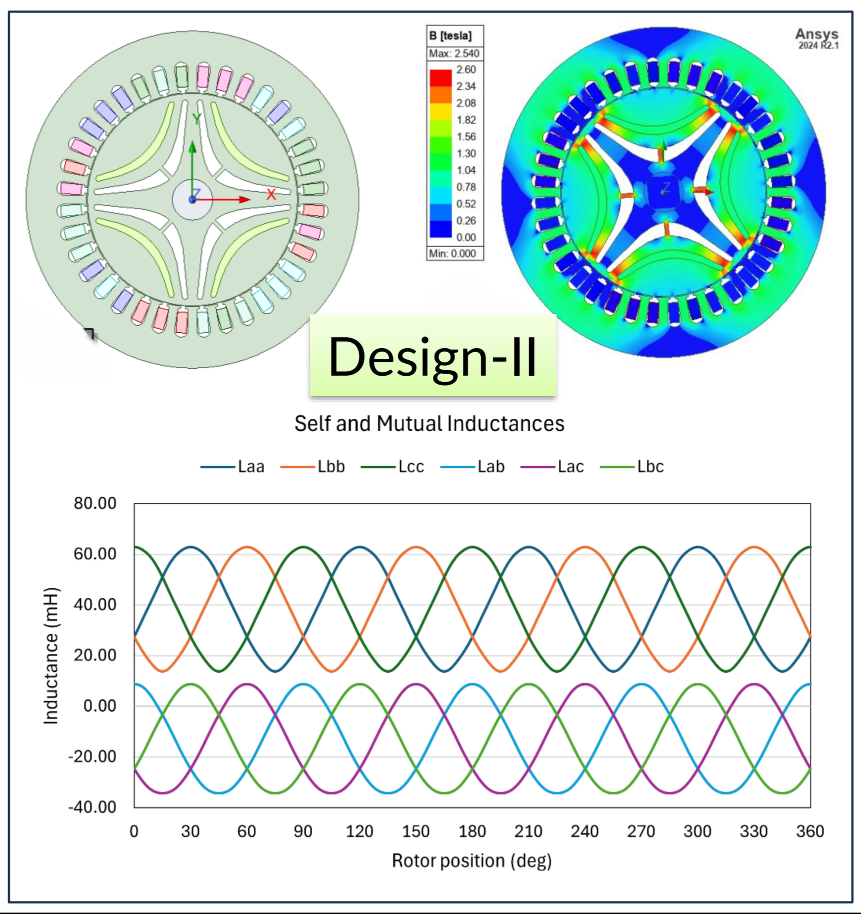
For phase a, $L_{aa}(\theta_r) = L_s + L_1 cos(2\theta_r)$

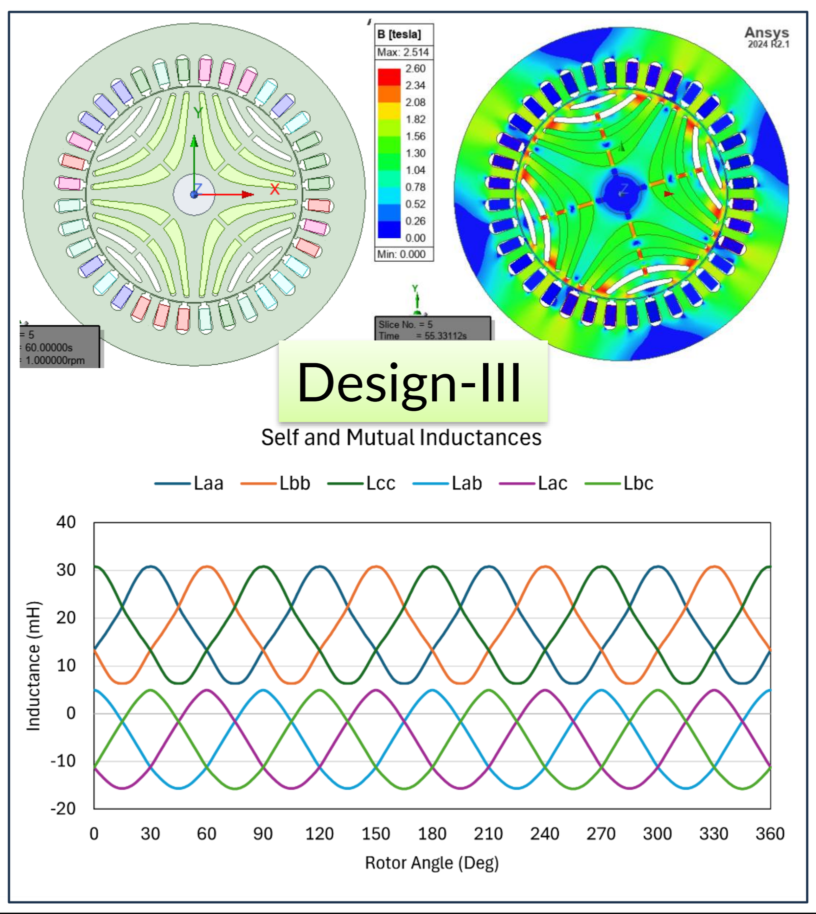
Phase b, $L_{bb}(\theta_r) = L_s + L_1 cos(2\theta_r - 2\pi/3)$

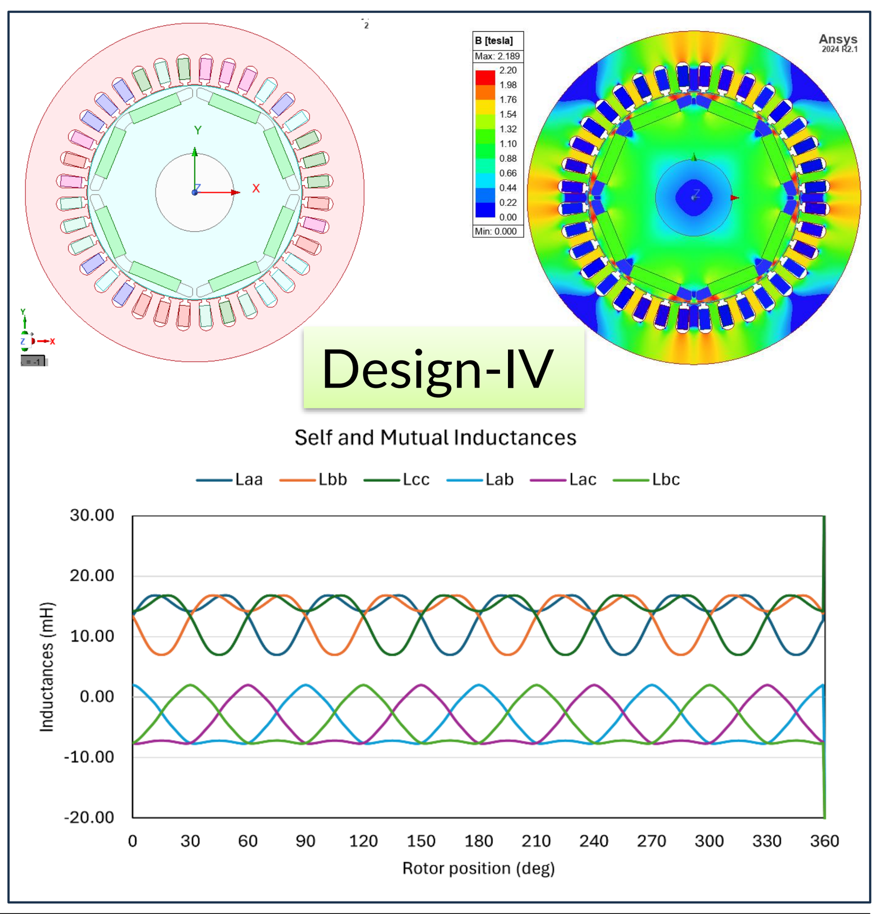
Phase c, $Lcc(\theta_r) = L_s + L_1 cos(2\theta_r + 2\pi/3)$

Where, L_1 quantifies the self-inductance variation due to rotor saliency.





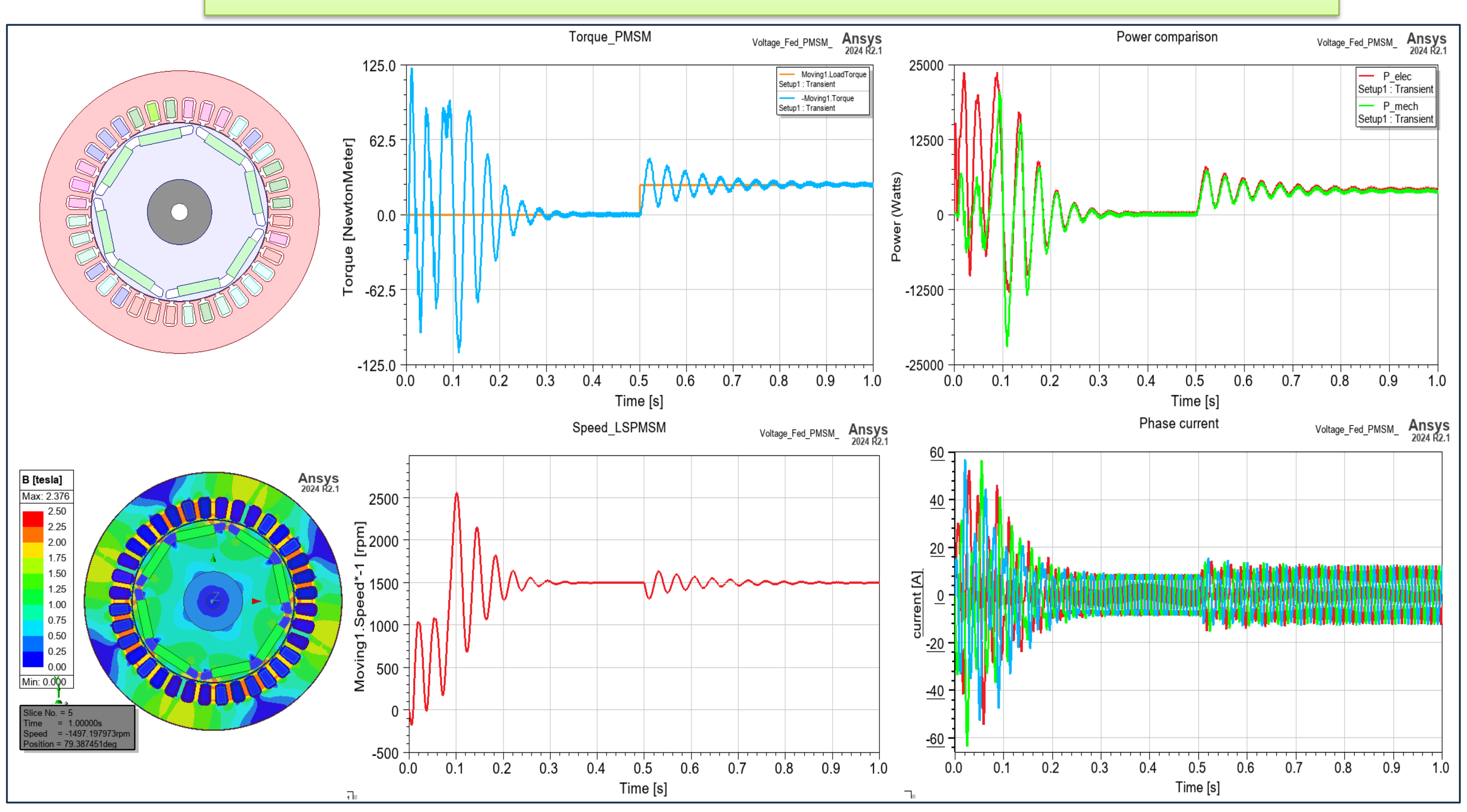




Result & Discussion

- The results shown above clearly demonstrate that rotor geometry alone is insufficient to generate meaningful saliency unless strong anisotropic features (e.g., flux barriers) are present. whereas permanent magnets introduce inherent saliency, even under zero current, by establishing directional flux paths.
- Among the four investigated rotor designs, a clear relationship between rotor topology and inductance variation was observed. The simple salient rotor designs I exhibited relatively low inductance variation, indicating weak magnetic anisotropy and limited saliency.
- In contrast, the introduction of strong flux barriers in design II produced a significant increase in saliency, with a large inductance variation, confirming the effectiveness of concentrated flux-path engineering.
- Whereas the design III demonstrated, that saliency can be moderated through distributed barrier design, resulting in smoother flux distribution and reduced saturation while maintaining adequate inductance variation.
- Our final design, design IV demonstrates that a rotor with distributed permanent magnets and a polygonal geometry produces moderate inductance saliency. The absence of strong flux barriers leads to smooth and sinusoidal inductance variation, uniform magnetic flux distribution, and reduced saturation and harmonic effects.
- Finally, the presented work implicates that in PMSM the rotor geometry can be designed to achieve a balanced trade-off between electromagnetic smoothness and inductance saliency, depending on the intended application.

Electromagnetic performance of Final Design (Design-IV)



Conclusion

The presented work confirms following outcomes-

- Rotor geometry is the dominant factor controlling inductance saliency.
- Permanent magnet excitation alone is sufficient to produce position-dependent inductance variation.
- Saliency can be tailored through rotor design to meet specific performance requirements.

This project is funded under MCST FUSION R&I-Research Excellence Programme (REP) 2024 via Vote No: E24G045-01