# Experimental Characterization of PMSM Hub Motor for Digital Twin Development

The development of a high-fidelity digital twin for an electric three-wheeler requires accurate modeling of the powertrain, particularly the traction motor and its interaction with vehicle dynamics. In the current project, a torque-driven digital twin is being developed using MATLAB/Simulink and Simscape Multibody, with applications in stability analysis, torque vectoring control, and virtual vehicle architecture evaluation.

This proposal requests access to the Power Electronics Laboratory facilities to experimentally characterize the PMSM hub motor intended for use in the three-wheeler platform.

## 1. Scope of Experimental Characterization

### 1.1 Electrical Parameter Identification

The following electrical parameters will be experimentally identified:

- Phase resistance (Rs)
- Phase inductance (Ld, Lq)
- Back-EMF constant (Ke)
- Torque constant (Kt)

These parameters are required for accurate current dynamics and torque production modeling in the PMSM motor block used in MATLAB/Simscape.

### 1.2 Efficiency Characterization

A major focus of the proposed work is the characterization of motor efficiency in terms of energy input versus torque output.

Motor efficiency will be computed as:

$$\eta = (T \times \omega) / (V \times I)$$

Efficiency measurements will be carried out by sweeping torque levels at fixed motor speeds and repeating the procedure across multiple speeds within the operating range of the motor.

The outcomes will include:
• Efficiency versus torque curves at selected speeds
• A two-dimensional efficiency map as a function of torque and speed

These efficiency maps are critical for accurate energy-per-kilometer estimation and realistic battery power modeling in the digital twin.

### 1.3 Thermal Characterization (Optional)

If feasible, thermal characterization will be performed to obtain:

• Winding and casing temperature rise under continuous load
• Thermal time constants and thermal resistance

These parameters will support torque derating logic and safe operating limits in simulation and control studies.

## 2. Expected Outputs and Deliverables

### 2.1 Parameter Set for MATLAB/Simscape

The following parameters will be obtained and integrated into the simulation models:

• Electrical parameters (Rs, Ld, Lq, Ke, Kt)
• Mechanical parameters (J, friction coefficients)
• Thermal parameters (if measured)

These parameters will be directly used in the PMSM motor block and associated powertrain models in MATLAB/Simscape.

### 2.2 Efficiency Maps and Performance Curves

The experimental work will produce:

• Efficiency versus torque plots at different speeds
• Torque–speed operating envelope
• Two-dimensional efficiency lookup tables for digital twin integration

## Motor Parameters

Motor Parameters:

Motor Type: BLDC / PMSM Hub Motor
Rated Power: 1200 W
Rated Voltage: 60 V
Continuous Torque: 36.35 Nm
Peak Torque (Stall): 72.7 Nm
Rated Speed: 410 RPM
No-load Speed: 455 RPM
Rated Current: 40 A
Peak Current: 80 A
Peak Output Power: 1920 W
Wheel Size: 12 inch
Motor Configuration: Single shaft with disc brake
Motor Direction: CW / CCW
IP Rating: IP67
Battery Configuration: 60 V, 50 Ah (2 batteries in system)
Maximum Vehicle Speed: 50 kmph
Slope Capability: 7 degrees
Payload Capacity: 250 kg