TÜVNORD

HDV GTR Pilot Phase

In-Vehicle Battery Durability

eCitaro & eActros300

Manuel Hagemann | TÜV NORD Mobilität, IFM – Powertrain/Emissions | 09.07.2024

Agenda

- Overview Test Results
- Insights Procedure Execution
- Internal / External measurement comparison

Test Setup

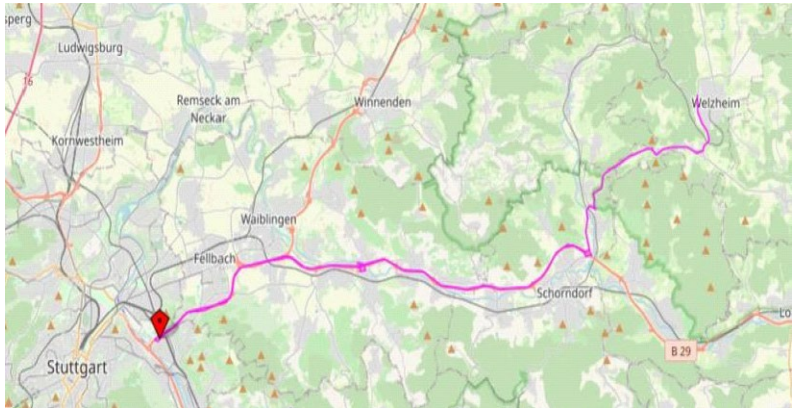
eActros 300 (with/without Trailer)

Weight: 24,5 / 37 t

Constant speed phase with cruise control

Signals from CAN-bus + GPS + Temp

Driving routes from flat to hilly (220 – 355 km)

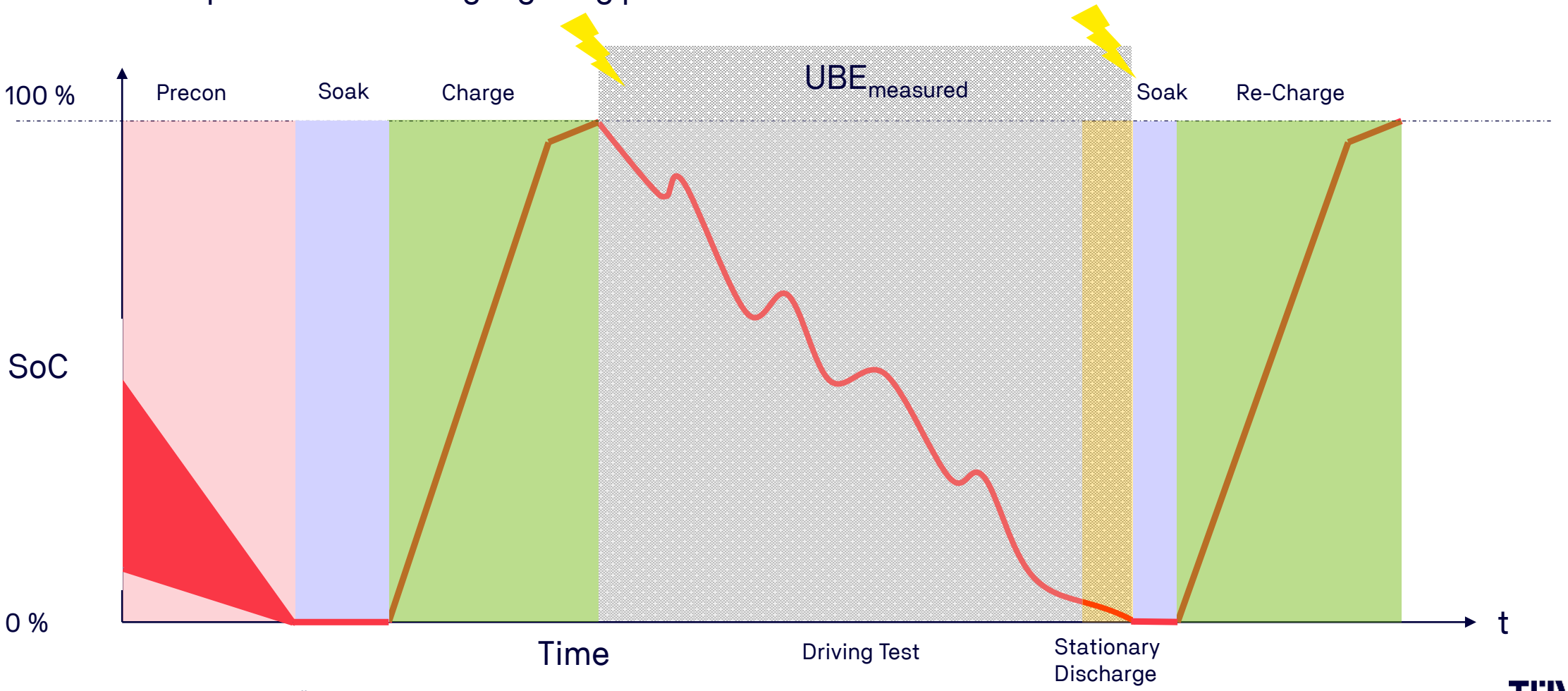


TÜVNORD

Test procedure

Method 1b

Variation of procedure and highlighting problems



TÜVNORD

Test results

- eCitaro 190 kWh – single test event
- eActros 309 kWh – five tests with different load and track profiles

Model	Discharge capacity UBC	Discharge Energy UBE	On-board SOCE	Measured SOCE	Trip distance	Weight	Speed profile	Track profile
eCitaro, #01	274,84 Ah	181,25 kWh*	99,87%	95,395%	170 km	Ca. 13.6t	Mix City to Motorway	Hilly + Flat
eActros 300, #02	772,850 Ah	306,612 kWh	99,278%	99,466%	356,54 km	Ca. 24,5t	Range, very smooth	Flat
eActros 300, #03	773,496 Ah	306,865 kWh	99,077%	99,549%	363,45 km	Ca. 24,5t	Range, very smooth	Flat
eActros 300, #04	773,401 Ah	300,084 kWh	98,965%	99,537%	227,23 km	Ca. 37t	Power, smooth	Hilly
eActros 300, #05	768,989 Ah	302,135 kWh	99,037%	97,878%	247 km	Ca. 37t	Range, smooth	Flat
eActros 300, #06	768,665 Ah	302,386 kWh	98,663%	97,860%	256 km	Ca. 37t	Range, smooth	Flat

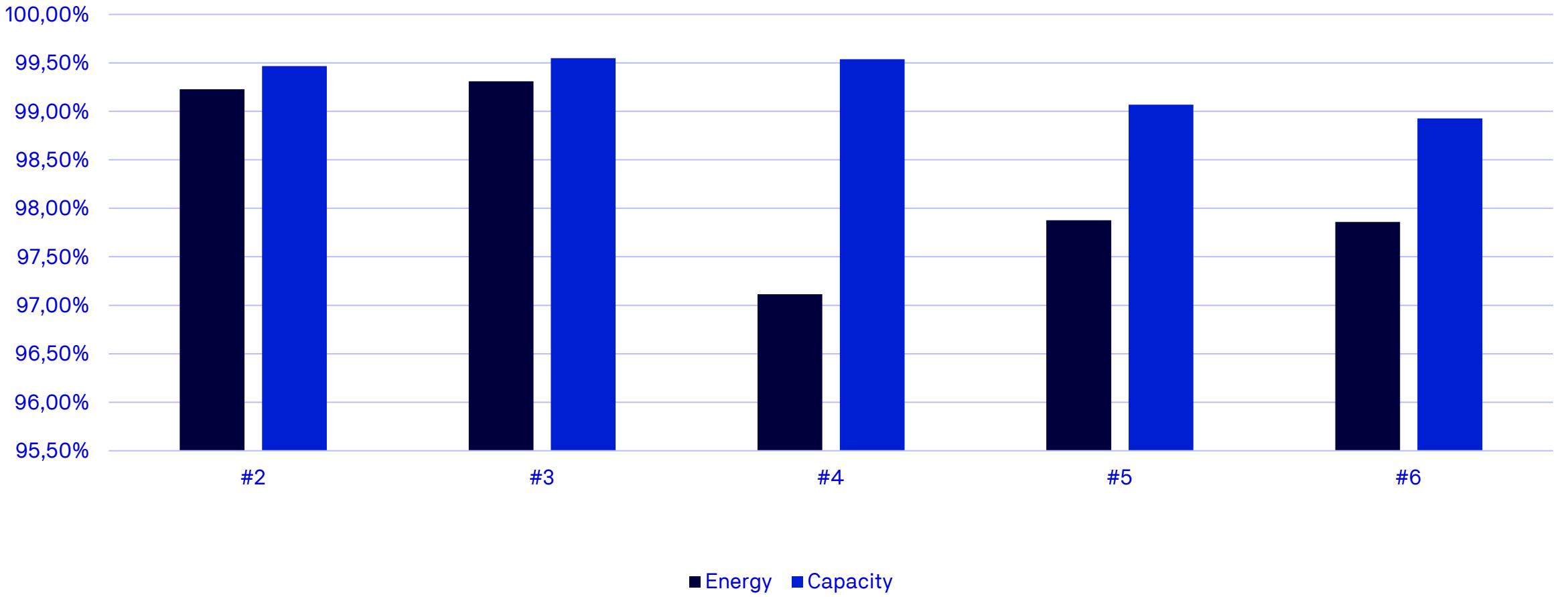
*Display SoC after recalibration at 4.5%
Discharge Energy UBE (with calibration) = 181,25 + 8,5 = 189,75 kWh
Measured SOCE (with calibration) = 189,75/190 = 99,87%

TÜVNORD

Test results

Comparison Discharge / Capacity - Energy

- Standard deviation SOCE: 0,9722%
- Standard deviation SOCC: 0,2926%



TÜVNORD

Insights Test Procedure

Method 1b

- Focus Topics
  - Break-Off criterion
  - Driving route (altitude, boundaries)
  - Vehicle load
  - Charging process
  - Driver breaks
  - Vehicle operation

Insights Test Procedure

Method 1b

- Focus Topics
  - Break-Off criterion
    - Current draft version suggests:
      - *the 4s criterion while driving @ regional characteristic target speed, or*
      - *Stationary discharge until warning indication appears*
    - ECE R100.03 requires a low-voltage warning of REESS on vehicle level
      - It is described very vaguely and could be adjusted with updates/customer settings
    - **Proposal:**
      - **Choose to stationary discharge until no driving mode/traction is possible**
  - Problem:
    - Both approaches are highly dependend on boundary conditions (speed, consumption and warning concept)
    - It is likely to find different break-off points for seperate testing laboratories / vehicle configurations
    - With no reproducible break-off points we may find even more uncertainty in UBE measurement
    - Probably no one-fits-all solution in possible
      - Use case szenarios are highly individual

Insights Test Procedure

Method 1b

- Focus Topics
  - Driving Route
    - Current draft version suggests:
      - *Smooth acceleration and deceleration*
      - *0.5-1 km/h /s if possible*
    - **Proposal:**
      - **Criterion not suitable for deceleration because of traffic / road safety / driving assistence**
      - **Exclusion of any kind of „Boost“ mode to eliminate high currents**
      - **Similar approach as for RDE (ECE-R168) may be a good alternative with a few adjustments**

- Problem:
  - Driving route alone is not sufficient to describe effect on traction system
  - C-Rate (charge/discharge) is additionally affected by vehicle mass and acceleration
  - As long as there is no precise description of how to drive and how to deal with unexpected driving events, we may find invalid test runs
  - Acceleration can be influenced, but deceleration depends on traffic and is safety-relevant

TÜVNORD

Insights Test Procedure

Method 1b

- Focus Topics
  - Vehicle load and speed
    - Current draft version suggests:

      The test shall be carried out on road with the regional characteristic speeds and payload per Gross Vehicle Weight (GVW) and Gross Combination Weight (GCW) in agreement with the responsible authorities . [and not exceeding xx% of the GVW/GCW .]
    - **Proposal:**
      - **Table for different vehicle categories and mission profiles**
      - **More precise description of vehicle speed**
        - **Amount highway, rural, urban segment**
        - **Speed is not a suitable single parameter for a break-off criterion (e.g. C-Rate may be better)**

- Problem:
  - It is unclear how vehicle will be used in real world
  - How to deal with incomplete vehicles?
  - Both GVW and GCW are to be tested for a single vehicle?
  - Beside maximum value it may be helful to set a minimum value as well
  - Combination of load and route lead to different C-Rates

TÜVNORD

Insights Test Procedure

Method 1b

- Focus Topics
  - Charging process
    - Current draft version suggests:
      The battery shall be charged at full with the highest normal charging power available according to vehicle specification [≤150kW] [as defined in paragraph 6.1.1 .] . Record the charge current and voltage and the elapsed time required to reach the fully charge battery.
    - **Proposal:**
      - **If not limited by manufacturer it may be allowed to temporarily exceed 150kW.**
      - **Balancing procedure according to manufacturers recommendation (e.g. reference manual)**

- Problem:
  - Charging power is normally not limited to a specific value. For CCS charging <150kW a test mode may be necessary
  - Right now it is not foreseen to exceed 150kW temporarily
  - Charging power can be influenced by other vehicles at EVSE
  - Balancing behaviour and recharge after relaxation can´t be forseen precisely
    - State of full charge with small tolerance, which may lead to different UBE/UBC

Insights Test Procedure

Method 1b

- Focus Topics
  - Driver breaks
    - Current draft text is quite strict

Driving time (h)¤	*Maximum total break (min)*¤
every each 1h ¤	10¤
More than 4h¤	Shall be based on the manufacturer's recommendation or regional authority ¤

    - For vehicles with long range more than one driver is required
    - **Proposal:**
      - **Breaks to be set with more flexibility**
      - **Set a certain soak time before stationary discharge to increase break-off equivalence**

- Problem:
  - Depending on traffic and organizatoin it may be necessary to deviate from table
  - Driver breaks may influence relaxation time and resulting depth of discharge if chosen wisely.
  - Effect of breaks on discharge behaviour of cells needs to be investigated further
    - May lead to different break-off results

TÜVNORD

Insights Test Procedure

Method 1b

- Focus Topics
  - Vehicle operation
    - Current draft version suggests:
      - If necessary a test operation mode is allowed
    - **Proposal:**
      - **Default driving mode shall be selected if not otherwise described by manufacturer**
      - **Description of every driving mode on vehicle behaviour**
      - **Range/Eco driving mode may be helpful staying within smooth driving requirement (-> lower C-rates)**
- Problem:
  - Influence of driving mode has to be explained
  - Operating window of REESS must not be changed
  - Ignition has to be set „on“ to receive on-board data
  - Measurement files to be seperated for each segement of test procedure
    - e.g. to secure relevant files

Insights Test Procedure

Conclusion

- Method 1b can be executed with small deviations from requirements (e.g. acceleration/deceleration, driver breaks)
- Calculated UBC and UBE with standard deviation of:
  ~ 0,293 % UBC
  ~ 0,972 % UBE

- Route (topology, speed segments) has an influence on vehicle power demand and test result
- Vehicle load has to be taken into account for reproducable testing
- Information about vehicle behaviour during charging process is highly important to guarantee a fully charged battery
- Break-Off criterion needs to be precisely determined and shall be the same at certification and in-service

- Further tests for influence of temperature would help to estimate the influence
- Although we have a great thermal mass (batteries) we find a decrease of temperatures during soak&charge at times with low c-rates
- Timing of driver breaks may have an influence on cell relaxation. Effect on bigger batteries to be evaluated

TÜVNORD

Internal / External measurement comparison

eActros 300 – prepared vehicle

- Current draft version suggests:
  - *The on-board measurement data of the voltage can be used during the in-service testing only when the accuracy and frequency of on-board measurement data is confirmed during the Type Approval Test and a safe inspection point is made available for the direct measurement verification.*
  - *A safe inspection point shall be made available for the direct measurement verification also during in-service testing.*

- **Proposal:**
- If necessary, it shall be possible to measure current and voltage without the influence of shield currents

- Problem:
  - Right now there are no direct measurement points available and depending on load and component influencing shield currents may result.
  - On customer vehicles a great burden (time, cost, availability) may result if wiring harness has to be changed
  - Even with validation of on-board measurement data at TA a direct measurement is required according to draft text

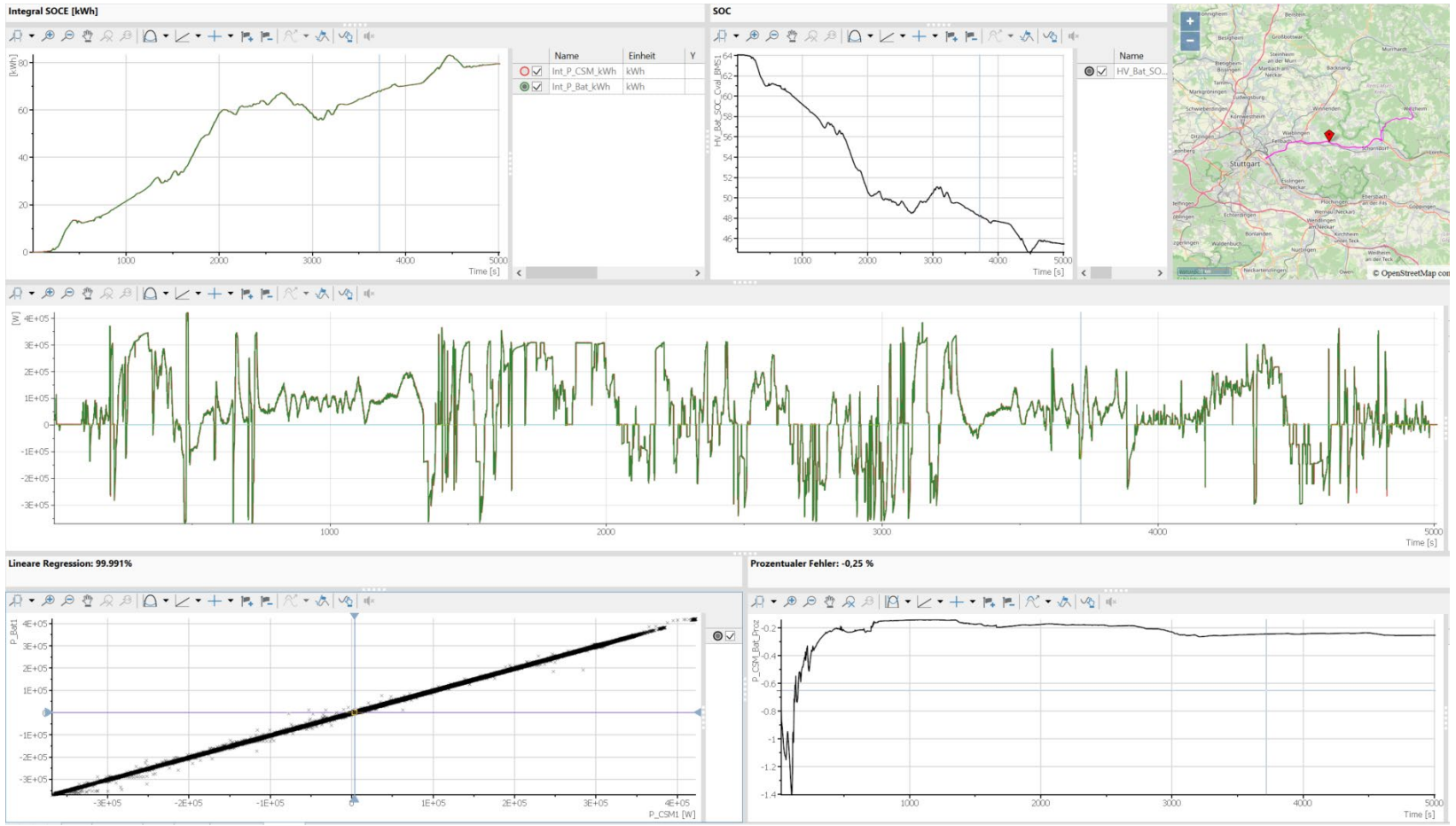
TÜVNORD

Internal / External measurement comparison

eActros 300 – prepared vehicle

- Comparison of CAN measurement with external measurement (HIOKI and CSM modules)
- Influence of measurement data rate for calculation not critical (10 Hz to 1 Hz: failure of 0,3%)
- Coverage of most critical driving/usage scenarios to detect a possible deflection of signals
  - Constant speed
  - High acceleration
  - High recuperation
  - High Power Brake Resistor (HPR) not tested yet

Measurement accuracy: SOCE [kWh] based on battery measurement vs. CSM

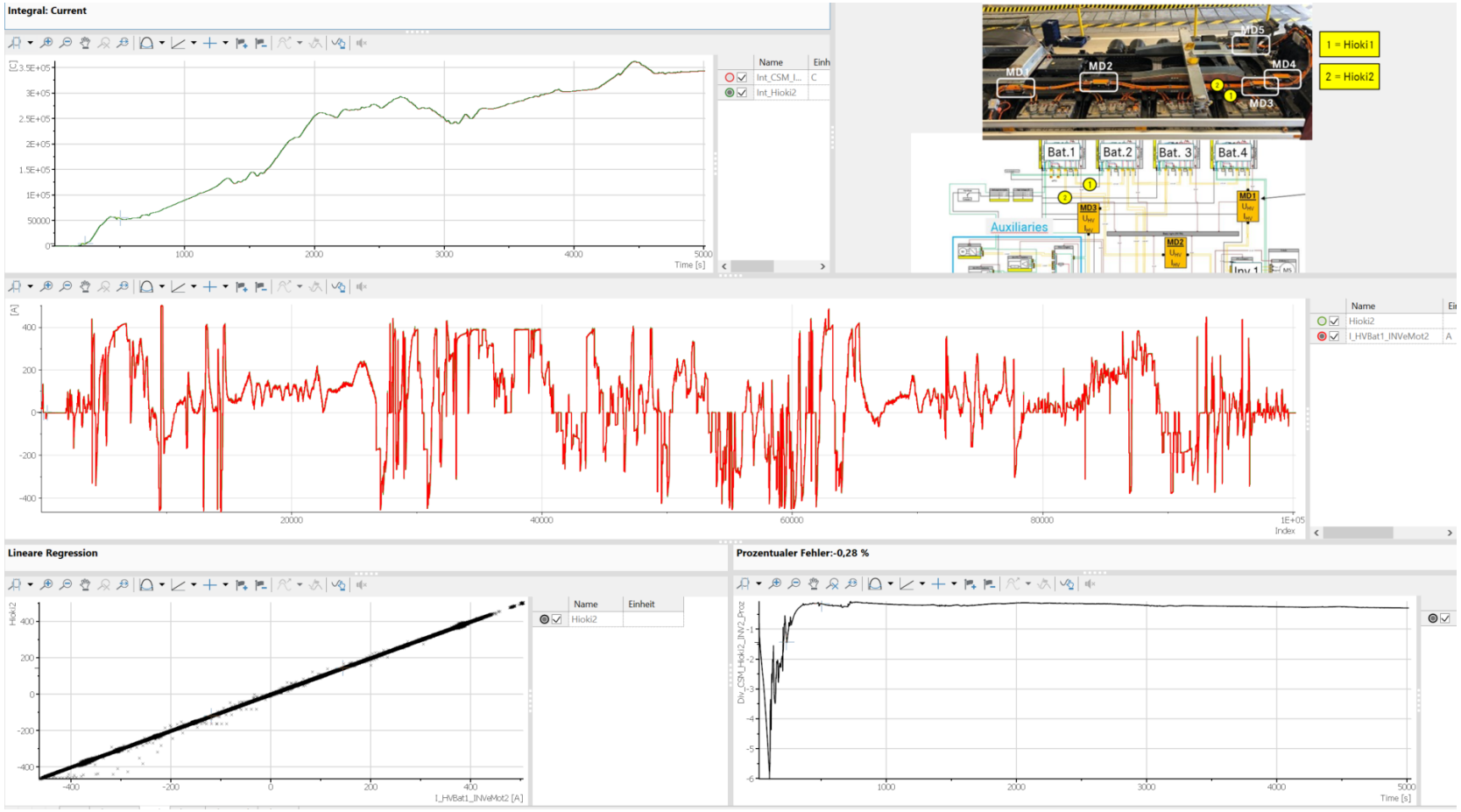


Key take-aways:

- Results based on 1.3h drive
- No brake resistor influence included
- Sum failure: **0.25 %**

TÜVNORD

Measurement accuracy: Current [A] based on Hioki vs. CSM



Key take-aways:

- Results based on 1.3h drive
- No brake resistor influence included
- Sum failure: **0.28 %**

TÜVNORD

Contact

Manuel Hagemann
Technical Expert
mhagemann@tuev-nord.de
+49 (0)160 888 4473