Sensorless Position Tracking for Steer-by-Wire Applications

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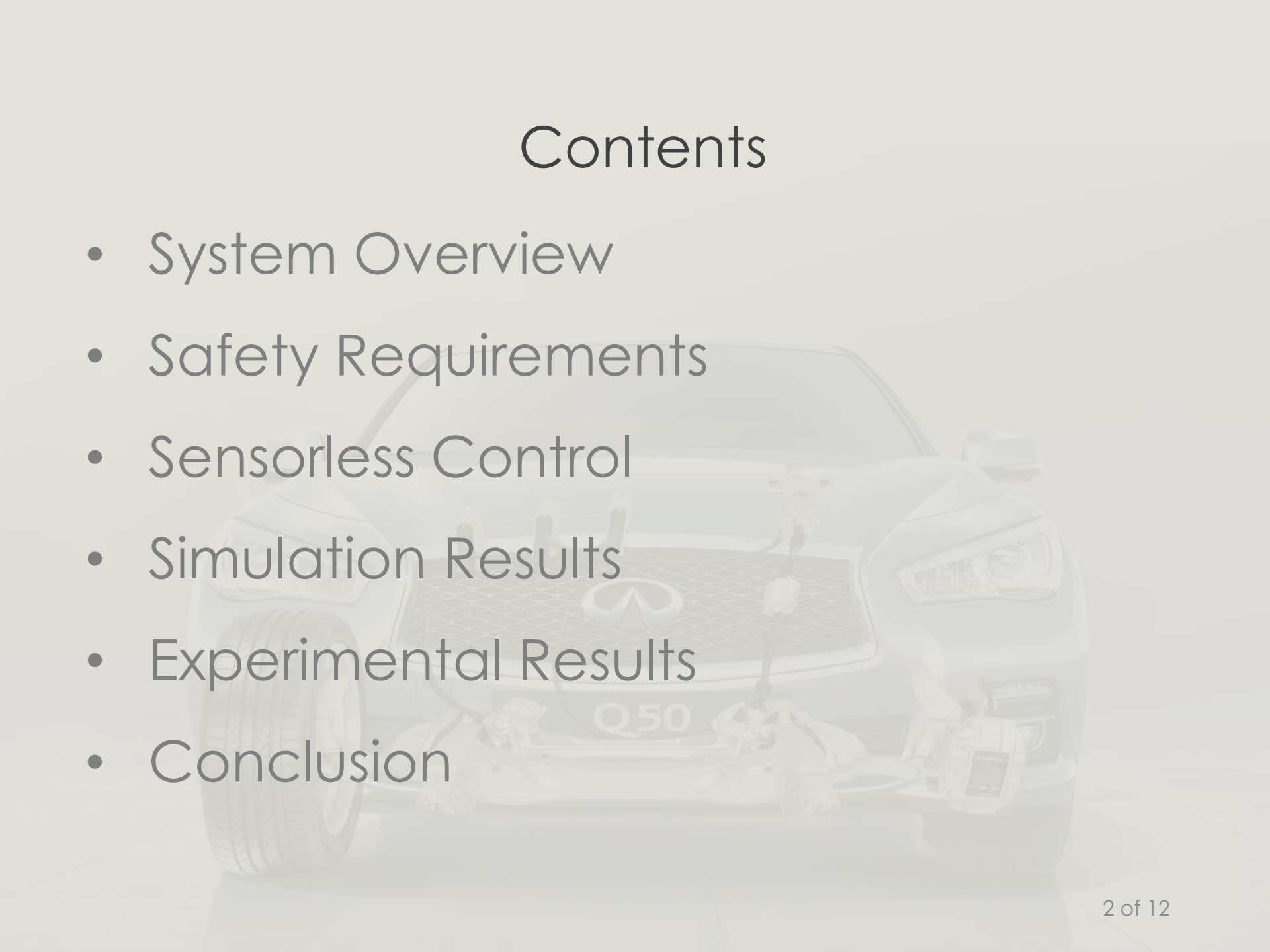


Steer-by-Wire Overview

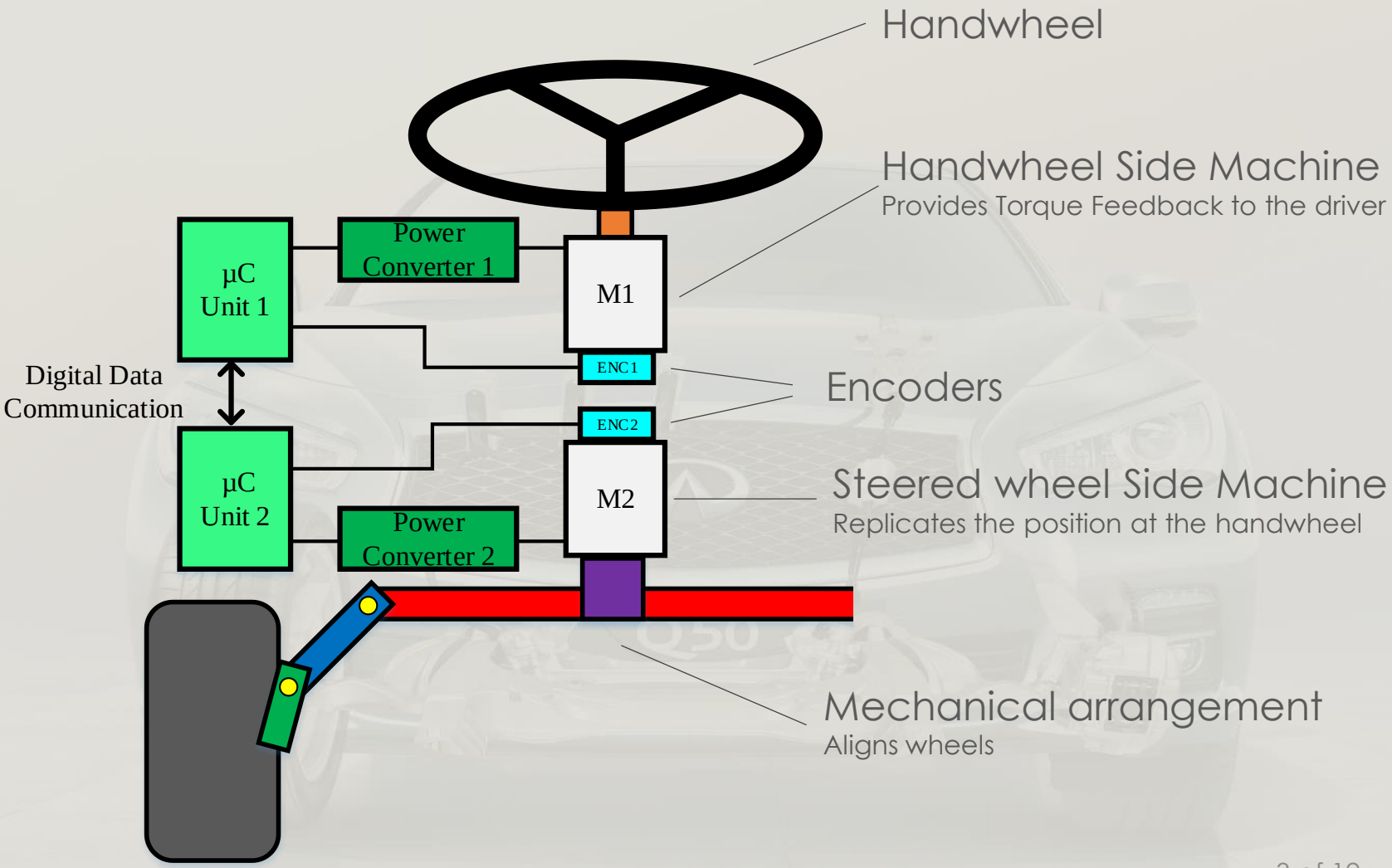


Figure 1: Steer-by-Wire System Diagram

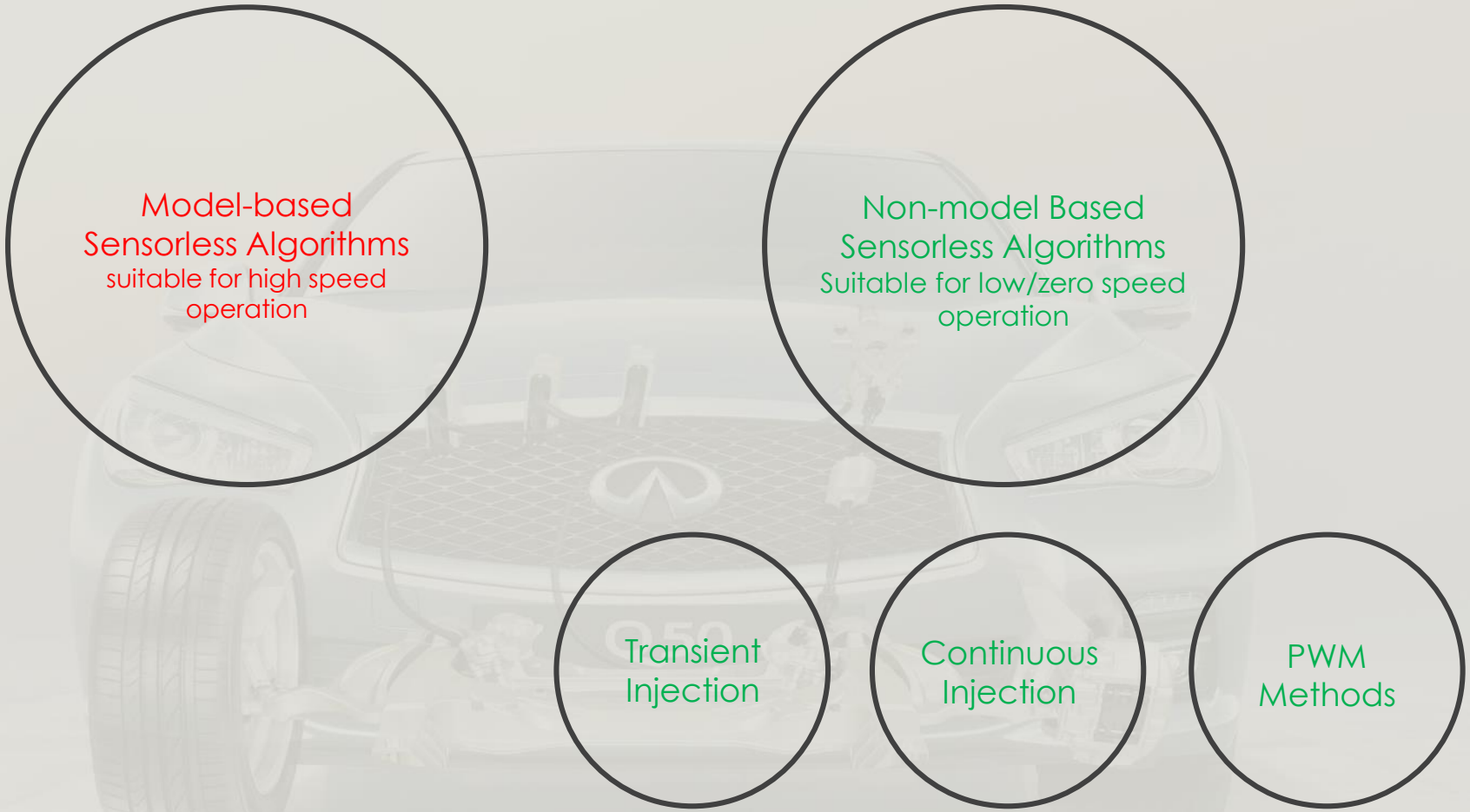
Safety Requirements in Steer-by-Wire

Critically dependent on position measurements at both Handwheel and Steered wheel sides

To improve the safety and reliability additional backup measurement mechanisms are introduced.

This research proposes the use of sensorless algorithms for backup.

Sensorless Control



Sensorless Control

High Frequency Continuous Injection

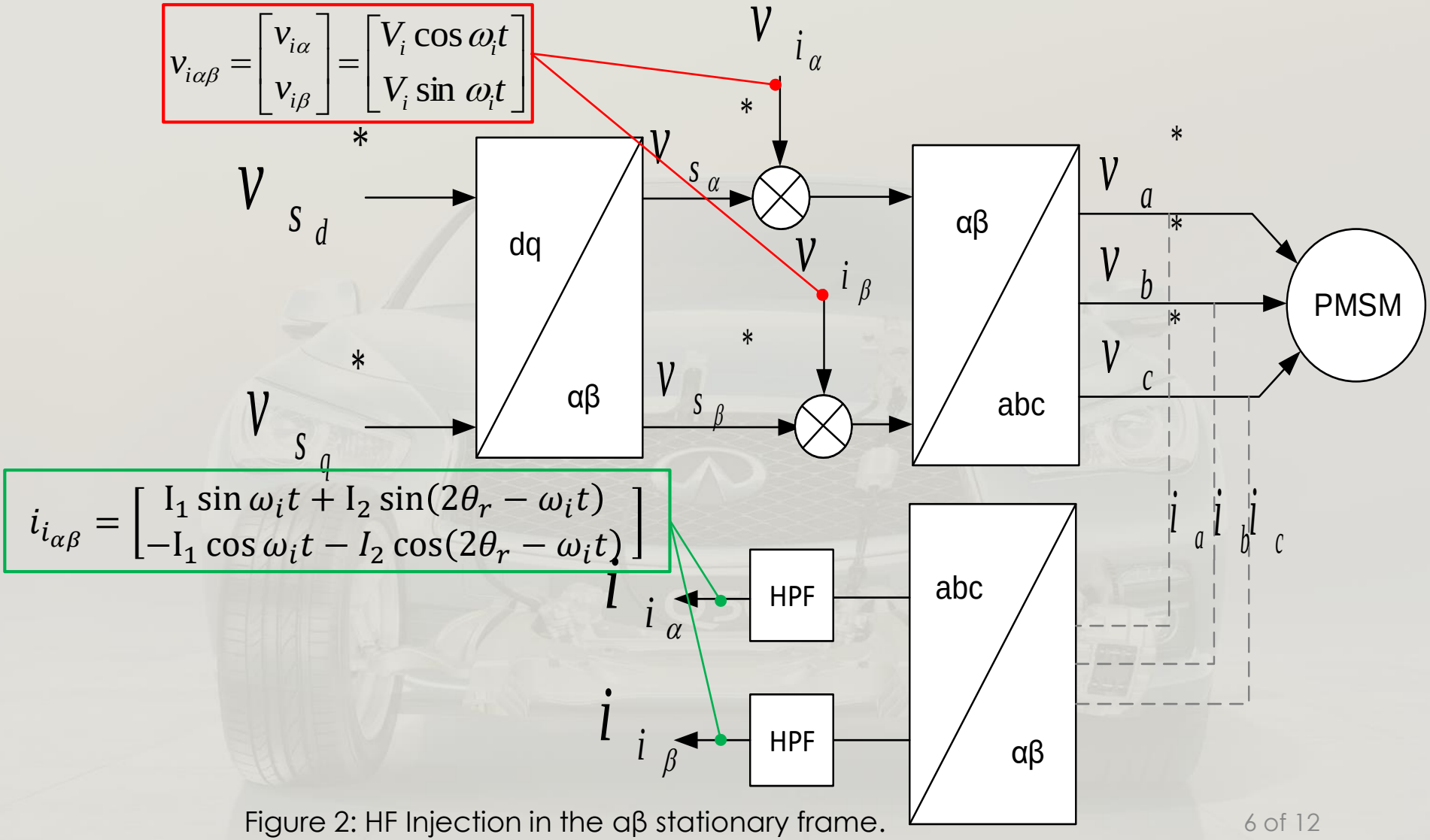


Figure 2: HF Injection in the αβ stationary frame.

Sensorless Control
High Frequency Continuous Injection

$$\varepsilon = \mathrm{I}_1 \sin\left[2(\omega_i t - \hat{\theta}_r)\right] + \mathrm{I}_2 \sin\left[2(\theta_r - \hat{\theta}_r)\right]$$

$$\varepsilon = \mathrm{I}_2 \sin\left[2(\theta_r - \hat{\theta}_r)\right]$$

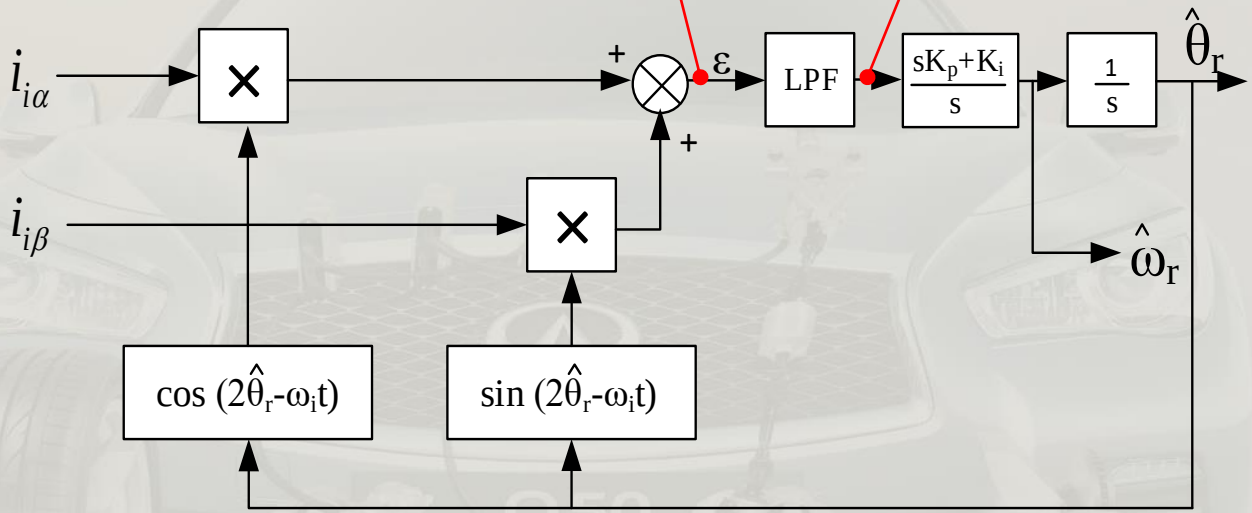


Figure 3: PLL rotor position/speed estimator with heterodyning.

Simulation Results for Simulink Model

Injection Voltage 5% of DC Link Voltage at 2 kHz

2 Nm Load applied at 0.75 s

Position Error = 0.8 %
Speed Error = 5 %

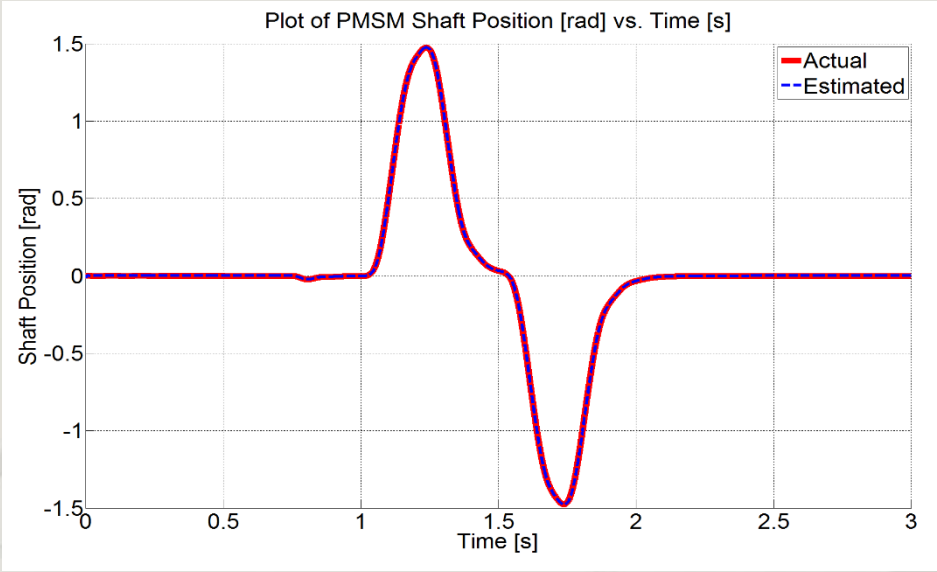


Figure 4: Simulation, Actual and Estimated Shaft Position [rad] vs. Time [s]

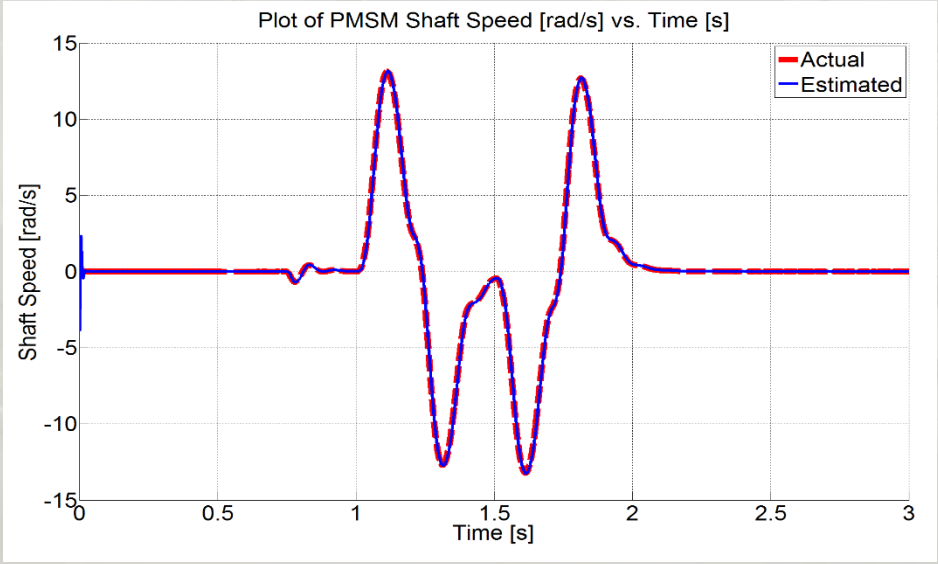


Figure 5: Simulation, Actual and Estimated Shaft Speed [rad/s] vs. Time [s]

Experimental Setup

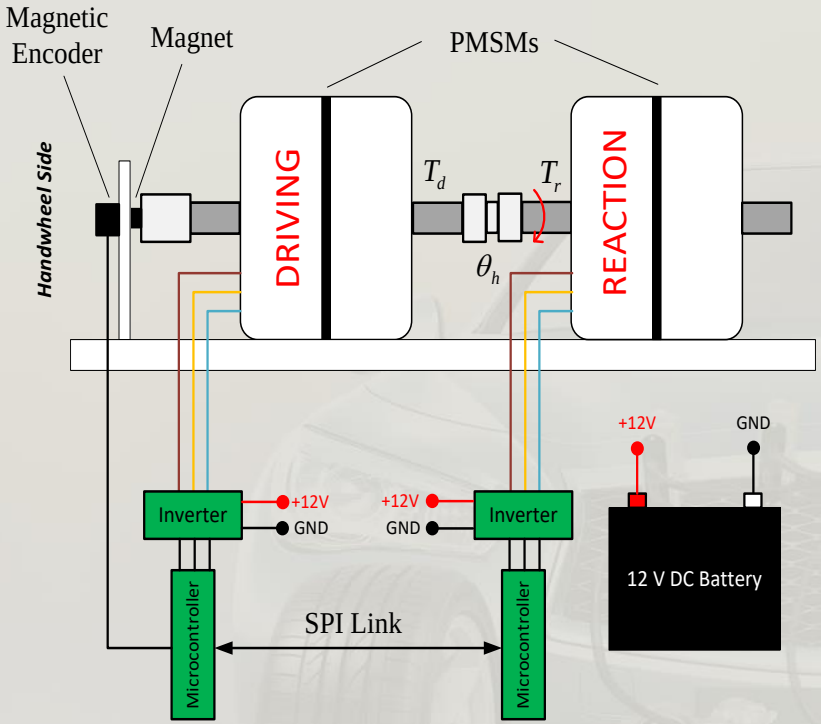


Figure 6: Steer-by-wire handwheel side setup illustration

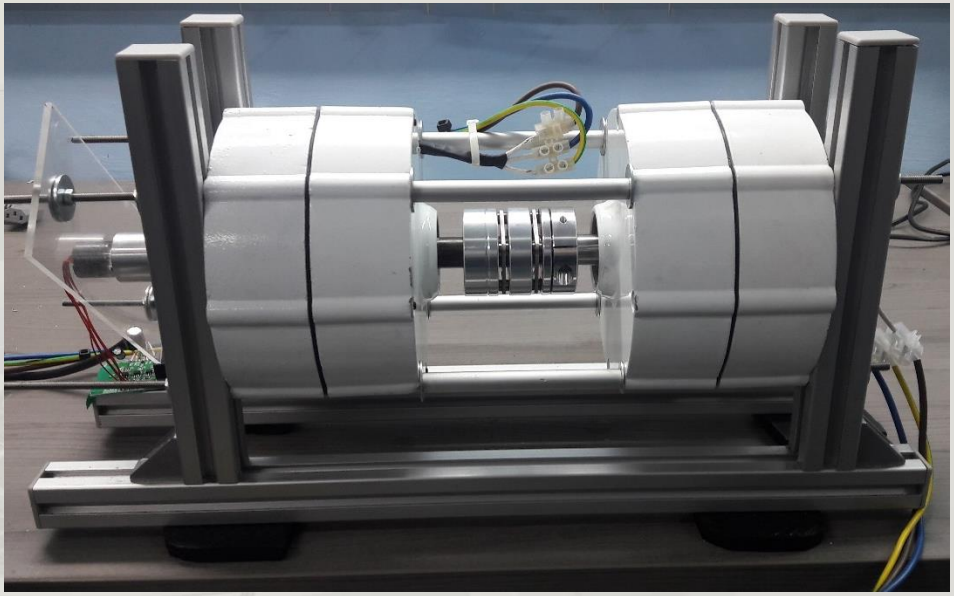


Figure 7: Steer-by-wire handwheel side PMSMs on experimental setup

Preliminary Experimental Results

Injection Voltage 20 % of DC Link Voltage at 2 kHz

No Load Condition

Position Error = 14 %
Speed Error = 50 %

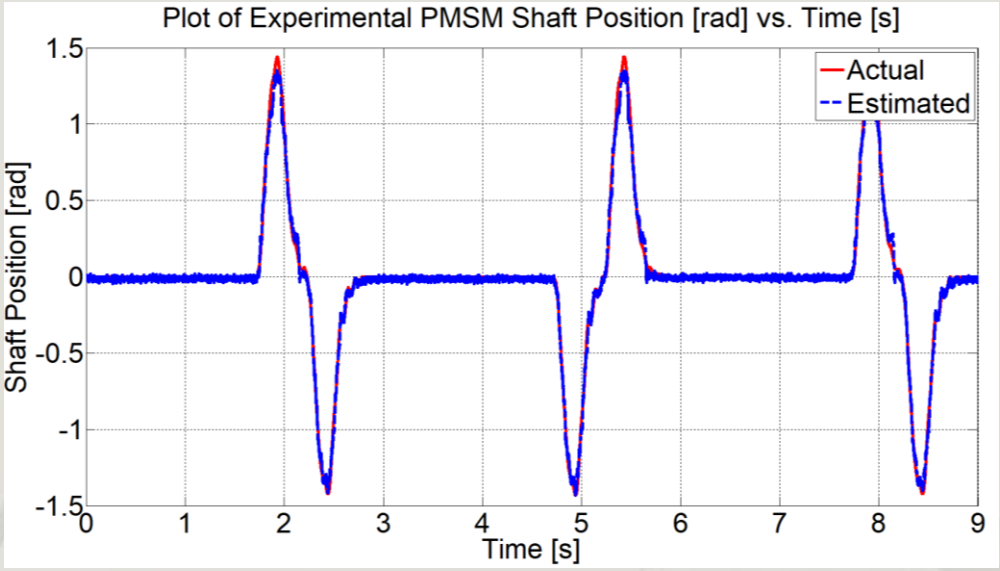


Figure 8: Simulation, Actual and Estimated Shaft Position [rad] vs. Time [s]

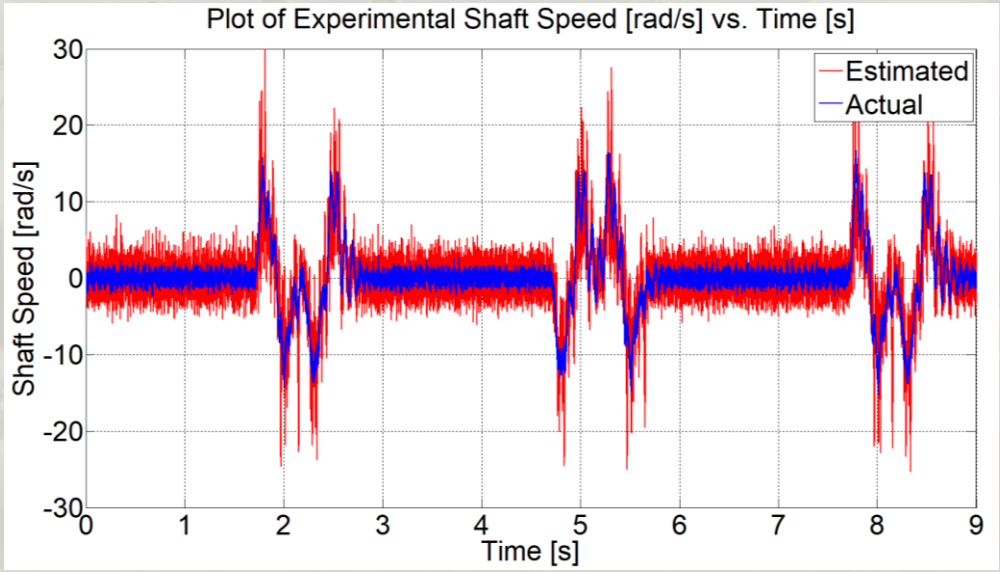


Figure 9: Simulation, Actual and Estimated Shaft Speed [rad/s] vs. Time [s]

Conclusions

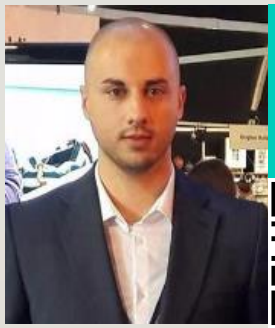
Error in experimental estimates is higher than that observed in simulation due to non-ideal drive

Non-ideal parameters include inverter switching harmonics and machine asymmetries

Sensorless enhancements are currently being implemented to compensate for non-ideal effects on electrical angle estimate.

Discussion

Authors



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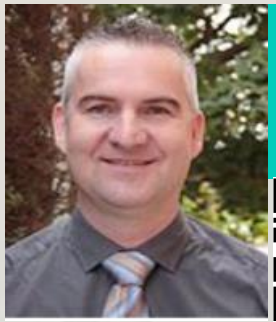

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