EVE IWG 71th session
SOCE verification, open items and pilot phase

May 27th

-online-

6.3.2. Verification procedure
6.3.3. Statistical Method for Pass/Fail decision for a sample of vehicles

6.3.2. Verification procedure

In order to verify the SOCE monitor, the value for the usable battery energy shall be measured at the time of the verification and the related value from the monitor shall be collected before the verification test procedure. To support future improvement of the GTR, indicator values shall be collected again after the verification test procedure. Those indicators read after the verification test procedure shall not be considered in the Part A verification.

The measured SOCE value shall be determined by dividing the measured value for the usable battery energy by the certified value for the usable battery energy, in accordance with the procedure defined in Annex 3 of this GTR, respectively, expressed in per cent.

$$SOCE_{measured} = \frac{UBE_{measured}}{UBE_{certified}} * 100$$

In cases where $UBE_{measured}$ is higher than the $UBE_{certified}$, the $SOCE_{measured}$ shall be set to 100 per cent.

6.3.3. Statistical Method for Pass/Fail decision for a sample of vehicles

An adequate number of vehicles (at least 3 and not more than 16) shall be selected from the same monitor family for testing following a vehicle survey (see Annex 1) which contains information designed to ensure that the vehicle has been properly used and maintained according to the specifications of the manufacturer. The following statistics shall be used to take a decision on the accuracy of the monitor.

For evaluating the SOCE monitor normalised values shall be calculated:

$$x_i = SOCE_{read,i} - SOCE_{measured,i}$$

Where

$SOCE_{read,i}$ is the on-board SOCE read from the vehicle i ; and

$SOCE_{measured,i}$ is the measured SOCE of the vehicle i.

For the total number of N tests and the normalised values of the tested vehicles, x_1, x_2, ... x_N, the average X_{tests} and the standard deviation s shall be determined:

$$X_{tests} = \frac{(x_1 + x_2 + x_3 + \cdots + x_N)}{N}$$

and

$$s = \sqrt{\frac{(x_1 - X_{tests})^2 + (x_2 - X_{tests})^2 + \ldots + (x_N - X_{tests})^2}{N-1}}$$

For each N tests $3 \leq N \leq 16$, one of the three following decisions can be reached, where the factor A shall be set at 5:

(a) Pass the family if $X_{tests} \leq A - (t_{P1,N} + t_{P2,N}) \cdot s$

Effect of „apparent battery aging/healing“ for energy based test procedures according to 6.3 Part A (5% criterion)

Certification measurement (day 1)

Actual battery SoH (capacity):		100 %
Displayed SoH:		100 %
Vehicle weight:		10t
Route topography:	flat	
Discharge energy (cert):	**312 kWh**	
SOCE (energy):	-	

In-service measurement (day 2)

Actual battery SoH (capacity):		100 %
Displayed SoH:		100 %
Vehicle weight:		39t
Route topography:	hilly	
Discharge energy (in-service):	**295 kWh**	
SOCE (energy):	94,5 %	

→ Failed

In-service measurement (day 1000)

Actual battery SoH (capacity):		95 %
Displayed SoH:		95 %
Vehicle weight:		39t
Route topography:	hilly	
Discharge energy (in-service):	280 kWh	
SOCE (energy):	89,7 %	

→ Failed

Certification measurement (day 1)

Actual battery SoH (capacity):		100 %
Displayed SoH:		100 %
Vehicle weight:		39t
Route topography:	hilly	
Discharge energy (cert):	**295 kWh**	
SOCE (energy):	-	

In-service measurement (day 2)

Actual battery SoH (capacity):		100 %
Displayed SoH:		100 %
Vehicle weight:		10t
Route topography:	flat	
Discharge energy (in-service):	**312 kWh**	
SOCE (energy):	105,7 %	

→ passed

In-service measurement (day 1000)

Actual battery SoH (capacity):		**95 %**
Displayed SoH:		95 %
Vehicle weight:		10t
Route topography:	flat	
Discharge energy (in-service):	296,4 kWh	
SOCE (energy):	**100,5 %**	

→ passed

The in-vehicle discharged energy is influenced by boundary conditions like topography, amount of recuperation, vehicle weight, actual temperature and more. A spread higher than 5% must be expected for the same vehicle used within is operation window. This makes the discharge energy for in-vehicle measurements an inappropiate parameter. False failed (case #1) and tampering would be possible (case #2).

Effect of „apparent battery aging/healing“ for capacity based test procedures

Certification measurent (day 1)

Actual battery SoH (capacity):		100 %
Displayed SoH:		100 %
Vehicle weight:		10t
Route topography:	flat	
Discharge capacity:	779 Ah	
Calculated SoH (energy):	-	

In-service measurent (day 2)

Actual battery SoH (capacity):		**100 %**
Displayed SoH:		100 %
Vehicle weight:		39t
Route topography:	hilly	
Discharge energy:	777 Ah	
Calculated SoH (energy):	**99,7 %**	

→ **passed**

In-service measurent (day 1000)

Actual battery SoH (capacity):		**95 %**
Displayed SoH:		95 %
Vehicle weight:		39t
Route topography:	hilly	
Discharge energy:	738 Ah	
Calculated SoH (energy):	94,7 %	

→ **passed**

Certification measurent (day 1)

Actual battery SoH (capacity):		100 %
Displayed SoH:		100 %
Vehicle weight:		39t
Route topography:	hilly	
Discharge energy:	777 Ah	
Calculated SoH (energy):	-	

In-service measurent (day 2)

Actual battery SoH (capacity):		**100 %**
Displayed SoH:		100 %
Vehicle weight:		10t
Route topography:	flat	
Discharge energy:	779 Ah	
Calculated SoH (energy):	**100,3 %**	

→ **passed**

In-service measurent (day 1000)

Actual battery SoH (capacity):		**95 %**
Displayed SoH:		95 %
Vehicle weight:		10t
Route topography:	flat	
Discharge energy:	738 Ah	
Calculated SoH (energy):	**94,9 %**	

→ **passed**

Charge/discharged based capacity is very robust against boundary conditions of vehicle usage. No tampering possible.

Key messages UBC vs. UBE

- Differences in test method operating points inpacting and leading to artificial „aging“
- Additionally to that, Voltage measurement comes always with added inaccuracies:
  - BMS ↓
  - CAN-BUS ↓↓
  - External equipment ↓↓↓
- Positioning, packaging and different sizing adding to error propagation, too
- Usable energy is much more sensitive to test boundary conditions (slope, speed, acceleration, recuperation) – with capacity those impacts are neglectable – but the real battery aging is in both cases the same
- In general, the highest possible accuracy of on-board current and voltage prediction is of ultimate importance for us and therefore our customers

UBC verification of SOCE prediction Part A & certification

$$SOCE_{measured} = \frac{UBE_{measured}}{UBE_{certified}} * 100$$

$$x_i = SOCE_{read,i} - SOCE_{measured,i}$$

$$X_{tests} = \frac{(x_1 + x_2 + x_3 + \cdots + x_N)}{N}$$

$$s = \sqrt{\frac{(x_1 - X_{tests})^2 + (x_2 - X_{tests})^2 + \ldots + (x_N - X_{tests})^2}{N-1}}$$

(a) Pass the family if $X_{tests} \leq A - (t_{P1,N} + t_{P2,N}) \cdot s$

$$x_i = SOCE_{read,i} - \frac{UBE_{measured}}{UBE_{certified}} * 100$$

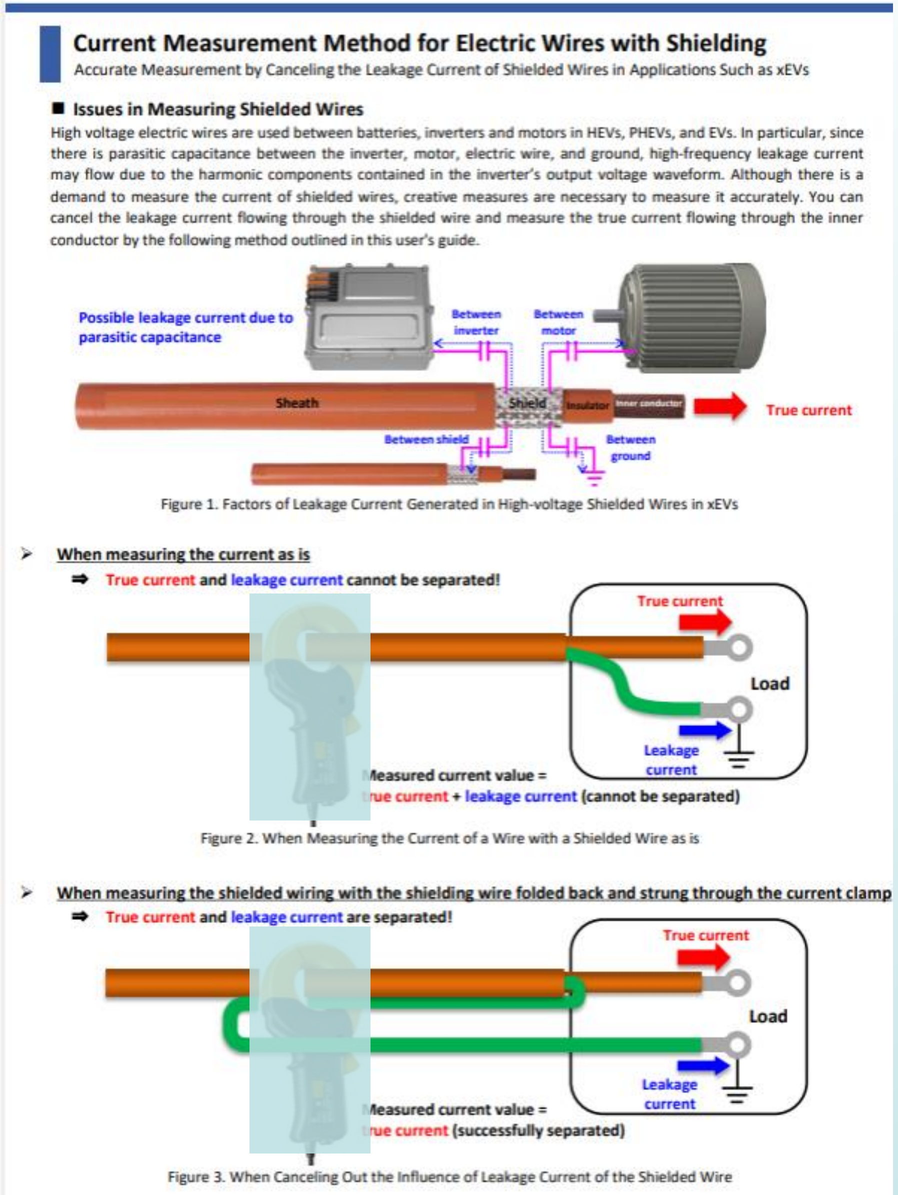
$$SOCE_{read,i} = \frac{UBE_{BMS,pack}}{UBE_{certified}} * 100$$

$$x_i = \frac{\sum UBE_{BMS,pack}}{UBE_{certified}} * 100 - \frac{UBE_{measured}}{UBE_{certified}} * 100$$

Just an example; ***SOCE**$_{read}$* routine may differ from OEM to OEM

#	***UBE**$_{measured}$* verification	comments	Resulting formular
1	Verify Current, Multiply with on-board Voltage to get ***UBE**$_{measured}$*	Accuracy low, feasibility limited and external influences of voltage measurement too high	$x_i = SOCE_{read,i} - \frac{I_{external} * U_{monitored}}{UBE_{certified}} * 100$
2	Verify current and Voltage begin of life externally on pack level By that, sensors are being certified life-long (see also EU-VI PEMS)	On test rig level, accuracy of signal verification is very high and approved/well established	*xI,j = I,read – I,measured* *xU,j = U,read – U,measured* *xI,U,j*
3	Verify current and Voltage in alignment with authorities	Depending on ech cps authority	No formular needed anymore
4	Verify ***UBE**$_{measured}$* by comparing charged energy with on-board energy	Using the charge cycle to verify UBE ***UBE**$_{discharged}$* and ***UBE**$_{charged}$* may be subject to a maximum allowed deviation of e.g. 5% (comparing slides 3 & 4)	$x_i = SOCE_{read,i} - \frac{UBE_{charged}}{UBE_{certified}} * 100; UBE_{certified} = UBE_{charged,begin\ of\ life}$

Shielded cables - example for Manual of external measurement equipment: invasive measurement



Current Measurement Method for Electric Wires with Shielding

Accurate Measurement by Canceling the Leakage Current of Shielded Wires in Applications Such as xEVs

■ **Issues in Measuring Shielded Wires**

High voltage electric wires are used between batteries, inverters and motors in HEVs, PHEVs, and EVs. In particular, since there is parasitic capacitance between the inverter, motor, electric wire, and ground, high-frequency leakage current may flow due to the harmonic components contained in the inverter's output voltage waveform. Although there is a demand to measure the current of shielded wires, creative measures are necessary to measure it accurately. You can cancel the leakage current flowing through the shielded wire and measure the true current flowing through the inner conductor by the following method outlined in this user's guide.

Figure 1. Factors of Leakage Current Generated in High-voltage Shielded Wires in xEVs

➢ When measuring the current as is

⇒ True current and leakage current cannot be separated!

Figure 2. When Measuring the Current of a Wire with a Shielded Wire as is

➢ When measuring the shielded wiring with the shielding wire folded back and strung through the current clamp

⇒ True current and leakage current are separated!

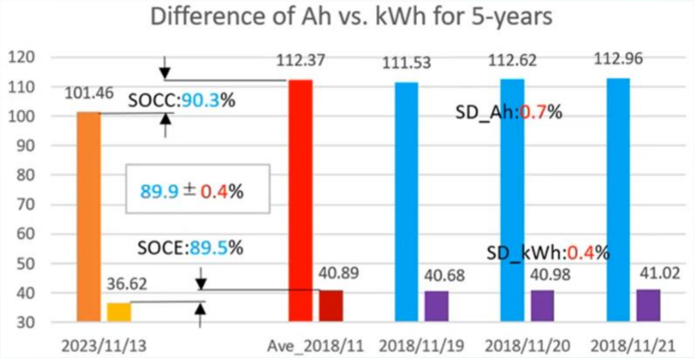
Figure 3. When Canceling Out the Influence of Leakage Current of the Shielded Wire

Comments

- *"Although there is a demand to measure the current of shielded wires, creative measures are necessary to measure it accurately."*
- **Solution advise cancel the leakage current flowing through the shielded wire and measure the true current flowing through the inner conductor**
- **During pilot phase we might be able to show, if that is feasible and the value of deviations against on-board equipment and/or sensors**
- In general, thinking on in-service measurements with customer vehicles, non-invasive procedures must be the key priority considering:
  - Complex battery packaging (positions & sizes)
  - Complicated body superstructure (Rigids)
  - Customer vehicle availability (invasive → time, effort)

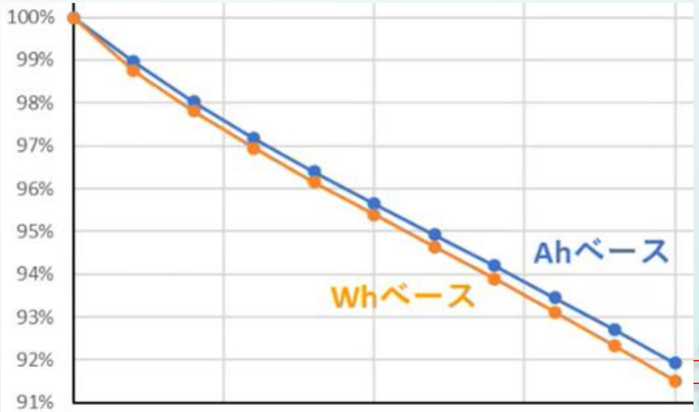
Comparison of the difference in deteriorationbackward between SOCE_UBE and SOCC_UBC

Dufferece in in-vehicle REESS deterioration backward; SOCE_UBE(Wh) vs. SOCC_UBC(Ah)



[UBE(Wh)]-[UBC(Ah)]
89.5% - 90.3%
=**-0.8%**

[UBE(Wh)]-[UBC(Ah)]
≒**-1.0%**

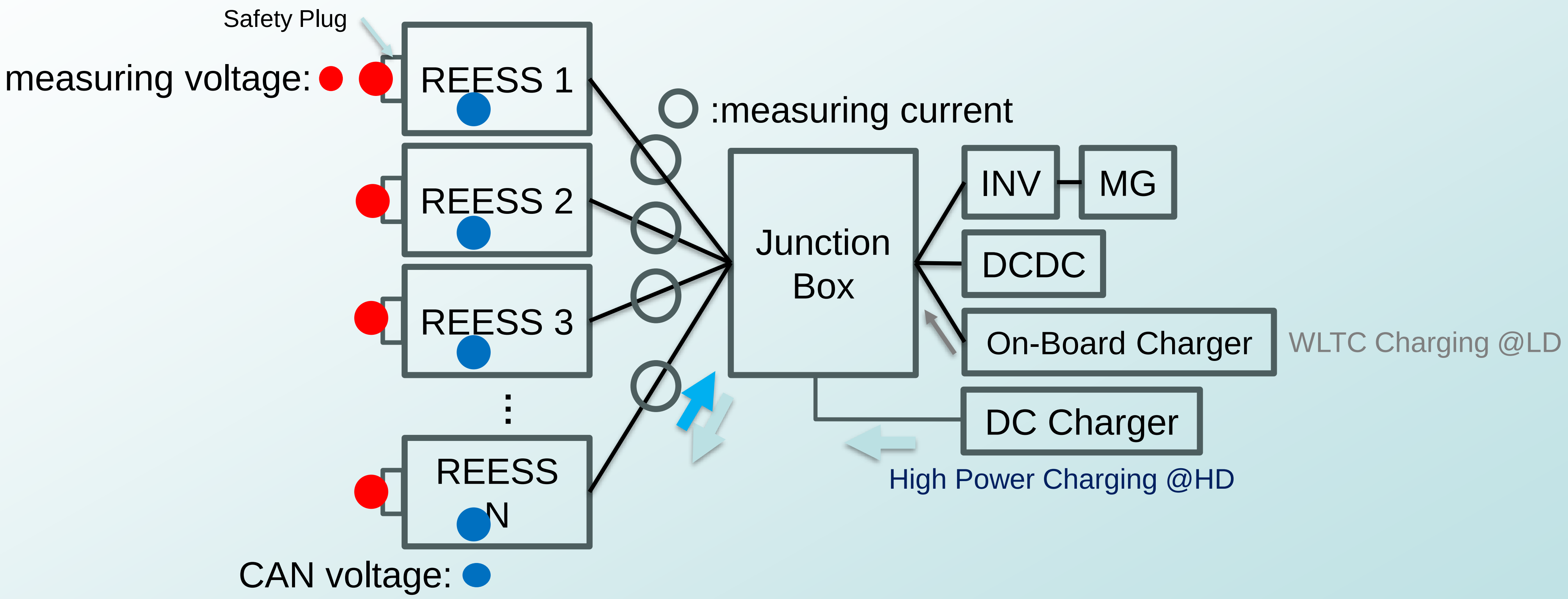


[UBE(Wh)]-[UBC(Ah)]
≒**-0.5%**

【Result】[UBE(Wh)]-[UBC(Ah)]=**-1.0 ~ -0.5%**

CAN voltage measurement sensor accuracy

➢Each REESS charging/discharging performance_kWh/Ah :
Voltage & current measureable point / CAN value output points
➢Difference between measurement value and CAN value required accuracy ≦ Measuring device allowable accuracy±1.0% rdg. @ discharge & chage



【Result】
There are test results where the difference between the measured voltage value and CAN voltage value exceeds 1 % during High Power charging(e.g. 2-Crate)

Annex 3, Part A, 1.2 Measurement requirements

Table A3/1
Measurement items and required accuracy

Item	*Units*	*Accuracy*	*Remarks*
Electrical voltage	V	±0.3 % FSD or ±1 % of reading	Whichever is greater. Resolution 0.1 V.
Electrical current	A	±0.3 % FSD or ±1 % of reading	Whichever is greater. Resolution 0.1 A.
Room/ambient temperature	K	±1 °C, with a measurement frequency of at least 0.033 Hz	
Time	s	± 10 ms; min. precision and resolution: 10 ms	

Item	*Units*	*Accuracy*	*Remarks*
Electrical power	W	[…]	Charging discharging electrical power ~~of the bidirectional charger/ bidirectional power supply~~, [i.e. accuracy, calibration]
Discharge rate		[…]	
Bidirectional charger/ bidirectional power supply/…		[…]	AC, DC …

Comments

- The measurement accuracies are adapted from the UN Regulation No. 154 - light duty passenger concerning measurement of electric energy consumption and electric range (WLTP) which is a dynamometer test
- Adjustment of required accuracy to use on-board measurement devices
- OICA proposal: Electrical voltage ±1% FSD or ±2 % of reading

Annex 3, Part A, 2.1.1.1.5. Measurement frequency

2.1.1.1 5. Measurement frequency

All the items in Table A3/1 of paragraph 1.2 of this annex, unless specified otherwise in the table, shall be measured and recorded at a frequency equal to 20 Hz for discharging and 0.033Hz for charging.

Family Concpet

6.1.1. For Part A: Verification of the Monitor

Only vehicles that are substantially similar with respect to the following elements may be part of the same monitor family:

(a) Algorithm for estimating on-board SOCE;

(b) Sensor configuration (for sensors used in determination of SOCE estimates);

(c) Characteristics of battery cell which have a non-negligible influence on accuracy of monitor;

(d) Type of vehicle (HD-PEVs or HD-OVC-HEVs)

(e) Declared highest normal charging power ~~or C rate~~.

(f) Type of battery (dimensions, type of cell, including format and chemistry, capacity (Ampere-hour), nominal voltage, nominal power, different/several battery configuration (number of cells in series and mode of connection) or different number of battery packs;

-(g) Test procedure for vehicle type

Comments

- (a),(b) and (g)
- (c) and (f) to be explained and aligned
- See als OICA 4-columns document starting from pages 20 ff.

Family Concpet

6.1.2. For Part B: Verification of Battery Durability

Only vehicles that are substantially similar with respect to the following elements may be part of the same battery durability family:

(a) Vehicle category

(b) Type and number of electric machines, including net power, construction type (asynchronous/ synchronous, etc.), and any other characteristics having a non-negligible influence on battery durability;

(c) Type of battery (dimensions, type of cell, including format and chemistry, capacity (Ampere-hour), nominal voltage, nominal power;

(d) Battery management system (BMS) (with regards to battery durability monitoring and estimations);

(e) Passive and active thermal management of the battery;

(f) Type of electric energy converter between the electric machine and battery, between the recharge-plug-in and battery, and any other characteristics having a non-negligible influence on battery durability;

(g) Operation strategy of all components influencing the battery durability;

(h) Declared highest charging power, i.e., normal, ultra† or Mega Watt‡ charging

At the request of the manufacturer, with the approval of the responsible authority and with appropriate technical justification, the manufacturer may deviate from the above criteria for families.

Comments

- As long as final MPRs are not monitored and set for HDV, points a), b), e) and f) are questionable.
- Focus must be on definition for battery families not vehicle. The electric machine is irrelevant for the battery durability. Use case would be more relevant.

Pilot Phase – alignment within OICA

<u>Guidelines agreed to have in common:</u>

- 1a or 1b or 2 based on v17-update text
- Tests to be done at OEMs premises
- No other OEM will participate at other pilot phase tests
- Technical Service or authority is witnessing the tests as applicable in the short notice
- Details as:
  - road gradient, break-off criteria, pass/fail tolerance, repeatability, reproducability,
  - Accuracy requirements, frequncy requirements
  - Testing devices, battery construction/geometry impact on testing devices/locations
- Participation during tests:
  - 1-3 days
  - Whole day
  - Part day
  - Result evaluation
- External verification of voltage and current: OEMs try to organize measurement clamps (preferrably HIOKI as mutual industry standard)
  - At least break-out boxes will be used

Pilot Phase location and timing

	CW25	CW26	CW27	Point of contact	Method	Confirmation	Vehicle
Volvo			Sweden, Hällered Proving Ground, Whole week	Elie Garcia, Elie.garcia@volvo.com	1a	Yes	1x N3 Truck, >16t (Rgid or Tractor)
Scania		Sweden, Södertällje, whole week		Rong Sun, Rong.sun@scania.com	1a	Yes	1x N3 Truck, >16t (Rigid/Tractor)
Daimler Truck	Germany, Stuttgart, 19.-21. June	Germany, Stuttgart, whole week	Germany, Stuttgart whole week	Axel Trentzsch, axel.trentzsch@daimlertruck.com	1b	Yes	1x N3 Truck, 1x M3 Bus, >16t (Rigid/City)