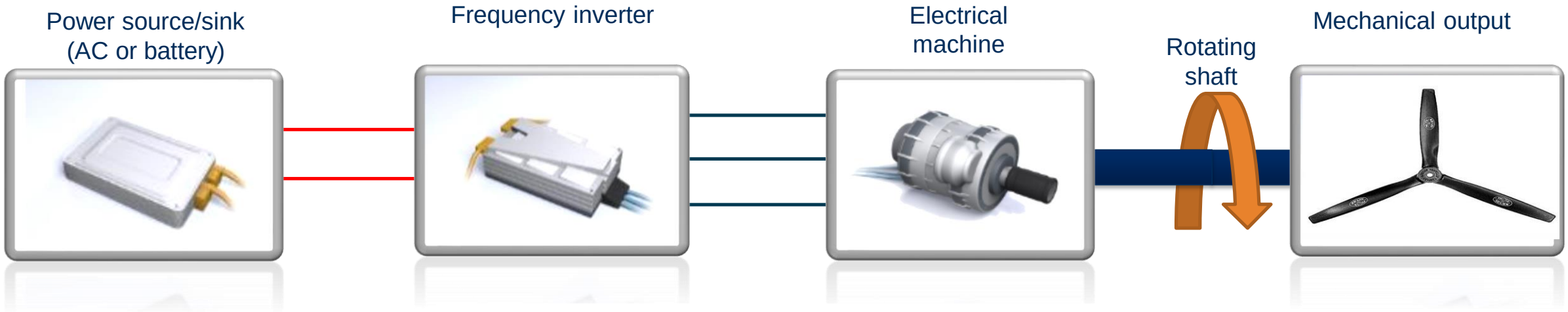
Electric Motor NVH Case Study and Analysis

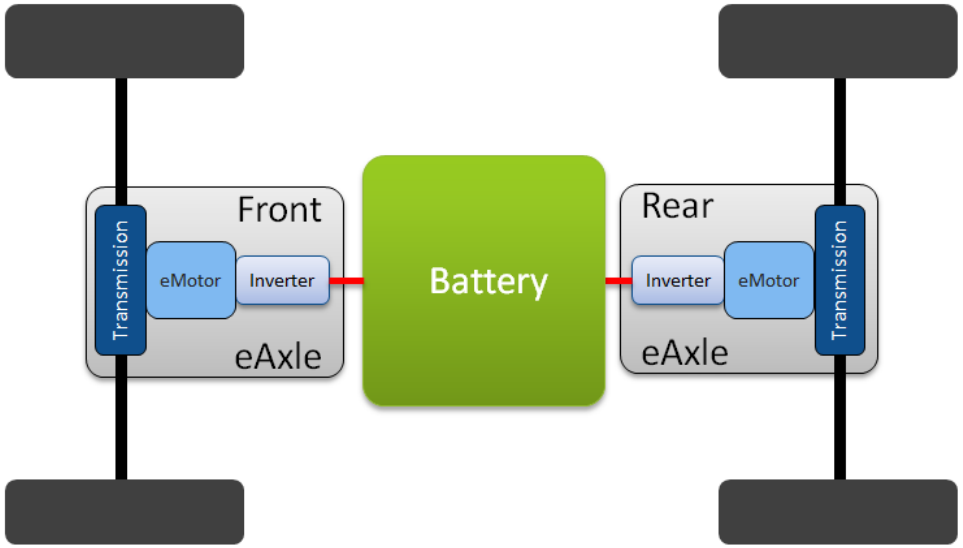
Agenda

1. Introduction to vibration in electric machines
2. Measurement of NV and Electrical signals
3. Efficiency mapping with vibration
4. NVH Ramps with efficiency

Introduction to Vibration In Electric Machines

Simple Measurement Chain - Electric & Mechanical Measurements





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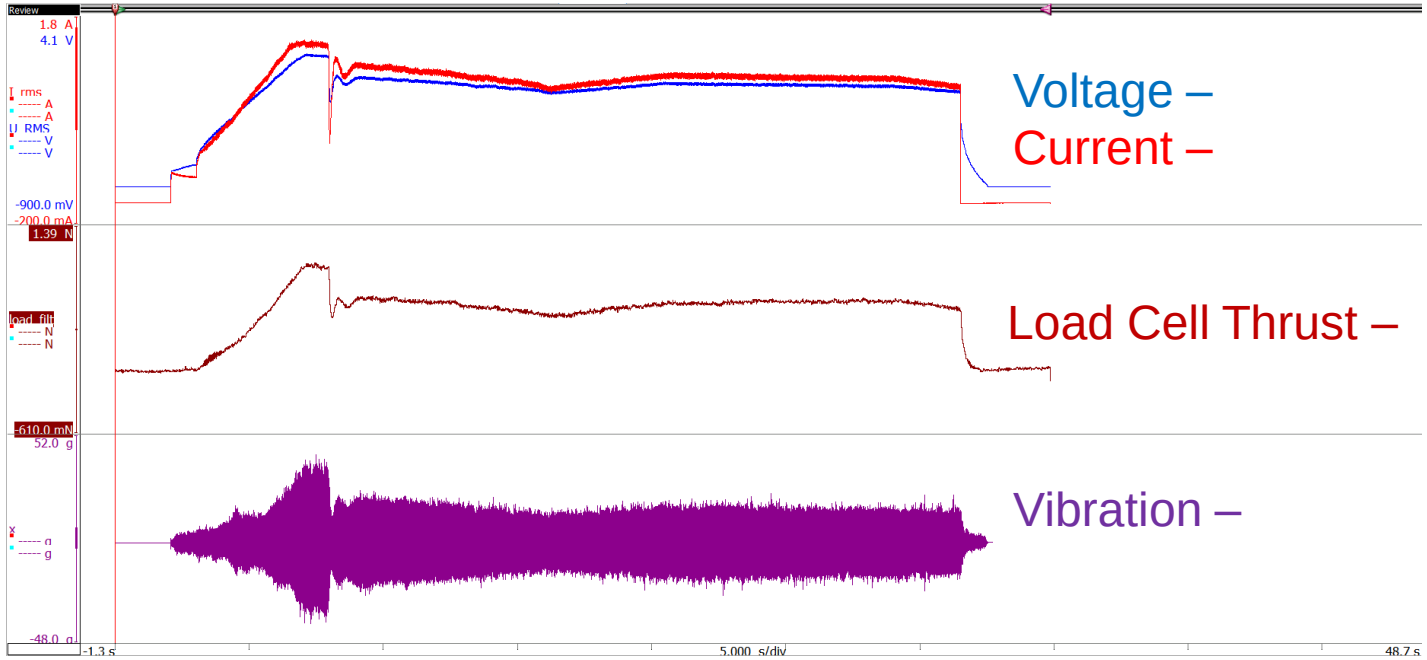
Why Measure Both?

Benefits of combined testing

- Single test to do both
  - **Reduction costs**
- Communication between groups
  - **Faster development**
  - Easier communication to vehicle simulation
- Sound design
- Fatigue characterization
- Failure testing
- Resonance tracking
- End of line characterization



Propeller motor startup with load and vibration measurements

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Case Study

Characterization of a Traction Motor

Test Machine

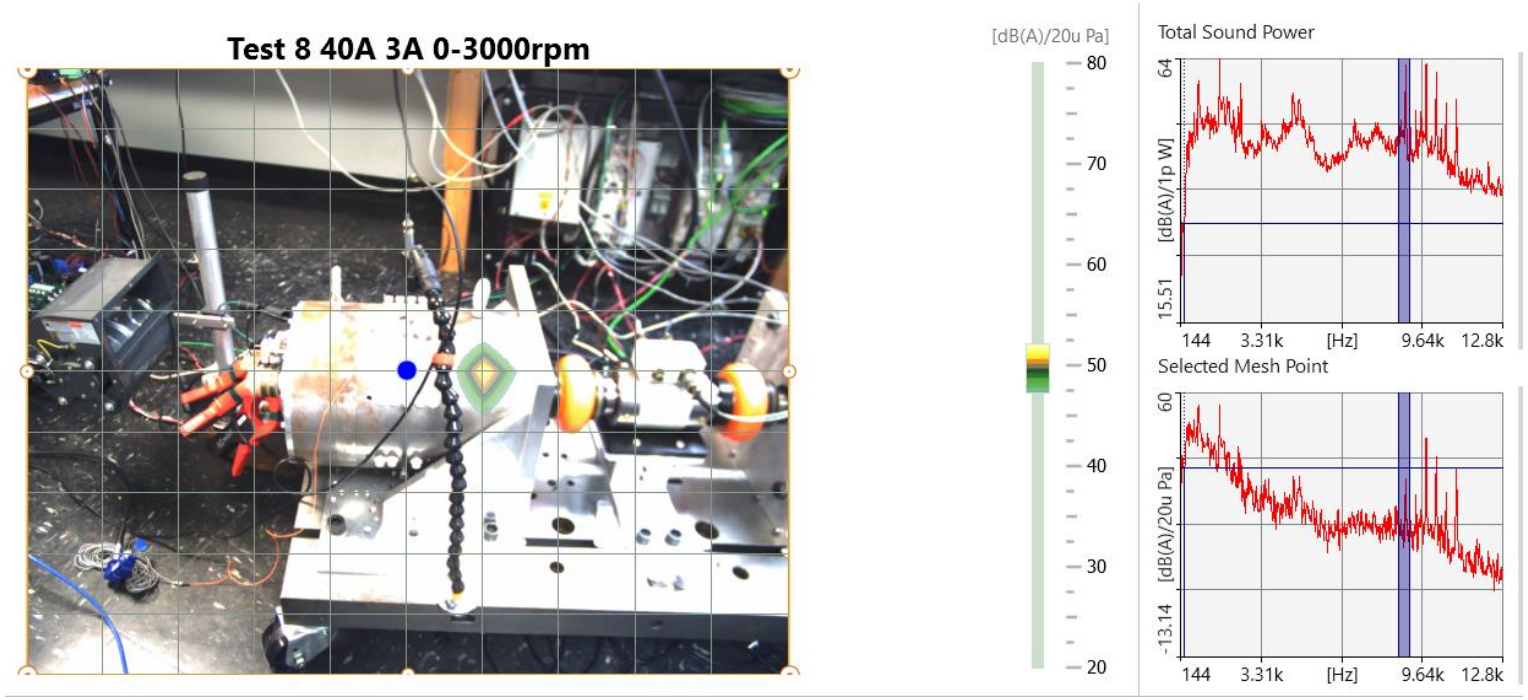
- Three phase traction motor
- PM & wound field excitation
- Eight poles

Tests Run

- Point by point efficiency map
- Ramps at different loadings

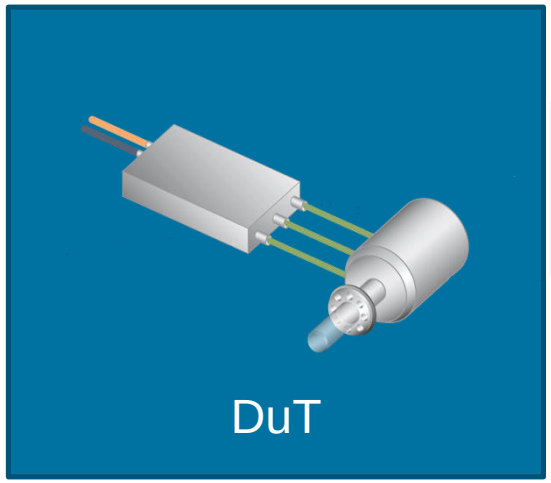
Measured Quantities

- Inverter voltage & current
- Torque and Speed
- Vibration
- Noise



Acoustic camera picture of a test motor

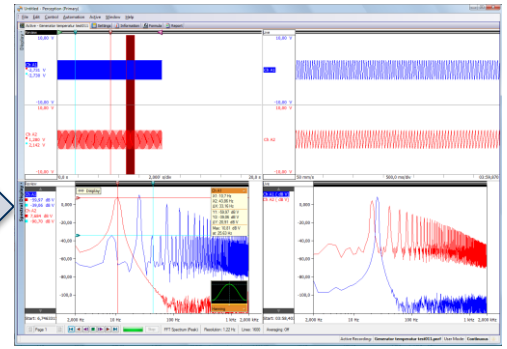
Electric Powertrain and NVH Testing



Voltage
Current
AND
Acceleration

ALL
synchronously and
continuously
recorded with eDrive

Time domain and
FFT display
in Perception



Post process analysis in
BKconnect

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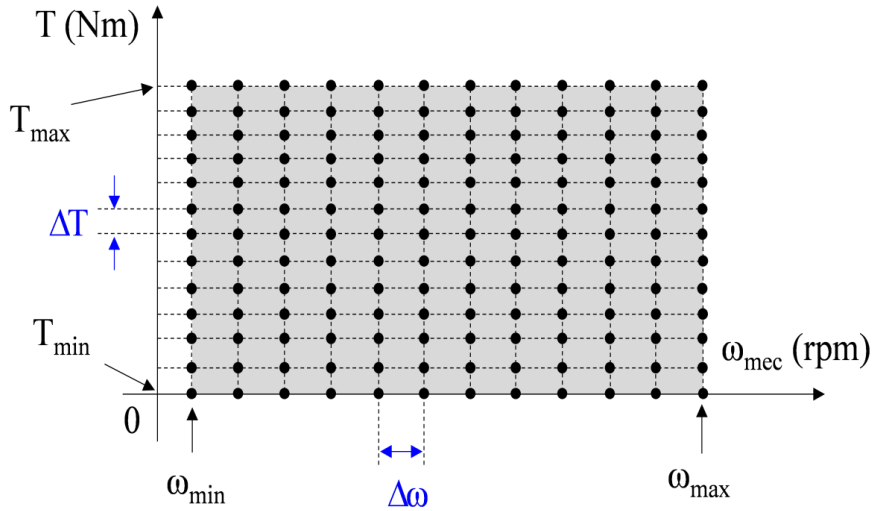
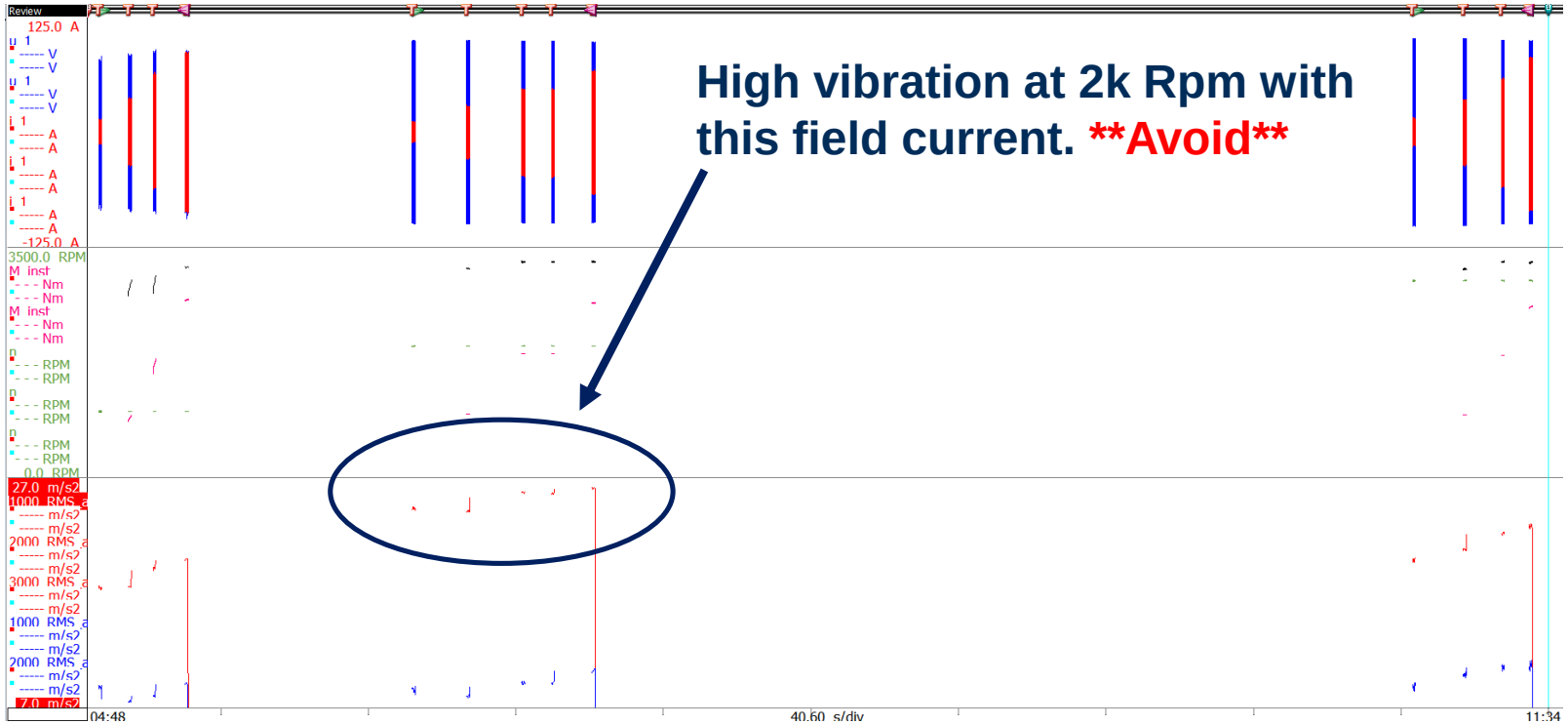
Efficiency Mapping With Vibration

Efficiency Mapping

- Series of static torque and speed points where efficiency is measured
- Record many signals
  - torque & speed
  - Voltage & current
  - Control
  - Vibration
- Can monitor how control effects vibration
  - Avoid certain states
  - Faster communication with other teams



Voltage –
Current –
Torque –
Speed –
Efficiency–
RMS accel1 –
RMS accel2 –



Recorded & calculated data points for motor efficiency map

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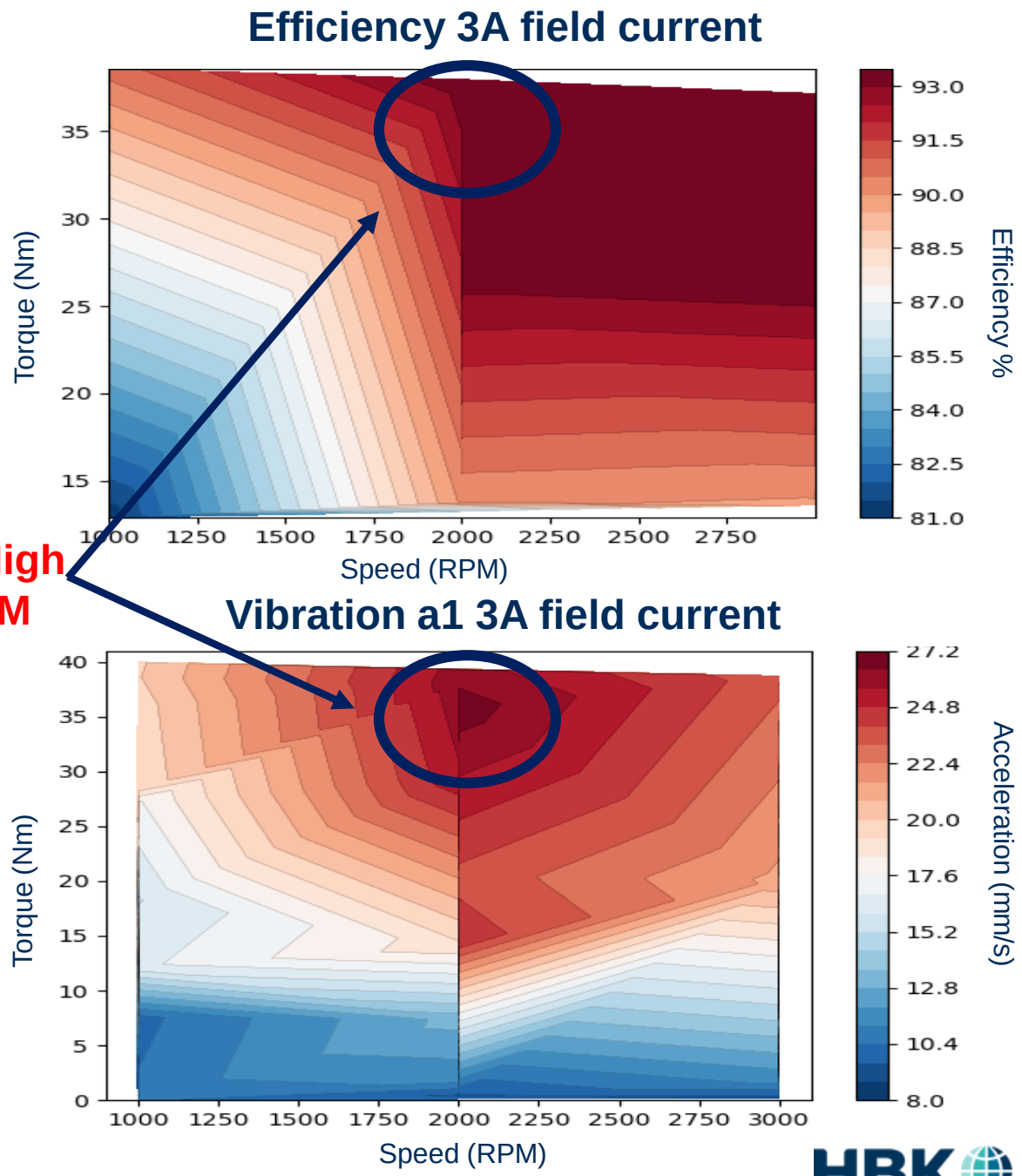
Efficiency & Vibration Mapping

- From these acquired points a “Efficiency Map” is often generated
  - X – Speed (RPM)
  - Y – Torque (Nm)
  - Contour – Efficiency %
- Gives an idea of the optimal operation
- Can also be plotted for RMS vibration
  - Shows general trend of the vibration
  - Identifies hot spots
- Allows for analysis of system level interactions

High Efficiency, High Vibration at 2kRPM



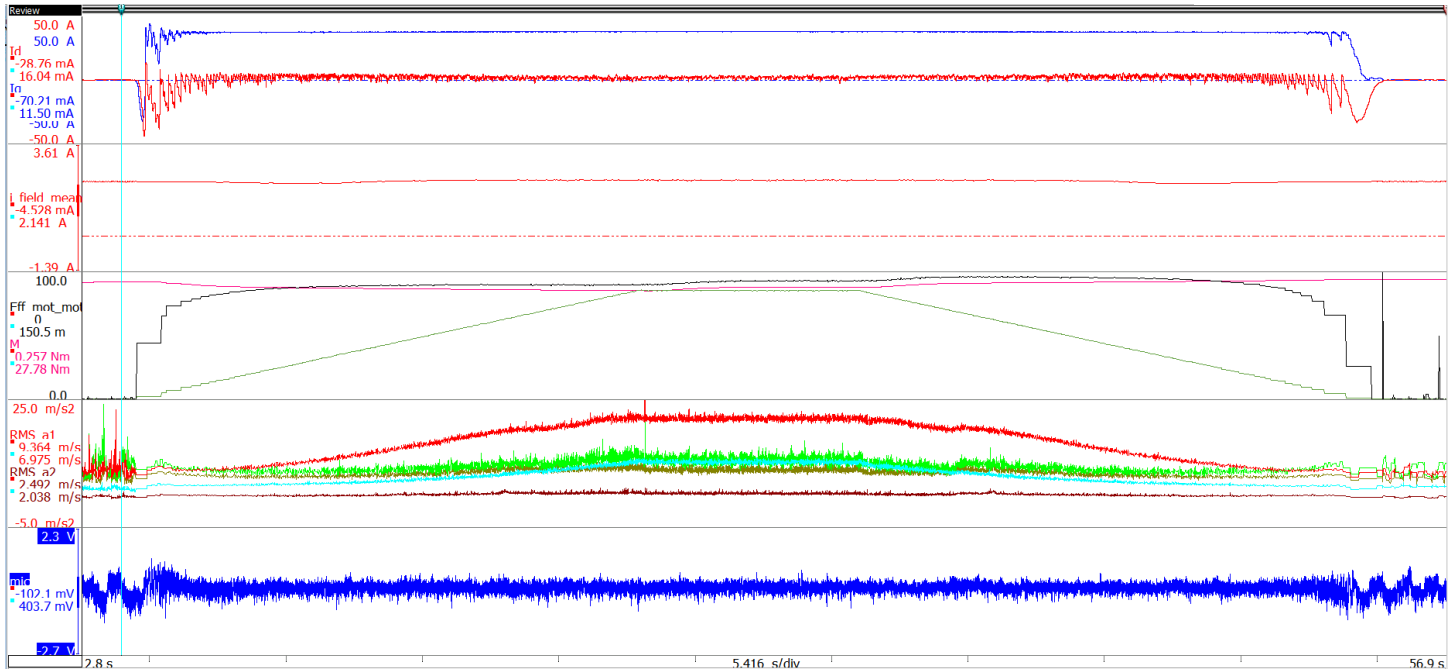
Efficiency and vibration heat maps for DUT

Ramps With Efficiency

Electrical Analysis of Motors and Drives During Sweeps

Iq –
Id –
Ifield –
Torque –
Speed –
Efficiency–
Accel –
Mic –

- A ramp test involves setting a fixed torque and ramping speed
  - Common NVH test
- Efficiency can be measured with a dynamic measurement technique
- Understand how electrical state effects vibration
- Single test for NVH, efficiency, calibration



Ramp test showing state, efficiency, noise, vibration, and control variables during a ramp test.

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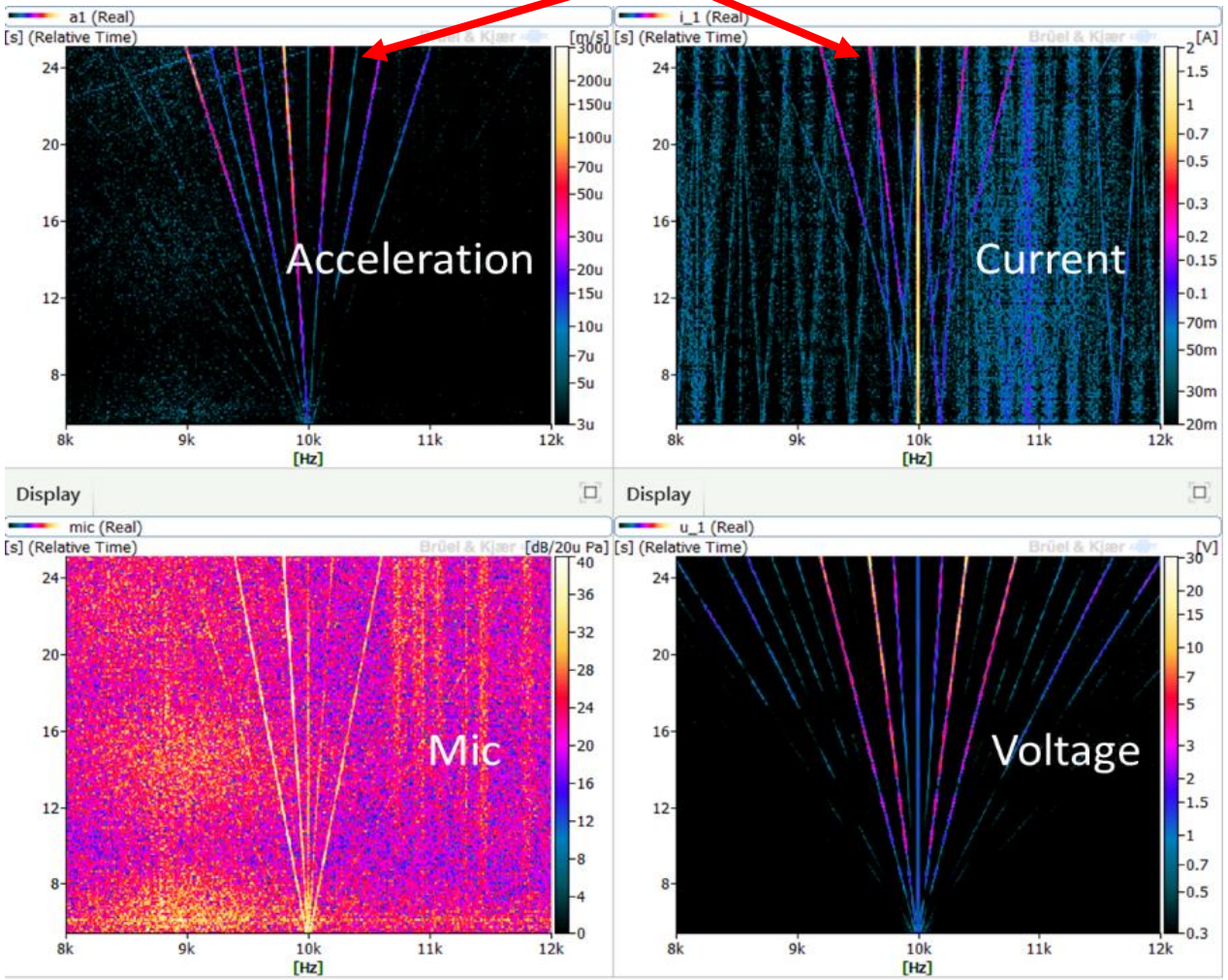
Spectral Analysis of the Inverter

- Test took place in acoustically noisy environment
- Clear traces of switching noise
- Relation between voltage, current, acceleration and noise
- Allows us to identify source path contribution to noise and vibration

Strong currents blades line up with weak acceleration blades



Spectrum plots of acceleration, microphone, and current for full loading ramp tests from 0-3000RPM

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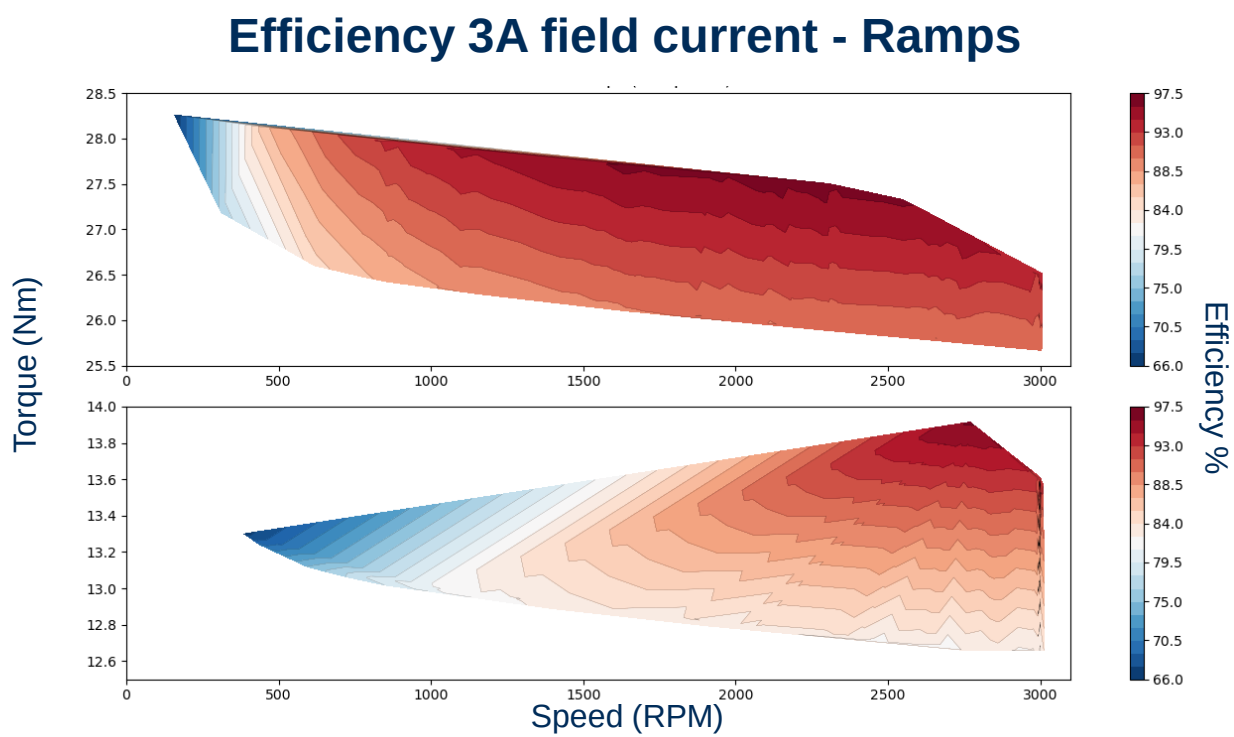
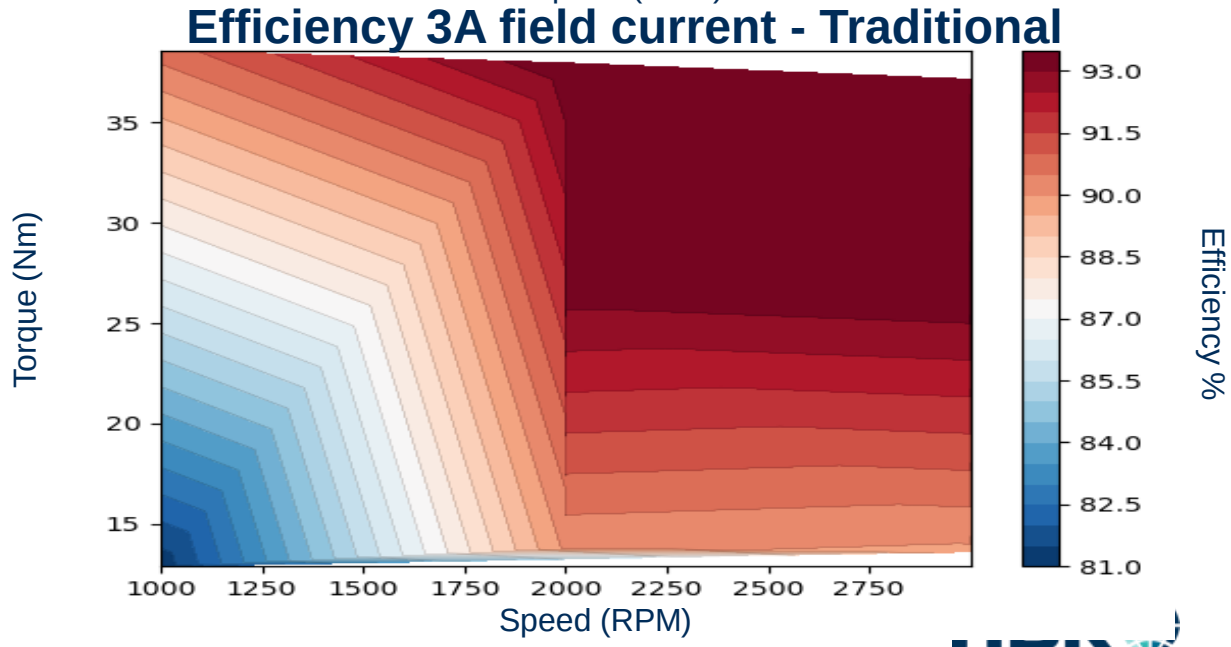
Efficiency from ramps

- Ramps efficiency can be used to plot efficiency
  - Requires dynamic power measurement
  - Requires high bandwidth torque
- Results can be used by NVH to gauge how their changes effect efficiency
- Close correlation to point by point map





Efficiency heat maps for DUT

Questions?

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HBK Electric Power Test