Introduction to Measuring Electric Power During Transients – Part 1

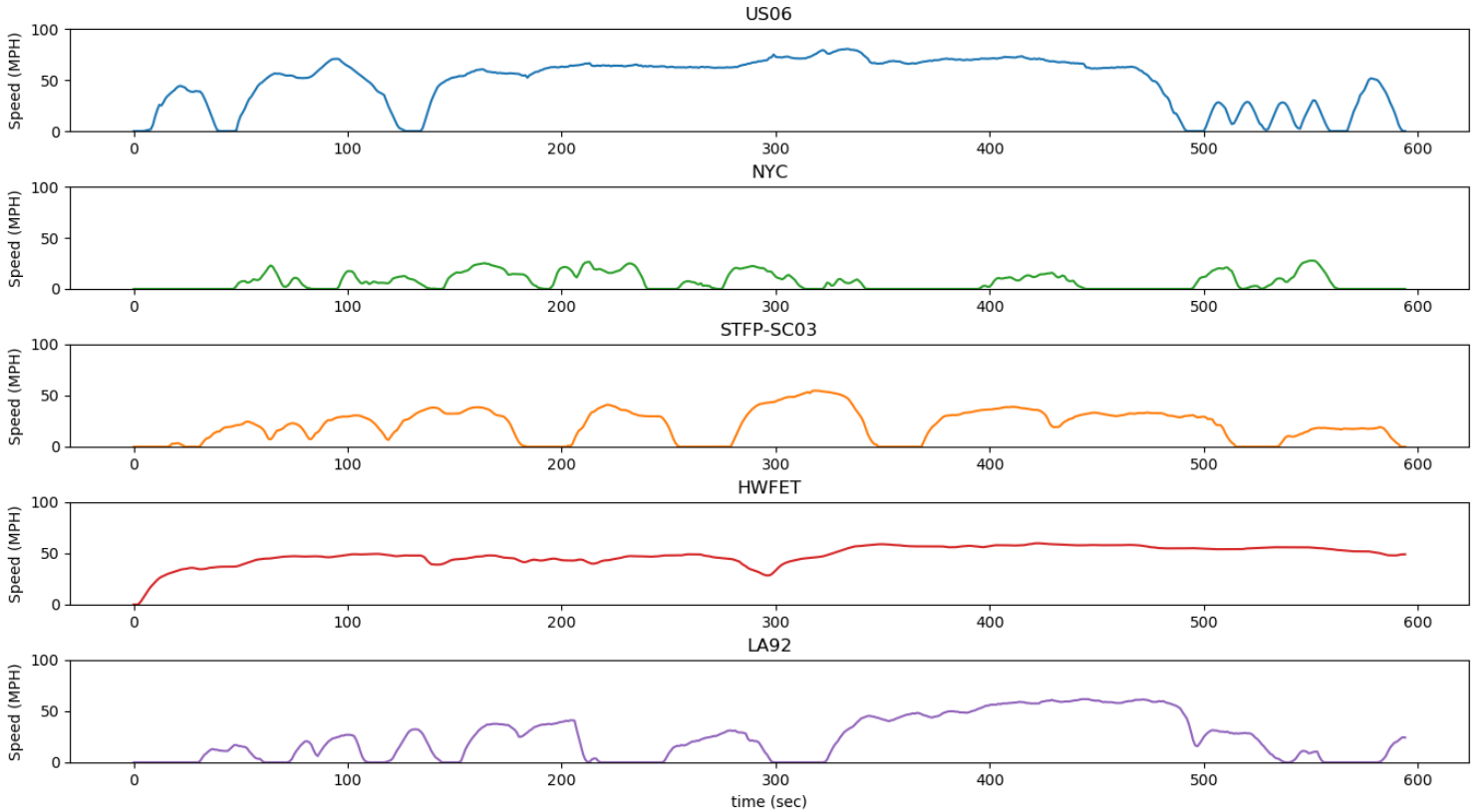
Agenda

1. Transient testing introduction
2. Transient power testing challenges
3. Why is transient power different
4. HBK value for transient power testing
5. Test validation

Transient Power Testing
For Electric Powertrain

Drive Cycle Tests – Understand the Energy Use of a Vehicle

- Series of speeds vs time under given conditions
- Common indicator of vehicle fuel economy
- Useful test for benchmarking or validation
- R&D uses to optimize range
- Whole test or small portions of the test



Variety of different drive cycles truncated to 10 minutes

Constantly Changing Frequency!

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Dyno and vehicle level testing

- Characterize final product
- Motor/inverter control calibration
- Driver experience
- Compare supplier parts
- Competitor benchmarking
- Vehicle energy usage

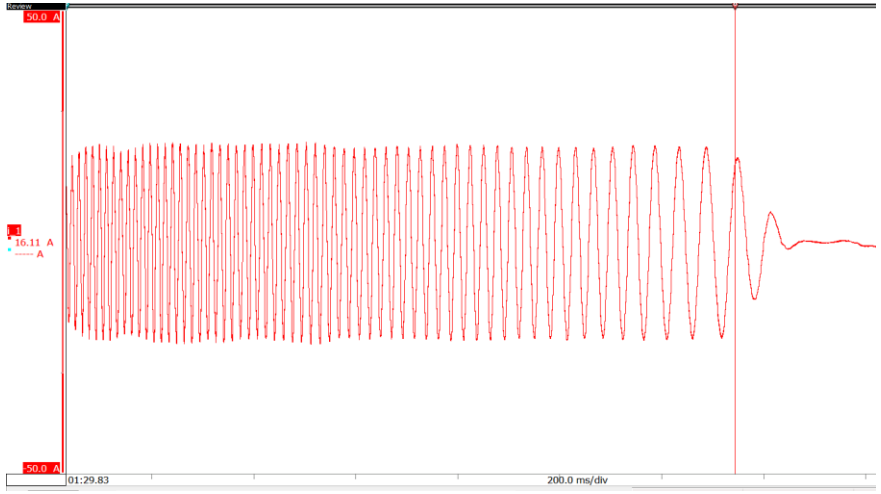
Challenges for Transient Power Testing

In Electric Powertrain

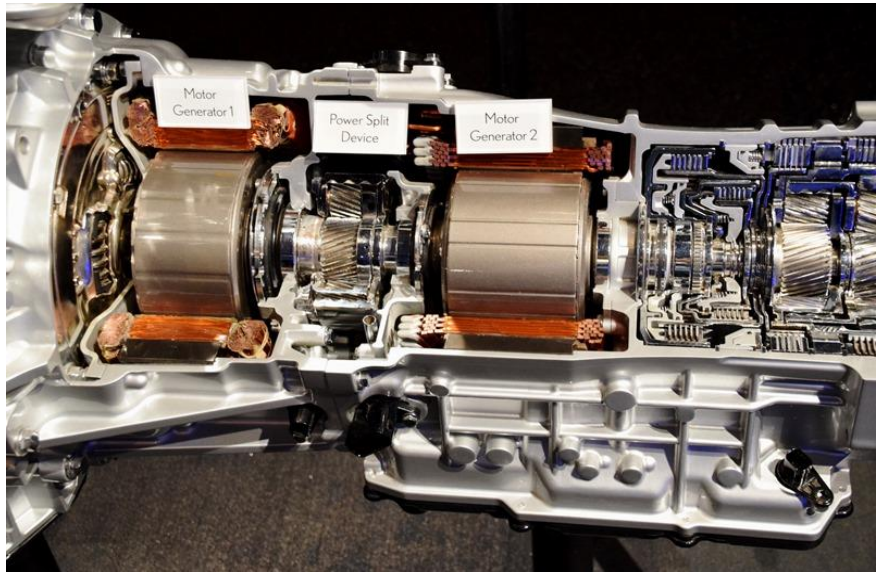
Unique Challenges of Testing Transient Power and Efficiency

- No steady state frequency
  - Vehicle speed is constantly changing
  - **Traditional power analyzers require a fixed frequency**
  - Traditional data recorders cannot measure PWM

- Constantly changing states
  - Transients
  - Clutches
  - Multiple machines
  - Temperature
  - Road surface (ice!)



Dynamic current signal of an electric vehicle stopping



Hybrid transmission with a high level of complexity

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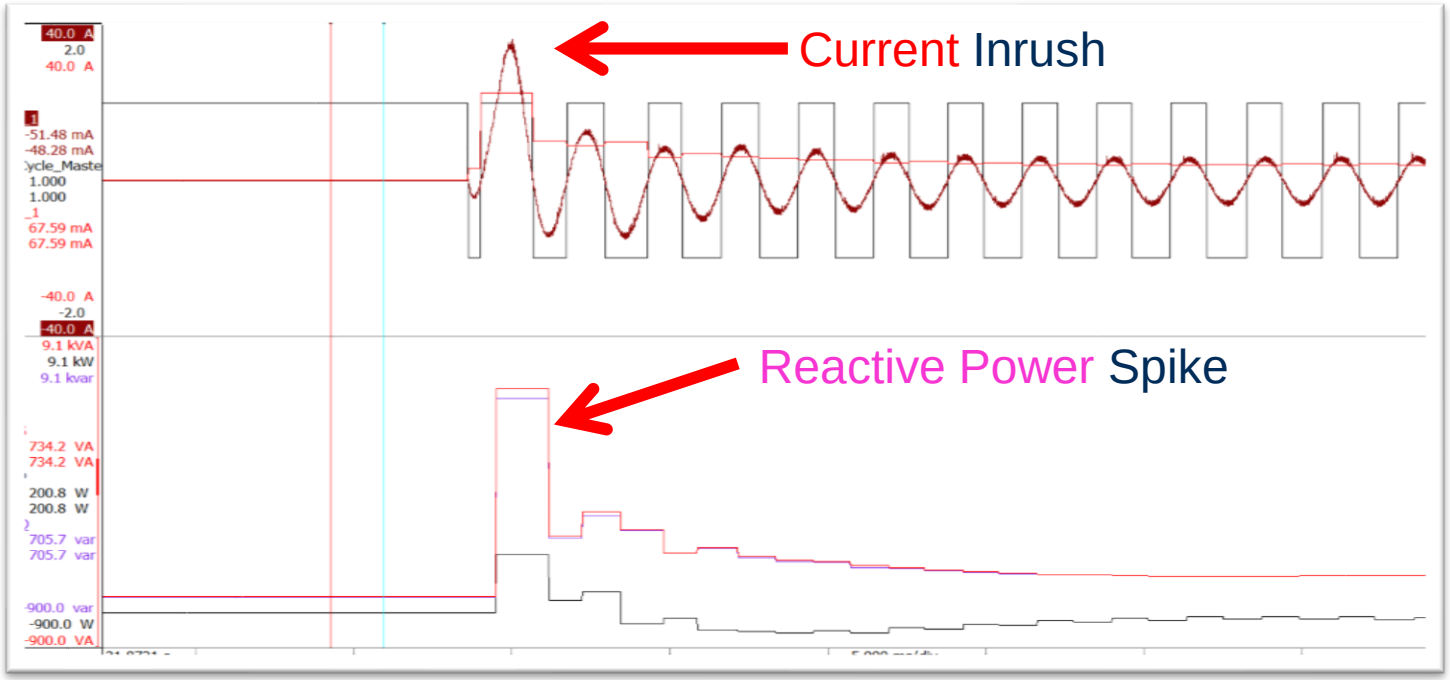
Why is Transient Power Different?

Importance of Dynamic Power Measurement

- At motor start, stop, or change of state there are losses associated with state change
- Frequency is changing
- Large reactive power during the transient resulting in inefficiency
- Dynamic power measurements needed to understand actual efficiency during use

Current –
Voltage –
Power –
Reactive Power –
Apparent Power –



Top – current suddenly applied to an electric motor (maroon), cycle detect (black), RMS current (red)
Bottom – Power, reactive power, and apparent power for a dynamic load change

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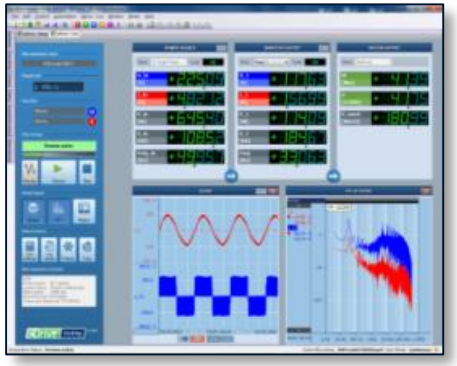
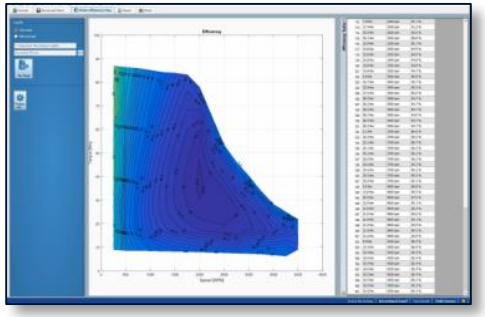
HBK Value for Transient Power Test

eDrive Value

- Dynamic power measurements
- Time alignment of all signals
- Accurate energy measurements
- Future proof your testing capabilities
- Auditable testing – data recorded for review
- Simplifies measurement chain
  - Sensors → Aquisition → Software





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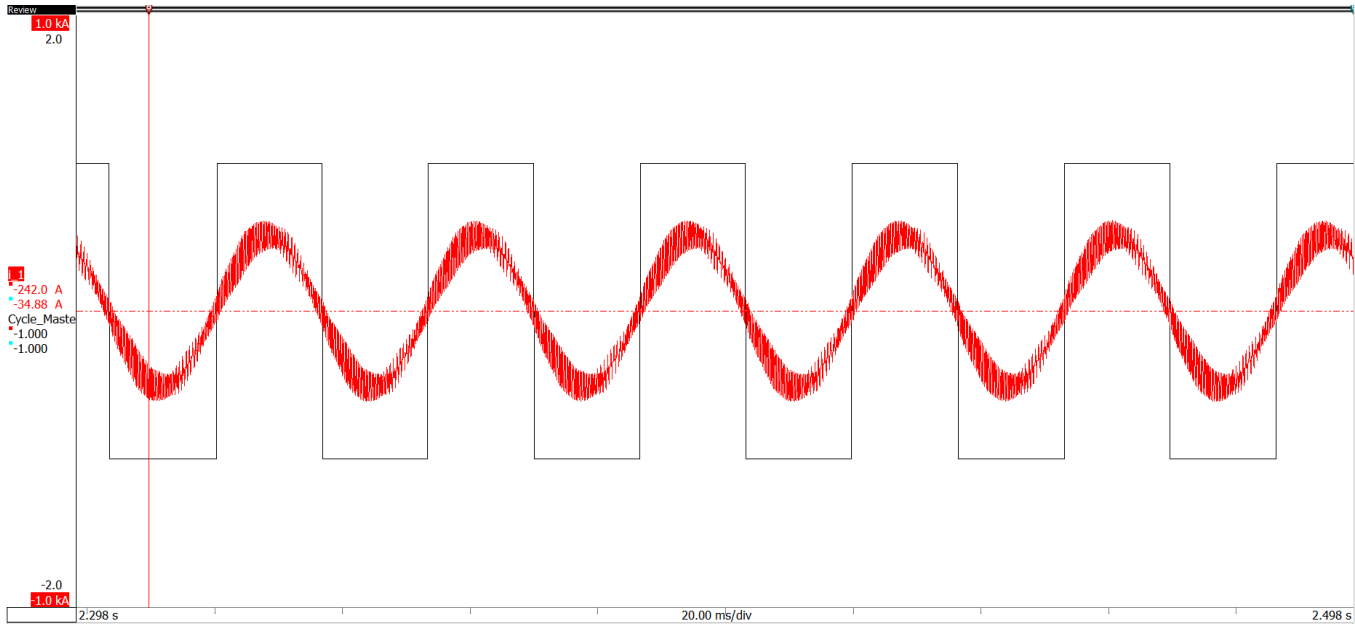
eDrive: Cycle Detection

- To compute any power result the “cycles” of the signals are needed
- Detecting the cycles via zero crossings is difficult due to noise
- The eDrive **hardware** detects the cycles using advanced digital algorithms in a DSP
- RMS values, power, efficiency, and advanced calculations are done on the cycle basis
- Calculations on the ½ cycle basis and then many cycles are averaged together

Current –
Cycle Indication –



Current (red) and cycle detect (black) for a single phase of a three phase system. This highlights the cycle detect identifying ½ cycles for calculation

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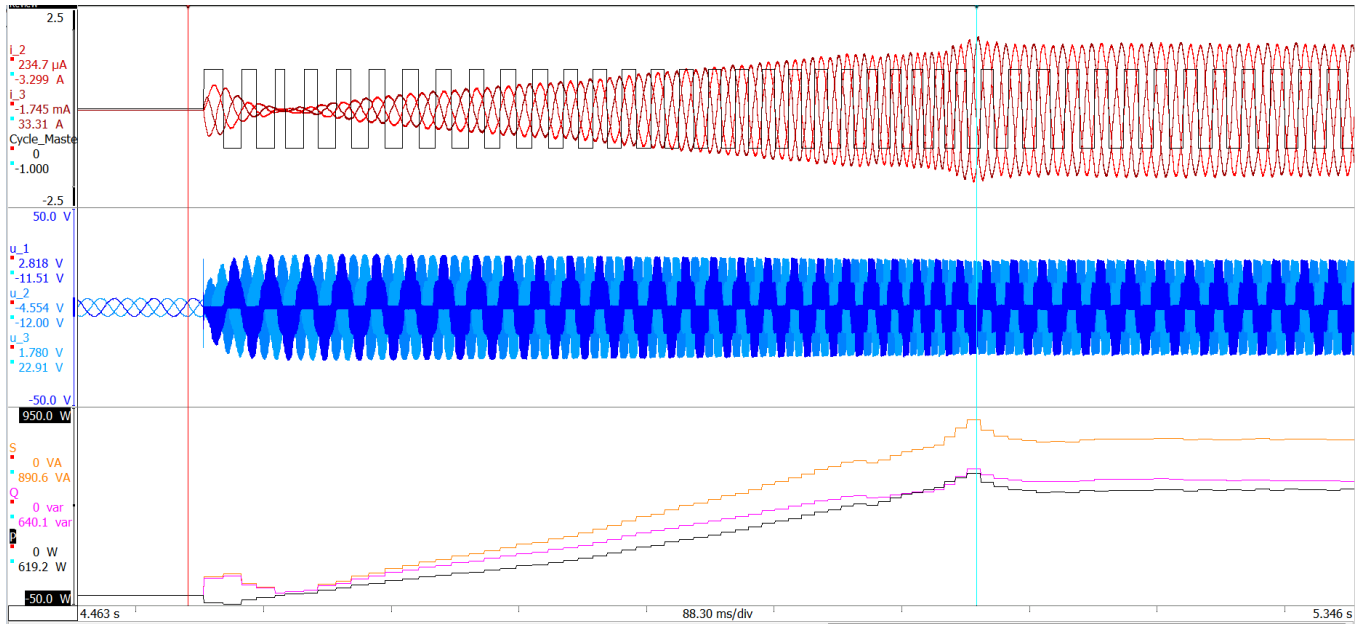
Dynamic Testing with Cycle Detect

Current –
Voltage –
Power –
Reactive Power –
Apparent Power –

- Drive cycles and in vehicle testing require dynamic power measurements
- Cycle detect allows measurement of signals as frequency is changing
- Dynamic testing lets users characterize real world scenarios
- Dynamic power measurement enables the ability to reverse engineer electric drive systems



Scooter acceleration from 0 speed showing a ramp from 0 to full power.
Top – Three phase currents (red) and cycle detect (black)
Middle – Three phase voltages (blue). Note back emf and PWM operation
Bottom – Apparent power (orange), reactive power (purple) and real power (black)

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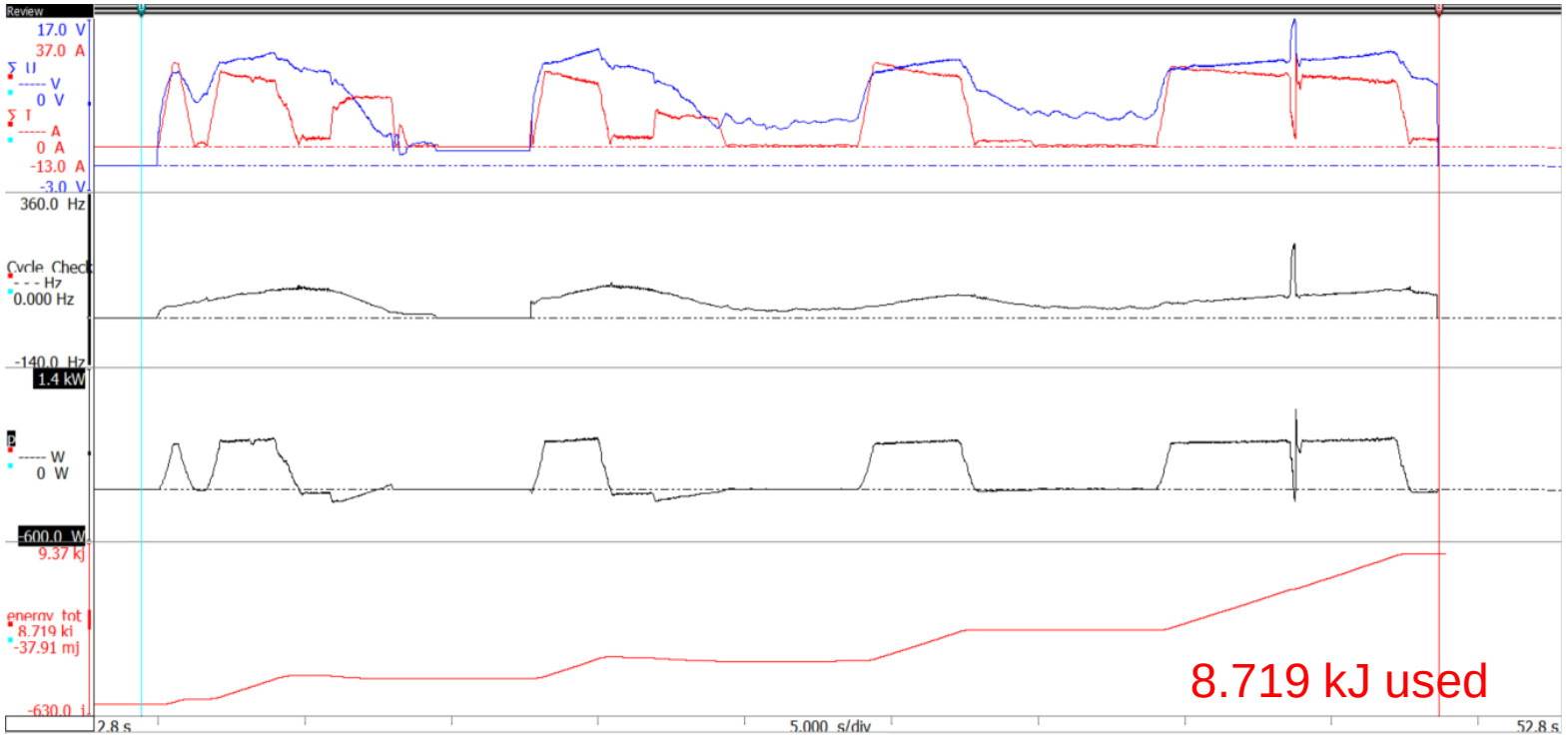
Test Example

Energy Used During a Drive Cycle

RMS Current –
RMS Voltage –
Cycle Frequency –
Power –
Energy –

- Drive cycles performed on:
  - Dyno
  - Chassis dyno
  - Vehicle runs
- Used to understand energy usage
- Require dynamic power tracking
  - Cycle detect to follow fundamental



Cycle averaged signals and energy usage for an example vehicle drive cycle

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Conclusion

Conclusion

- HBM eDrive system is an effective way of measuring in vehicle power flow
- It can be used to measure vehicle energy on a dyno, on a chassis dyno, or in vehicle
- Cycle detect allows for an accurate dynamic power measurement
- Raw data ensures that calculations of power and energy are correct

HBK Trivia:

What 2 things to Lightning and Inverters have in common?

1. **They have really fast electrical transients (lightning 30 µsec, IGBT 50 nsec)**
2. **They are both tested with the HBM Power Testing products**

Questions?

Mitch Marks
Business Development at HBK - Hottinger, Brüel & Kjær

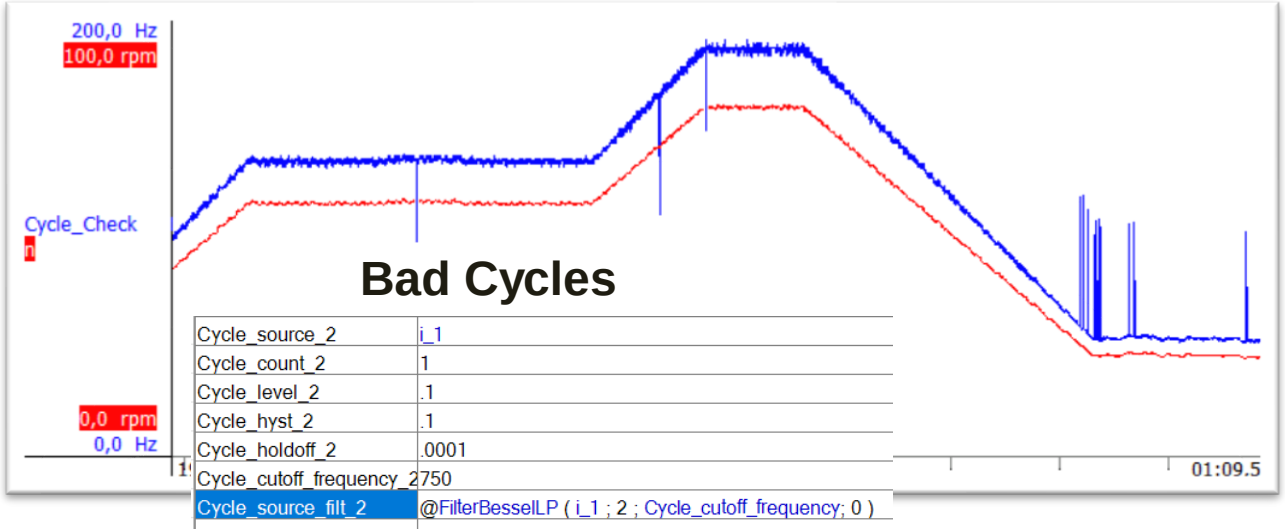
HBK Electric Power Test

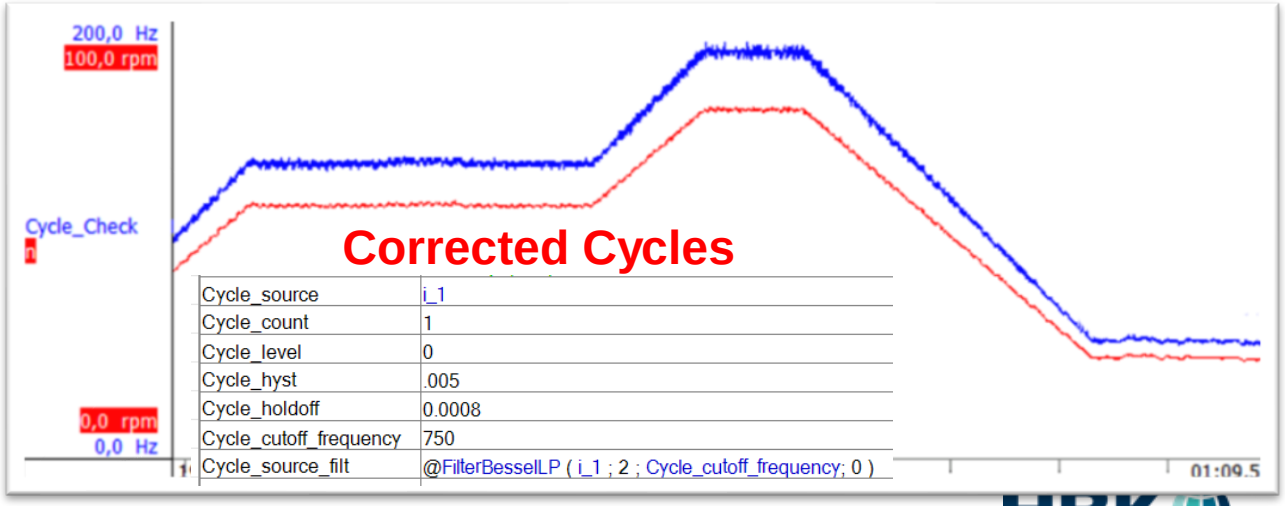
Test Validation

Raw Data & Transparent Equations

Auditability and Transparency through Equations and Data

- All power analyzers will get averaging period wrong occasionally
- With raw data and equations you can **correct wrong measurement periods**
- Extra cycles → jump in frequency
- Missed cycles → Drop in frequency
- **Correction available with raw data and editable equations**
- Rerun tests without physically redoing them





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