Application Package for Testing: E-Library

Use Case: Parameter Identification

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Presenter

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Content

E-Library Overview

E-LIBRARY FOR E-MOTORS

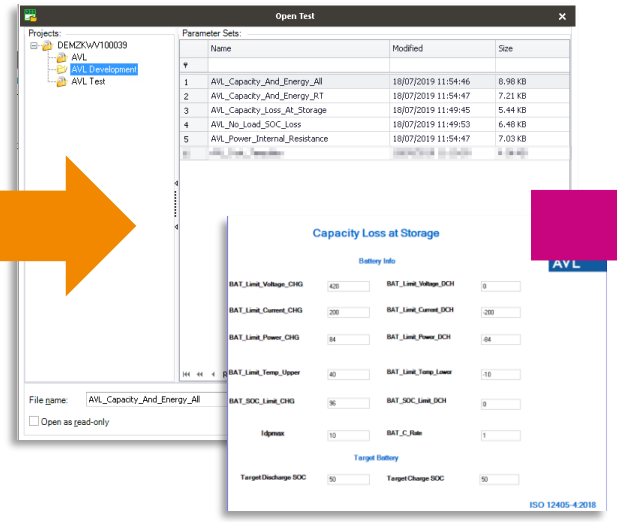
Application Packages Comprising:

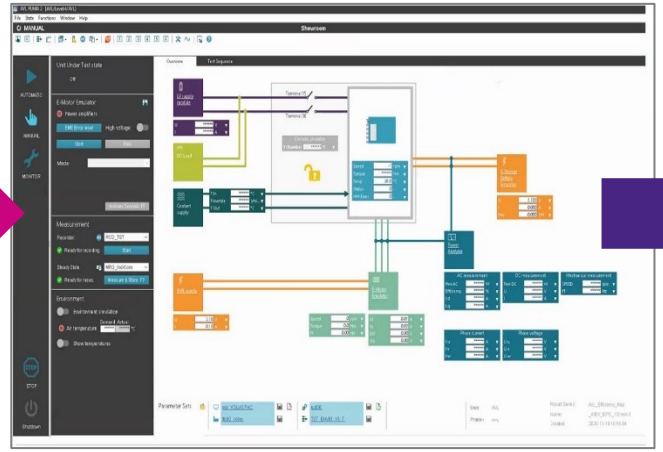
- **Customizable test parametrization**
- **Ready to run global standard tests**
- **Built-in data analysis & reporting**

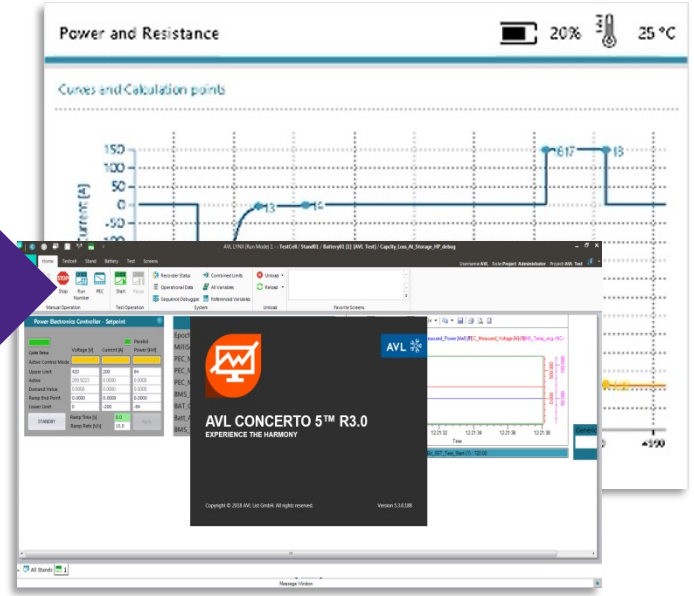
E-Library Workflow

SIMPLE WORKFLOW FOR CONVENIENT TESTING OPERATION

One Time Set Up & Integration







1

Test Selection and Parametrization

2

Test Run Execution

3

Data Analysis and Reporting

E-Library: E-Motor Test Package

E-LIBRARY for E-Motor/E-Drive Pack 1* provides the following Parameter Identification, functional and performance tests in line with industry standard methodology and data intelligence combined with added value from AVL's extensive experience.

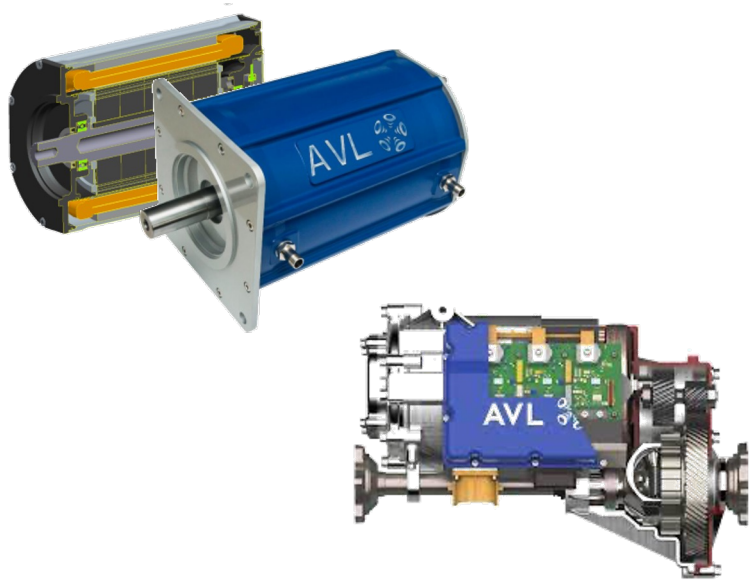
Further modular packs are planned to be released soon.

FUNCTIONAL & PERFORMANCE TESTS

- Direction of Rotation
- Inverter Phase Connection
- Cogging Torque***
- Torque Ripple
- Back EMF***
- Peak and Continuous Performance
- Efficiency Map
- Short Circuit – Current
- Short Circuit – Torque
- Locked Rotor Check**

CHARACTERIZATION TESTS

- IPMSM Parameter Identification***

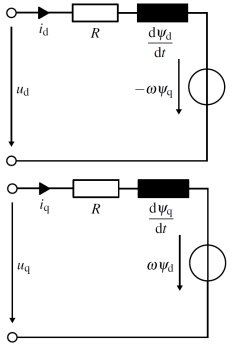


** Requires added HW – Stall Brakes.
*** Valid for IPMSM

* This set of procedures represents the most used standard tests. Additional tests can be added on demand or easily be created by the customer.

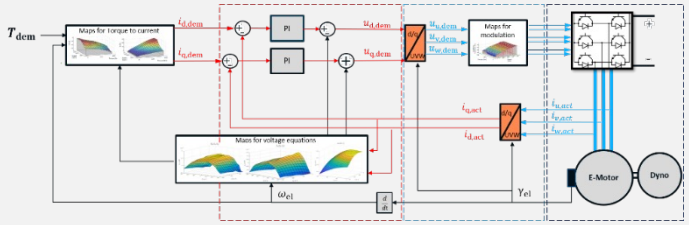
Content

Parameter Identification: IPMSM

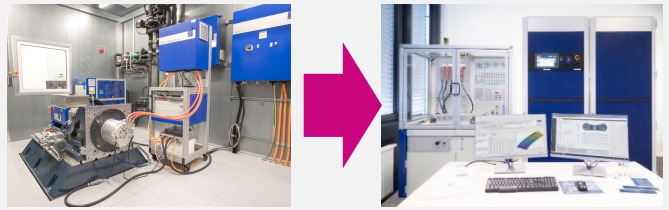


- Number of pole pairs
- Ohmic stator resistance
- Flux linkage maps
- Inductance maps
- Current set-point maps

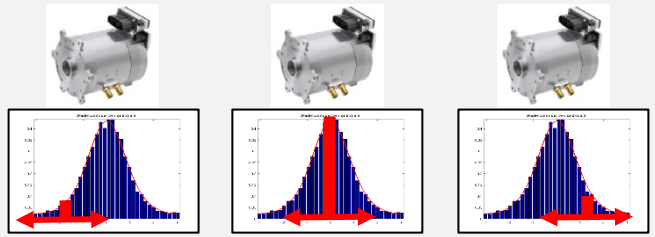
Inverter Controller Optimization



E-Motor Emulation on Inverter TS



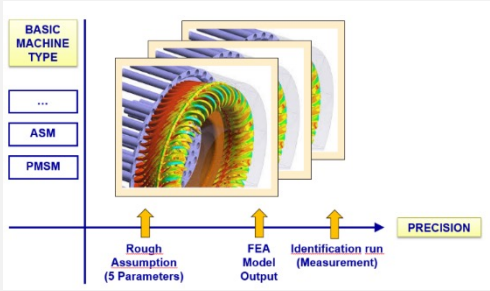
Benchmarking



Parameter Identification: IPMSM

Motor parameters are identified on E-Motor Performance TS with high precision

- Under steady-state measurements with current controlled UUT
- At constant stator and rotor (magnet) temperature levels



Pole-pair & Stator Resistance

Mostly known beforehand (Nameplate or design value)

Effortless detection if unknown

No repetition required

Resolver Angle Calibration

Needed for absolute rotor position

Performed by AVL X-ion™ Power Analyzer

No repetition required

Flux Linkage Maps

Obtained by automatic test routine

Steady-state conditions with temperature monitoring

Repetitions recommended

Post-processing for inductance & current set-point maps

IPMSM Temperature Monitoring

Flux linkage maps are obtained under stable stator and rotor (magnet) temperature conditions

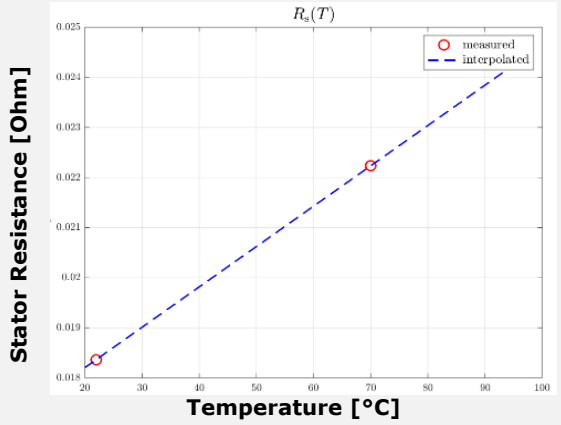
Stator Winding Temperature

Measured directly from the windings

- PT100, PT1000, NTC etc. sensors

Stator resistance increases linearly with the winding temperature

Measured stator resistance at room temperature & 70°C



Rotor (Magnet) Temperature

Wireless measurement solutions (usually N/A)

- Telemetry, optical pyrometers etc.

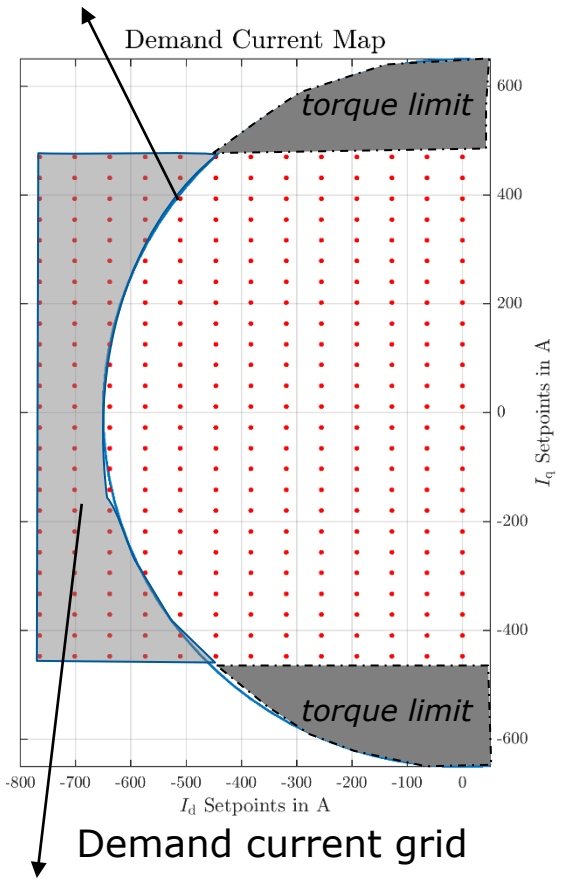
Alternatively, estimated by **back-EMF** measurement

PM flux linkage decreases quasi-linearly with the increasing magnet temperature

Unstable magnet temperature leads to inaccurate parameter identification

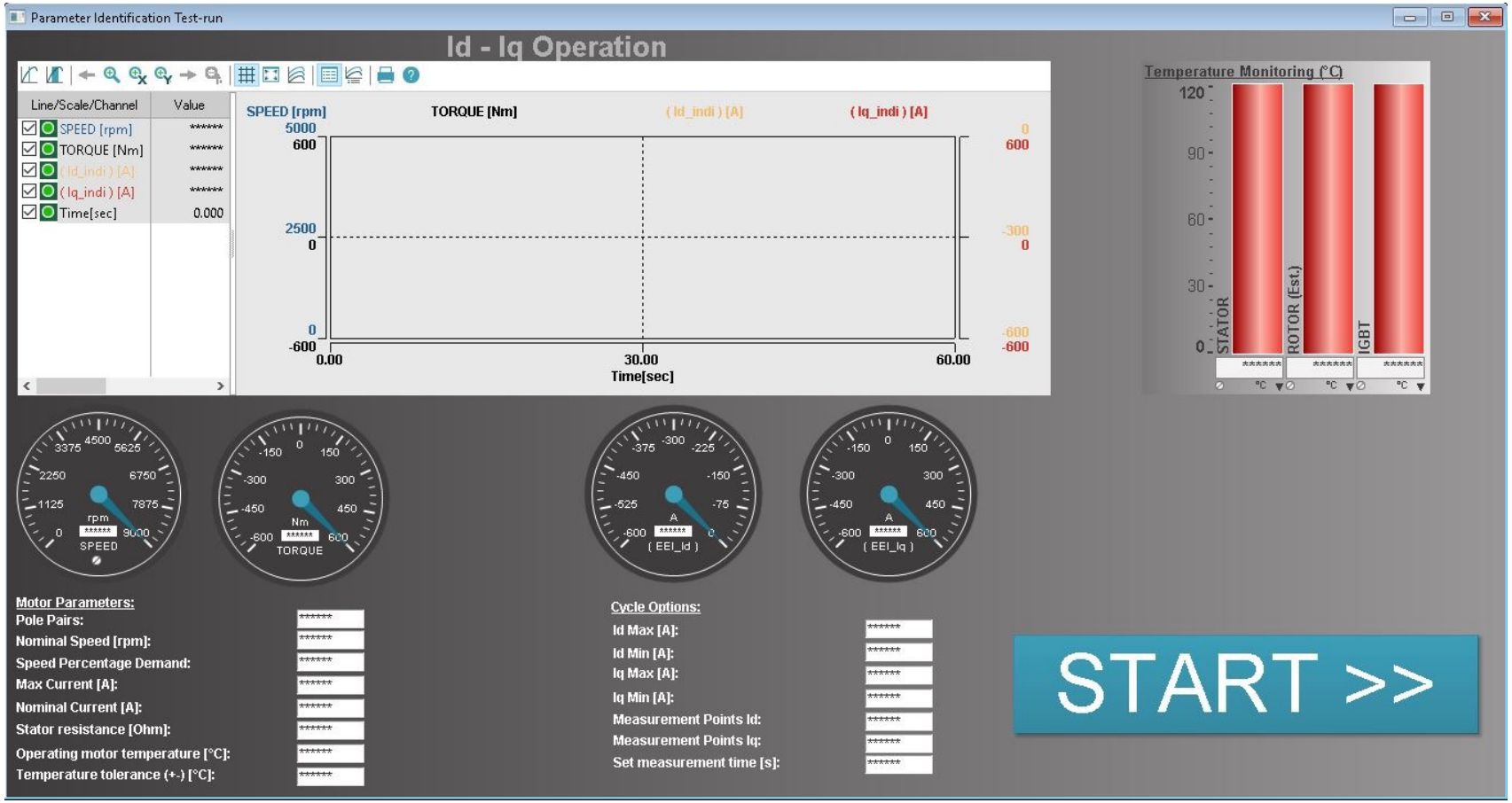
IPMSM Parameter Identification Test

Inverter current limit



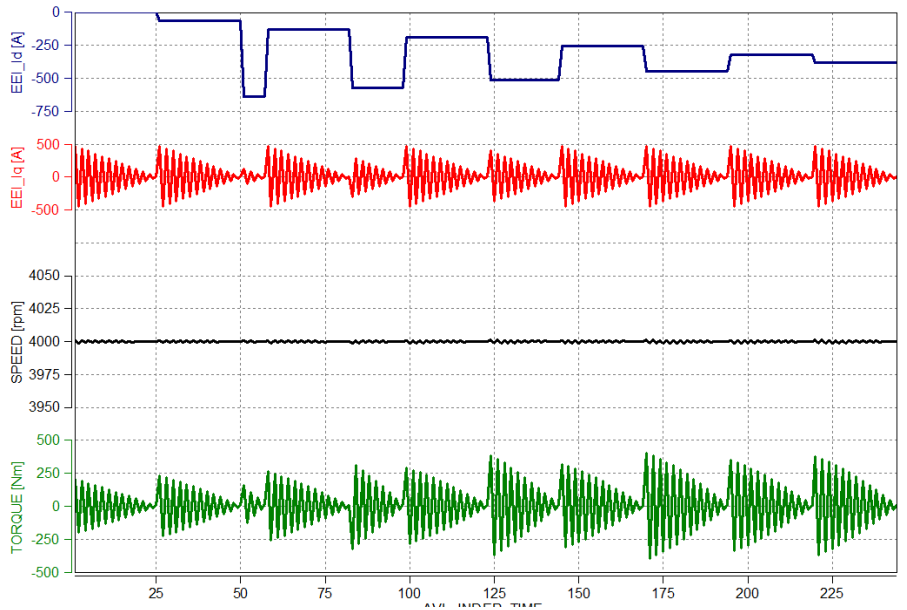
Demand current grid

Overcurrent
(to be extrapolated)

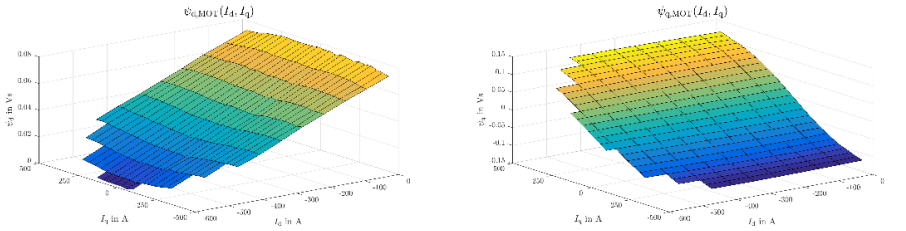


Test-run parametrization window

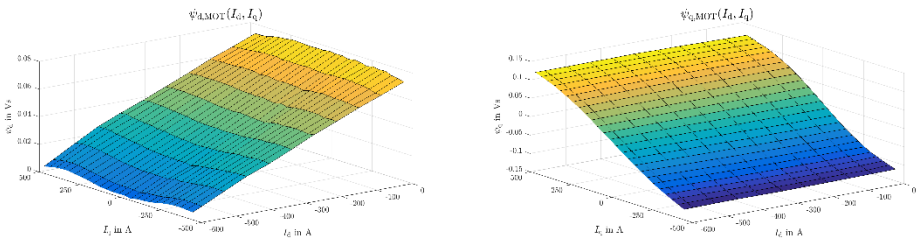
IPMSM Parameter Identification Test



Resulting Maps



(extrapolated)



Process Summary

Once the IPMSM pole-pair number and stator resistance are known, back-EMF vs temperature profile should be obtained.

Parameter identification test run is prepared with this information and executed based on a demand current grid (cartesian) with temperature monitoring.

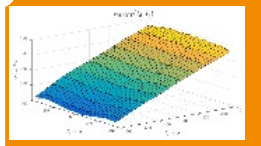
Flux-linkage values are calculated on each executed grid point and mapped.

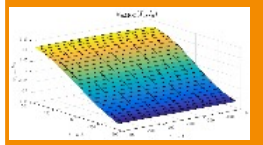
Test duration: ~90 Mins

Result: Flux linkage maps

Goal: Emulate, Optimize, Benchmark

Flux Linkage Maps





E-Motor Emulation

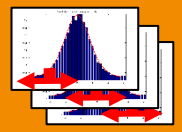
Use testbed-based flux linkage maps to parametrize the E-Motor Emulator with high precision

Inductance & Current Setpoint Maps

Post-process testbed-based flux linkage maps to optimize the inverter controller

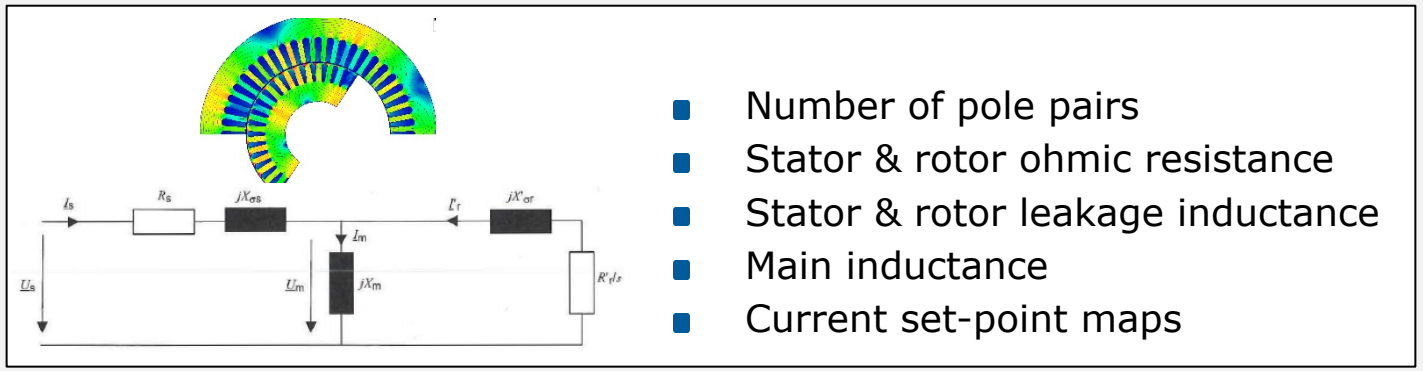
Benchmark

Compare testbed results with simulated design targets



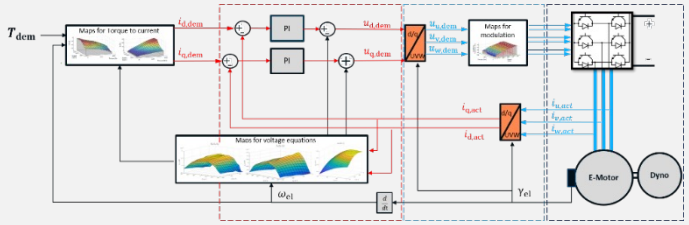
Content

Parameter Identification: IM

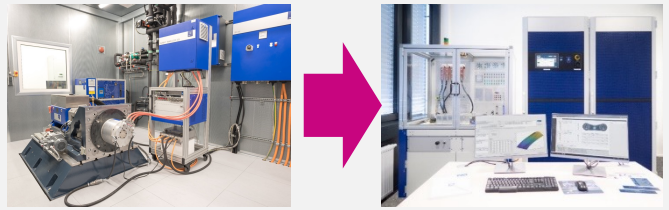


- Number of pole pairs
- Stator & rotor ohmic resistance
- Stator & rotor leakage inductance
- Main inductance
- Current set-point maps

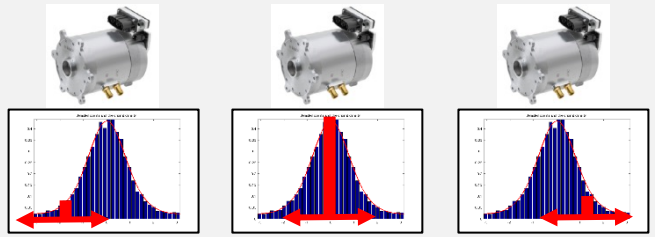
Inverter Controller Optimization



E-Motor Emulation on Inverter TS



Benchmarking



Parameter Identification: IM

Blocked rotor test (e.g.: stall brake) is performed for the parameters below

Power, voltage, current (fundamental) and $cos\varphi$ are measured

Stator Leakage Inductance

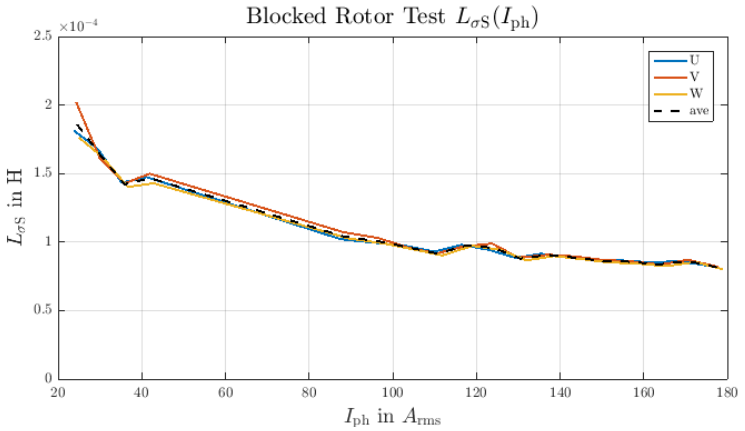
Blocked rotor test is performed according to DIN EN 60034-28 (VDE 0530-28)
U/f or I/f control applied by the inverter
Stator-only **(no rotor)** component test achieves higher accuracy

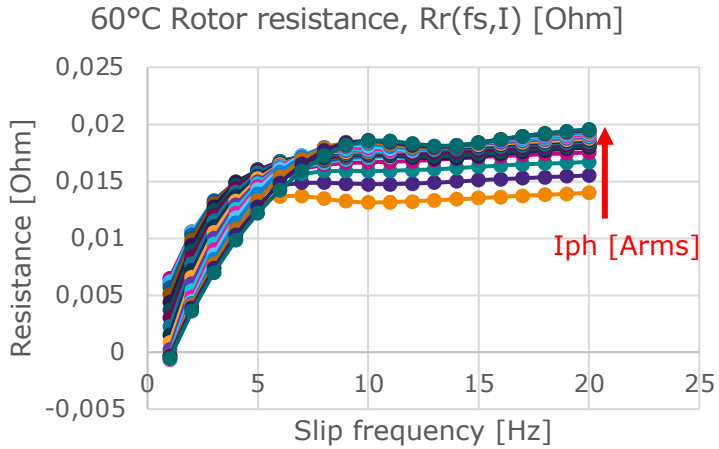
Rotor Leakage Inductance

Same procedure as above can be followed
Rotor leakage inductance is extracted from imaginary part of total impedance

Rotor Resistance

Same procedure as above can be followed
Performed under different temperature levels
Rotor resistance is extracted from the real part of total impedance





Parameter Identification: IM

To identify the main inductance, no-load test is performed **with disconnected shaft**

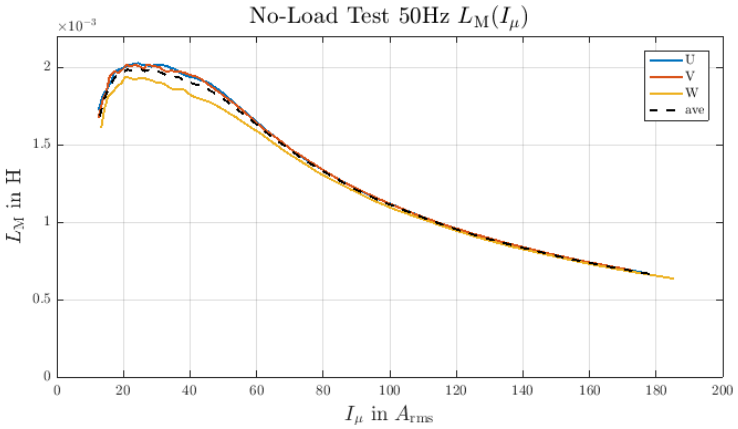
Power, voltage, current (fundamental) and $cos\varphi$ are measured

Main Inductance

No-load test is performed according to DIN EN 60034-28 (VDE 0530-28)
U/f or I/f control applied by the inverter
Main inductance is extracted from the imaginary part of total impedance

Future Work

Focus on E-Motor Emulation on Inverter TS
Standardization with customer aspects



Parameter Identification: SRM

Switched reluctance motors are not common in automotive applications

Promising due to simplicity and advancements in control algorithms

Position-based Flux Linkage & Inductance

Possible to identify with stall-brake tests
Voltage, current, speed, position to be measured in steady-state

Future Work

Research in NVH with AVL CAMEO™ calibration software
Pilot customer projects with tailored solutions for parameter identification

Q & A

Contact

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