Expand the usage of E-Motor / E-Axle / Inverter Test systems
Use Cases & Applications Overview

Additional Features

- Custom Instability Protection
- Battery emulation

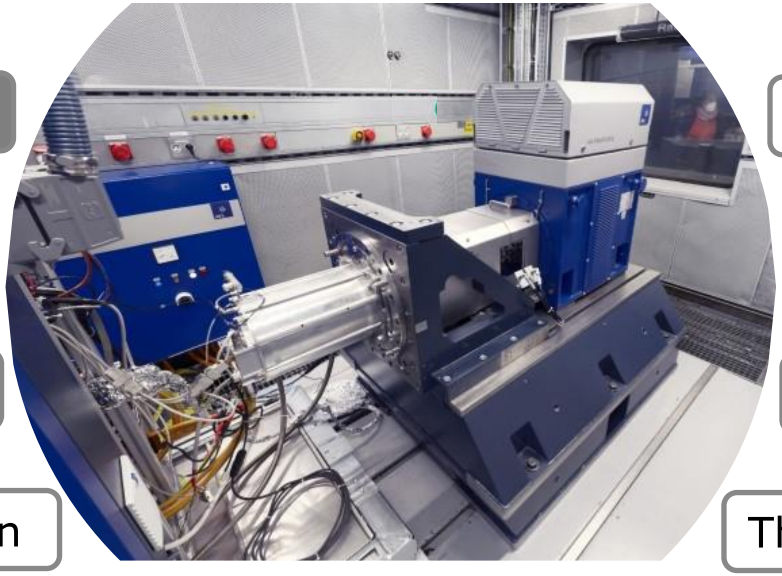
Racing

EMC-Testing

Durability/ Robustness Testing

NVH Optimization

Efficiency optimization



Standard Test E-Library

Base Calibration

Drivability

Thermal Management Calibration

Calibration of dynamic vehicle behavior

Calibration lateral dynamics

Base Calibration on E-Drive Testbed

From Motor parameter identification to advanced controller parametrization

Coverage of all relevant base calibration tasks

Fully automated test runs combined with DoE

Efficiency increase based on proven toolchain

Due to intelligent operation point selection and powerful conditioning system

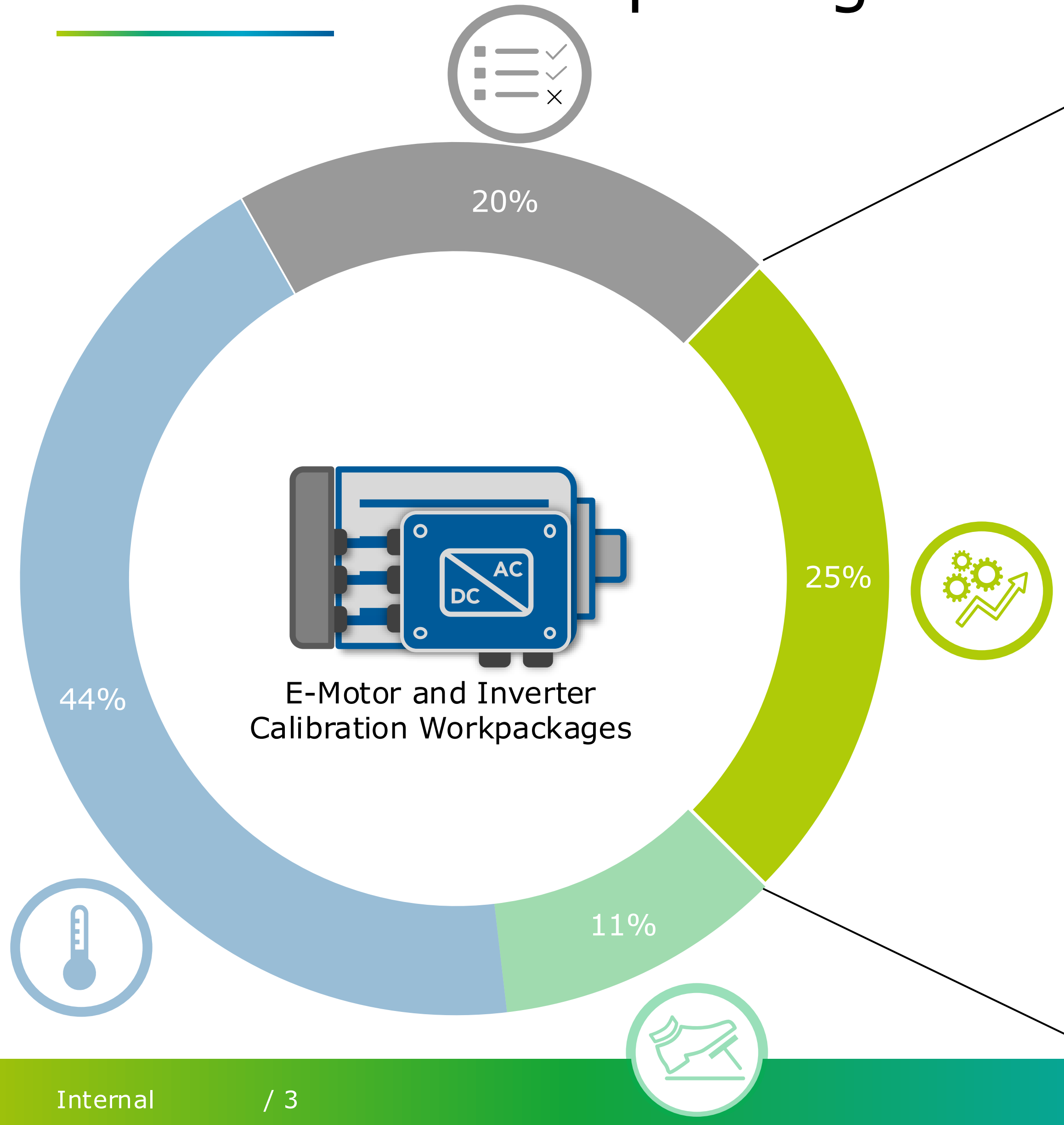
Stable temperature conditions

Optimization of multi dimensional objectives

Optimization of system behavior by balancing competing KPI’s (e.g. NVH vs. efficiency)

Calibration Workpackage Base Calibration

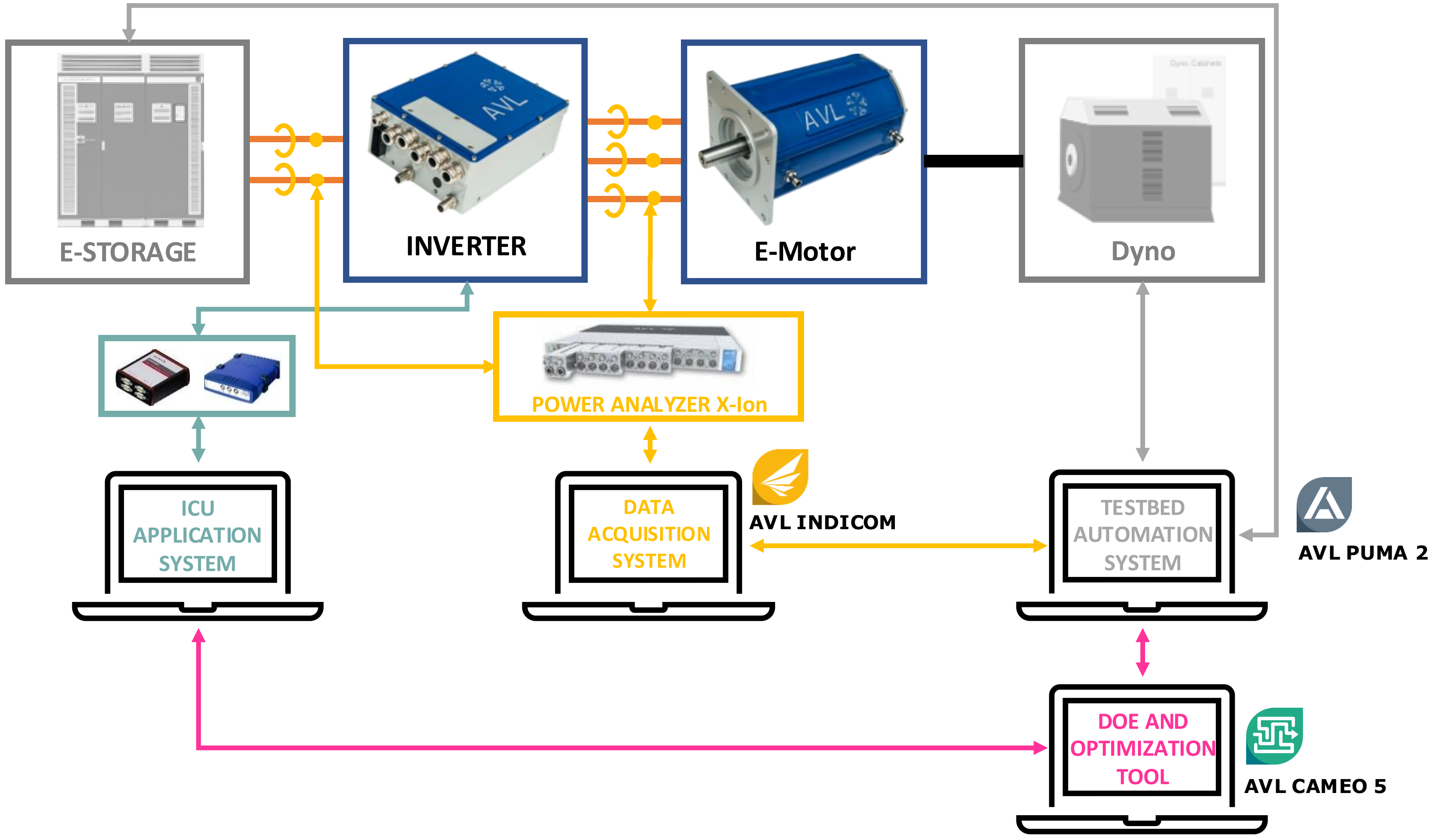
- Drivability
- Thermal Management
- Base
- Diagnosis



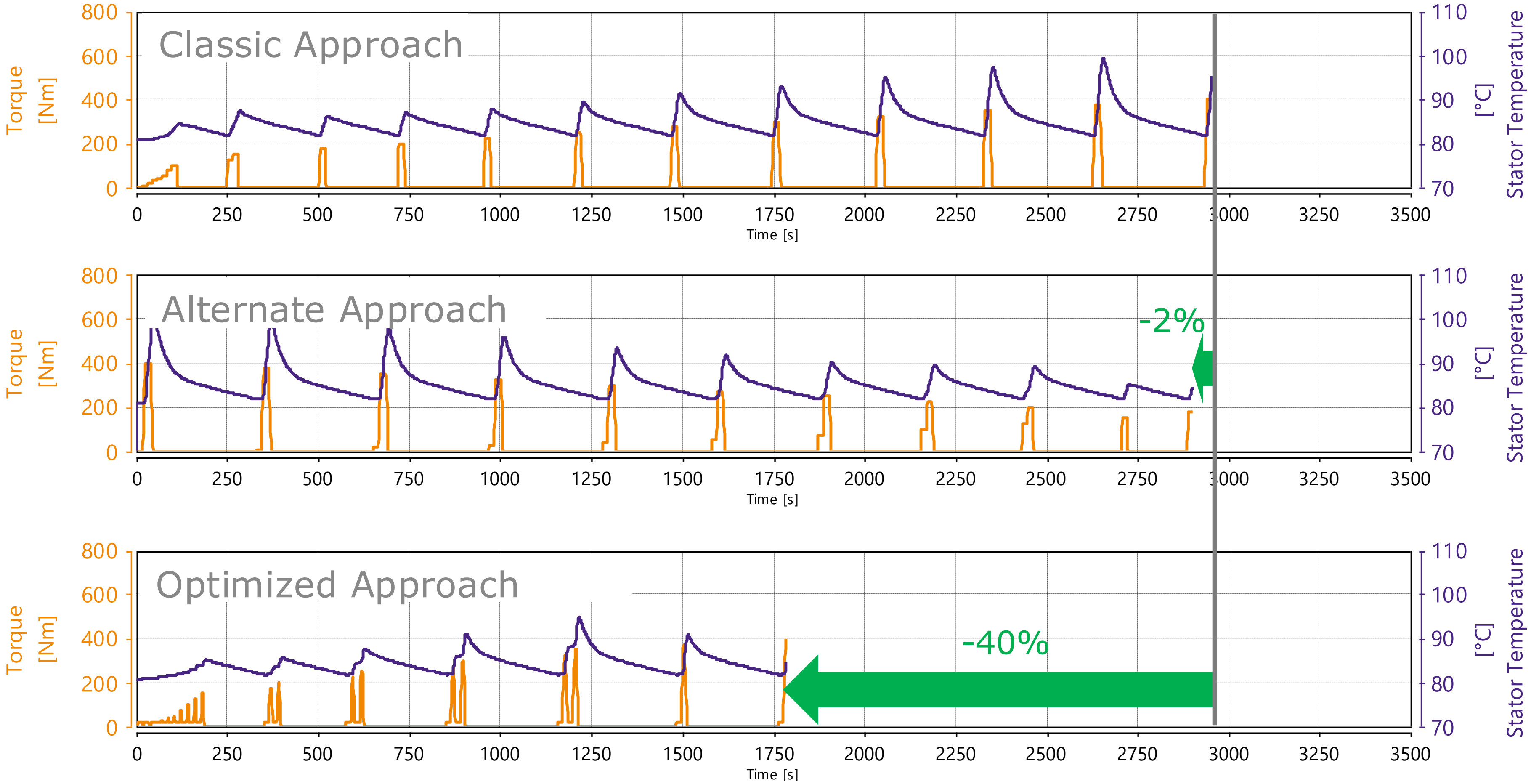
Calibration Tasks

Calibration of motor parameters	Back EMF
	Field weakening parameters
	Machine parameters
Sensor & Actuator calibration	Resolver calibration - offset/angle - Position & speed measurements
	Sensor characteristic - Current, voltage, temperature
Calibration of current controller	AC - Voltage evaluation - Phase current calculation - Phase current controller calibration
	DC - Comparison internal external measurement
	Calibration PWM control - Efficiency vs. NVH and DC-Ripple
	NVH Optimization - Reduction of harmonics
Speed / voltage controller	Calibration of speed/voltage controller parameters - Torque & speed accuracy

Advanced E-Motor/E-Axle Test System



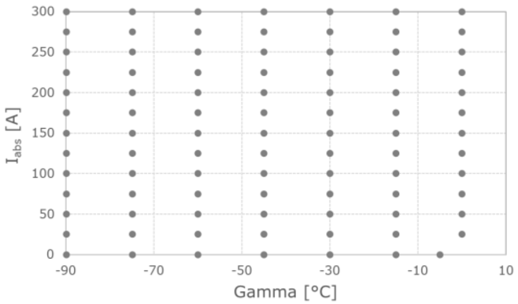
E-Motor Mapping



- Stator Temperature is the limiting factor
- By planning measurement points in a well-fitting order and staying in the operation point for a very short duration, slows down the heat up → reduced cool down phase
- Running the test fully automated, a fast data acquisition and storing the measurement file automatically speeds up the process

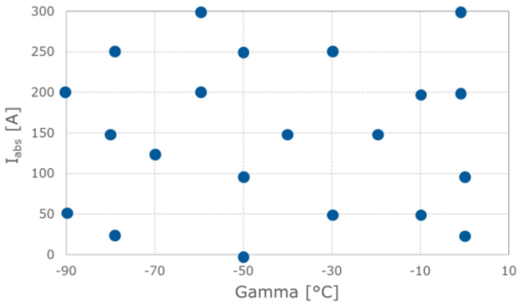
E-Motor Parameter Identification With Active DoE

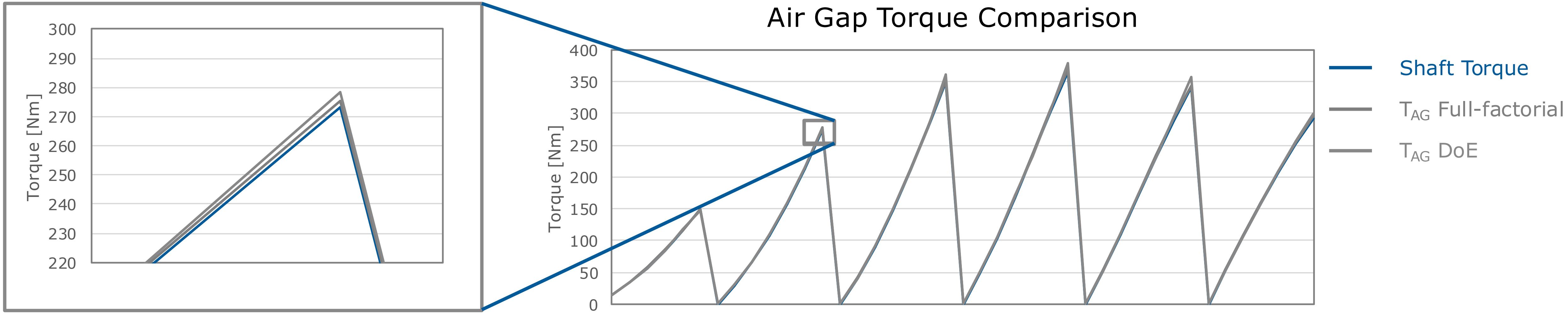
Conventional Full-factorial Mapping



Time Reduction
~50%

Active DoE



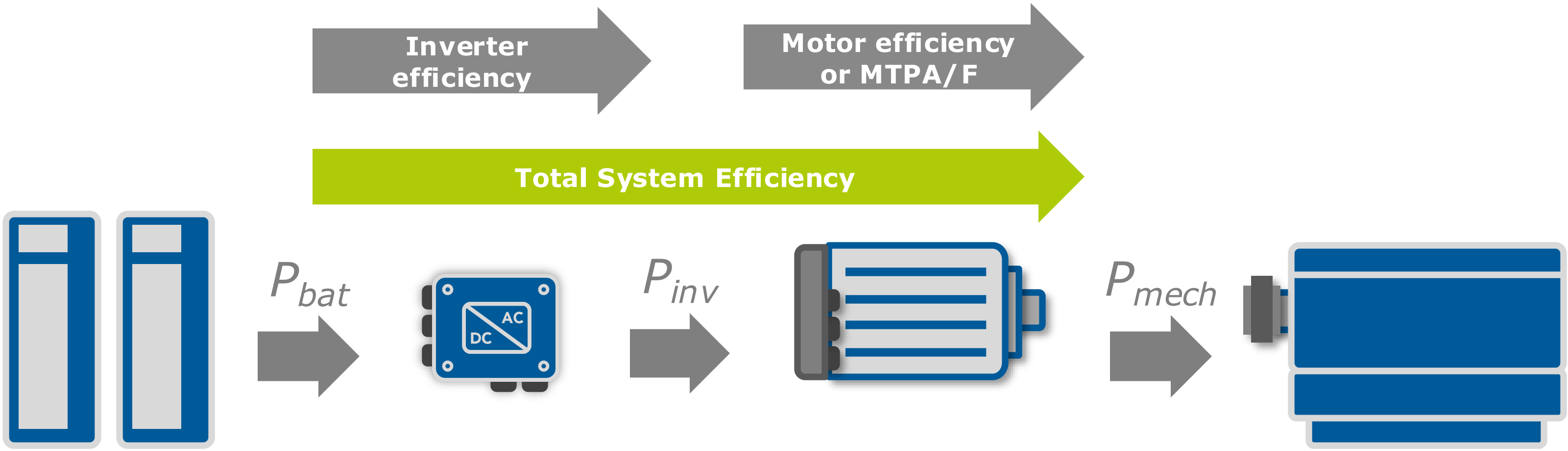


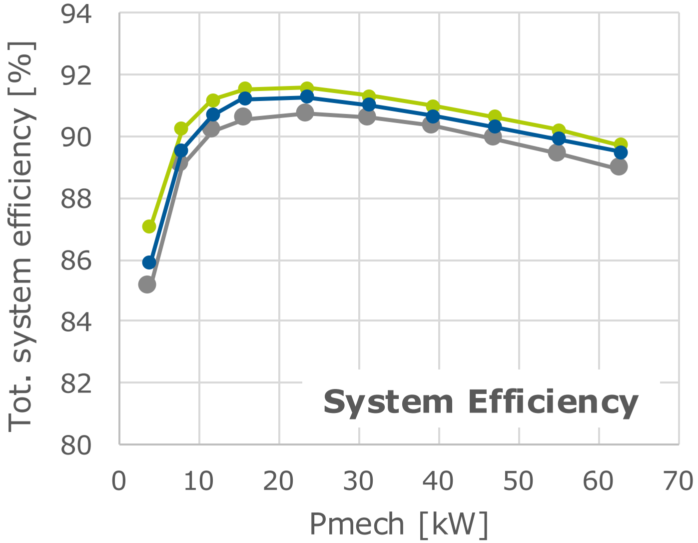
Efficiency Optimization

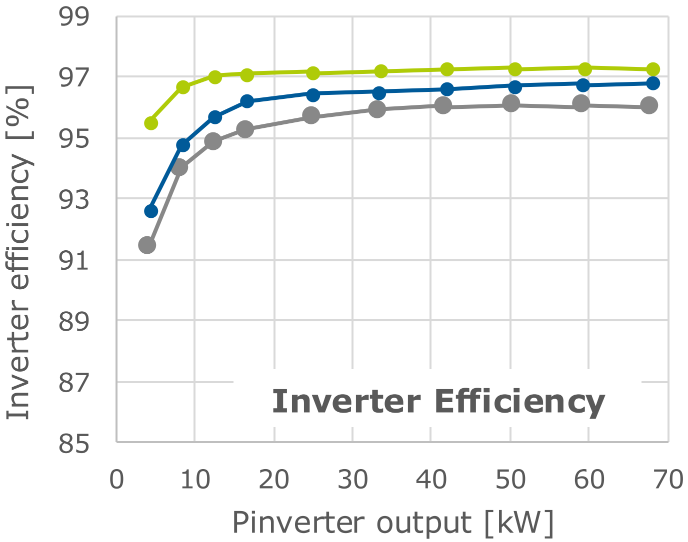
Baseline (MTPA)

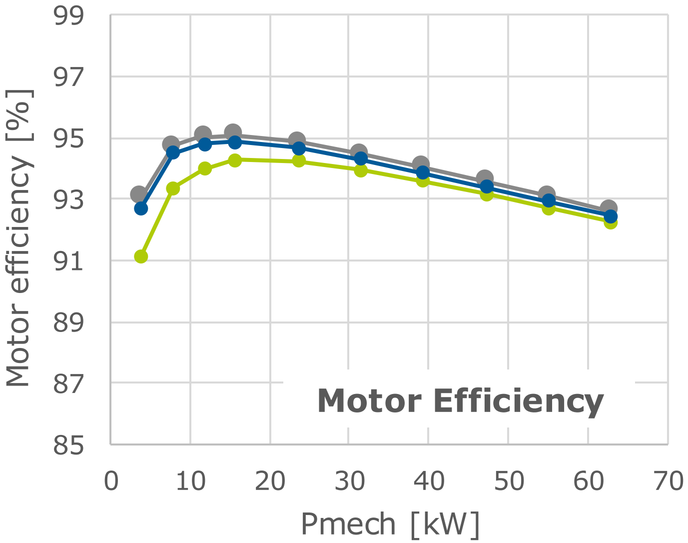
Best Total Efficiency

THD Limited







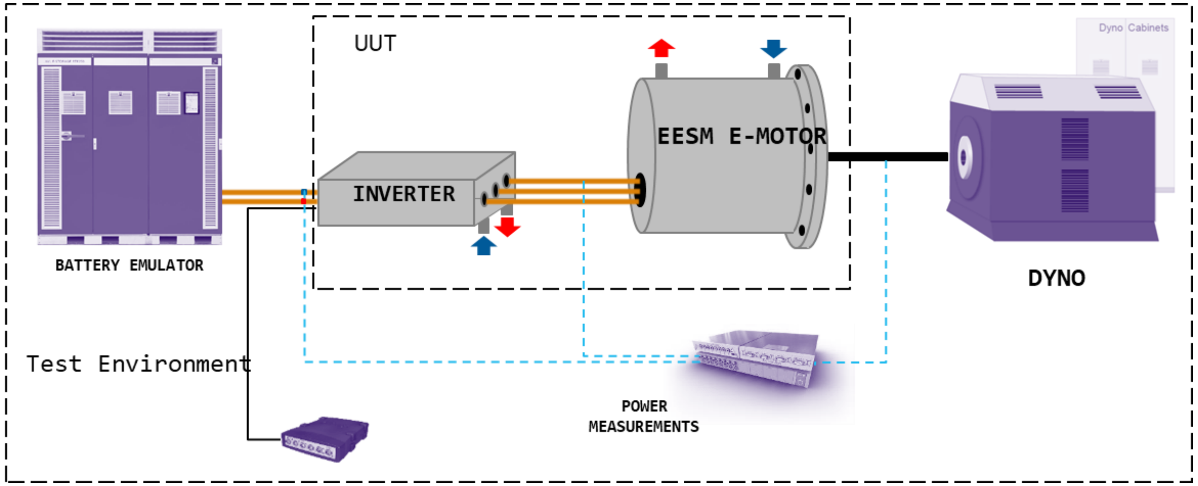


Renault
Optimization of an externally exited synchronous machine

RENAULT

AVL CONCERTO™ Data processing and KPI calculation

AVL CAMEO™ DoE planning, Test executing and optimization



Scope and benefits

Scope

- Toolchain integration at customer specific environment
- Optimizing Maximum Torque per Ampere (MTPA) with active DoE
- Search for best efficiency with active DoE

Performance

- More than 40% reduction of time for MTPA calibration
- 30-50% less measurement points necessary due to active DoE
- Best efficiency calibration automated as it is not possible to do easily in a manual approach

Quality

- Continuous monitoring of limits
- Integration of conditioning cycles in the active DoE
- Highest torque accuracy for MTPA calibration (<0.05% deviation)

Hitachi Astemo
Optimization of E-Drive Calibration

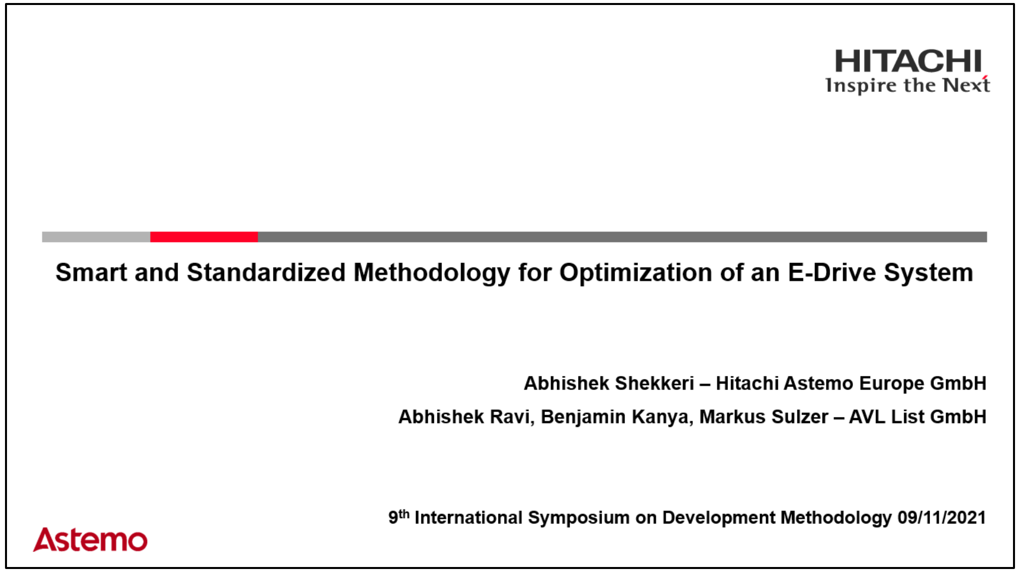
HITACHI
Inspire the Next
Astemo

AVL CONCERTO™ Data processing and KPI calculation

AVL CAMEO™ DoE planning, Test executing and optimization

AVL PUMA™ Testbed Automation

AVL Xion™ Power Analyzer


HITACHI
Inspire the Next

Smart and Standardized Methodology for Optimization of an E-Drive System

Abhishek Shekkeri – Hitachi Astemo Europe GmbH
Abhishek Ravi, Benjamin Kanya, Markus Sulzer – AVL List GmbH

9th International Symposium on Development Methodology 09/11/2021

Astemo

Joined publication at Development Methodology Symposium

Scope and benefits

Scope

- Toolchain integration at customer
- Optimization of Current Controller
- Automated reporting
- Optimizing with DoE approach

Performance

- More than 50% reduction of time due to methodology approach
- Higher testbed utilization
- Reduced Manpower required

Quality

- Better result quality
- Standardized reporting

Base Calibration on E-Drive Testbed

TIME

- 40% reduction of time for calibration tasks
- 50% less measurement points necessary due to active DoE

COSTS

- Efficient and effective testbed usage (24/7)
- Increased testbed utilization due to high automation
- Total Cost of Ownership reduction up to 40%

QUALITY

- Increased result quality via higher test coverage and statistical result analysis (DoE)
- Automated operation of the UUT safely in borderline conditions (field weakening, current instability, …)

NVH Optimization

Methodic approach to reduce NVH e.g. via harmonic current injections

Reduction of NVH with application kbow-how

Fully automated test runs

based on proven toolchain
24/7 usage available

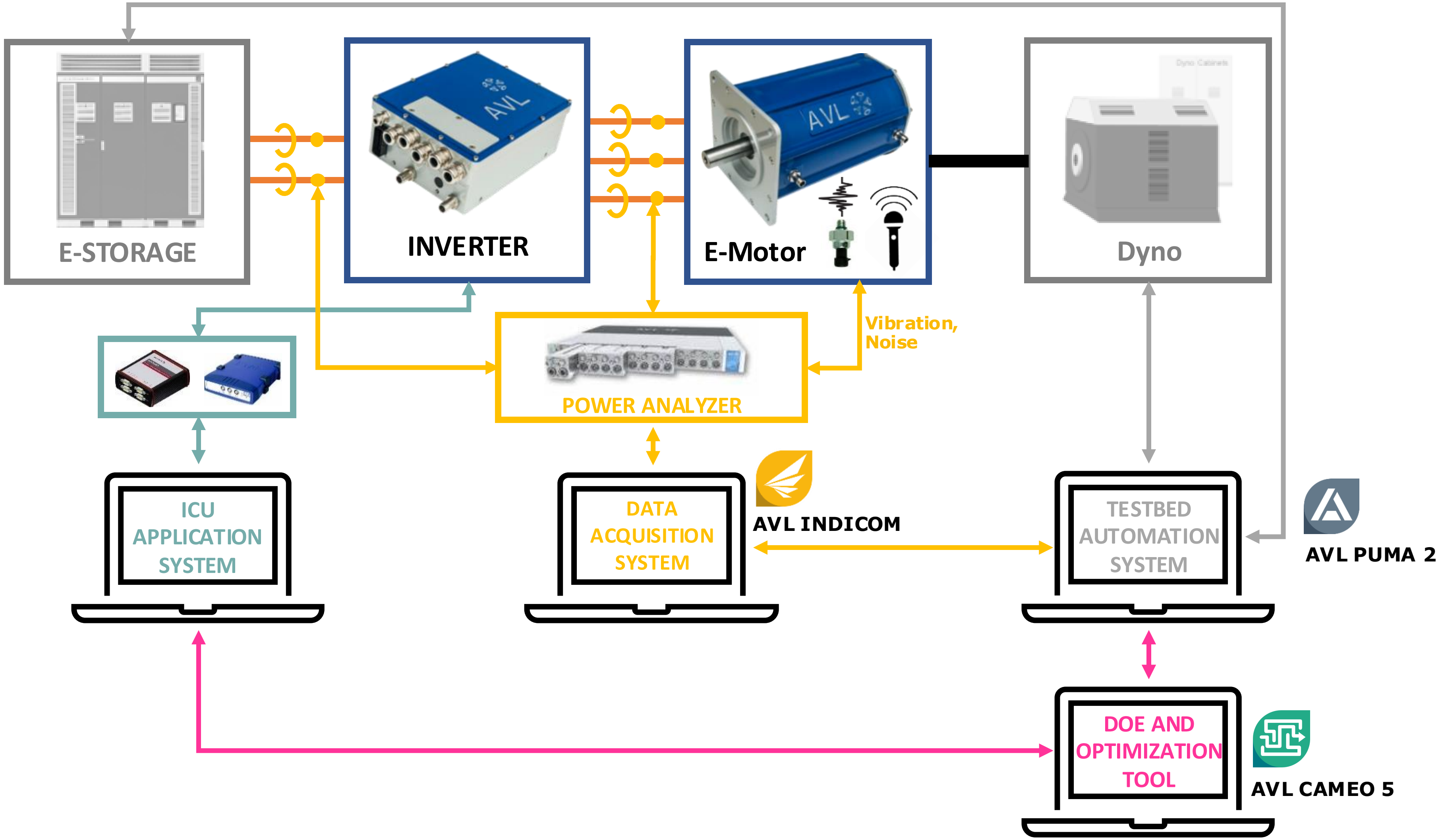
Measurement data acquisition of high frequency signals

Accurate noise and vibration measurement

Optimization of multi dimensional objectives

Optimization of system behavior by balancing counteracting KPI's (e.g. efficiency vs. NVH)

Advanced E-Motor / E-Axle Test System for NVH



Customer Reference - NVH Optimization for E-Axle Current Harmonic Injections

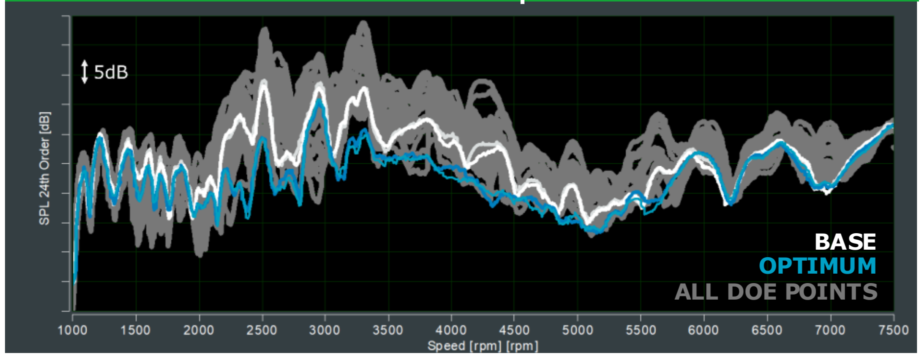
Asian OEM

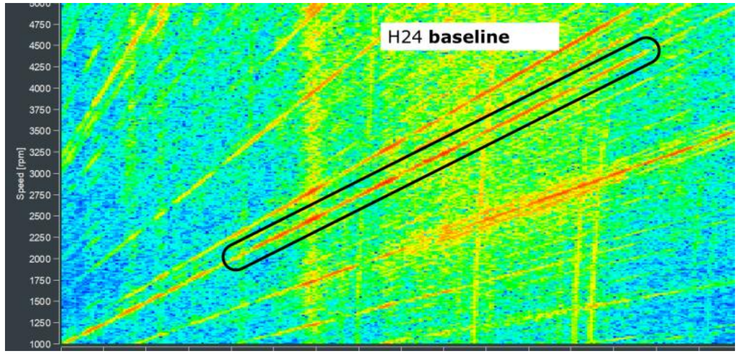
- Calibration of current harmonic injections (phase + amplitude) for acoustic NVH reduction of critical harmonics
- Optimization of calibration via DoE and map shaping methodology
- Run-up: speed ramp from low to high at constant torque levels

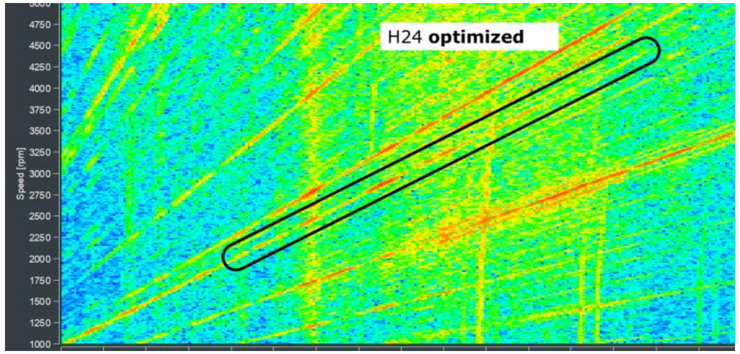
Customer project results:

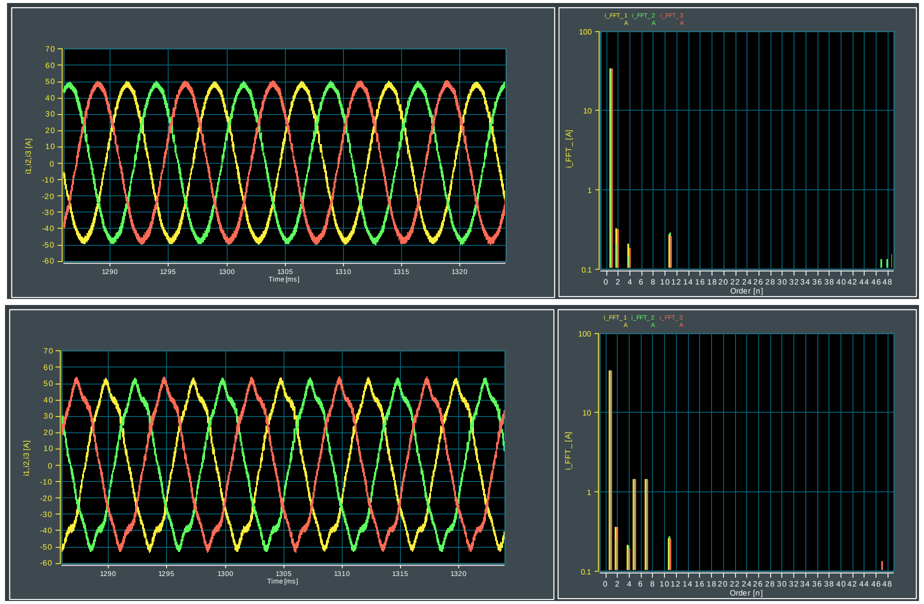
- Reduction of 24th mechanical harmonic up to 15dB, more than what customer was able to reach with manual calibration
- Time savings: 12 weeks → 3 weeks

Mid Torque







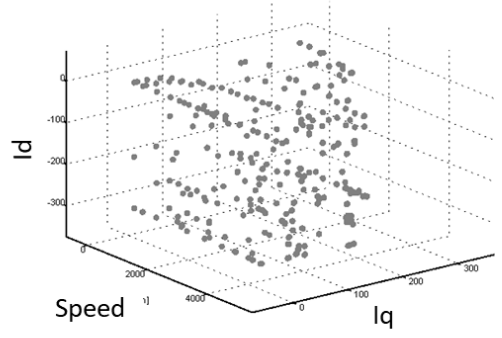


Optimization of Torque ripple (NVH) and Efficiency

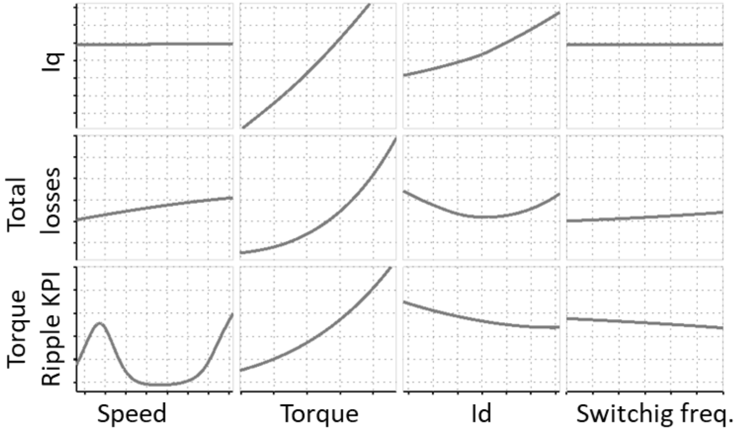
Variation parameter:
- Id
- Iq
- Switching frequency
- Control strategy

Optimization of:
- Efficiency
- Torque Ripple

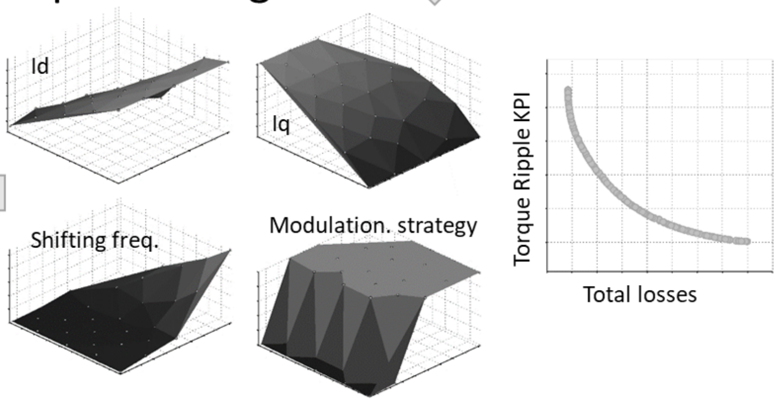
Automated *ActiveDoE* measurements:



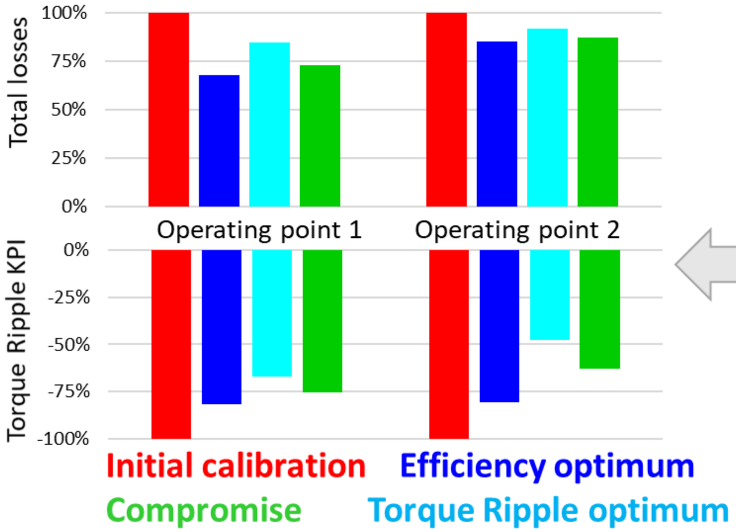
Model creation:



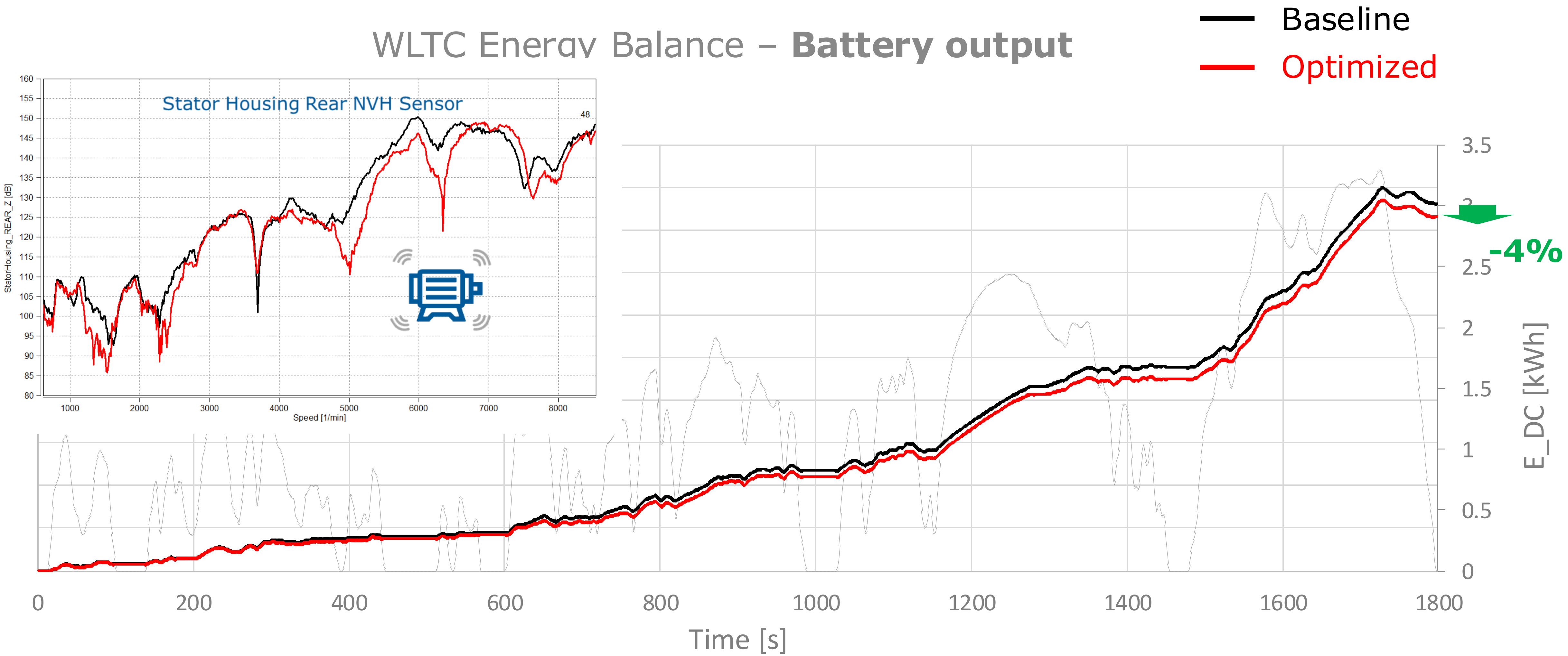
Optimierung:



Verification:



Efficiency and NVH Optimization



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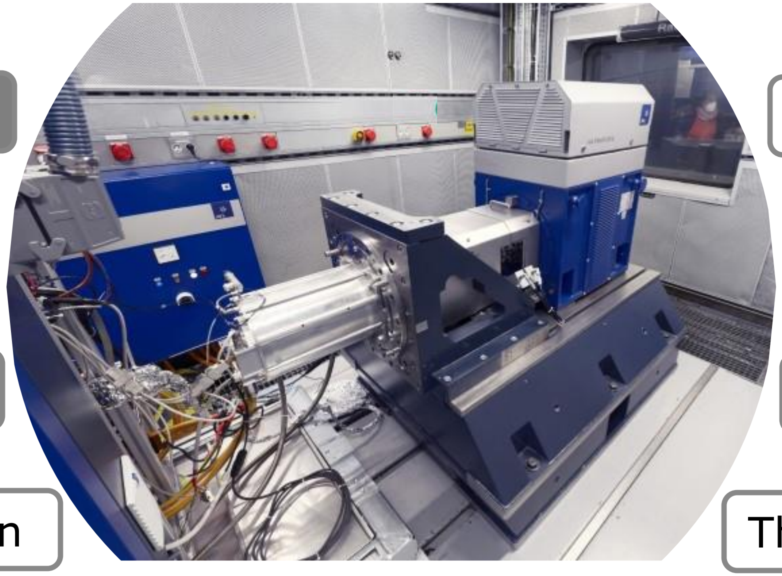

Racing

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Calibration lateral dynamics

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Drivability

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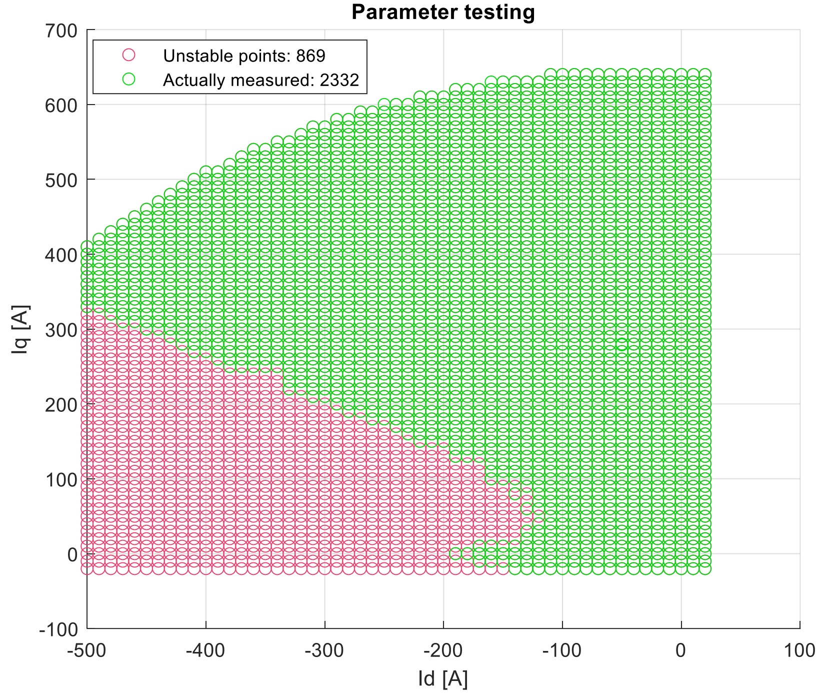
Calibration of dynamic vehicle behavior

Example – Parameter Identification

Custom instability protection is a game changer



	w/o CIP	with CIP (digIO)
Total number of required measurement points	3200	
Points with unstable operation	869 (27%)	
Interruption caused by instability	6-9 days*	7 hours²
Total time for measurement program by having the exact same result	11-17 days	5 days

- 100% automated autonomous test run
- 50-70% Time Saving
- No damage due to instabilities

*considering a operator is all the time present at the testbed and reacts immediately. 10-15 minutes to restart

² 30 seconds to go to the next point after detecting instability

The AVL Solution

AVL INDICOM
E-Power Toolbox

AVL PUMA 2

AVL CAMEO 5

AVL X-Ion
Power Analyzer

Application System

Proven Benefits

Performance

- 100% automated autonomous test run
- Up to 70% Time Saving

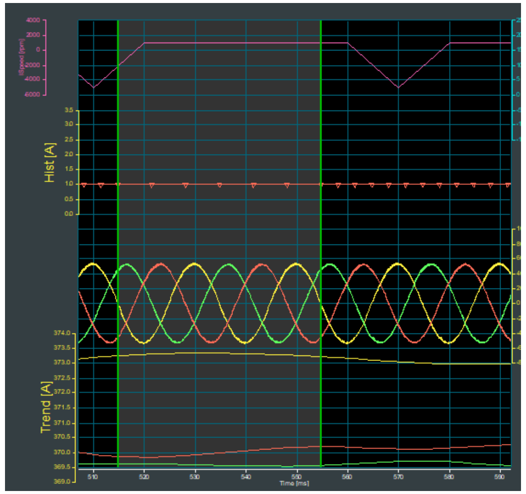
Quality

- Seamless integration and operation
- Proven toolchain
- No damage due to instabilities
- Patented algorithm

- **AVL X-Ion Power Analyzer:** Power measurement
- **AVL INDICOM E-Power Toolbox:** KPI Calculation and visualization
- **AVL PUMA 2:** Testbed operation
- **AVL CAMEO 5:** Test planning and automation, automated optimization

What do we mean by “Current Instability”

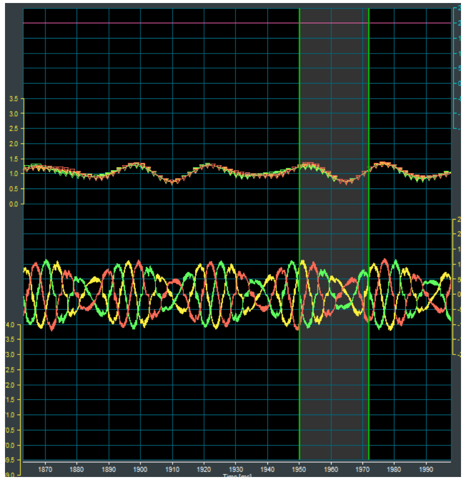
stable



We can stay in the point

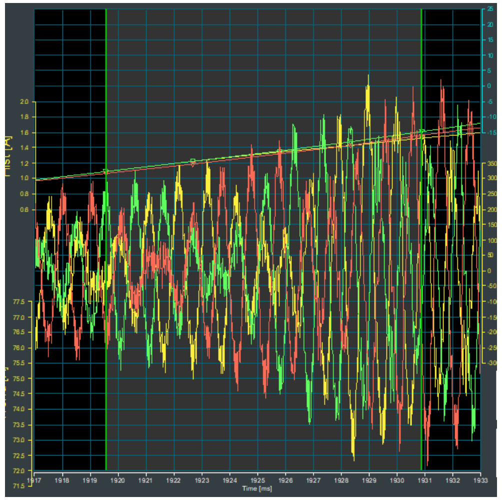
No action required

Unstable but not short-time dangerous



We can stay in the point for a certain time, but the point is not stable at all.

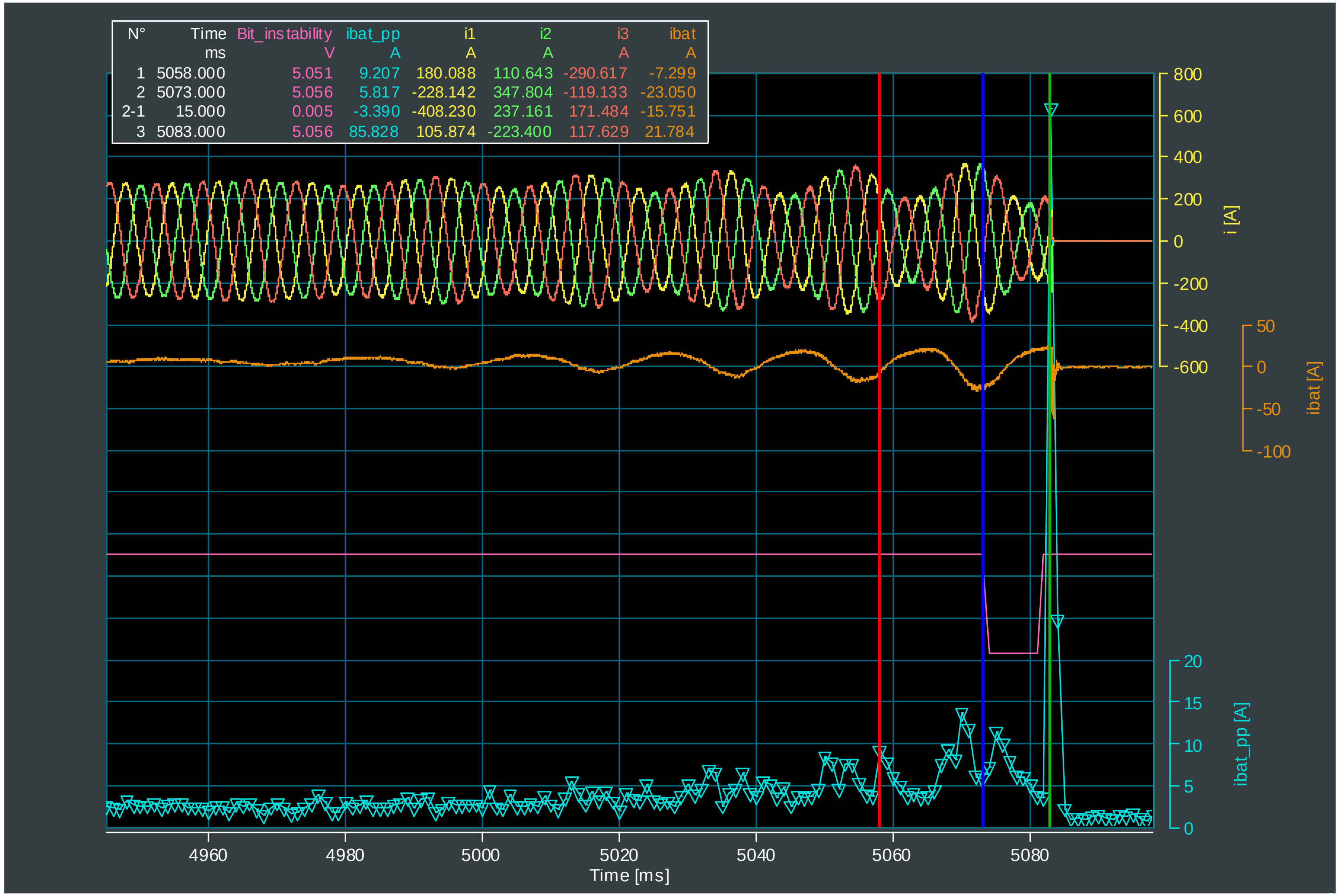
Unstable and escalating



Reaction time of around 20ms required

Immediate reaction to stable operation point

Example instability during operation
Reaction



E.g.
KPI to detect instability ibat_pp
Ibat_pp limit = 9A.

Red cursor: an instability is detected, ibat_pp > 9

Blue cursor: IndiCom sends the flag to PUMA due to instability detected, 15ms later.

Green cursor: the protection system in PUMA switched in safety the inverter to standby, 10ms later.

Potential Use Cases

Current Controller Optimization

Efficiency Optimization

Peak Performance Testing

Dynamic and Transient operation (driving cycles, vehicle simulation)

Conclusion

Time saving

Significant reduction of testbed downtime and increase of efficiency

Safety

Protecting the UUT of self destruction. Especially in early development phases

Cost reduction

Faster result generation due to more effective testing

Future Development

CIP is ready for other use cases and those are being developed