



Electric Power- and Efficiency- Analysis in Road Tests

CSM web seminars

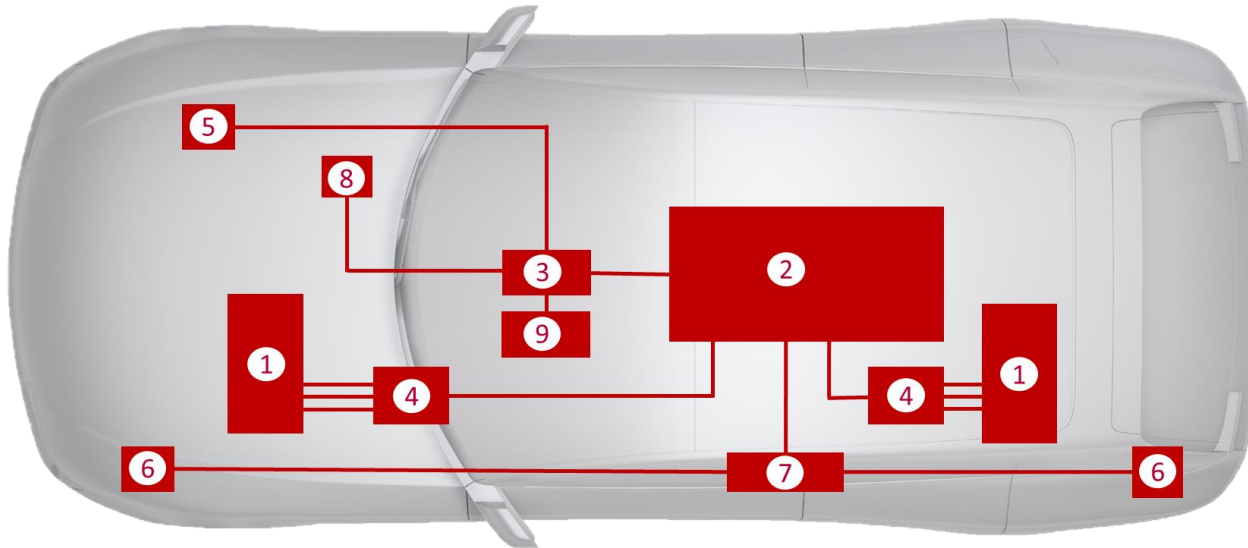
CSM **Xplained**
measurement technology

VECTOR 



Innovative Measurement and Data Technology

Electrical driven vehicles



- | | | |
|------------------|---------------------|-------------------|
| ① E-Motor | ④ Power Electronics | ⑦ OnBoard Charger |
| ② HV Battery | ⑤ Compressor | ⑧ PTC Heater |
| ③ HV Distributor | ⑥ Quickcharge Unit | ⑨ DC/DC Converter |

Development task

- ▶ Develop a vehicle that sells
 - ▶ Technical superior
 - ▶ Drive experience
- ▶ Ultimately, with profit
 - ▶ Time
 - ▶ Manpower
 - ▶ Resources, e.g. testbenches

Challenges

- ▶ Efficiency
- ▶ Charging
- ▶ Safety and Robustness
- ▶ NVH


have solutions
to all of them!

Knowing your electrical power



Direct current:

$$P = UI$$

Alternating current:

Complex power

$$S = U \cdot I$$

Active power

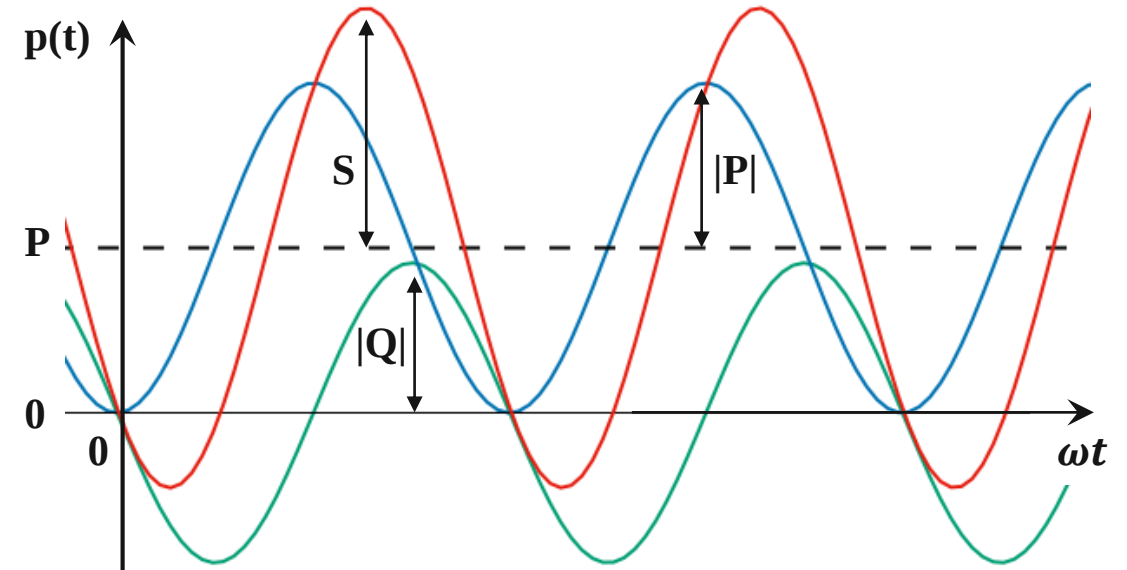
$$P = \frac{1}{\omega t} \int_{t_1}^{t_2} u \cdot i \, dt$$

Reactive power

$$Q = \sqrt{S^2 - P^2} = UI \cdot |\sin \varphi|$$

3-phase effective power

$$P_{eff} = P_1 + P_2 + P_3$$



Knowing your electrical power



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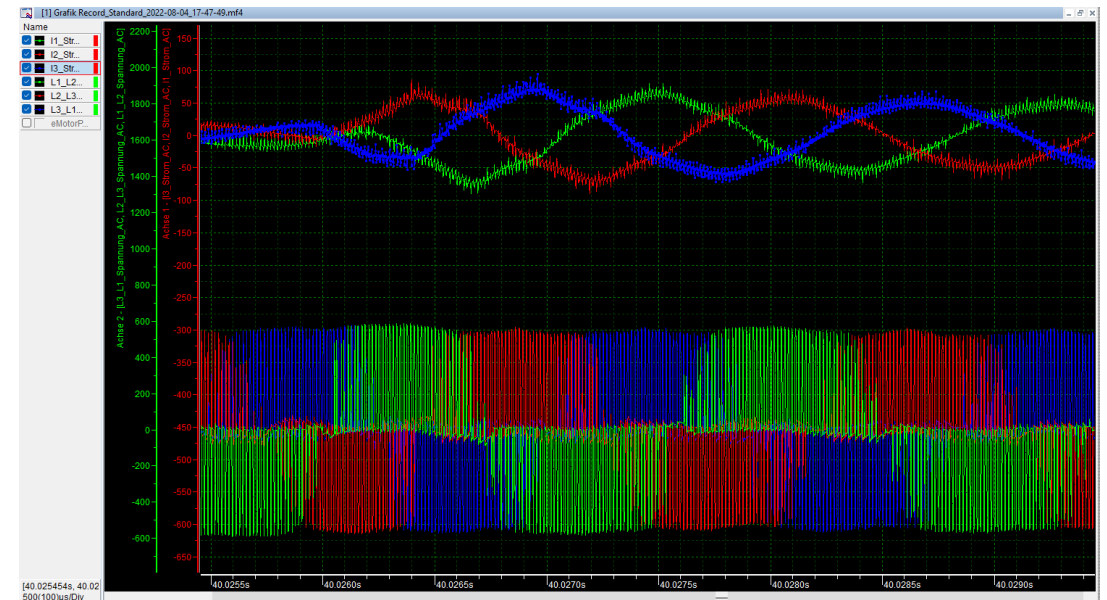
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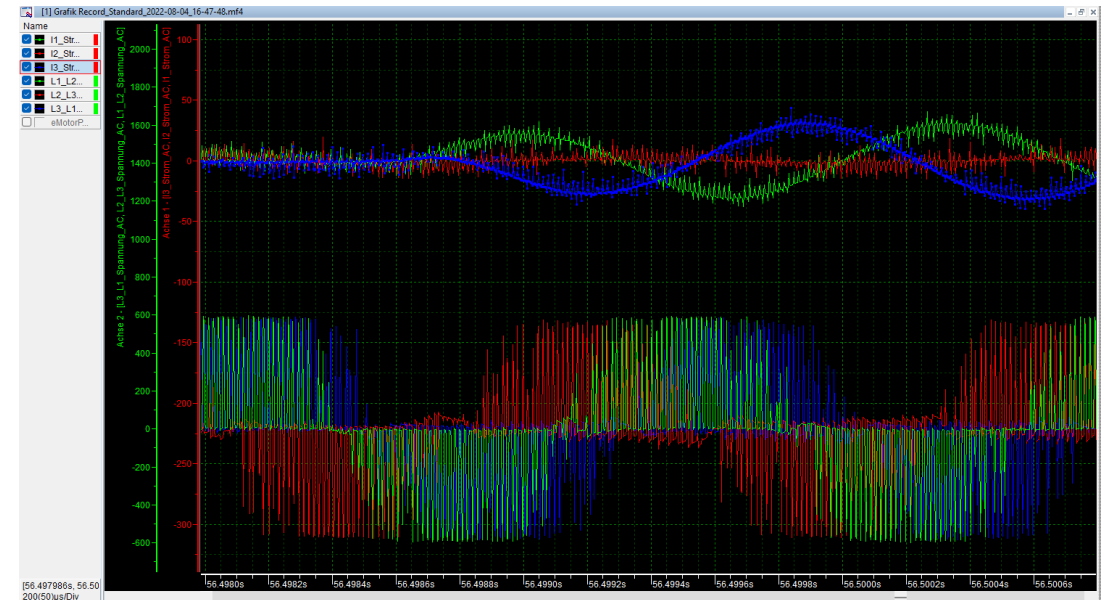
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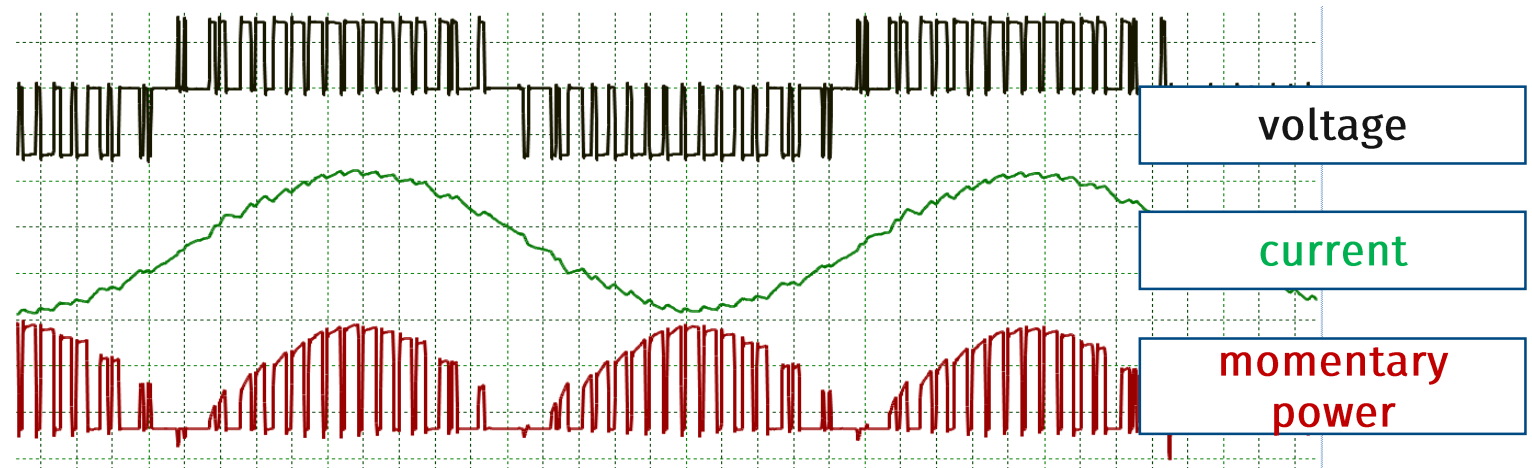
Synchronization is a must!



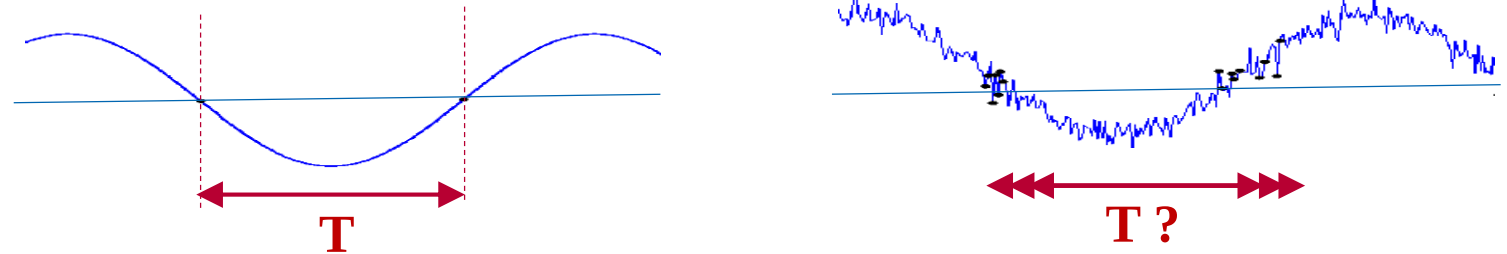
Frequency Determination

Determination of electrical frequency is challenging

- ▶ Voltage is no sinus wave
- ▶ Noisy signal
- ▶ Electrical frequency changes with driving situation
- ▶ Frequency estimation should be possible within one periode



$$P = \frac{1}{\omega t} \int_{t_1}^{t_2} u \cdot i \, dt$$



Knowing your electrical power

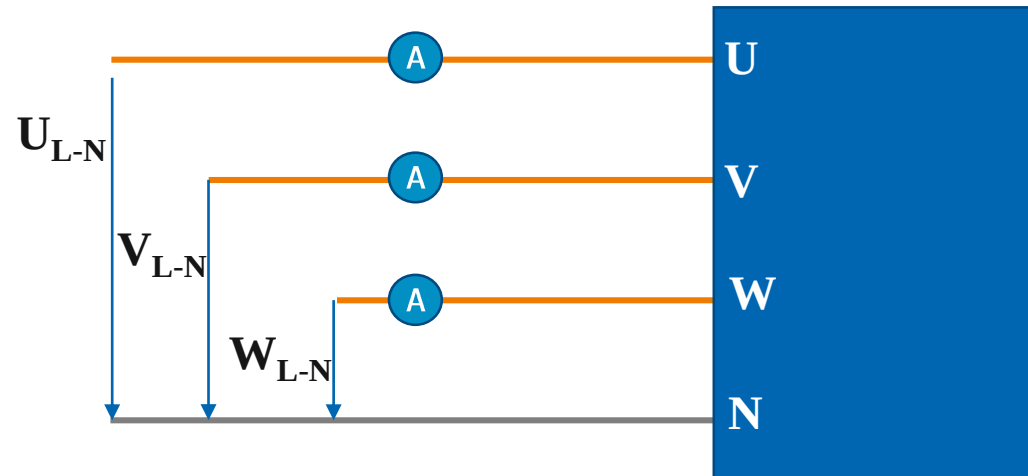
4 wire e-Motor. N as a common reference.

Easy to determine the **phase power** (P_1 , P_2 and P_3).

Total power is the summation of each phase power

$$\blacktriangleright P_{total} = P_1 + P_2 + P_3$$

3-Phase System with 4 wires (N-Wire)

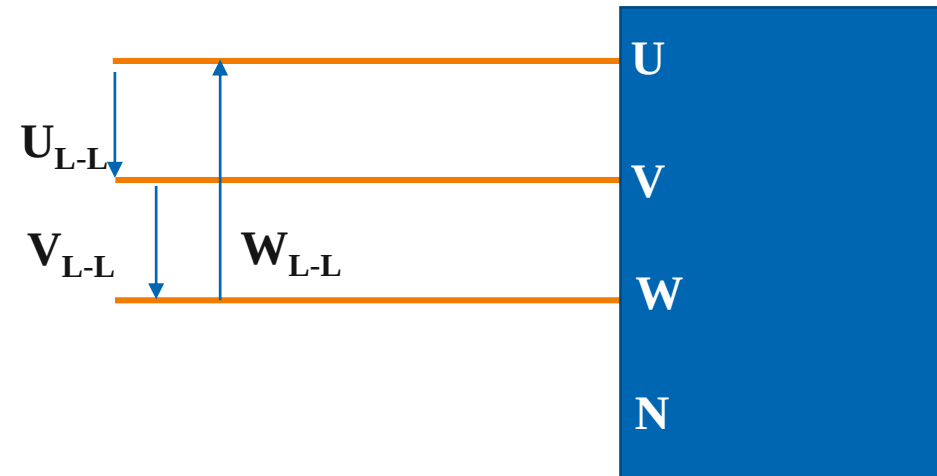


Knowing your electrical power

Typically, neutral wire is not available for an e-motor

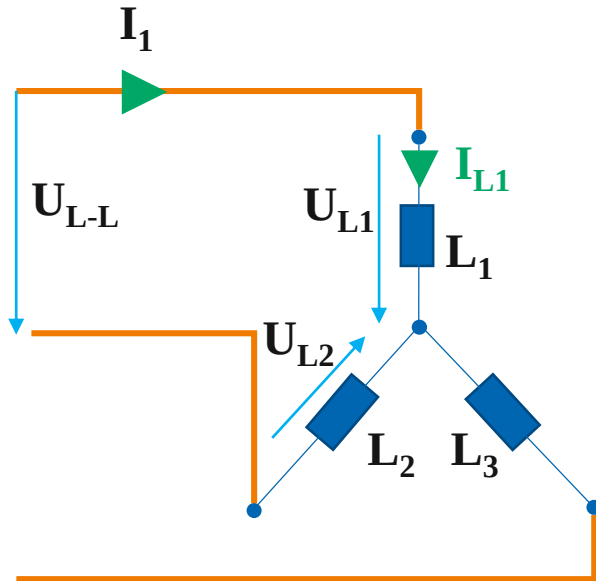
- ▶ Measure 3 **line-to-line voltages**
- ▶ Line-to-line voltages must be transformed to phase voltage to obtain the total power
- ▶ Transformation depends on the e-motor itself

3 Phase System with only 3 wires



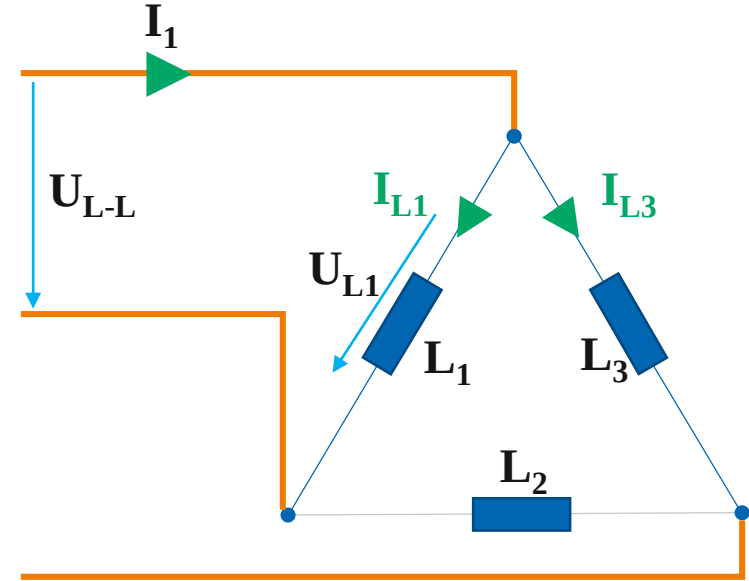
Knowing your electrical power

Star Connection



$$U_{L-L} \neq U_{L1}$$

Delta Connection



$$I_1 \neq I_{L1}$$

$$P_1 = \frac{1}{\omega t} \int_0^T u_1 \cdot i_1 dt$$

Power-Analysis with CSM and Vector

Power analyzer are typically

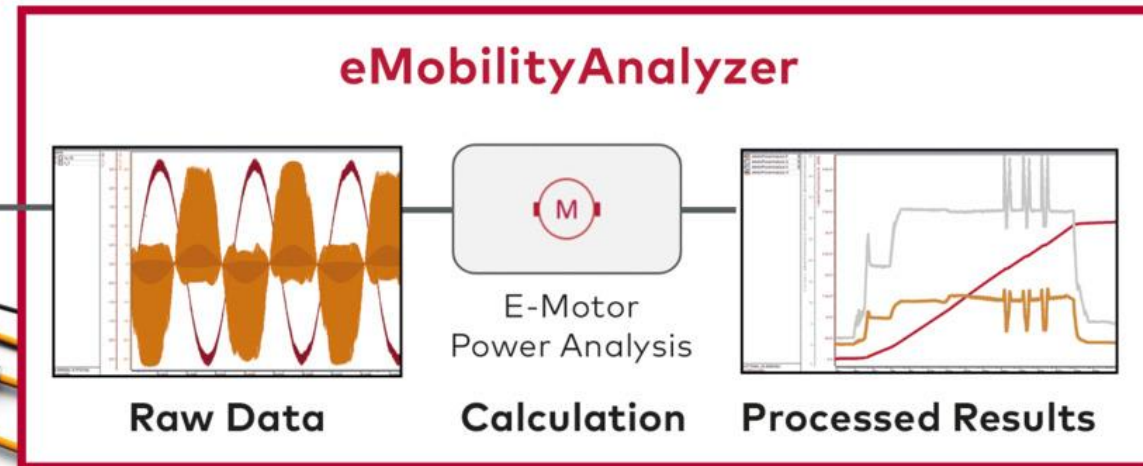
- ▶ Very precise
- ▶ In-lab: Limited synchronization methods to further signal sources, e.g. ECU
- ▶ Challenging offline analysis



Power-Analysis with CSM and Vector

Power analyzer are typically

- ▶ Very precise
- ▶ In-lab, in-vehicle, on/off road drive test use
- ▶ Support of various sensors, bus networks and protocols
- ▶ MDF → well established offline analysis tools, e.g. vSignalizer



CSM Measurement Modules

The right measurement system for your application!

- ▶ Measure voltages, currents, temperatures, strain,...
- ▶ Measurement sample rates up to 2 MHz per channel
- ▶ Safe mode of operation



eMobilityAnalyzer, a function library for vMeasure and CANape

eMotorPowerAnalysis calculates all electrical parameters of an electrical Motor **online and offline**

► Inputs:

- Phase voltages U_{12} , U_{23} , U_{31}
- Currents I_1 , I_2 , I_3

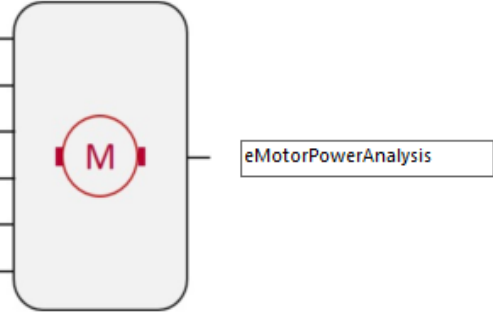
► Outputs:

- Active power P
- Complex power S
- Reactive power Q
- Efficiency factor λ
- Electrical frequency f
- Total work W
- Effective values per phase U_{rms} , I_{rms}
- Calculation within one electrical cycle
- Calculation results are synchron to further measurement records:
 - Power electronics, BMS, mech. power, ...

Description
E-Motor Power Analysis
This function calculates the effective power of a 3-phase system based on a detected period in the current signal. It uses the 3 phase voltages and the 3 phase currents as input.

Configuration

U12: ...
U23: ...
U31: ...
I1: ...
I2: ...
I3: ...



Parameter

Integration interval [ms]:
Cycles min.:
Pre-filtering current and voltage of outputs
Apply Lowpass: ☐ Cutoff frequency [Hz]:
Sync Input
☒ Current ☐ Voltage
RMS min.:
Frequency min. [Hz]: Frequency max. [Hz]:
Motor type
☒ Star ☐ Delta

Students Development Tasks

Development of a Formula E student competitive vehicle

Starting Point: e-Motor and inverter for industrial application

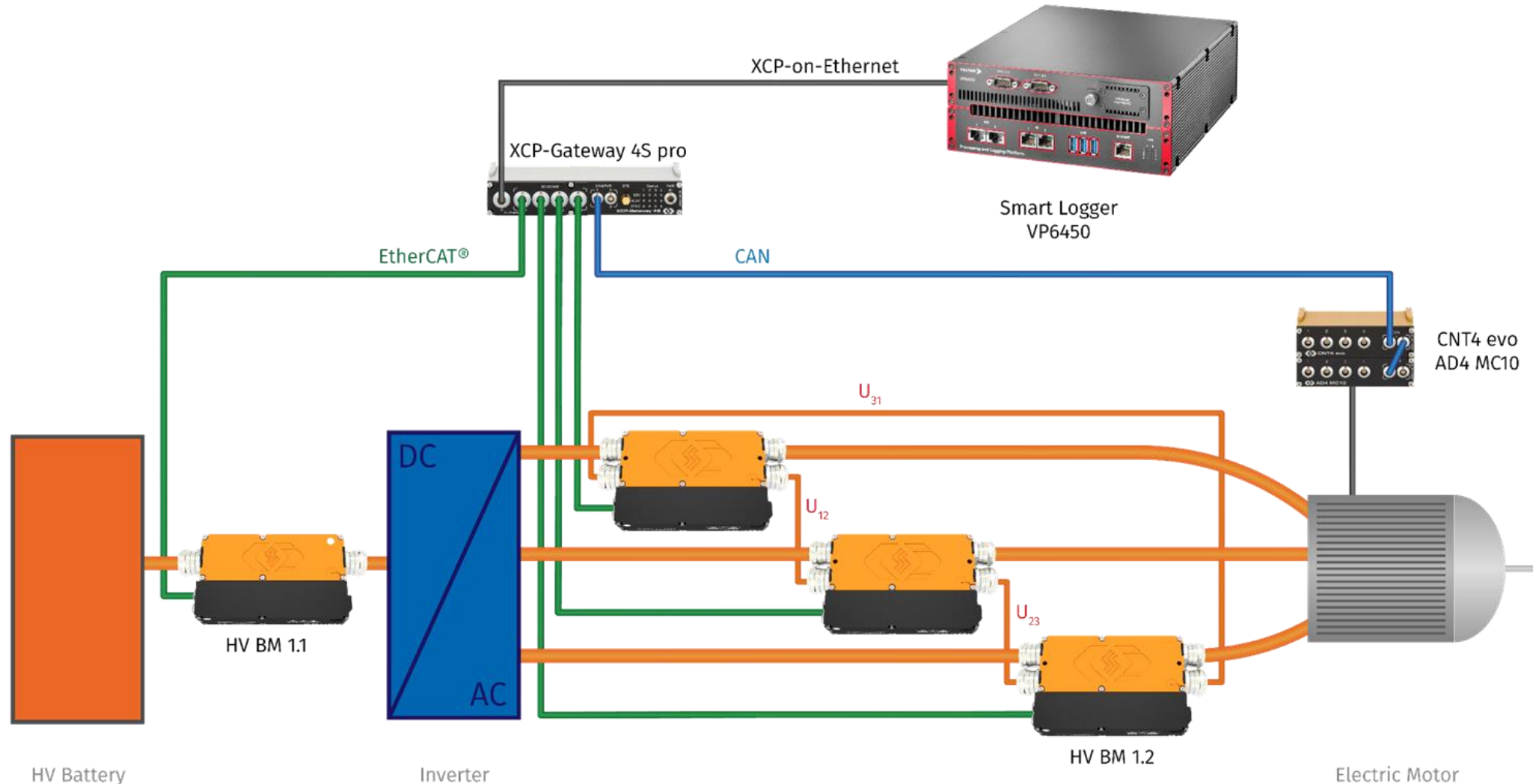
- ▶ Almost steady state operation
- ▶ Changing torque, yet constant revolution
- ▶ Low dynamic

Requisite for competitive vehicles:

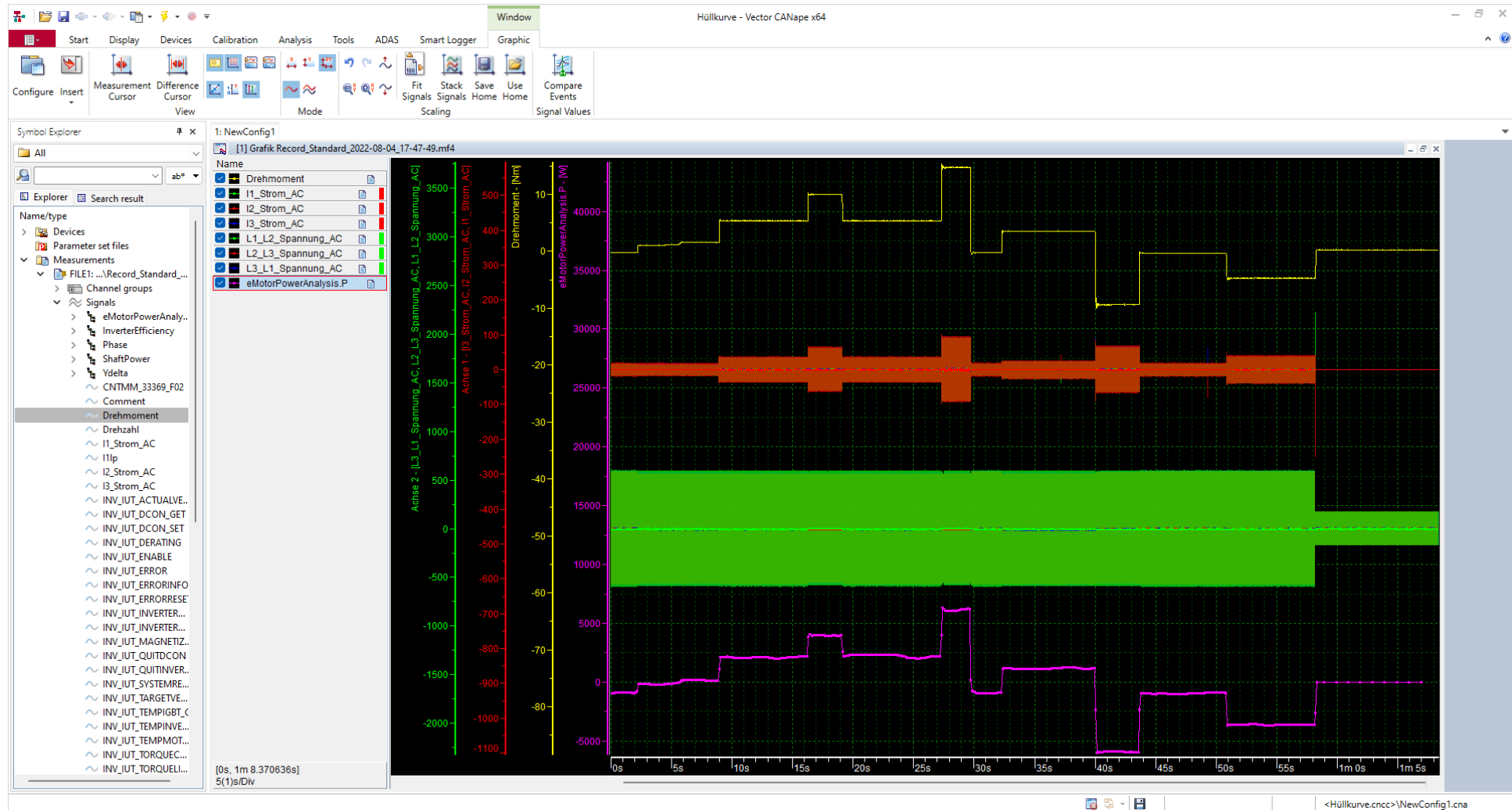
- ▶ Varied revolution
- ▶ Varied torque
- ▶ High dynamic response
- ▶ Still highly efficient



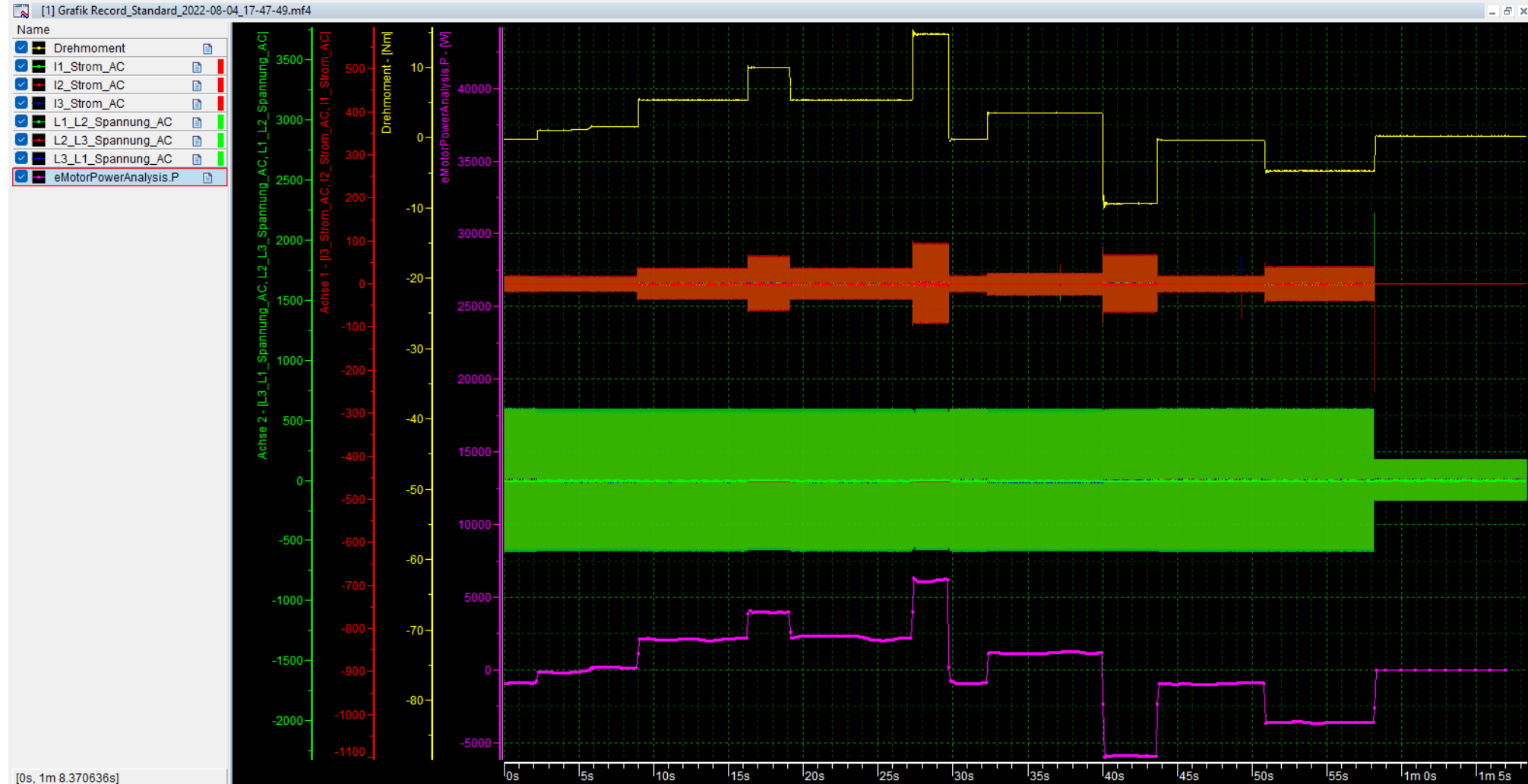
Test Setup for Next Generation Automotive Engineers



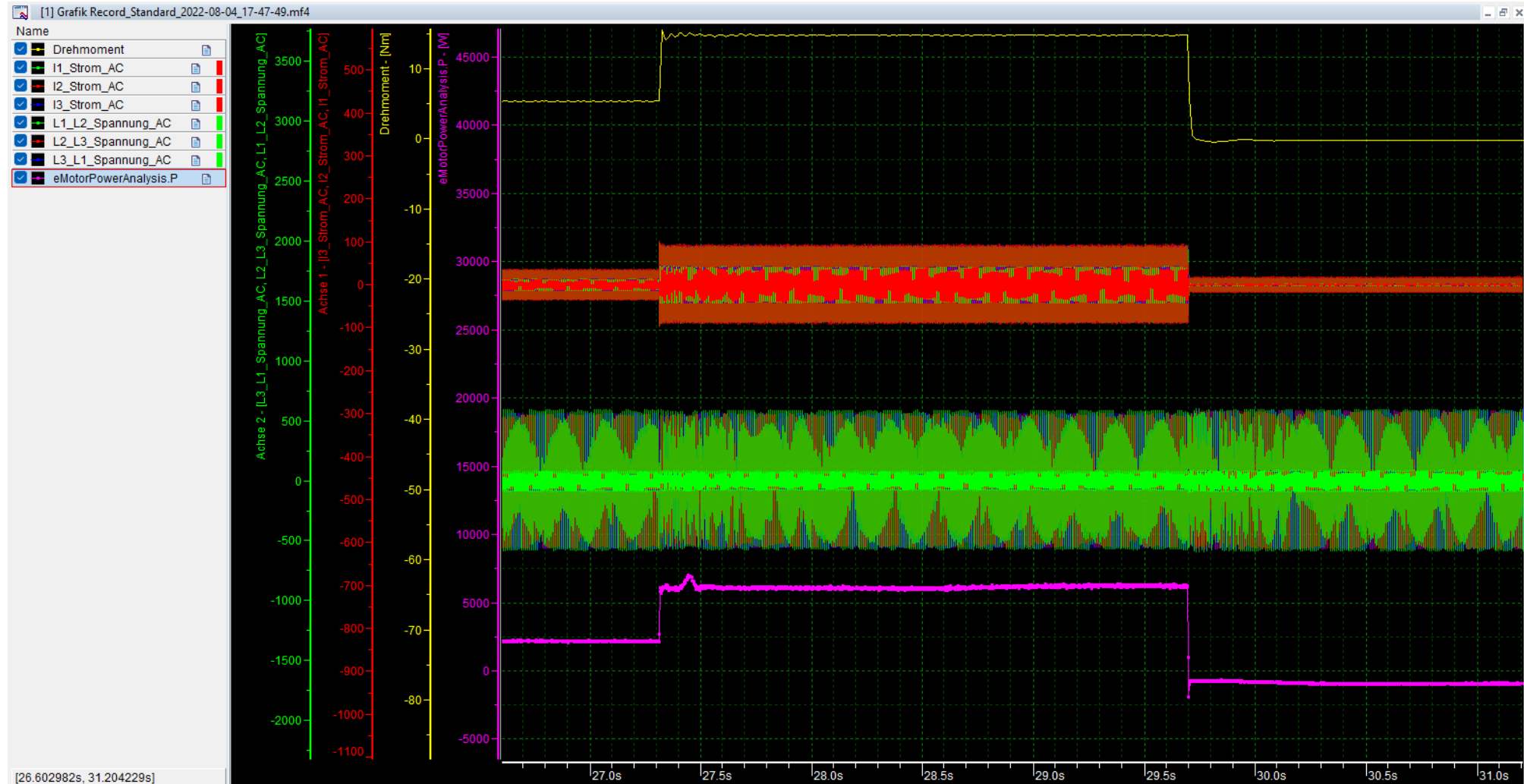
Data Analysis and Interpretation



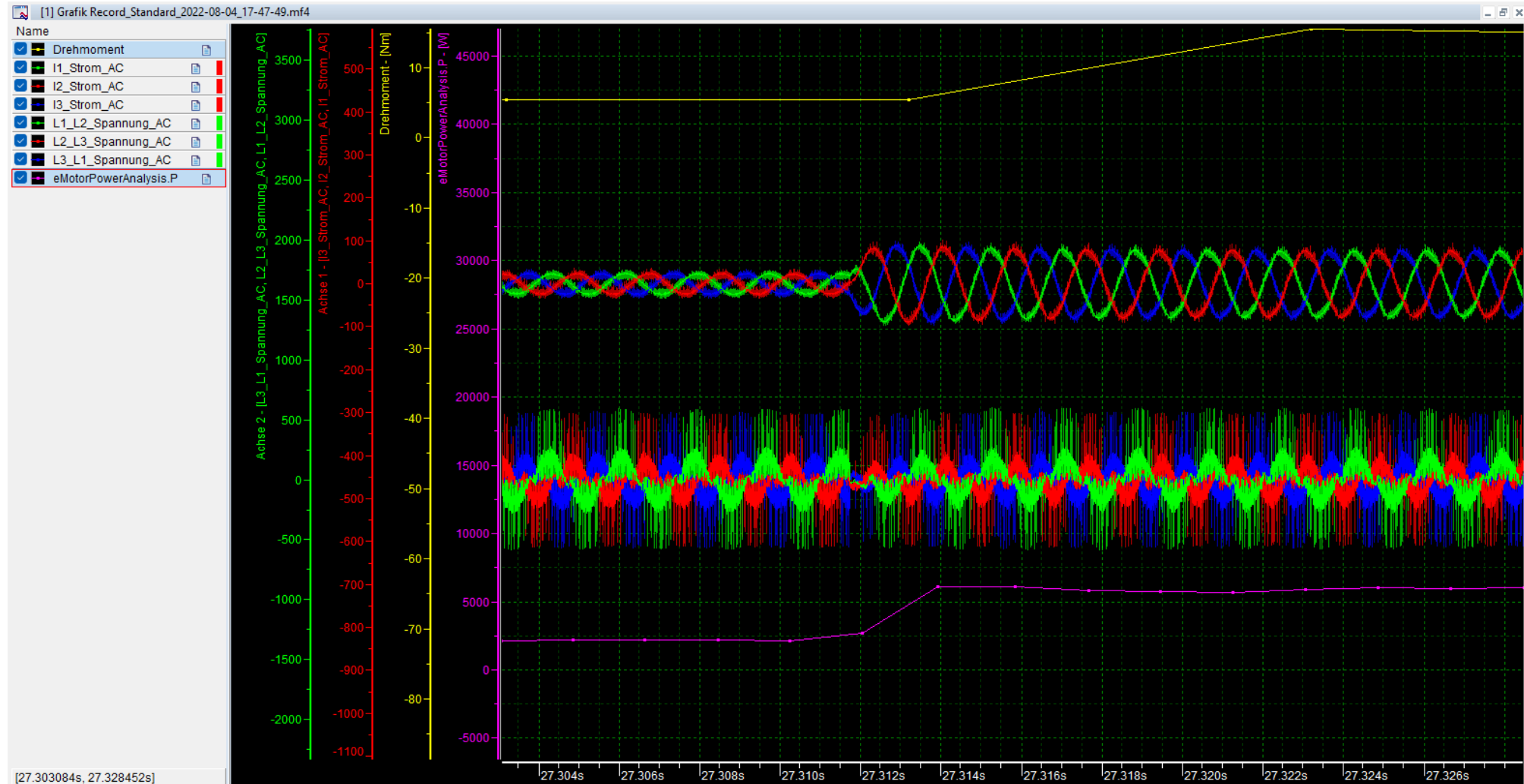
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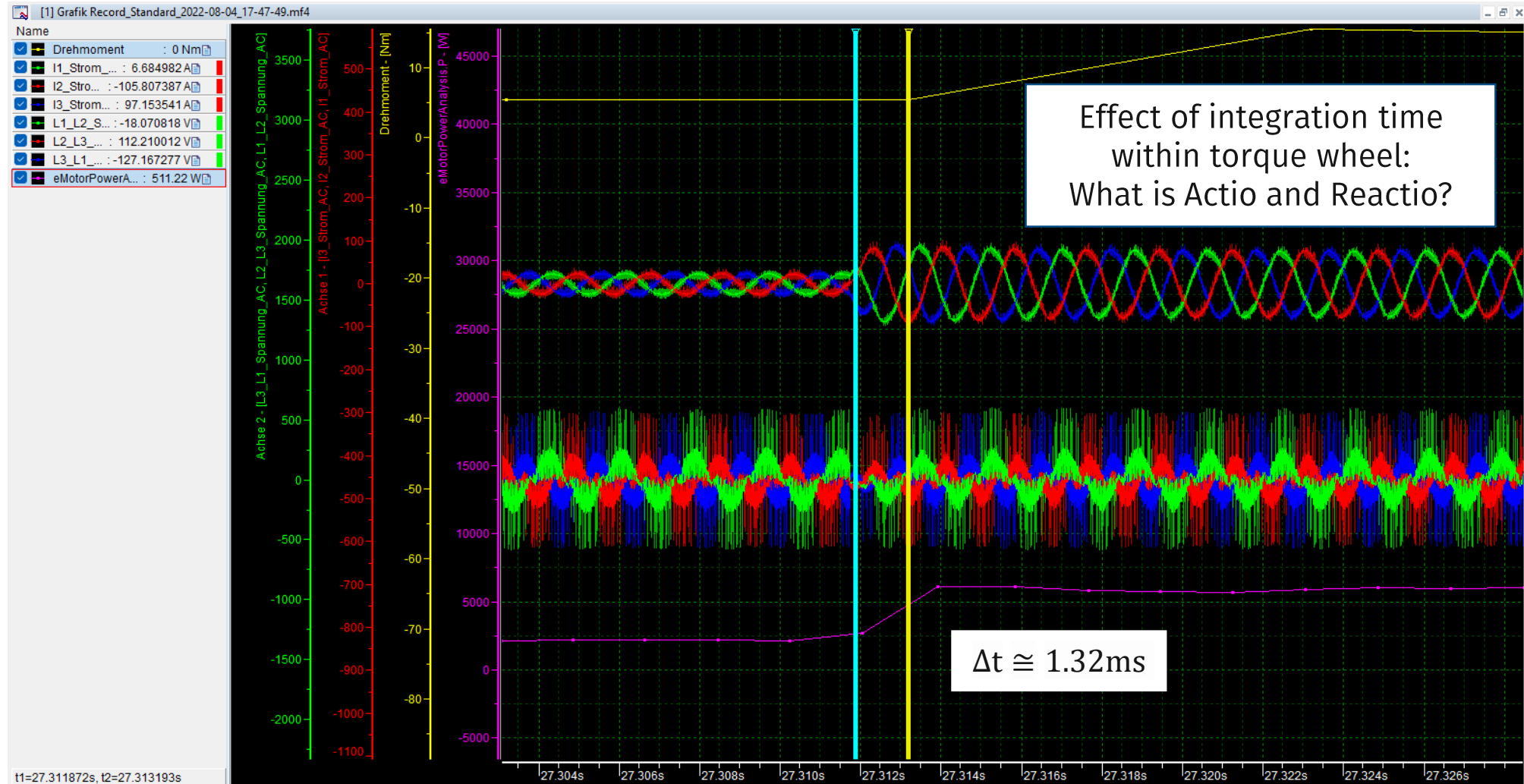
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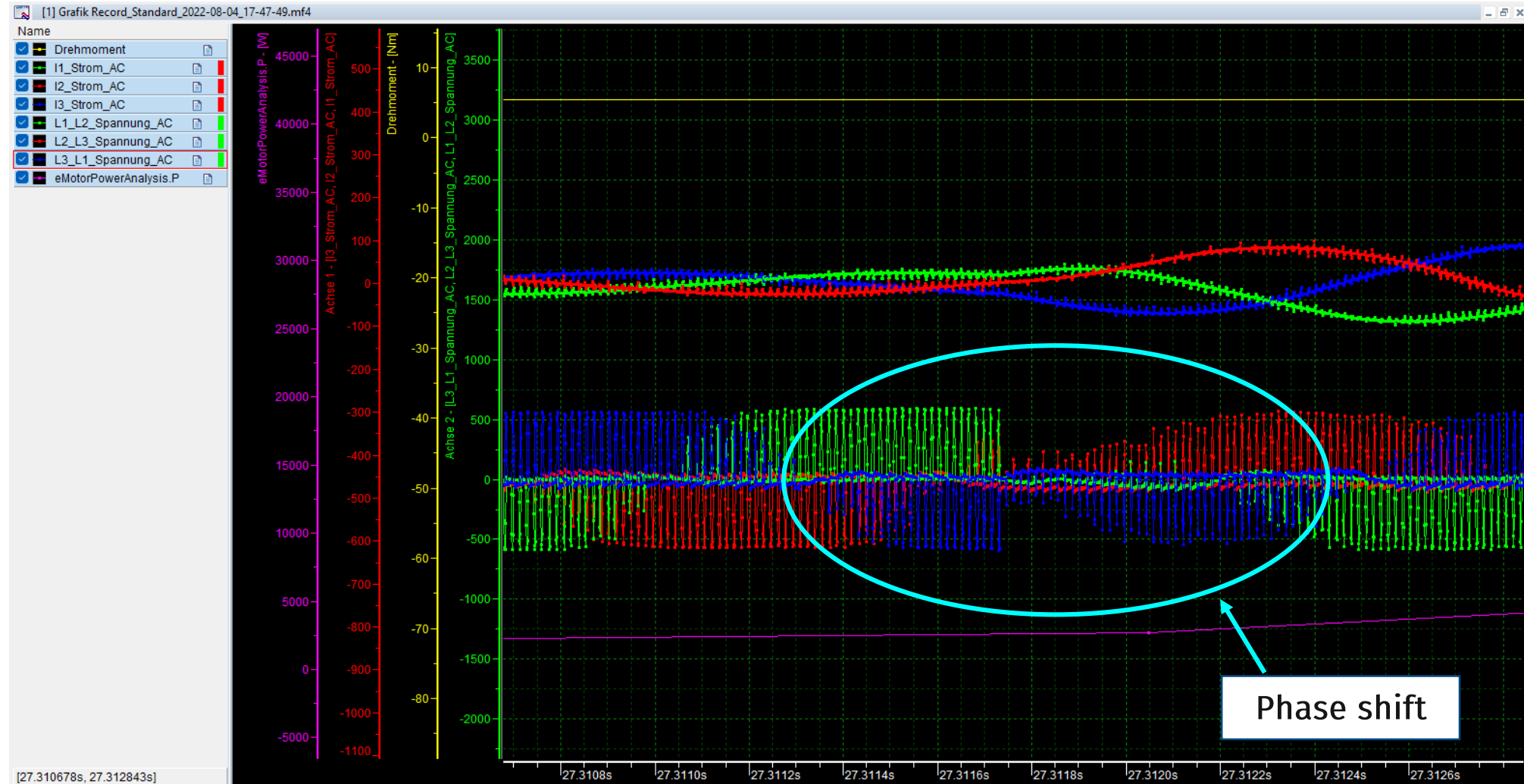
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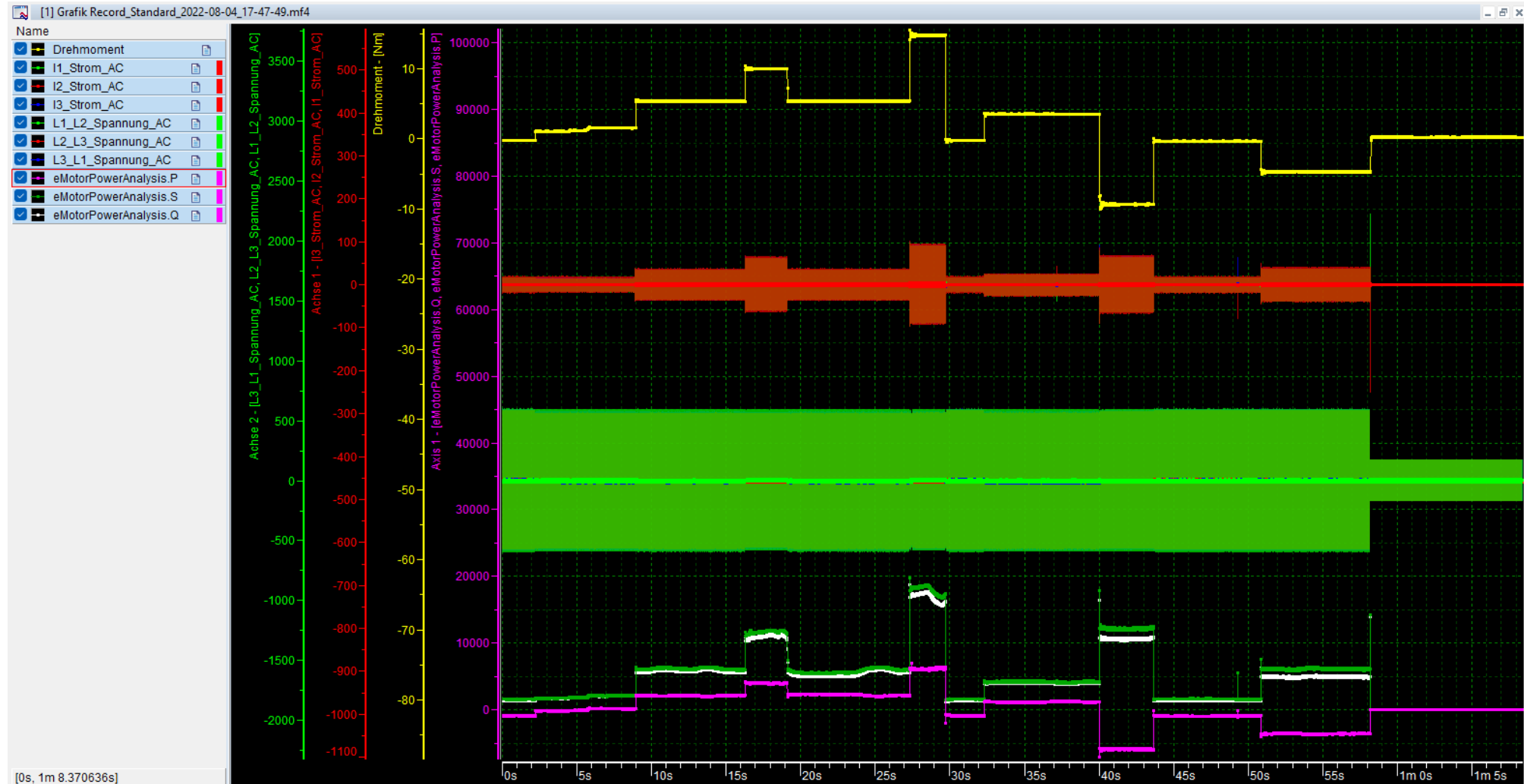
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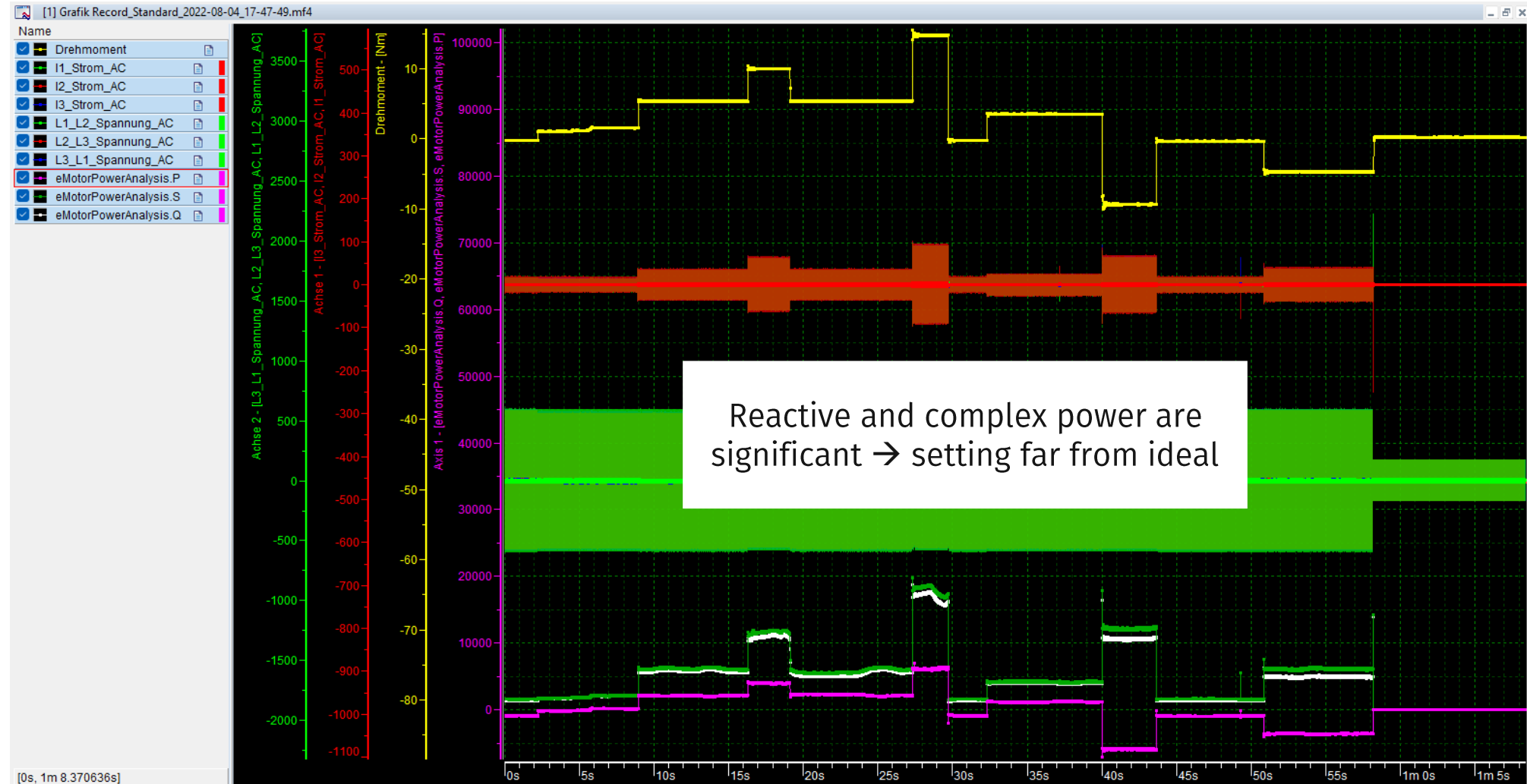
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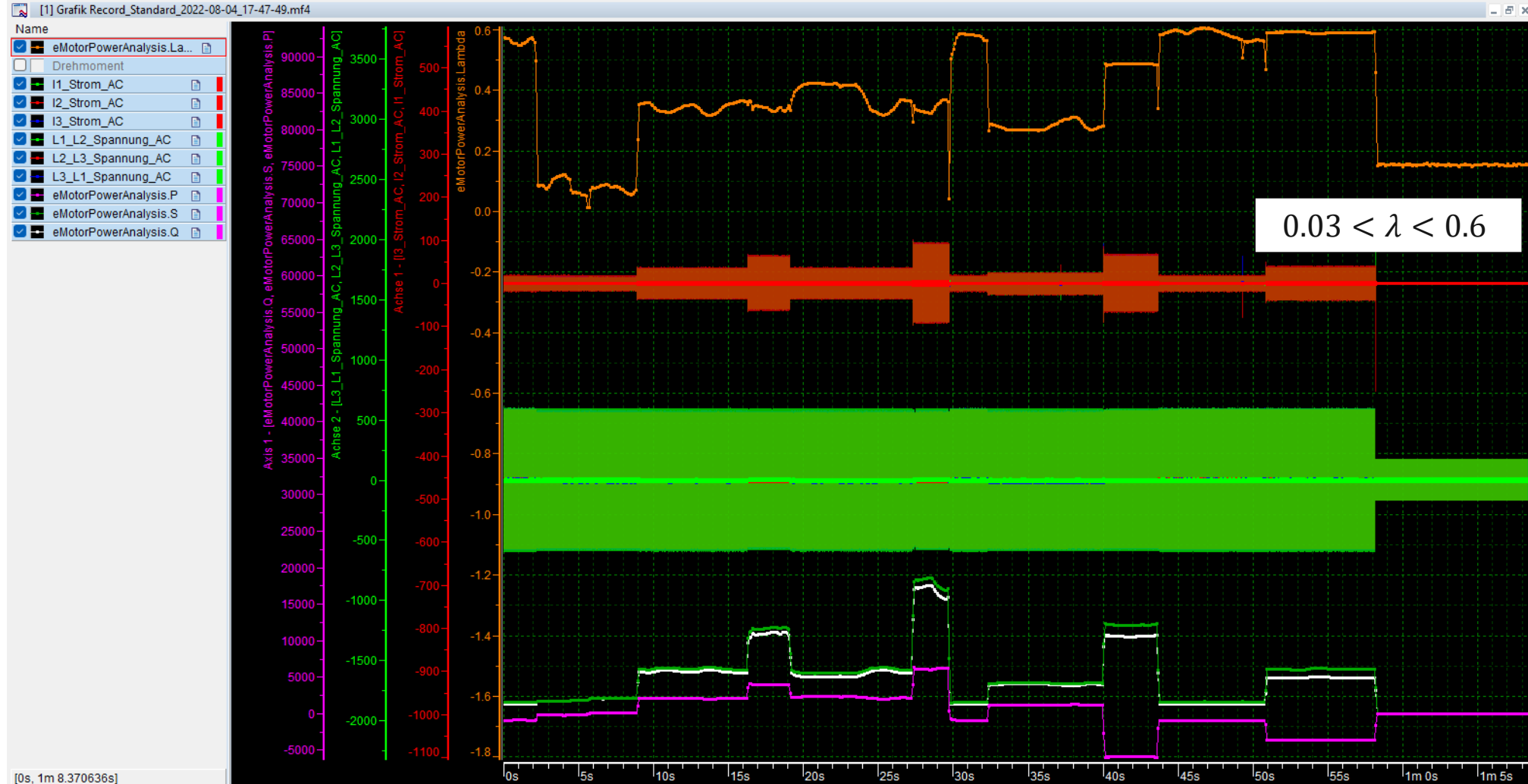
Data Analysis and Interpretation



Data Analysis and Interpretation



Data Analysis and Interpretation



Summary

CSM and Vector together have tools to tackle current and future development tasks in developing next generation electrical driven vehicles

- ▶ Measuring devices for all kinds of physical probes
 - ▶ Safe operation
 - ▶ Robust equipment
 - ▶ Reliable and reproducible results
 - ▶ High dynamic range
- ▶ Measurement software to record and online process acquired data
 - ▶ eMobilityAnalyzer function library
 - ▶ Synchronous acquisition of multiple signal sources, e.g. via IEEE1588
 - ▶ Optimized workstations for testing
- ▶ Not limited to the development of electrical driven vehicles
 - ▶ Get in touch with us to find the ideal measurement solution for your development task!

About CSM

CSM has been setting technological standards for decentralized measurement technology in vehicle development for over 35 years. Our CAN bus and EtherCAT® measurement devices support worldwide renowned vehicle manufacturers, suppliers and service providers in their developments.

Continuous innovation and long-term satisfied customers are our guarantee for success. Together with our partner Vector Informatik, we have developed an easily scalable and powerful E-Mobility Measurement System for hybrid and electric vehicles and are constantly expanding the areas of application. With our high-voltage safe measurement systems designed for fast and synchronous measurements and power analyses, we actively accompany the change to **E-Mobility**.

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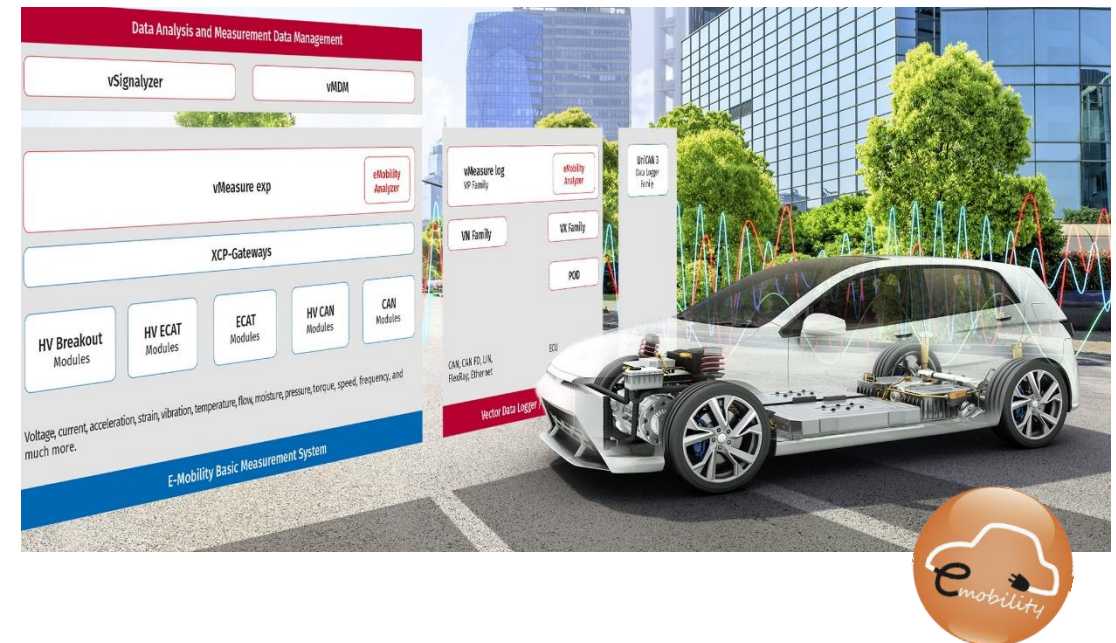
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of CSM Xplained, please visit

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CSM Xplained
measurement technology