- D1.1 – List of requirements for smart batteries

- VERSION -

VERSION 2.0	

- PROJECT INFORMATION -

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- DELIVERABLE INFORMATION -

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CONTRIBUTING PARTNERS	IFAG, BMW, VMI, CNRS, CEA, FAURECIA, UAVR, INSA
NATURE	
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Deliverable Review

	Reviewer #1: Olivier RACCURT		
	Answer	Comments	Type*
1. Is the deliverable in accordance with			
(i) The Description of actions?	☒ Yes ☐ No		☐ M ☐ m ☐ a
2. Is the quality of the deliverable in a status			
(i) That allows it to be sent to European Commission?	☒ Yes ☐ No		☐ M ☐ m ☐ a
(ii) That needs improvement of the writing by the originator of the deliverable?	☐ Yes ☒ No		☐ M ☐ m ☐ a
(iii) That needs further work by the Partners responsible for the deliverable?	☐ Yes ☒ No		☐ M ☐ m ☐ a

	Reviewer #2: Wilhelm Maurer		
	Answer	Comments	Type*
1. Is the deliverable in accordance with			
(i) The Description of actions?	☒ Yes ☐ No		☐ M ☐ m ☐ a
2. Is the quality of the deliverable in a status			
(i) That allows it to be sent to European Commission?	☒ Yes ☐ No		☐ M ☐ m ☐ a
(ii) That needs improvement of the writing by the originator of the deliverable?	☐ Yes ☒ No		☐ M ☐ m ☐ a
(iii) That needs further work by the Partners responsible for the deliverable?	☐ Yes ☒ No		☐ M ☐ m ☐ a

* Type of comments: M = Major comment; m = minor comment; a = advice

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1. Introduction

In the INSTABAT project, a proof of concept for a multi-sensor platform should be developed, which is capable of monitoring battery key parameters and correlating them with battery physico-chemical degradation processes. The Battery Management System (BMS) of such a "Smart Battery" receives in real-time the output data from the physical/virtual sensors of the platform, enabling accurate assessment of the cell internal states. The benefits of such an improved monitoring shall be demonstrated primarily by load- & unload-lifetime cycling, and by high-power battery charging, which is regarded as essential for EV applications.

In this deliverable, the functional requirements for smart batteries are compiled with specific focus on full battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) in passenger vehicle applications. From this perspective, the following four requirements are regarded as top priority:

1. The detection or anticipation of safety-critical states and ageing mechanisms, so that countermeasures can be taken to avoid battery critical events, or at least to be able to send a timely warning signal.

2. The development of adaptive SoC-, SoH- and SoP-estimators, which allows reliable performance in different environmental conditions and over the whole battery lifetime incl. second life application.

3. Sensor-based battery operational strategies, which for example, improve fast charging and provide an adaptive Depth of Discharge (DoD) performance range larger than the standard range with fixed limits.

4. For mass production of BEVs, the limited computing power of the target E/E system has to be taken into consideration, to minimize the tradeoff between the added value of an extended battery operation range versus the added cost of the different smart battery functionalities.

The full list of requirements on functional level are derived und collected in [1], which represents the basis requirements in the INSTABAT project. Each requirement is connected to a generic validation procedure as a guideline for the individual technical work packages.

In a further list, the sensor capabilities including information such as sensor type, majority level, data acquisition and so on are defined. Finally, a correlation between both lists, considering both the physical sensors and options for virtual sensors is provided.

2. List A: Requirements for a Smart Battery Cell

Requirement list for the derived sensor is shown in Fig. 1. In general, the functions in List A are assigned to common Use-Cases, which are discussed in section 4 in detail.

Specific values for sampling rates, accuracies etc. are clustered in the List of Sensor capability in [1], and not shown here in the text due to its complexity.

ID	Requirements	Validation	Requirement Context	Priority	PS	VS	MP	WP1	WP2	WP3	WP4	WP5
1	Pouch cell with the following characteristics: Cell capacity: dependent on cell format/Dimension Cathode material: robust cell chemistry (NMC 622) Anode material: Graphite w.(<5%)/wo. Silicium material		Cell specifications	high			x					
2	Specific energy: 200 Wh/kg on the cell level		Cell specifications	low			x					
3	C-Rate capability: 0.3C charge/0.5C discharge continuous		Cell specifications	high			X					
4	Sensor must be fully functional in the following temperature ranges: Temperature range test chamber for storage: -40 °C to +80 °C Temperature range test chamber for cycling tests: -25 °C to +55 ° C.Max. Temperature of the cell core: chemistry-dependent, approx. + 80 °C; Max. Temperature of cell housing: chemistry-dependent, approx. + 60 °C; Max. Temperature of cell terminal: chemistry-dependent, approx. + 70 °C	Sensor can be tested in dummy cells without active cell chemistry in the full temperature range.	Environmental condition	medium	x		x		x			x
5	Sensor must be functional in the cell (robust against different cell chemistry and pressure up to 2 N/mm² in a prismatic cell).	Stability to electrolyte and pressure can be tested separately. Sensor should deliver stable, plausible values in the long term in real cells.	Environmental condition	medium	x				x			x
6	It must be possible to connect cells up to 1000 V in series and up to 5p (prismatic cells) in parallel. A higher parallel connection is normal for cylindrical cells, which should be taken into account.	validation through concept design	Environmental condition	low	x	x			x	x		
7	The maximum number of intelligent cells in a pack could be up to 500 (prismatic) units. For cylindrical cells it is possible with a much higher number of cells	validation through concept design	Environmental condition	low	x	x			x	x		
8	Plating during fast charging need to be identified or estimated	Implemented as virtual sensor for battery monitoring	BMS Functions/Use case	high		x	x				x	x

9	In case of a standard fast charging process the cells should be charged from 10% to 80% SOC (based on the cell current capacity) with in the following time period. Following boundary conditions have to be considered: charging time 20 min. for cells with 200 wh/kg at 35°C starting temperature charging time 25 min. for cells with 250 wh/kg at 35°C starting temperature Target battery lifetime: 3F3N (3 fast charging followed by 3 normal charging with CC 0.3C) 1800 cycle until 70% rest capacity	Applying the standard current (0.3C for charging and 0.5 C for discharging) for SOC adjustment. Performing cell individually optimized fast charging profile from SOC 10% to SOC 80% at 35°C test temperature. Repeat the fast charging cycle until the specified number of cycles hast been reached	BMS Functions/Use case	high	x	x	x					x
10	Cell state of charge (SoC) must be able to be determined with a frequency of 0.1 Hz and an accuracy of 2%.	Applying a driving cycle (provided by BMW) at defined temperatures [for example 40 ° C, 25 ° C, 10 ° C and 0 ° C, -10 ° C]. The cycle is stopped at certain time and the cell is discharged with a defined current (e.g. 1/ 3C) until the end-of-discharge voltage is reached. The external temperature in climatic chamber remains the same during the driving cycle and the discharge. The reference state of charge can be compared with the estimated state of charge determined by the algorithm.	BMS Functions/Use case	high		x	x				x	x
11	The state of health must be available with an accuracy of 2% based on the nominal capacity.	Cells are applied with ageing test. The aging tests are interrupted every 50 cycles and, once thermal equilibrium has been reached, capacity test can be carried out at reference temperature. Cells are then loaded with an application-oriented current profile (consisting of discharge with driving profile, breaks and CCCV charging phases). The measured full discharge capacity can be compared with the capacity determined by the algorithm during the application load.	BMS Functions/Use case	high		x	x				x	x

12	Specification of battery power prediction: Maximum power for 1s: +/- 5% accuracy Maximum power for 10s: +/- 5% accuracy Continuous power for 30min: +/- 10% accuracy. The power prediction for charging and discharging must be available within a frequency of 200 Hz.	Cycle the cells with a driving cycle provided by BMW. At certain SOC [90%, 70%, 40%, 10% and 5%], the cycling is interrupted and a pulse test (discharge) is carried out. The tests can be carried out at different temperatures and with different current rates. In these cases, operating limits were violated after x seconds during the pulse test and can be compared with the prediction with BMS algorithms.	BMS Functions/Use case	medium		x	x				x	x
13	Internal cell resistance (eg. 10s R_dc) should be estimated within accuracy of at least 10% based on the current value.	Applying a comparative measurement on the test bench. Measurement conditions are based on test specification including different SOCs [90%, 70%, 40%, 10% and 5%] are approached. After the relaxation, current pulses are performed. The measured value for R_dc 10s can be compared with the determined one by the algorithm. The tests can be repeated at different temperatures for example [40 ° C, 25 ° C, 10 ° C and 0 ° C, -10 ° C].	BMS Functions/Use case	high		x	x				x	x
14	Increased self-discharge due to cell ageing (> factor 5 vs. BOL value or reference cells) should be detected	Measurement of voltage loss and comparison with with BOL status or reference cell.	BMS Functions/Use case	low			x				x	x
15	The algorithm can be upscaled to a large pack system	Validation with multiple cells within a simulation test bench	BMS Functions/Use case	low							x	x
16	The cells with physical sensors should meet the requirements of safety tests with HL <= 4 and may not perform worse in safety tests than reference cells without sensors.	Carrying out the safety tests.	Safety	high	x		x			x		x
17	The state with "Cell outside the operating voltage limit" must be detected and recorded.	Applying overcharge and deep discharge test of the cell.	Safety	high			x			x		x
18	Cell internal short circuit must be detected and communicated within 50 ms during operation	Nailtest can be carried out to replace an internal short circuit. The short-circuit event must be detected and communicated within 50 ms.	Safety	high			X			x		x

19	Cell external short circuit must be detected and communicated within 50 ms during operation	External short circuit test: The detection and communication of the short circuit event must take place within 50ms.	Safety	low			x			x		x
20	Short circuits between the signals should not lead to dangerous situations		Safety	high	x				x			
21	Recording of the data/Measurement histogram per cell should be available.	Repeated execution of the specified driving cycle, reading out the signal histogram.	Demonstrator	high			x					x
22	A mixed configuration of cells should be possible.	validation through concept design	Demonstrator	low			x		x			
23	Cell-critical situations should be detected by sensors (physical or virtual), especially during operation	Abuse tests can be carried out. Sensors combined with algorithms should recognize and communicate the critical states before any safety event.	Demonstrator	high			x		x	x	x	x
24	Sensor signals should be brought together at a central point on the cell for further evaluation	Evaluation through implementation	Demonstrator	high			x		x	x		x
25	The data integrity must be ensured	Validation through sending incorrect values.	Demonstrator	medium			x					x
26	Line breaks, short circuits between signals and cells should be detectable during cell measurement.		Demonstrator	high			x					x
27	extended cycle life and calendaring life for sensor cells and electric and electronic component are required. for example, 5000 cycle life and 20 years calendaring life till battery end of service (cell dependent, therefore the definition is open)		second life application	medium								
Total number of requirements:	27											

Figure 1. List of the requirements for smart batteries.

3. List B: Sensor Capabilities

Within INSTABAT project a broad variety of sensor types has been considered and a usability study has been performed. Figure 2**Erreur ! Source du renvoi introuvable.** gives an overview of all considered and valid sensor types. For each sensor type, the correlation to the requirements for a smart battery cell (List A) is given additionally via.

- Direct Contribution of the Sensor to Requirement
- Indirect Contribution of Sensor to Requirement
- Constraints on the Sensor

Thus, it gives us a clear overview how the functional requirements can be fulfilled with the sensor cells, and the constraints can already be considered during the development phase as well. To get more details about the sensors and their requirements Appendix 1 must be considered.

ID	Sensor type	Senosr Capability measured/estimated parameters	Correlation with physico-chemical phenomena	Direct Contribution to Requirement (Output of sensor)	Indirect contribution to Requirement (Correlated to sensor output -> BMS)	Constraints on the Sensor from Requirement
1	Fiber Bragg Grating (FBG)	Temperature and heat flow, pressure, strain	Solid Electrolyte Interphase (SEI) growth, internal resistance increase, capacity loss	4 and 5 (temperature data); 9 (pressure and SEI correlation); 23 (thermal runaway)	6, 7, 17, 19 and 20 (temperature and strain data); 22 (providing data values); 28 (temperature and pressure performance evaluation)	7 (Data quantity and fibers handling);
2	Reference electrode	"Absolute" potential, impedance and polarization	Lithium plating, internal resistance and SEI / CEI (Cathode Electrolyte Interface) growth on each electrode	9 Plating fast charging	13. Cell Degradation, Impedance increase SOC/SOH Estimation	7 (Data quantity and handling); Stability of RE
3	Luminescence	Temperature, Li+ concentration	SEI growth, internal resistance increase, capacity loss, lithium plating, loss of active materials	4 and 5 (temperature data); 10 (Li+ concentration/distribution)	13. Impedance increase	
4	Photo-acoustic (PA)	CO2 concentration	Ageing, CO2 gas released from electrolyte decomposition giving information about the SEI formation, safety-critical situations		11. CO2 concentration in ppm	4. Storage and operating temperatures 5. pressure 27. second life
5	E-based electro-chemical estimation	Li+ concentration and distribution, "absolute" potential and polarization	Electrolyte polarization, lithium plating, irreversible electro-chemical reactions	10 (Li+ concentration/distribution)	8 (absolute potential), 11 (absolute potential), 12 (Li concentration, Surface Li+ concentration, Absolute polarization), 13 (absolute potential)	6 (scalability), 7 (scalability)
6	T-based (thermal battery state estimator) Kalman filter	Temperature and heat flow, pressure, strain	Electrolyte degradation, capacity fade, ageing and thermal runaway	23 (Temperature and thermal runaway detection)	11, 14 and 15 (Temperature)	7 and 25 (Excessive data analysis)

Figure 2. List of sensor capabilities

4. Use-Cases

In the following, certain common and/or critical use cases are described, for which the sensors and the further functionalities of a smart battery cell will be beneficial.

4.1 Detection of safety-critical conditions and cell ageing mechanisms over time

Regardless of the operating condition of an electric vehicle (such as driving, parking, charging), it would be very valuable to the customer if safety-critical events of an individual cell are recognized and communicated in the early phase. The battery BMS could due to this error message either take stabilization measures such as maximizing cooling or issue a warning message (warning indicator, horn, message in the infotainment display and via smartphone app or direct message to emergency services ...) to the customer. The target at the end is always to ensure maximum customer safety.

The challenges for the sensor cells are that some of these safety-critical states could occur more spontaneously or with strong latency (a few hours after the vehicle has been parked), i.e. that the sensors run the risk of overlooking the problems. For these error cases, it is necessary that the sensor system is triggered by itself and can wake up the BMS independently.

Besides, in order to fulfill the life expectation for EV and second life applications (15 to 20 years in total) applications, an accurate determination of battery health and performance is essential. To achieve this task, applications with smart cells will be studied under the scope of INSTABAT project.

4.2 Detection of battery states and parameters during operation and over lifetime

Battery parameters and states have to be determined by the BMS. The commonly used and required states and parameters are listed in the following

- State of charge (SOC)
- State of health (SOH) and remaining useful life
- Residual energy and driving range
- Impedance parameters and Power estimation

Taking SOC estimation as an example. Typically, the used operational window of EV batteries is limited. Fig. 2 shows the related SOC operating range of a battery. Overcharging and overdischarging a battery may cause permanent damage. An accurate SOC estimation allows an optimum battery control to prevent the battery from posing a risk and to prolong the lifetime as well.

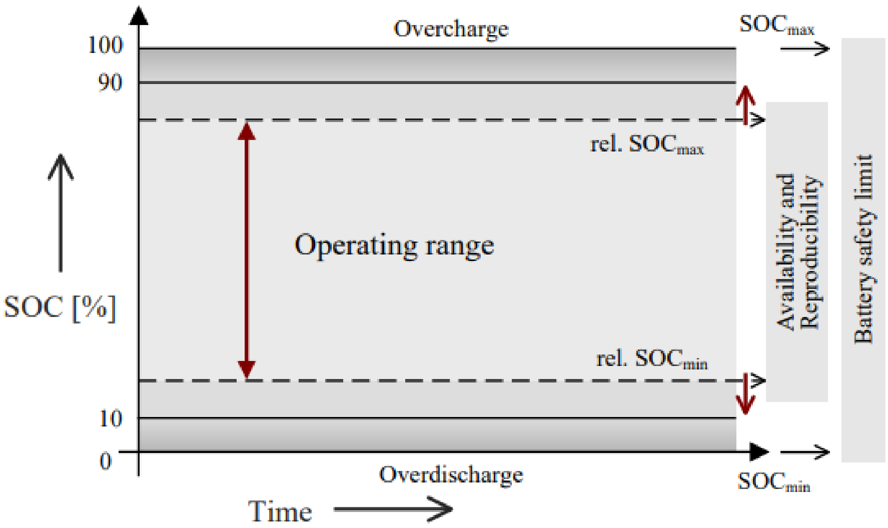

Figure 2. Different operating ranges of a lithium-ion battery

For EV applications, batteries deliver not only a certain amount of energy during operation but also provide a certain power in various situation. The power of the battery can be limited by various battery conditions, such as voltage, current, SOC, temperature, ageing and could only be estimated indirectly based on the previous load history. Therefore, an accurate determination of the battery internal parameters is one of the basic and important tasks under the scope of sensor cells.

In order to evaluate the performance of sensor cells or to validate the developed BMS algorithms in WP 2 to WP6, Worldwide Harmonized Light Vehicles (WLTP) test procedure could be applied. This standard profile is divided into four parts with different average speeds: low, medium, high, and extra high.

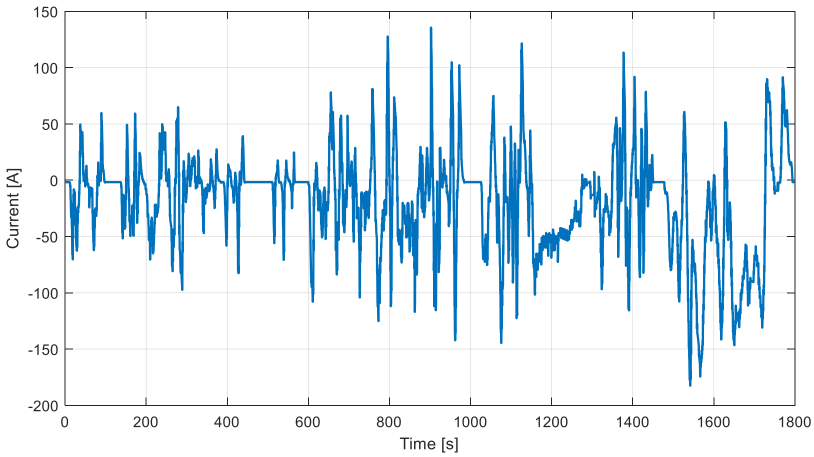

Figure 3. WLPT driving cycle as an example for evaluating the cell and BMS performance

The current sequence, shown in figure 3, is for example derived from a vehicle model. It features dynamic charge and discharge current, as well as rest periods, corresponding to EV or HEV operation including regenerative braking. For the sake of cell validation, current amplitude need to be further downscaled to the INSTABAT cell capacity.

4.3 Cell fast charging

The fasting charging capability in terms of charging speed, Coulomb efficiency and ageing effects is currently one of the most important competitive features of the EVs. The sensor data should be used in connection with innovative algorithms for an optimized fast charging strategy. Cell ageing should be either kept constant with an accelerated charging time or charging the cell must faster with extended battery cycle life to cell end of life.

In this customer situation, the sensors and date communication have to work very quickly so that changes in cell status, determined by cell physical or virtual sensors, can be regulated dynamically.

4.4 Computing of (virtual-) sensor data

Over the past decade, a dramatic increase in the functionality and complexity of software embedded systems in the automotive industry can be observed, the number of controllers with computing power and memory show only in comparable only limited growth. Therefore, additional algorithms with optimized efficiency become more demanding.

A further level of complexity is created when additional data are created and communicated within a large battery pack. Measurement, analogic-digital (AD) conversion, and data transmission should be carried out within the specified cycle time of the control unit. Since the battery system must be controlled in real-time, the demands on software safety, performance, and durability arise.

Through the application with real battery pack is not under the scope of INSTABAT Project. Combining of different sensor data or applying further estimation algorithms should be possible for a large pack system.

5. Further Technical details

Both detailed list of battery key parameters with the associated test criteria and a collect of sensor capabilities with an allocation to the responsible work packages can be found in the attached Excel table [1].

In this chapter, few points are focused and discussed in more detail.

5.1 Reliability of the sensor data

One of the most important criteria for sensor data, on which the algorithms are based, must be reliable. That means both physical and virtual sensors should deliver reliable measured values over the entire life of the cell.

For INSTABAT project, development of different sensors has to take the robustness against the influences of environmental conditions into account. Further, calibration procedures before the sensor integration or during measurement need to be developed. The measuring accuracy in the entire measuring chain should also be assessed in the multi-sensor platform.

5.2 Sensor integration

The integration of sensors into the cell must also be considered during the development phase. It includes the compatibility with the cell architecture, battery chemistry inside the cell (especially electrolyte composition), the implementation of an electrical connection and general safety consideration and so on. This topic regarding requirements for the sensors integration into the cells are defined in Task 1.2.

5.3 Data communication

For multi-sensor platform it is important that the sensor data can be communicated in a stable and secure manner. The reliability should be evaluated especially for sensors with high sensitivity against external signal influence. To simplify communication for INSTABAT demonstrator, it is very recommended if all signals can be already digitalized at cell level. The communication technology itself must also meet the requirements for security and interference stability.

5.4 Data Acquisition

To provide the most accurate battery state estimator, it is essential to be careful with the acquisition settings for each sensor. The digital conversion resolution and the sampling rate of sensor signals have to meet the algorithm input requirements. The sensor measurements has to be time synchronized to be used by time based algorithm. This synchronization among the sensor's data can be performed by hardware electronics or through the data communication architecture. Digitized sensor data format should fit with signal processing control unit performance and capability.

5.5 Energy /power consumption

It must be ensured that the energy or power consumption of physicals sensors remains at a low level in order not to lose the advantages of sensor-based operation strategy in different operation modes of the sensor system.

6. Appendix

[1] LIST_28012021_INSTABAT_Requirement_correlation_final.xlsx

ID	Requirement	Validation	Requirement Context	Remarks	Priority	PS	VS	MP	WP1	WP2	WP3	WP4	WP5
1	Pouch cell with the following characteristics: Cell capacity: dependent on cell format/Dimension Cathode material: robust cell chemistry (NMC 622) Anode material: Graphite w.(<5%)/wo. Silicium material		Cell specifications	NMC622/Gr. preferable to be startet with. (optional with less than 5% Silicum)	high			x					
2	Specific energy: 200 Wh/kg on the cell level		Cell specifications		low			x					
3	C-Rate capability: 0.3C charge/0.5C discharge continuous		Cell specifications		high			x					
4	Sensor must be fully functional in the following temperature ranges: Temperature range test chamber for storage: -40 ° C to + 80 ° C Temperature range test chamber for cycling tests: -25 ° C to + 55 ° C. Max. Temperature of the cell core: chemistry-dependent, approx. + 80 ° C Max. Temperature of cell housing: chemistry-dependent, approx. + 60 ° C Max. Temperature of cell terminal: chemistry-dependent, approx. + 70 ° C	Sensor can be tested in dummy cells without active cell chemistry in the full temperature range.	Environmental condition		medium	x		x		x			x
5	Sensor must be functional in the cell (robust against different cell chemistry and pressure up to 2 N/mm² in a prismatic cell).	Stability to electrolyte and pressure can be tested separately.	Environmental condition	Defination of pressure value depends on cell	medium	x				x			x
6	It must be possible to connect cells up to 1000 V in series and up to 5p (prismatic cells) in parallel. A higher parallel connection is normal for cylindrical cells, which should be taken into account.	validation through concept design	Environmental condition		low	x	x			x	x		
7	The maximum number of intelligent cells in a pack could be up to 500 (prismatic) units. For cylindrical cells it is possible with a much higher number of cells	validation through concept design	Environmental condition		low	x	x			x	x		
8	Plating during fast charging need to be identified or estimated	Implemented as vitural sensor for battery monitoring	BMS Functions/Use case		high		x	x				x	x
9	In case of a standard fast charging process the cells should be charged from 10% to 80% SOC (based on the cell current capacity) with in the following time period. Following boundary conditions have to be considered: charging time 20 min. for cells with 200 wh/kg at 35°C starting temperature charging time 25 min. for cells with 250 wh/kg at 35°C starting temperature Target battery lifetime: 3F3N (3 fastcharging followed by 3 normal charging with CC 0.3C) 1800 cycle until 70% rest capacity	Applying the standard current (0.3C for charging and 0.5 C for discharging) for SOC adjustment. Performing cell individually optimized fast charging profile from SOC 10% to SOC 80% at 35°C test temperature. Repeat the fast charging cycle until the specified nummber of cycles hast been reached	BMS Functions/Use case		high	x	x	x					x
10	Cell state of charge (SoC) must be able to be determined with a frequency of 0.1 Hz and an accuracy of 2%.	Applying a driving cycle (provided by BMW) at defined temperatures [for example 40 ° C, 25 ° C, 10 ° C and 0 ° C, -10 ° C]. The cycle is stopped at certain time and the cell is discharged with a defined current (eg. 1/ 3C) until the end-of-discharge voltage is reached. The external temperature in climatic chamber remains the same during the driving cycle and the discharge. The reference state of charge can be compared with the estimated state of charge determined by the algorithm.	BMS Functions/Use case		high		x	x				x	x
11	The state of health must be available with an accuracy of 2% based on the nominal capacity.	Cells are applied with ageing test. The aging tests are interrupted every 50 cycles and, once thermal equilibrium has been reached, capacity test can be carried out at reference temperature. Cells are then loaded with an application-oriented current profile (consisting of discharge with driving profile, breaks and CCCV charging phases). The measured full discharge capacity can be compared with the capacity determined by the algorithm during the application load.	BMS Functions/Use case		high		x	x				x	x

12	Specification of battery power prediction: Maximum power for 1s: +/- 5% accuracy Maximum power for 10s: +/- 5% accuracy Continuous power for 30min: +/- 10% accuracy. The power prediction for charging and discharging must be available within a frequency of 200 Hz.	Cycle the cells with a driving cycle provided by BMW. At certain SOC [90%, 70%, 40%, 10% and 5%], the cycling is interrupted and a pulse test (discharge) is carried out. The tests can be carried out at different temperatures and with different current rates. In these cases operating limits were violated after x seconds during the pulse test and can be compared with the predicition with BMS algorithms.	BMS Functions/Use case		medium		x	x				x	x
13	Internal cell resistance (eg. 10s R_dc) should be estimated within accuracy of at least 10% based on the current value.	Applying a comparative measurement on the test bench. Measurement conditions are based on test specification including different SOCs [90%, 70%, 40%, 10% and 5%] are approached. After the relaxation, current pulses are performed. The measured value for R_dc 10s can be compared with the determined one by the algorithm. The tests can repeated at different	BMS Functions/Use case		high		x	x				x	x
14	Increased self-discharge due to cell ageing (> factor 5 vs. BOL value or reference cells) should be detected	Measurement of voltage loss and comparison with with BOL status or reference cell.	BMS Functions/Use case		low			x				x	x
15	The algorithm can be upscaled to a large pack system	Validation with mutliple cells with in a simulation test bench	BMS Functions/Use case		low							x	x
16	The cells with physical sensors should meet the requirements of safety tests with HL <= 4 and may not perform worse in safety tests than reference cells without sensors.	Carrying out the safety tests.	Safety	Safety tests defined in proposol in Task 5.4. (overcharging and overheating of the cells)	high	x		x			x		x
17	The state with "Cell outside the operating voltage limit" must be detected and recorded.	Applying overcharge and deep discharge test of the cell.	Safety		high			x			x		x
18	Cell internal short circuit must be detected and communicated within 50 ms during operation	Nailtest can be carried out to replace an internal short circuit. The short-circuit event must be	Safety		high			x			x		x
19	Cell external short circuit must be detected and communicated within 50 ms during operation	External short circuit test: The detection and communication of the short circuit event must take	Safety		low			x			x		x
20	Short circuits between the signals should not lead to dangerous situations		Safety		high	x				x			
21	Recording of the data/Measurement histogram per cell should be available.	Repeated execution of the specified driving cycle, reading out the signal histogram.	Demonstrator		high			x					x
22	A mixed configuration of cells should be possible.	validation through concept design	Demonstrator		low			x		x			
23	Cell-critical situations should be detected by sensors (physical or virtual), especially during operation	Abuse tests can be carried out. Sensors combined with algorithms should recognize	Demonstrator		high			x		x	x	x	x
24	Sensor signals should be brought together at a central point on the cell for further evaluation	Evaluation through implementation	Demonstrator		high			x		x	x		x
25	The data integrity must be ensured	Validation through sending incorrect values.	Demonstrator		medium			x					x
26	Line breaks, short circuits between signals and cells should be detectable during cell measurement.		Demonstrator		high			x					x
27	extended cycle life and calendaricing life for sensor cells and electric and electronic component are required. for example, 5000 cycle life and 20 years calendaring life till battery		second life application		medium								
Anfor	27												

SECRET

Anforderungsanzahl: 27