Test Report issued under the responsibility of:

TEST REPORT

VDE-AR-E 2510-50:2017-05

Stationary battery energy storage systems with lithium batteries – Safety requirements

Report Reference No. ..... :	SZES240100004301
Date of issue..... :	2024-09-09
Total number of pages	47 pages
Testing Laboratory ……..:	SGS-CSTC Standards Technical Services Co., Ltd. Shenzhen Branch
Testing location ……:	No. 1 Workshop, M-10, Middle Section, Science & Technology Park, Shenzhen, Guangdong, China
Tested by (name + signature)..... :	Penny Lin
Approved by (name + signature) :	Dean Wang
Applicant's name ..... :	NINGBO DEYE ESS TECHNOLOGY CO., LTD
Address ..... :	No.568, South Rixian Road, Binhai Economic Development Zone, Cixi, Ningbo, Zhejiang, China
Test specification:	
Standard..... :	VDE-AR-E 2510-50:2017-05
Test procedure..... :	SGS-CSTC
Non-standard test method……..:	N/A
Test Report Form No. ..... :	TR_VDE 2510_50_2017
Test Report Form(s) Originator..... :	SGS-CSTC
Master TRF..... :	Dated 2022-01

Test item description .....:	Rechargeable LiFePO4 Battery (Rechargeable Li-ion Battery System)
Trade Mark .....:	Deye
Manufacturer.....:	Same as applicant
Factory .....:	Same as applicant
Model/Type reference .....:	AI-W5.1, AI-W5.1-B

Product descriptions.....:	Rechargeable Li-ion Battery System
Model differences.....:	N/A
Electrical Ratings .....:	Battery module: 51.2 V, 100 Ah Operating voltage range: 43.2-57.6 Vdc Max. charging current: 100 A Max. discharging current: 100 A Charging Temperature range: 0°C – 55°C Discharging Temperature range: -20°C – 55°C
Remarks / special functions.....:	Based on the parallel connection of battery modules, a system with up to 6 battery modules can be formed. Please refer to table for detailed parameters

Specification of battery system			
Model	Scalability	Maximum charge/discharge current, A	Weight, kg
AI-W5.1	2	180	124
	3	210	177
	4	240	230
	5	250	283
	6	250	336
AI-W5.1-B	1	100	74,5
	2	180	127.5
	3	250	180.5
	4	250	233.5
	5	250	286.5
	6	250	339.5

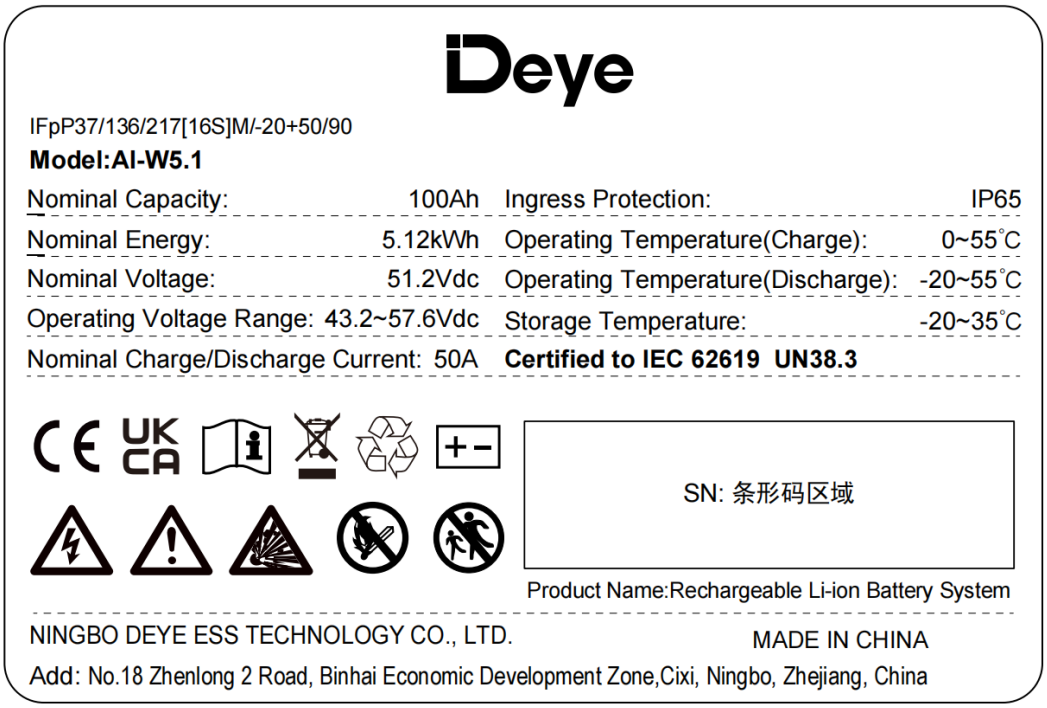
Specification for all models of battery system	
Rated capacity:	100 Ah
Rated voltage:	51.2 V
Max. charge voltage:	57.6 V
Discharge cut-off voltage:	43.2 V
Charge operating temperature:	0 to 55 °C
Specification of cell	
Model of component cell:	GSP34135214F
Rated voltage:	3.2 V
Rated capacity:	100 Ah
Maximum charge current:	120 A
Charge operating temperature:	0 to 60 °C

Sample tested:

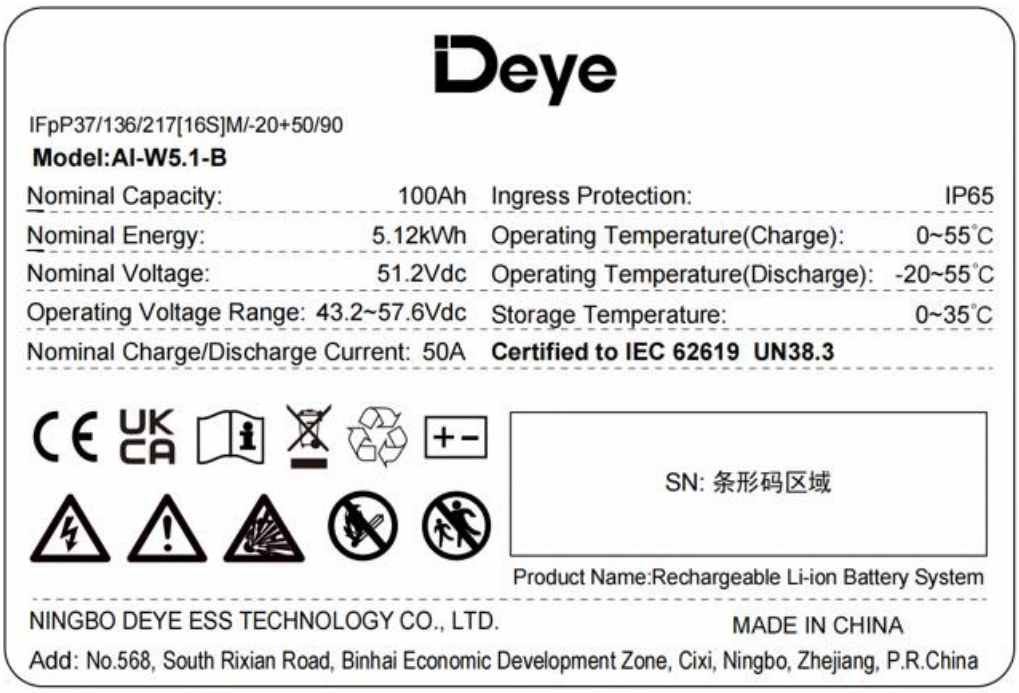
Remark: Also refer to appendix photo pages for details.

Copy of Marking plate

Label for Rechargeable Li-ion Battery System (For Model: AI-W5.1)



Label for Rechargeable Li-ion Battery System (For Model: AI-W5.1-B)

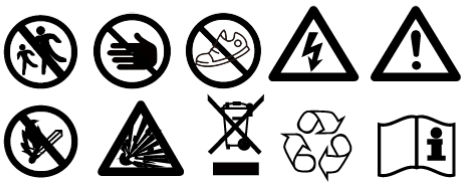


PDU (For Model: AI-W5.1)

Deye

Model:AI-W5.1-PDU1

Operating Voltage	40~60 Vdc
Nominal Current	250A
Operating Temperature	-20~55℃
Ingress Protection	IP65



SN: 条形码区域

Ningbo Deye ESS Technology Co.,Ltd. MADE IN CHINA

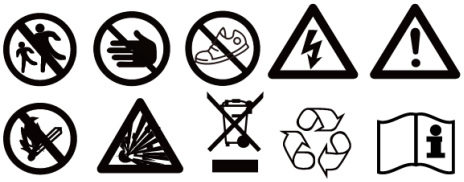
Add: No.18 Zhenlong 2 Road, Binhai Economic Development Zone,Cixi, Ningbo, Zhejiang, China

PDU (For Model: AI-W5.1-B)

Deye

Model:AI-W5.1-PDU1-B

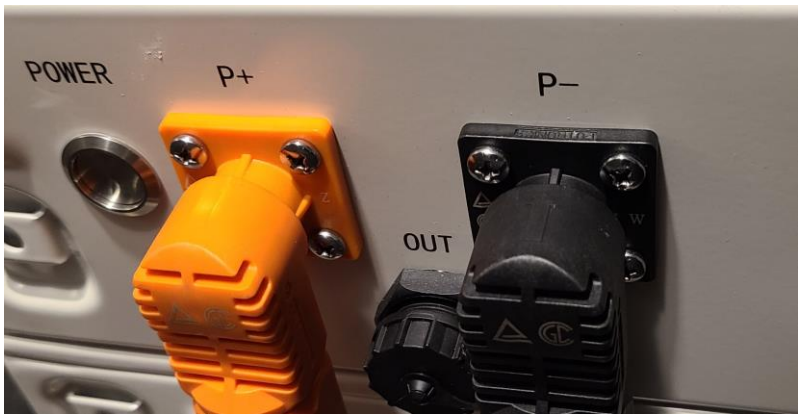
Operating Voltage	40~60 Vdc
Nominal Current	250A
Operating Temperature	-20~55℃
Ingress Protection	IP65



SN: 条形码区域

Ningbo DEYE ESS Technology Co.,Ltd. MADE IN CHINA

Add: No.568, South Rixian Road, Binhai Economic Development Zone, Cixi, Ningbo, Zhejiang, P.R.China



Remark:

The SN number “00701002AA141267” includes code for production date “AA14”, where the first A represents production year, the second A represents production month, and 14 represents production day. Specific coding rules are shown in the table below.

Year	A for year 2022, B for year 2023, ……, Z for year 2047
Month	1 for January, 2 for February, ……, A for October, B for November, C for December
Day	Exact day, 01 to 31

Critical components information:

Only following safety critical components were evaluated and/or tested, and were confirmed to comply with the standard requirements mentioned in this test report. Use of components not listed here may lead to non-compliance test results, and it's the sole responsibilities of the manufacturer to make sure all products should be produced in consistent way and only approved components can be used.

Object/part no.	Manufacturer/ trademark	Type/model	Technical data	Standard	Mark(s) of conformity
Cell	ZHUHAI GREAT POWER ENERGY CO., LTD.	GSP34135214F	Nominal Voltage: 3.2 Vdc Rated Capacity: 100 Ah	IEC 62619: 2017, EN 62619: 2017	TUV SUD (CB Report No.: 211-281930713-000, Certif. No.: SG PSB-BT-01731)
Protection IC(U22)	TEXAS INSTRUMENTS	IC TI BQ7695202PFBR	Overcharge Detection Voltage: 3.65 ± 0.005 V Over-discharge Detection Voltage: 2.7 ± 0.005 V Operating temperature range: -40~85°C	--	*
MCU(U8)	GigaDevice	IC GD GD32F305VET6 LQFP-100	Overcharge Detection Voltage: 3.6 ± 0.005 V Over-discharge Detection Voltage: 2.7 ± 0.005 V Operating temperature range: -40~85°C	--	*
MOSFET (Q44, Q45, Q48, Q49, Q52, Q51, Q53, Q54, Q57, Q58, Q62, Q63, Q66, Q67, Q73, Q74, Q64, Q65, Q68, Q69, Q77, Q78, Q81, Q82, Q60, Q61, Q71, Q72)	CRMICRO	CRSS042N10N	11 VDS: 100V VGS: ±20V ID: 110A RON: 3.6mΩ TJ: -55°C-150°C Tstg: -55°C-155°C	--	*
NTC	MURATA MFG CO LTD	NCU15XH103F6SRC	Resistance at 25°C: 10kΩ Tmax: 125°C	UL1434	UR (E137188)
-Alt.	Interchangeable	Interchangeable	Resistance at 25°C: 10kΩ Tmax: 125°C	UL1434	UR

PCB	Interchangeable	Interchangeable	Fire rating: V-0 Max temperature: 150 °C Min. thickness: 2 mm	UL796	UL
Heat shrinkable tubing	CHANGYUAN ELECTRONICS GROUP CO LTD	CB-HFT	Max Vrms: 600 Max Oper Temp: 125°C	UL224	UL (E180908)
Battery enclosure	NINGBO DEYE ESS TECHNOLOGY CO., LTD	SECC	Material: SECC Dimension: 1.5 mm	--	*
Lead wires (charge & discharge)	3Q WIRE & CABLE CO LTD	10269	4AWG Tmax: 105°C Vmax: 1000V	UL758	UL (E341104)
Alt.	3Q WIRE & CABLE CO LTD	10269	6AWG Tmax: 105°C Vmax: 1000V	UL758	UL (E341104)
Alt.	WUXI XINHONGYE WIRE & CABLE CO LTD	10269	4AWG Tmax: 105°C Vmax: 1000V	UL758	UL (E248566)
Alt.	WUXI XINHONGYE WIRE & CABLE CO LTD	10269	6AWG Tmax: 105°C Vmax: 1000V	UL758	UL (E248566)
Connector (For model No.: AI-W5.1)	CNNT	CHD-MX02-XXPXX CHD-MX02-XXRXX	Fire rating: V-0 Rated current: 250 A Rated voltage: 1000 V	IEC/ EN 61984	J 50573128
Connector (For model No.: AI-W5.1)	Shanghai Huzheng Electronic Technology Co.,Ltd	FSPC80180Q-70B4 FSPC80180P-70A4	V-0 Rated current: 250 A Rated voltage: 1500 V	IEC/ EN 61984	R 50475309
Connector (For model No.: AI-W5.1-B)	AVIC JONHON OPTRONIC TECHNOLOGY CO., LTD	DL17Z DL17T	V-0 Rated current: 150A Rated voltage: 120V	UL 1977	UL (E203642)
Connector (For model No.: AI-W5.1-B)	DEGSON TECHNOLOGY CO.,LTD.	ESS-250A-70-B/S-02 GH ESS-250A-70-B/S-OR-03 GH	V-0 Rated current: 25A A Rated voltage: 1500V	UL 4128	UL (E526028)

Fan	Shenzhenshi Yongyihao Electronic Co., Ltd.	YY6025H48W	Rated Current: 0.6 A, Rated Voltage: 60 V	IEC 60947-2	TÜV SÜD (Report No.: 682102012900 2)
Circuit breaker (For model No.: AI-W5.1-B)	Shanghai Liangxin Electrical Co., Ltd.	NDM3Z-250VM	Rated Current: 250 A, Rated Voltage: 1000 Vd.c. Rated Interruption Current:10kA	IEC 60947-2	TÜVRheinland (Cer. No.: R 50451893)
Circuit breaker (For model No.: AI-W5.1-B)	Shanghai Liangxin Electrical Co., Ltd.	NDB1-125 C125A/2P	Rated Current: 125 A Rated Voltage: 80 V	IEC 60947-2	TÜVRheinland (CB Cer. No.: CN219E1X 001, Report No.: 00901-CB2021CQC-099396)
Alt. (For model No.: AI-W5.1-B)	TENGEN	TGBG-125 2P	Rated Current: 125 A, Rated Voltage: 125 V	IEC 60947-2	TÜVRheinland (Cer. No.: R 50383310)
Relay (For model No.: AI-W5.1-B)	Ningbo Jinhai Electric Co., Ltd	HF157F/60-2Z25FDJ12	Rated Current: 10 A Rated Voltage: 60 Vd.c.	IEC 61810-1:2015	TÜVRheinland (Cer. No.: R 50403813)

* Tested with appliance

Summary of testing:

This test report shows that submitted sample(s) have been evaluated and tested to comply with applicable requirements in Stationary battery energy storage systems with lithium batteries – Safety requirements, VDE-AR-E 2510-50:2017-05.

No decision rule is specified by standard, when comparing the measurement result with the applicable limit according to the specification in that standard. The decisions on conformity are made without applying the measurement uncertainty ("simple acceptance" decision rule, previously known as "accuracy method").

Select a battery module as a representative, and all tests will be conducted on a separate battery module.

Attachment: --

Amendment history: None-

All test data are copied from original test report ref. No. SZES230200082601 dated 2023-04-17, with follow changes:

- **Addition of a new model No. 'AI-W5.1-B', which is identical with original model No. 'AI-W5.1' except for model No., trademark and internal structure.**
- **Add fan and circuit breaker in PDU, see attachment for detail;**
- **Add relay & circuit breaker in battery module, see critical components information for detail;**
- **Alt. connector for model No.: AI-W5.1-B, see critical components information for detail;**
- **Change address of applicant, factory and manufacturer to 'No.568, South Rixian Road, Binhai Economic Development Zone, Cixi, Ningbo, Zhejiang, China';**
- **Change of internal structure of battery module, PDU and base.**

All tests are considered on model RW-M6.1. After comparison, it is deemed necessary to conduct additional tests on the RW-M6.1-B according to cl 6.2.4.

Both models have the same battery cells and circuits, except for the layout, switches, and terminals.

Possible test case verdicts:	
- test case does not apply to the test object.....:	N/A
- test object does meet the requirement.....:	P (Pass)
- test object does not meet the requirement .....:	F (Fail)
Testing.....:	
Date of receipt of test item .....:	2023-02-14, 2024-01-02
Date (s) of performance of tests .....:	2023-02-14 to 2023-03-28, 2024-01-04 to 2024-02-29

General remarks:

The test results presented in this report relate only to the object tested.
This report shall not be reproduced, except in full, without the written approval of the Issuing testing laboratory.
"(see Enclosure #)" refers to additional information appended to the report.
"(see appended table)" refers to a table appended to the report.

Throughout this report a comma (point) is used as the decimal separator.

VDE 2510-50			
Clause	Requirement + Test	Result - Remark	Verdict
1	**Scope – product covered:**		—
	This VDE application guide specifies the safety requirements for stationary battery energy storage systems (BESS) with lithium batteries.		P
	The scope is limited to applications in private households and small businesses (except medical applications).		P
4	**Risk assessment and methodology for functional safety**		P
4.1	**Risk assessment**		P
	The manufacturer shall conduct a risk assessment of the BESS resulting in the following: a) **risk analysis:** detection and identification of hazards for all life cycle phases (production, storage, transport, installation, operation, maintenance, disassembly, recycling); and all system levels (system, pack, module, cell block, cell, cell material), resulting from as well as affecting the BESS; b) **risk evaluation:** determination of the severity and probability of the risk and assessment of the acceptability of the resulting level of risk; c) **risk reduction:** measures for reduction of unacceptable risks and verification of their effectiveness. Subsequently, the risk assessment process is repeated.		P
	The reliability of the implemented risk reduction measures shall meet the functional safety requirements.		P
	Functional safety requirements shall be assessed in accordance with at least one of the standards listed below: 1) IEC 61508 or 2) ISO 26262-2; 3) ISO 13849-1:2016-06; 4) IEC 62061:2005 + A1:2012 + A2:2015.	The functional safety requirement was evaluated according to ISO 13849-1 (SGS Report No. SZFS240100000101).	P
	Risks remaining after risk assessment shall be indicated in the instructions for the operator. Additionally, suitable information shall be given on how to control the remaining risks.		P
	Based on the system conditions and the risk assessment, the manufacturer shall define a safety integrity level for the safety critical components (HW/SW) and the BESS paths. The construction requirements resulting from the intended level shall be met.		P
4.2	**Requirements**		P
	The methodology and documentation of the risk assessment is evaluated to ensure that all risks are eliminated or reduced to an appropriate level. In addition to the mere documentation inspection, the risk reduction measures are verified under practical conditions. For this purpose, the constructional and functional safety shall be tested as follows.		P

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Clause	Requirement + Test	Result - Remark	Verdict
	Furthermore, risks or weak points identified as a result of functional safety considerations may lead to extended testing. This is intended to determine the hazard level and the verification of the safety of the BESS under practical conditions.		P
5	**General requirements**		P
5.1	**CE marking** When placing the BESS on the market, the manufacturer is obliged to observe the (German) Product Safety Act (de: Produktsicherheitsgesetz) which includes the CE marking. Verification is carried out by checking the EC conformity declaration of the manufacturer.		P
5.2	**Electromagnetic compatibility (EMC)**		P
	Compliance with the protection objectives regarding electromagnetic compatibility shall be demonstrated in accordance with the current European Directive. This can be achieved using the list of harmonized standards in the Official Journal of the European Union. Standards to be applied to BESS intended for household and business applications are, for example: – IEC 61000-6-1:2005; – IEC 61000-6-3:2006 + A1:2010.		P
5.3	**Low Voltage Directive (LVD)**	Device was considered to be out of LVD scope (voltage less than 75VDC)	N/A
	Compliance with the protection objectives of the current European Low Voltage Directive (LVD) shall be demonstrated. This can be achieved using the list of harmonized standards in the Official Journal of the European Union. Depending on the use and condition of the BESS and its installed components, these can be, for example: – IEC 62368-1:2014, mod. + Cor.:2015 – IEC 60529:1989 + A1:1999 + A2:2013.		N/A
5.4	**Inverter/converter**		N/A
	Where inverters and/or converters are components of a BESS, they shall conform to the following: – IEC 62109-1 or – IEC 62477-1.		N/A
5.5	**Grid integration**		N/A
	If the storage system is intended to be connected to the low voltage grid in Germany, reference shall be made to the following documents: a) VDE-AR-N 4105; b) VDE-AR-E 2510-2.		N/A
6	**Constructional safety requirements**		P
6.1	**General requirements**		P
	The following hazards (as shown in table 1) shall be considered in the construction of a BESS as a complete system:		P

VDE 2510-50			
Clause	Requirement + Test	Result - Remark	Verdict

	Table 1 – Test standards for compliance with the product safety requirements <table><tr><th>Hazard classes</th><th>DIN EN 62477-1 (VDE 0558-477-1)</th><th>DIN EN 62109-1 (VDE 0126-14-1) and DIN EN 62109-2 (VDE 0126-14-2)</th><th>DIN EN 61010-1</th></tr><tr><td>Electrical hazards</td><td>x</td><td rowspan="2">Part 1, Clause 7</td><td rowspan="2">Clause 6</td></tr><tr><td>Protection against electric shock</td><td>x</td></tr><tr><td>Mechanical hazards</td><td>x</td><td>Part 1, Clause 8, Part 1, Clause 13</td><td>Clause 7 8.2</td></tr><tr><td>Thermal hazards</td><td>x</td><td>Part 1, 4.3</td><td>Clause 10</td></tr><tr><td>Chemical hazards</td><td>x</td><td>Part 1, Clause 12</td><td>Clause 11</td></tr><tr><td>(Hazards due to radiation)</td><td>x</td><td>–</td><td>Clause 12</td></tr></table>		P
6.2	**Tests**		P
6.2.1	**General** Tests for which the number of test samples is not indicated shall be conducted using one test sample. The tests are type tests.		P
6.2.2	**Insulation resistance test**		N/A
6.2.2.1	**Test objective**		N/A
6.2.2.2	**Test procedure**		N/A
	Depending on the type and application of the BESS, the insulation resistance test is conducted as follows:		N/A
	1) testing at system level; 1.1) AC coupled systems shall be subjected to all-pole testing at the point of connection to the household grid according to DIN VDE 0100-600 (VDE 0100-600). During each test run (L/PE, N/PE, L/N), the complete current circuit between the connection point and the inverter is tested; any switching and disconnecting elements in the AC circuit shall be closed and fuses shall be put in place.		N/A
	1.2) DC coupled systems are tested as described in 1.1) with their switching and disconnecting elements closed and fuses in place, but with the following modification:		N/A
	When measuring the insulation resistance between the DC contacts and the protective conductor potential of the system, the polarity of the test voltage shall be observed.		N/A
	For measurements between the positive terminal of the battery and the ground, the negative terminal of the test equipment shall be connected to the positive terminal of the battery. The positive terminal of the test equipment is connected to the protective conductor potential of the battery accordingly (see Figure 1).		N/A

VDE 2510-50			
Clause	Requirement + Test	Result - Remark	Verdict
	For measurements between the negative terminal of the battery and the ground, on the other hand, the positive terminal of the test equipment shall be connected to the negative terminal of the battery. The negative terminal of the test equipment is connected to the protective conductor potential of the battery accordingly.		N/A
	For both tests, the complete current circuit between the connection point and the cells shall be tested.		N/A
	For the purpose of testing between the positive and the negative terminal, the current circuit shall be disconnected at the point closest to the cells by means of the dedicated switching, disconnecting or fuse elements (in order to ensure that the test voltage is not applied to the cells).		N/A
	1.3) Hybrid systems provided with AC and DC charging/discharging interfaces shall be tested in accordance with 1.1) on the AC side and with 1.2) on the DC side.		N/A
	2) testing conducted at pack and module levels; The insulation resistance of systems with a modular structure where subcomponents are DC coupled and disconnected from the system for installation, maintenance, transport or disassembly purposes is tested in accordance with 1.2).		N/A
	For all tests, the voltage level depends on the equipment under test (according to Table 3) with a minimum value of 500 V DC.		N/A
6.2.2.3	**Requirements**		N/A
	For all measurements, an insulation resistance of at least 100 Ω/V in relation to the final charge voltage of the battery shall be reached. The level of the relative and the absolute value of insulation resistance as well as the tested measurement path shall be documented. The leakage current shall not exceed 10 mA.		N/A
	Where systems are provided with an insulation monitor, it shall be disconnected during testing. Alternatively, external testing of the insulation resistance may be conducted during the dead times while the insulation monitor is not taking any measurements.		N/A
6.2.3	**Dielectric strength test**		N/A
6.2.3.1	**Purpose** Testing is only required for test objects rated as dangerous to touch both during normal operation and in case of a single fault of the disconnecting element in accordance with DIN EN 61010-1 (VDE 0411-1), 6.3.		N/A
6.2.3.2	**Test procedure**		N/A
	First, the insulation resistance test shall be conducted.		N/A

VDE 2510-50			
Clause	Requirement + Test	Result - Remark	Verdict
	This shall be followed by the dielectric strength test. The level of the test voltages is determined by: – the altitude of the BESS: according to the manufacturer's specification; – the pollution degree: according to the manufacturer's specification; – the overvoltage category: depending on the type of inverter (if provided) and on the possible DC connection of supplies (e.g. PV); – the operating voltage of the equipment under test: according to the manufacturer's specification; – the degree of insulation (basic insulation or double/reinforced insulation).		N/A
	Electrical circuits where an AC test voltage may lead to damage of components (e.g. Y capacities) shall be tested using DC voltage. This is calculated as: $\hat{u} = \sqrt{2} \times U_{\mathbf{eff}}$		N/A
	Table 2 gives the applicable insulation requirements (basic insulation B or double/reinforced insulation V/D). These shall be specified subject to the electrical properties of the respective circuits (SELV or supplied by the mains voltage circuit). The specified insulation properties (B or V/D) then determine the level of test voltage to be used for the dielectric strength test as shown in Table 3.		N/A
	After the dielectric strength test is completed, the insulation resistance measurement shall be repeated. The test voltages shall be determined in accordance with the applicable product safety standard. If differing test voltages are derived, the higher value shall be applied.		N/A
6.2.3.3	**Requirements** After conduction of each test, the compliance criteria in accordance with the applied relevant standard shall be met.		N/A
6.2.4	**Internal short-circuit (propagation test)**		P
6.2.4.1	**Purpose** Objective of the test is to verify that the effects of the propagation of hazardous cell reactions to adjacent surrounding cells or components are limited by design.		P
	Verification shall be conducted by propagation testing in accordance with Figure 2 which is evaluated according to the type of BESS		P
6.2.4.2	**Test procedure**		P
	a) Test object: For the propagation test procedure, it is recommended to start the examination of propagation behavior at a lower level of the system (module, cell block) and if the test is failed, to repeat the test at successively higher levels of the system (see Figure 3).		N/A
	Alternatively, the test may be conducted directly at system level (or at the level of a representative system comprising at least two modules).		P

VDE 2510-50			
Clause	Requirement + Test	Result - Remark	Verdict
	For both options, a cell within a cell collective (serially or parallel-connected cells) shall be manipulated such as to induce thermal instability and to cause a cell reaction. Testing shall be conducted at a maximum operating temperature of the cell within the system and a final charge voltage within the operating range.		P
	b) Procedure: The following procedures are available: 1) overcharging; 2) overheating; 3) short-circuiting (short-circuit resistance ≤ 5 mΩ); 4) overvoltage impulses leading to internal short-circuits; 5) testing by means of a nail; or 6) other procedures recommended by the cell manufacturer.	Overheating method	P
	c) Measurement methods: The propagation of the reaction of a manipulated cell shall be metrologically recorded. Thermal effects shall be measured by means of additional temperature sensors according to the respective test level which shall be applied to adjacent cells or higher levels of the system. Venting processes or electrolyte leakage can be determined by means of weight comparisons (before/after) or (thermographic) video recordings during the test run.		P
	d) End of test: The test ends when no more cell reactions occur, any resulting propagation effects are completed and further changes of the test result are not to be expected.		P
6.2.4.3	**Requirements**		P
	Depending on the type of the BESS, different passing criteria apply: – single solutions (small storage systems with a single closed case for cell blocks and higher-level system components); – stackable BESS (systems with their modules stacked directly on top of or directly beside one another, see 6.2.6. The results of both options shall be taken into account in the risk evaluation. If applicable, further measures for minimizing risk shall be derived from this and verified.	Single pack	P
6.2.5	**Propagation test: single solutions**		P
6.2.5.1	**Purpose** In case of single solutions, type related propagation of the cell defects described in 6.2.4 to adjacent cells, components or the system cannot be precluded. In case of burning of the cell or the storage system, the fire shall not propagate to the surrounding environment.		P
6.2.5.2	**Test procedure** Testing shall be conducted according to 6.2.4.		P

VDE 2510-50			
Clause	Requirement + Test	Result - Remark	Verdict
6.2.5.3	**Requirements** Component verification: For the purpose of fire protection, each single module shall be equipped with a fire protection enclosure in accordance with DIN EN 62368-1 (VDE 0868-1), M 4.3, 6.4.8. The fire protection enclosure may be the secondary lithium battery itself or that of the device in which the secondary lithium battery is contained.	Metal enclosure was used	P
	The presence of this fire protection enclosure shall be demonstrated by means of the test report, by visual inspection of the relevant materials or by submitting the data sheet of the secondary lithium battery.		P
	Test verification: Hazards (liquid electrolyte, fire, explosion or ejected parts) shall not propagate beyond the system boundaries (except vented gases which are considered separately in 7.10.3).		P
6.2.6	**Propagation test: stackable BESS**		N/A
	6.2.6.1 Purpose For stackable solutions, hazards as described in 6.2.4 shall be limited to a permissible area. Cell defects shall propagate neither from module to module nor from module to system level.	Single pack	N/A
6.2.6.2	**Test procedure** Testing shall be conducted according to 6.2.4.		N/A
6.2.6.3	**Requirements** Component verification: For the purpose of fire protection, each single module shall be equipped with a fire protection enclosure in accordance with DIN EN 62368-1 (VDE 0868-1), M 4.3, 6.4.8. The fire protection enclosure may be the one of the secondary lithium battery itself or that of the device in which it is contained.		N/A
	The presence of this fire protection enclosure shall be demonstrated by means of the test report or visual inspection of the relevant materials or by submitting the data sheet of the secondary lithium battery.		N/A
	Test verification: – Cell defects shall only propagate within the module in which the thermal instability of the cell was intentionally caused. – A propagation from this module to an adjacent module shall be precluded by testing (see above). – Hazards (liquid electrolyte, fire, explosion or ejected parts) shall not propagate beyond the system boundaries (except vented gases which are considered separately in 7.10.3).		N/A
7	**Functional safety requirements**		P
7.1	**Battery management system (BMS)**		P
	For safety reasons, the battery management system (BMS) shall ensure compliance with the permissible operating range of the cell. This requires the monitoring of at least the following parameters: 1) voltage of each cell/cell block; 2) current of the battery system; 3) temperature of the cells.		P

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Clause	Requirement + Test	Result - Remark	Verdict
	The function of monitoring the parameters can be represented in the BMS by software, hardware or a combination of the two.		P
	Whenever a malfunction of the BMS occurs or the operating range of the cell is exceeded, the BMS shall switch the battery or the entire BESS into a safe state.		P
	The safety-related functions of the BMS shall be implemented such that, even under single fault conditions, the BESS switches into a safe state.		P
	Conformity shall be demonstrated by conducting the following tests in accordance with 7.3 to 7.10.		P
7.2	**Software requirements** Where safety-related functions are represented in the BMS entirely by software-based functions, the software shall be designed as safety-related software. This requires compliance with the requirements described in Clause 4. Where application specific standards exist, they shall be applied.		P
7.3	**Plausibility of voltage measurement**		P
7.3.1	**Purpose** The uncertainty of the BMS voltage measurement resulting from the test shall be taken into account for the evaluation of subsequent tests.		P
7.3.2	**Test procedure** For carrying out the test, the battery system shall be set to its normal operating condition at room temperature (BMS active, charge/discharge circuit closed). Afterwards, the following measured voltage values shall be recorded simultaneously: – voltage of three cells, randomly (BMS, test rig); or – voltage of three cell blocks, randomly (BMS, test rig).		P
7.3.3	**Requirements** The following parameters shall be documented: – uncertainty of the BMS cell/cell block voltage measurement; – measurement uncertainty of the calibrated test rig.		P
	The determined uncertainties shall be taken into account in the subsequent tests (for voltage-relevant requirements).		P
7.4	**Detection of non-disconnectable switching elements**		P
7.4.1	**Purpose** The test is used to check the function for detection of defective (non-disconnectable) switching elements such as electromechanical disconnecting elements or semiconductors.		P
7.4.2	**Test procedure**		P
	For carrying out the test, the battery system shall be set to its normal operating condition at room temperature (BMS active, charge/discharge circuit closed). The following test is divided into two steps:		P

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Clause	Requirement + Test	Result - Remark	Verdict
	1) simulation of non-disconnectable switching elements under conditions of disconnection under load: With the charge/discharge circuit in the closed condition, a switching element within the charge/discharge circuit is manipulated (simulation of adhering contactor or continuous semiconductor). By means of an external command or a fault simulation, the BMS shall be manipulated to interrupt the DC load circuit. During this, bypassing of the manipulated switching element shall be detected and the load circuit shall be interrupted by the next element of the safety chain. Redundancy shall also be ensured if the redundant switching element is installed externally and triggered via communication paths. Communication faults are dealt with in accordance with 7.10.		P
	2) Switching-on in the presence of a non-disconnectable switching element: A previously simulated fault leading to opening of the redundant switching element is now reset/eliminated. As a result, the BMS shall be requested again to close the switching elements. The test ends when no further change of the switching condition is to be expected.		P
7.4.3	**Requirements** If a fault under load occurs, the BESS shall interrupt the charging/discharging process by means of the next higher or an equal disconnecting element of the safety chain.		P
	Disconnecting elements which are externally triggered by the BESS via communication paths shall also be effective in case of a failure of the communication path (see 7.10.1).		P
	The BESS shall prevent automatic reconnection of the charge/discharge circuit in the presence of a nondisconnectable disconnecting element.		P
	The BESS shall not switch on again unless a skilled person has been consulted and the fault has been eliminated.		P
7.5	**Open-circuit detection of sensing line**		P
7.5.1	**Purpose** The test is used to check the correct function of the open-circuit detection of sensing lines.		P
7.5.2	**Test procedure** For carrying out the test, the battery system shall be set to its normal operating condition at room temperature (BMS active, charge/discharge circuit closed). Then, an exemplary interruption shall be simulated in the sensing lines dedicated to the following functions: 1) voltage measurement on cell/cell block; 2) current measurement; 3) temperature measurement.		P

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Clause	Requirement + Test	Result - Remark	Verdict
	After interruption of the sensing line and the resulting reaction of the BESS, the simulated fault shall be eliminated and the BESS reset to its initial condition. The test shall be repeated for each of the functions listed above.		P
7.5.3	**Requirements** The BMS shall interrupt the load circuit in time before the operating range of the cell is exceeded.		P
7.6	**Checking the interlocking function for lockout**	Interlock function was not used	N/A
	The interlocking function check is conducted and evaluated at system level in accordance with DIN EN 62040-1 (VDE 0558-510), 5.6.		N/A
7.7	**Functional test for load reduction (derating)**		P
7.7.1	**Purpose** For the safe operation of the battery system, it shall be ensured at all times that the operating range of the cell indicated by its manufacturer is not exceeded. The objective of the following test is to check the correct function of the BMS in reducing the load during normal operation.		P
	The objective is to demonstrate compliance with the threshold values for load reduction in the charge/discharge direction in relation to temperature and time as defined by the cell manufacturer.		P
7.7.2	**Test procedure** Prior to the test, the battery system is stored at room temperature for at least 12 h. Subsequently, the storage system shall be set to its normal operating condition and subjected to a current profile which represents a charging and discharging process under maximum load. During this, the test rig simulates the control behavior of a charge controller/inverter for the BMS. The inverter incorporated in the system may be alternatively used as a power source/sink.		P
	Possible ways of checking the current and voltage limits at different cell temperatures are as follows: – software simulation of temperature values; – hardware simulation of temperature values (e.g. by replacing existing temperature sensors with potentiometers or equivalent); – checking the limit values at the respective ambient temperatures following a homogenization period of at least 12 h with the BMS in the inactive condition.		P
	Throughout the duration of the test, the following measured values shall be recorded: – battery voltage upstream/downstream of fuse links or disconnecting devices (BMS), if applicable; – battery voltage downstream of the disconnecting elements (test rig); – overall battery current (test rig, BMS); – single cell voltages (BMS)/cell block voltages (BMS); – temperatures (BMS, test rig).		P

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Clause	Requirement + Test	Result - Remark	Verdict
7.7.3	**Requirements** For carrying out the test, it is assumed that a specification of the cell is provided by its manufacturer. This shall contain at least information on the following properties: – constant charge/discharge current (/const,chr, /const,dchr); – charge/discharge current as a function of time (/chr(t), /dchr(t)); – charge/discharge current as a function of temperature (/chr(T), /dchr(T)).		P
	In addition, the following requirements shall be met: – measurement and documentation of the numerical values and the recording rate for battery voltage, battery current, single cell voltages (or cell block voltage) and temperatures of the equipment under test;		P
	– the battery system shall not exceed at any point of the current profile the operating range of the cell defined by its manufacturer.		P
7.8	**Functional test with exceeding the operating range limits**		P
	For the safe operation of the battery system, it shall be ensured at all times that the operating range of the cell indicated by its manufacturer is not exceeded. The following tests shall be used to check the BMS for its correct function and reaction in case a fault of a charger/inverter occurs.		P
7.8.1	**Checking the voltage monitoring under conditions of overcharge**		P
7.8.1.1	**Purpose** Overcharging beyond the permissible final charge voltage of the cell shall be prevented. The following test shall be used to demonstrate that the BESS already interrupts the charging process even before the operating range limit of the cell is exceeded.		P
7.8.1.2	**Test procedure** The test for monitoring the voltage of the system under conditions of induced overcharge shall be conducted in accordance with E DIN EN 62619 (VDE 0510-39):2014-04, 9.2.2.		P
7.8.1.3	**Requirements**		P
	In addition to the requirements described in DIN EN 62619 (VDE 0510-39), the following applies: – the BESS shall interrupt the charging process at the latest when the maximum cell voltage is reached; – the following values shall be used for the evaluation: 1) the final charge voltage specified by the cell manufacturer; 2) the maximum cell voltage determined by the BMS at the point of the charging process being interrupted by opening of the charge/discharge circuit; 3) the measurement uncertainty of the BMS determined according to 7.1.		P
7.8.2	**Checking the voltage monitoring under conditions of deep/forced discharge**		P

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Clause	Requirement + Test	Result - Remark	Verdict
7.8.2.1	**Purpose** The test shall be used to check the behavior of the battery system in case of exceeding the minimum cell voltage defined by the cell manufacturer. Distinction is made between the following two cases: 1) deep discharge: one or more cell voltages (OCV) drop below a minimum permissible value without discharge by means of a charger/inverter (e.g. self-discharge); 2) forced discharge: one or more cell voltages (CCV) drop below a minimum permissible value when the discharge amount is exceeded by the charger/inverter (e.g. communication fault between BMS and inverter).		P
7.8.2.2	**Test procedure**		P
	When conducting the test, the battery system is discharged to the final discharge voltage and then set to its normal operating condition (BMS active, charge/discharge circuit closed) at room temperature. Next, the voltage change of a cell shall be simulated. This can be achieved by software simulation or by electrical tapping of the single cell voltage measurement. In both cases, a uniformly decreasing single cell voltage is simulated to the BMS.		P
	The voltage characteristic starts with the measured actual cell voltage before the test. Then, the voltage shall be decreased successively until a reaction of the BMS occurs. The voltage change is stopped, when, due to the opening of the charge/discharge circuit, the battery system automatically opens the load circuit or the lower limit of the cell voltage is exceeded by more than 10 %.		P
	If automatic shutdown does not occur when the minimum cell voltage is exceeded, the test is to be considered as failed and is terminated. If the system shutdown occurs at the latest when the minimum cell voltage is reached, the test is continued.		P
	The manipulated cell voltage is then increased uniformly to 10 % more than its minimum value. When the value returns to within the operating range of the cell, the charge/discharge circuit shall remain open (no automatic restart).		P
	Throughout the test duration, the following measured values shall be recorded: – battery voltage upstream and downstream of the disconnecting elements/devices (BMS); – battery voltage downstream of the disconnecting elements (test rig); – single cell voltages (BMS, including the voltage of the simulated/manipulated cell).		P
	7.8.2.3 Requirements		P
	The values indicated in the test procedure shall be measured and documented.		P

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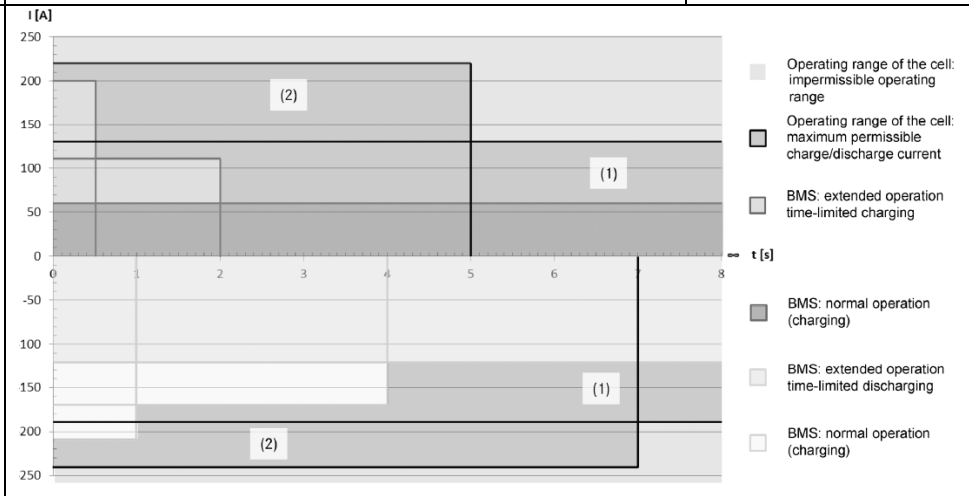
Clause	Requirement + Test	Result - Remark	Verdict
	Interruption of the imaginary discharging process shall be ensured by automatically opening the charge/discharge circuit (e.g. disconnecting elements) at the latest when the minimum final discharge voltage of the cell defined by its manufacturer is exceeded.		P
	Furthermore, the manufacturer shall provide technical measures to ensure that a restart requires consultation of a skilled person.		P
7.8.3	**Checking the current monitoring**		P
7.8.3.1	**Purpose** The BESS shall prevent that the maximum permissible charge/discharge current of a cell is exceeded. The following test shall demonstrate the functionality of current monitoring used by the BESS to interrupt the charging/discharging process even before the safe operating range limits of the cell are exceeded.		P
7.8.3.2	**Test procedure** The BESS is connected to the DC side of the test rig. The test rig shall simulate a malfunction of the inverter/charger during the charging and discharging process. During this, the maximum current permitted by the BMS shall be exceeded for one representative charging and discharging process.		P
	It is assumed that the operating range limits of the BMS are set lower than those of the cell. Therefore, if the operating range permitted by the BMS is exceeded, the charge/discharge circuit shall be opened before the limits of the cell are exceeded. – charging/discharging procedure: The procedure for charging/discharging with overcurrent shall correspond to the operating ranges of the BMS and the cell.		P
	 **Figure 4 – Example of safe operating limits of BMS and cell at room temperature**		P

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Clause	Requirement + Test	Result - Remark	Verdict
	This results in the following test options (figure 4): a) checking the current monitoring within the permanently permissible range of charge/discharge current (1): Following the preconditioning (discharging to the final discharge voltage), the BESS is first charged/discharged with a current 5 % lower than the maximum nominal current of the BMS. Then, the charge/discharge current shall be gradually increased (e.g. dI/dt = 0,5 A/s) until the BMS interferes by opening the charge/discharge circuit or the operating range of the cell is exceeded.		P
	b) checking the current monitoring within the time-limited charge/discharge current range (2): Following the preconditioning (charging to the final charge voltage), the system shall be charged/discharged with a current 5 % lower than the maximum nominal current of the BMS until the BMS interferes by opening the charge/discharge circuit or the operating range of the cell is exceeded.		P
	Throughout the duration of the tests, at least the following values shall be measured and recorded: – battery current (test rig, BMS); – BMS signals for performance control (addressed to test rig); – temperatures (BMS, test rig).		P
7.8.3.3	**Requirements** The BMS shall open the charge/discharge circuit in both the charging and the discharging case at the latest when the safe operating range of the cell is exceeded.		P
7.8.4	**Checking the temperature monitoring under conditions of an excessively high temperature**		P
7.8.4.1	**Purpose** The test shall be used to check the reaction of the battery system in case the maximum operating temperature defined by the manufacturer is exceeded.		P
7.8.4.2	**Test procedure** The maximum operating temperature of the BESS is determined by the maximum cell temperature defined by the manufacturer at which the cell is still free of safety-critical damages. $T_{\text{max, cell, Betrieb}} \geq T_{\text{max, system, Betrieb}}$ The corresponding lower temperature shall be used as the test temperature.		P
	With the BMS in the inactive condition, the battery system is preconditioned to the test temperature minus 5 K for at least 12 h.		P
	Then, the system shall be set to its normal operating condition (BMS active, charge/discharge circuit closed) and a temperature profile shall be applied. For this purpose, the ambient temperature of the storage system shall be heated gradually at a rate of 1 K/h until the test temperature is exceeded.		P

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Clause	Requirement + Test	Result - Remark	Verdict
	Throughout the duration of the tests, the following measured values shall be recorded: – battery voltage upstream and downstream of the disconnecting elements or devices (BMS); – battery voltage downstream of the disconnecting elements (test rig); – single cell voltages/cell block voltages (BMS); – temperatures (BMS, test rig).		P
7.8.4.3	**Requirements**		P
	The values indicated in the test procedure shall be measured and documented.		P
	The system shall automatically stop the charging/discharging process at the latest when the maximum temperature for safe operation of the cell is exceeded. The ambient temperature measured by the test rig shall be used as the parameter for evaluating the temperature threshold for disconnection.		P
	Even in case of a communication fault or of a malfunction of the charger/inverter, it shall be ensured that the battery system is disconnected in time.		P
	After the first time the temperature exceeds the maximum cell temperature and falls below it, the system shall not automatically restart.		P
	Restart of the battery system shall require consultation of a skilled person.		P
7.8.5	**Checking the temperature monitoring under conditions of excessively low temperature**		P
7.8.5.1	**Purpose** The test shall be used to check the reaction of the battery system in case the minimum temperature of the system defined by the manufacturer is exceeded.		P
7.8.5.2	**Test procedure** For this purpose, the minimum system temperature depends on the minimum cell temperature for safe operation defined by the manufacturer. $T_{\text{min, cell, Betrieb}} \geq T_{\text{min, system, Betrieb}}$ The corresponding higher temperature shall be used as the test temperature.		P
	Two methods may be applied for testing:		P
	a) Actual ambient temperatures: With the BMS in the inactive condition, the battery system is preconditioned to test temperature plus 5 K for at least 12 h. Then, the system shall be set to its normal operating condition (BMS active, charge/discharge circuit closed) and a temperature profile shall be applied. For this purpose, the ambient temperature of the storage system shall be cooled gradually below the test temperature at a rate of 1 K/h.		P

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Clause	Requirement + Test	Result - Remark	Verdict
	Throughout the duration of the tests, the following measured values shall be recorded: • battery voltage upstream and downstream of the disconnecting elements or devices (BMS); • battery voltage downstream of the disconnecting elements (test rig); • single cell voltages (BMS); • temperatures (BMS, test rig).		P
	b) Simulated ambient temperatures: As an alternative to method a), the actual ambient temperatures of the climatic chamber are replaced by: • manipulation of the temperature sensors of the BESS; • software simulation; • other procedures.		N/A
7.8.5.3	**Requirements**		P
	The values indicated in the test procedure shall be measured and documented.		
	The system shall automatically interrupt the charge/discharge circuit at the latest when the minimum temperature for safe operation of the cell is exceeded. The ambient temperature measured by the test rig shall be used as the parameter for evaluating the temperature threshold for disconnection.		P
	In case of a communication fault or of a malfunction of the charger/inverter, it shall also be ensured that the battery system is disconnected in time.		P
7.9	**Checking the BMS measurands**		P
7.9.1	**Checking the current measurement**		P
7.9.1.1	**Purpose** The test shall be used to check the accuracy of the system-integrated current measurement sensors. The BMS measurement method for determining the current is to be checked in combination with the charger.		P
7.9.1.2	**Test procedure** The current profiles recorded in accordance with 7.7 shall be used to check the current measurements. For this purpose, the measurement deviation is evaluated with respect to the measurement paths: – overall battery current measured by the test rig (calibrated); – overall battery current measured by the BMS.		P
	In order to check the plausibility of current measurements in combination with the inverter, representative charging/discharging of the BESS (or a module) with 1C is carried out. The plausibility of the current measurement shall be checked with respect to the measurement paths: – overall battery current measured by the test rig via shunt (measurement resistance, calibrated); – overall battery current measured by the BMS.		P
7.9.1.3	**Requirements**		P

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Clause	Requirement + Test	Result - Remark	Verdict
	By measuring the current including associated tolerances, it shall be ensured that the maximum permissible current of the components under load is not exceeded at any time (including ripple currents (information provided by the manufacturer)).		P
	The BMS shall use an appropriate measurement method (sampling rate, calculation) to measure the charger currents with sufficient accuracy in order to ensure that the maximum permissible current of the components under load is not exceeded at any time (including ripple currents (information provided by the manufacturer)).		P
7.9.2	**Checking the temperature measurement**		P
7.9.2.1	**Purpose** The test shall be used to check the accuracy and function of the system-integrated temperature measurement (sensory equipment and temperature models, if any).		P
7.9.2.2	**Test procedure** Plausibility of the temperature measurement is checked in two steps:		P
	1) First, the uncertainty of the system-integrated temperature measurement shall be evaluated in relation to the temperature values measured by the test rig using the temperature profiles described in 7.8.4 and 7.8.5. The measurements are conducted after the preconditioning period of 12 h.		P
	The measurement uncertainty shall be calculated with respect to the measurement paths: a) temperatures (at all system levels, as applicable) measured by the BMS; b) ambient temperature of the equipment under test measured by the test rig (calibrated); c) temperature of the equipment under test measured by the test rig (calibrated);		P
	2) Secondly, the dynamic recording of the internal temperature measurement values is evaluated (thermal coupling of sensors with the components to be measured or dynamic characteristics of the temperature measurement circuit). The required thermal behavior of the battery shall be derived from the test described in 7.7. This requires thermal preconditioning of the system which is then subjected to a current profile leading to, for example, overheating of the cells. The measurement uncertainty shall be calculated with respect to the two measurement paths: a) temperatures (at all system levels, as applicable) measured by the BMS; b) temperature of the equipment under test measured by the test rig (calibrated);		P
	The equipment under test shall be prepared for both steps of the procedure.		P

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Clause	Requirement + Test	Result - Remark	Verdict
	Test rig sensors shall be positioned in the direct vicinity of the temperature measurement sensors installed by the manufacturer (Step 1): verification of measurement uncertainty.		P
	In addition, the test rig shall be able to determine temperatures of temperature-critical components, e.g. cells under load (Step 2): dynamic recording of measurement values. In this case, it shall be ensured that measuring points are positioned primarily in component assemblies (e.g. cell blocks) where higher temperature rises may occur (e.g. due to accumulation/build-up of heat).		P
	On components forming a temperature gradient across the component body, the point of the highest temperature shall be determined as the measurement point. The point of the highest temperature can be determined by such means as thermography.		P
7.9.2.3	**Requirements** The tolerances for BMS temperature measurements determined in Step 1 shall be taken into account when evaluating the functionality of the BMS (7.7).		P
	Step 2 shall demonstrate that the position and mechanical connection of the internal temperature sensors enable sufficiently accurate determination of temperature-critical components. For this purpose, the temperatures of safety-critical components shall always be correctly determined even when they are under electrical load. This means that the values measured by the BMS shall be within the operating range of the cell while taking into account the tolerance derived from Step 1.		P
7.10	**Reaction to failure of components or communication**		P
	A malfunction may lead to failure of safety-critical components such as: a) inverter/charger; b) BMS; c) safety controller (redundant BMS or monitoring unit); d) CSC (cell supervising circuit).		P
	Besides any implausible signals, failure of communication between the listed components shall also be considered.		P
	The safety-related functions of the BESS shall be implemented such that the BESS also switches into a safe state even in a condition of failure of listed components and of the communication between components.		P
	The following tests are used to demonstrate conformity.		P
7.10.1	**Communication failure**		P

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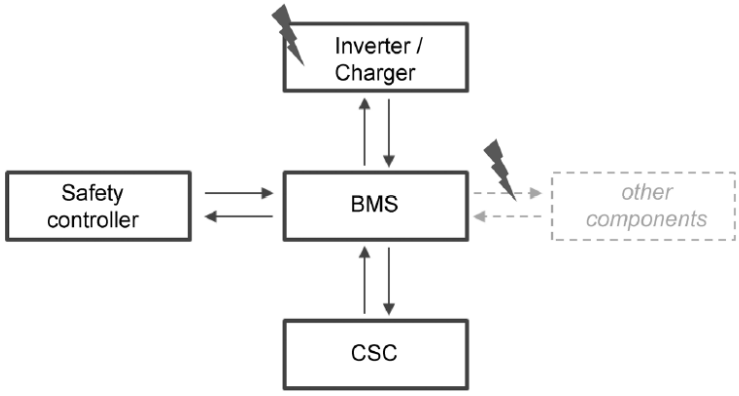
Clause	Requirement + Test	Result - Remark	Verdict
7.10.1.1	**Purpose** Failure of communication between two components representing safety-related functions by their interaction for measuring, controlling or regulating purposes shall not lead to an unsafe state. This also applies to the communication with components intended to be connected to and used with the BESS (e.g. connection of the BESS to already existing inverters/chargers).		P
7.10.1.2	**Test procedure**		P
	Example: BMS <> inverter/charger For carrying out the test, the battery system shall be set to its normal operating condition at room temperature (BMS active, charge/discharge circuit closed). Then, the BESS shall be charged/discharged. This can be achieved by using the dedicated inverter/charger. Alternatively, the BESS can be charged/discharged by using a test rig simulating the behavior of either the dedicated or any suitable inverter/charger by means of software.		P
	During loading, a failure of the communication between the BMS and the inverter/charger shall be induced (e.g. by hardware-induced disconnection of the communications paths). The test shall be stopped as soon as the BESS interrupts the charging/discharging process by opening the charge/discharge circuit or, at the latest, when the permissible operating range limits of the BESS are exceeded.		P
	In case the BESS interrupts the current flow due to the operating range of the BESS being exceeded, communication with the inverter/charger is restored. The charging/discharging process shall be continued by means of the test rig for a further 30 s. Then, the test is completed. The test shall be repeated with the safety-related communication paths mentioned in 7.10 as shown in Figure 5.		P
	 **Figure 5 – Example illustrating safety-related components and communication paths within the BESS**		P
7.10.1.3	**Requirements**		P
	The communication connections shall meet the safety requirements in accordance with the safety class specified in the risk analysis.		P

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Clause	Requirement + Test	Result - Remark	Verdict
	In case of a safety-related communication failure, the BESS shall interrupt charging/discharging processes by opening the charge/discharge circuit at the latest when the permissible operating range limits are exceeded.		P
7.10.2	**Component failure**		P
7.10.2.1	**Purpose** Failure of a component representing safety-related functions by measuring, controlling or regulating shall not lead to an unsafe state. This also applies to components intended to be connected to and used with the BESS (e.g. connection of the BESS to an already existing inverter/charger).		P
7.10.2.2	**Test procedure**		P
	Example: BMS <> inverter/charger For carrying out the test, the battery system shall be set to its normal operating condition at room temperature (BMS active, charge/discharge circuit closed). Then, the BESS shall be charged/discharged. This can be achieved by using the dedicated inverter/charger. Alternatively, the BESS can be charged/discharged by using a test rig simulating the behavior of either the dedicated or any suitable inverter/charger by means of software.		P
	During loading, a failure of the BMS shall be simulated.		P
	An appropriate method shall be chosen which results in a reversible failure of the BMS (overheating of BMS IC, temporary overvoltage at supply voltage of BMS IC, shutdown/disturbance of BMS clock/heartbeat, etc.)		P
	Besides the methods listed above, other scenarios are possible in which the function of only the BMS is disturbed but not that of adjacent components such as the CSC or safety controller.		P
	In case of a failure of the BMS, the operating ranges of the cells shall not be exceeded.		P
	After the functionality of the BMS has been restored, the charging/discharging process by means of the test rig shall be continued for a further 30 s. Then, the test is completed. The test shall be repeated with the components mentioned in 7.10.		P
7.10.2.3	**Requirements** The following requirements shall be met: – documentation of the component failure method; – in case of failure of a safety-related component, the BESS shall interrupt the charging/discharging processes by opening the charge/discharge circuit at the latest when the permissible limits of the operating range are exceeded.		P
7.10.3	**Cell/cell block failure**		P
7.10.3.1	**Purpose** In case of a defective cell or a cell block, the BESS shall switch into a safe state. The BESS shall inform and warn the user according to the type of defect, thereby enabling the user to escape from the hazard zone in time.		P

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Clause	Requirement + Test	Result - Remark	Verdict

7.10.3.2	**Test procedure (reactions in table 4)**		P
	Table 4 – Procedure for cell/cell block failure test		P

Possible failure/reaction scenarios	BESS reaction
1) Activating an electrical, mechanical or electromechanical intracellular protective function	BESS operation may continue if – the CID/OSD has electrically disconnected the cell safely from the rest of the storage system. – the CID/OSD has electrically disconnected the cell safely from the rest of the storage system without damaging any surrounding cells/components (e.g. by release of liquid/gaseous electrolyte, temperature rise in adjacent cells). – the reduced number of cells is detected by the BMS and the operating range for further charging/discharging processes is adjusted accordingly.
2) Increasing the cell temperature causing a temperature rise in the adjacent (healthy) cells in excess of the permissible operating range	– Shutdown, no automatic restart.
3) Leakage of liquid electrolyte	– Liquid electrolyte shall not be released from the storage system (containment device). – In case a short-circuit occurs as a successive fault, activating of the fuse link(s), opening of the charge/discharge circuit.
4) Venting of gaseous electrolyte 5) Burning of the cell, spark formation and ignition of vented gas mixtures 6) Explosion of the cell	– Visual-auditory warning of the user in accordance with DIN EN 981, message category DANGER – urgent rescue or protective measures. **Auditory signal** Minimum loudness of 85 dB(A) in accordance with DIN EN 14604, measured at a distance of 3 m, but not more than 110 dB(A). The frequency is limited to a maximum of 3,5 kHz. Available characteristic for the ON phase: – sweeping, – bursts, – alternating pitch (two or three frequency steps). NOTE Urgency can be implied by rapid rhythm, dissonance or high pitch. Temporal pattern: – continuous or alternating ON/OFF; – alternating ON/OFF; – continuous or alternating ON/OFF; – any danger signal shall have a temporal pattern clearly differentiated from EMERGENCY EVACUATION (see DIN EN 981, Table 1). **Visual signal** Red

7.10.3.3	**Requirements** The following requirements shall be met:		P
	Re 1) verification of the correct function of the CID/OSD by practical testing (e.g. according to 8.4.1, Overcharge) or testing by an accredited testing laboratory;		N/A
	Re 2) verification of the correct function of the temperature monitoring by practical testing (e.g. according to 7.8.4, Checking the temperature monitoring) or testing by an accredited testing laboratory;		P
	Re 3) visual inspection and, if applicable, verification of the correct function of the short-circuit protection device by practical testing (e.g. according to 8.1, External short-circuit) or testing by an accredited testing laboratory;		P
	Re 4) verification of the correct function of the warning device and annunciator by practical testing (e.g. according to 6.2.4, Internal short-circuit (propagation test)) or testing by an accredited testing laboratory.		N/A
8	**Reasonably foreseeable misuse**		P
8.1, 8.1.1	**External short-circuit**		P

VDE 2510-50			
Clause	Requirement + Test	Result - Remark	Verdict
	This test is intended to check the safety of the BESS in case of an external short-circuit. It shall be verified at two levels of testing that safety is ensured:		P
	1) cell level or cell block level: safety of the single cell or the parallel-connected cells (short-circuit path excluding external overcurrent protection device) (see 8.1.2);		P
	2) module/pack/system level: correct function of the overcurrent protection device and correct design of the electric paths in one or more cells, modules or battery packs, in serial or parallel connection (short-circuit path including overcurrent protection device) (see 8.1.3).		P
	The test according to 1) may be omitted provided external short-circuit at cell level or cell block level can be precluded by one of the following measures: a) the construction of the cell or cell block meets the requirements regarding double/reinforced insulation; b) no changes are made to the construction of the single cells or cell blocks on the operating site of the BESS (e.g. installation, disassembly, maintenance). The requirement according to a) is satisfied throughout the lifecycle phases of installation, operation (maintenance) and disassembly.		P
8.1.2	**Cell or cell block**		P
	External short-circuit testing at cell level or cell block level shall be conducted and evaluated in accordance with E DIN EN 62619 (VDE 0510-39) while taking into account the following deviations: – the impedance of the entire shorted circuit, including terminals/terminal leads, measuring resistor and short-circuit switch, shall be ≤ 5 mΩ; – the test object is preconditioned to the maximum operating temperature of the BESS as indicated by the manufacturer. Cells shall be subjected to thermal preconditioning for at least 6 h and cell blocks for at least 12 h.		P
8.1.3	**Module, pack, battery system**		P
8.1.3.1	**Purpose** The correct function of the short-circuit protection device is verified at module level, pack level and system level. This requires prompt interruption of the short-circuit current by the protective device in order to prevent resulting damage to the equipment under test.		P
	Where an overcurrent protection device is not provided at module level, the short-circuit current rating shall be checked at the next higher level, i.e. pack level. Where an overcurrent protection device is not provided at pack level, the short-circuit current rating shall be checked at the next higher level, i.e. battery system level.		P
	Prerequisite for conducting the test is the presence of an overcurrent protection device (at least at system level) on the one hand and a protection concept documented by the manufacturer on the other.		P

VDE 2510-50			
Clause	Requirement + Test	Result - Remark	Verdict
8.1.3.2	**Test procedure** The equipment under test is preconditioned to 100 % SOC and preheated to the maximum operating temperature of the BESS indicated by the manufacturer for at least 12 h.		P
	Then, the equipment under test shall be set to its normal operating condition (disconnecting elements closed, BMS active). The short-circuit with an impedance of 20 (+0/–10) mΩ is switched on within one second and maintained until one of the following criteria applies: – the overcurrent/short-circuit protection device has interrupted the short-circuit path and thereby the current supply; – an unsafe state occurs preventing the remaining test sequence (hazardous overheating, venting of gaseous electrolyte, fire, etc.).		P
	After interruption of the short-circuit, the equipment under test shall remain under observation until no further change of the test result is to be expected.		P
	The following applies to short-circuit application: – at module level or pack level (if a protection device is provided at this level): • between the main terminals (charge/discharge circuit between positive and negative terminal); • between shunt terminals (e.g. separate charge circuit between positive and negative terminal). – at system level; • between the main terminals (charge/discharge circuit between positive and negative terminal); • between shunt terminals (e.g. separate charge circuit between positive and negative terminal); • between the main terminals of the battery system and the inverter; • in direct vicinity of fuse links of the battery system, as far as accessible.		P
	The test shall be conducted with all passive or active integrated protective devices operating. All battery functions provided shall be fully operational throughout the entire test (e.g. BMS current/voltage measurement etc.). Interruption of the short-circuit voltage shall be fully automatic by means of the integrated switching elements or fuse links.		P
	Throughout the duration of the short-circuit, the measured values of the short-circuit current and the battery voltage shall be recorded with a frequency of at least 10 kHz. In addition, the ambient temperature and the temperature of the equipment under test (internal sensory equipment) shall be recorded.		P

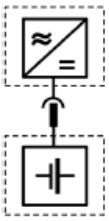
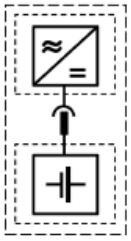
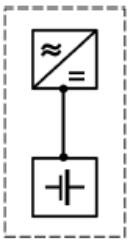
VDE 2510-50			
Clause	Requirement + Test	Result - Remark	Verdict
8.1.3.3	**Requirements** The following requirements shall be met: – the equipment under test shall neither exhibit any signs of fire or flames nor explode; – measurement and documentation of the values described in the test procedure; – evaluation of shut-down times of the overcurrent protection device(s) taking into account the measured current and voltage values; – evaluation of the insulating resistance in accordance with 6.2.2.		P
8.2	**Drop test**		P
8.2.1	**Purpose** It is assumed that the BESS and/or its component parts (incorporating cells) for puposes of a) installation; b) servicing/maintenance; c) repair; or d) disassembly are handled above the ground level and outside their transport packaging. This results in the risk of free fall and impact from transport or handling height.		P
	Even in case of such an impact, the safety of the BESS and its component parts shall be ensured such that the BESS and/or its component parts do not present any direct hazard.		P
8.2.2	**Test procedure**		P
	The following test methods shall be applied according to the respective weight of the equipment under test (can be conducted on a test object or single test objects, according to previous damage):		P
	1) test object having a weight of ≤ 50 kg:		P
	At the beginning of the test, the insulation resistance of the test object is measured.		P
	Afterwards, the test object is suspended from a device having a height of ≥ 1 m above the flat ground (concrete, covered with a metal plate, if applicable) and orientated. Then, a free fall under controlled conditions is initiated using a releasing device. Care shall be taken that the test object maintains its position and orientation until its impact on the ground.		P
	After the impact, the insulation resistance is measured again and the test object is subjected to visual inspection.		P
	The test sequence is repeated until 3 different falling orientations have been simulated. These are e.g. – 30° impact onto the edge of the shortest side length; – 30°/30° impact onto one corner; – perpendicular impact onto one front or rear panel or onto one side equipped with terminals. Generally, the 3 falling orientations shall be chosen such that the most severe damage of the test object is to be expected.		P
	2) Test objects having a weight ≥ 50 kg:		N/A
	At the beginning of the test, the insulation resistance of the test object is measured.		N/A

VDE 2510-50			
Clause	Requirement + Test	Result - Remark	Verdict
	Then, the test is conducted in accordance with E DIN EN 62619 (VDE 0510-39).		N/A
	After the impact, the insulation resistance is measured again.		N/A
	Having been subjected to those two test methods, the test object shall remain under observation until no further changes of the hazardous situation are to be expected.		N/A
8.2.3	**Requirements** Regarding 8.2.2, the following applies: – no fire, no explosion; – no venting; – no hazardous surface temperatures; – no ejected parts that may lead to injury of bystanders; – no direct access to active parts above the protective low voltage.		P
8.3	**Impact test**		P
8.3.1	**Purpose** Where cells or cell blocks for purposes of a) installation; b) servicing/maintenance; c) repair; or d) disassembly are handled outside their transport packaging, this presents not only the risk of free fall (see 8.2) but also the risk of unintended crushing (i.e. mechanical impact) (e.g. collision during replacement of cells).		P
	The test shall be used to demonstrate that an impact on one component (cell or cell block) does not lead to a hazard in its direct surrounding.		P
8.3.2	**Test procedure** Crushing (mechanical impact) shall be simulated by using the following test procedure. 1) E DIN EN 62619 (VDE 0510-39) Impact (at cell/cell block level).	IEC/EN 62619 cell report reviewed	P
8.3.3	**Requirements** See E DIN EN 62619 (VDE 0510-39)		P
8.4	**Thermal misuse**	IEC/EN 62619 cell report reviewed	P
	Thermal misuse is tested and evaluated in accordance with E DIN EN 62619 (VDE 0510-39) at cell/cell block level. Alternatively, conformity may be confirmed by testing carried out by an accredited test laboratory.		P
8.4.1	**Overcharge**	IEC/EN 62619 cell report reviewed	P
	The overcharge test is conducted and evaluated in accordance with E DIN EN 62619 (VDE 0510-39) at cell/cell block level. Alternatively, conformity may be confirmed by testing carried out by an accredited test laboratory.		P
8.4.2	**Forced discharge**	IEC/EN 62619 cell report reviewed	P

VDE 2510-50			
Clause	Requirement + Test	Result - Remark	Verdict
	The forced discharge test is conducted and evaluated in accordance with E DIN EN 62619 (VDE 0510-39) at cell/cell block level. Alternatively, conformity may be confirmed by testing carried out by an accredited test laboratory.		P
9	**Safety during transport**		P
	For both the cells and the modules of a battery system, the tests according to UN 38.3 of the currently valid edition of the United Nations Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria, shall be complied with and conformity shall be demonstrated.		P
	For road transport, particular attention shall be paid to special provisions and the current legislation relating to dangerous goods, in particular of the currently valid edition of the European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR). This also applies to batteries “for disposal” or “for recycling”.		P
	Other national transport regulations may be applicable.		N/A
10	**Inspection of markings**		P
10.1	**Crossed-out wheeled bin**		P
	Manufacturers placing a battery energy storage system on the market are obliged to observe the BattG (2006/66/EC) or the ElektroG (2012/19/EU) specifying the marking with the symbol shown in Figure 7. According to the type of BESS, the requirements regarding the positioning of the marking as presented in Table 5 can be derived.  Figure 7 – Marking symbol: crossed-out wheeled bin		P

VDE 2510-50			
Clause	Requirement + Test	Result - Remark	Verdict

Table 5 – Marking requirements

Type of BESS for which the following applies:		Example drawing including the subgroup of battery & inverter	Requirement
1)	– Subgroups of equipment installed in separate enclosures and locally separated from each other (e.g. battery module(s), inverter/converter, smart meter) – Subgroups of equipment that can be safely split up by the end user, e.g. by load free pulling of plugs		– Marking applied to battery module(s) (BattG (2006/66/EC) § 2, Paragraph 3; § 17, Paragraph 1 ff.)) – Marking applied to subgroup(s) of equipment (e.g. inverter) if within the scope of the ElektroG, § 2
2)	– Subgroups of equipment installed in separate enclosures which are assembled to the final equipment in a shared enclosure on site by the end user (e.g. stackable solution, see also 6.2.6)		– Marking applied to battery module(s) (BattG (2006/66/EC) § 2, Paragraph 3; § 17, Paragraph 1 ff.)) – Marking applied to subgroup(s) of equipment (e.g. inverter) if within the scope of the ElektroG, § 2
3)	– BESS as a single equipment containing subgroups together with the battery in a shared enclosure thus forming a unit which cannot be split up or opened by the end user (e.g. single solution)		– Marking applied to the overall enclosure of the BESS (BattG (2006/66/EC) § 2, Paragraph 3; § 17, Paragraph 1 ff.))

			N/A
10.2	**Marking and designation**		P
	A marking inspection in accordance with DIN EN 62620 (VDE 0510-35), Clause 5, shall be ensured (visual inspection). The presence of markings shall be documented.		P
11	**Documentation requirements**		--
	It shall be ensured that the BESS documentation contains the following indications provided by the manufacturer:		P
	– instructions for the correct operation including information on controls and indicators;		P
	– instructions for behavior in case of a fault;		P
	– hazard warnings, residual risks resulting from risk assessment;		P
	– information on the installation site under consideration of the environmental impacts		N/A
	• installation height, safety distances and position;		N/A
	• ambient temperature and humidity;		P
	• pollution degree (IP protection);		P
	• risk of external fire;		P
	• radiation;		N/A
	• vibration;		N/A
	• corrosive gases and liquids;		N/A
	• escape routes;		N/A
	• markings;		P

VDE 2510-50			
Clause	Requirement + Test	Result - Remark	Verdict
	– information on safe transport;		P
	– contact information of skilled persons responsible in a service case;		N/A
	– contact information of disposal companies responsible in case of disposal.		P
	Conformity is verified by inspection of documents (visual inspection).		P

Table 6.2.2 Insulation resistance test					N/A
Insulation / Parts Under Test between	Test Voltage (Vd.c.)	Duration (s)	Measured resistance (ohm)	Leakage current (mA)	Remarks and/or verdict
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Supplementary information:					

Table 6.2.3 Dielectric strength test results				N/A
Insulation / Parts Under Test between	Test Voltage (Va.c/d.c.)	Duration (s)	Insulation breakdown?	Remarks and/or verdict
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Supplementary information:				

Table 8.1.2 External short-circuit - Cell or cell block				P
Sample No.	OCV before test (V)	S-C resistance (mohm)	Cell temperature (°C)	Observation
M1-Cell	3.341	5	125.3	No hazard
M2-Cell	3.340	5	120.7	No hazard
M3-Cell	3.339	5	123.4	No hazard
Supplementary information:				

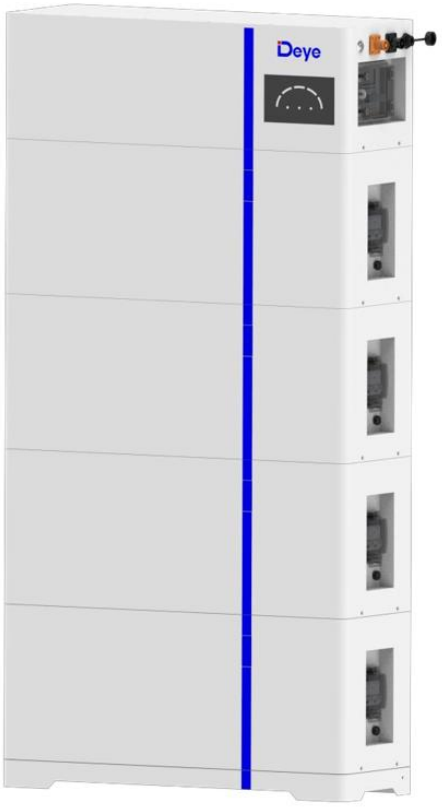
Table 8.1.3 External short-circuit – Module/pack/system				P
Sample No.	OCV before test (V)	S-C resistance (mohm)	Cell temperature (°C)	Observation
M1	53.9	18.9	54.8	No hazard
Supplementary information:				

Table 8.2 Drop test				P
Sample No.	OCV before test (V)	Drop height	Drop location	Observation
M2	53.9	50 mm	Edge and corner	No hazard
Supplementary information:				

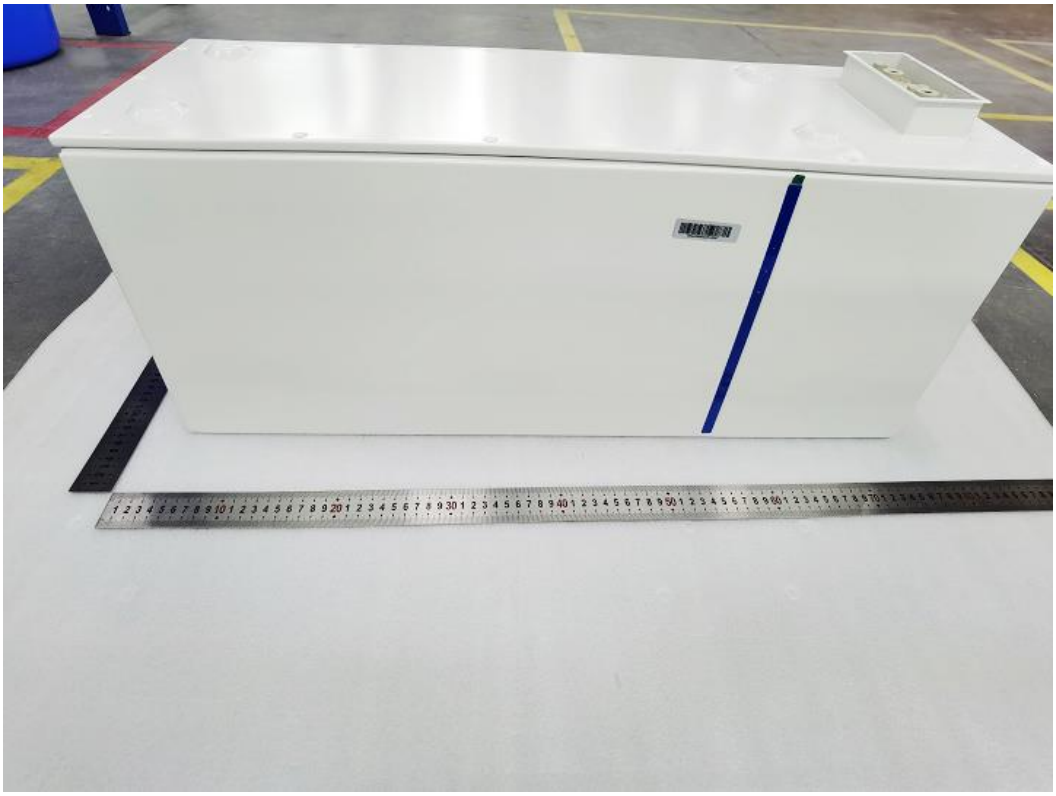
Appendix: Photos

External view of battery system (For model: AI-W5.1)

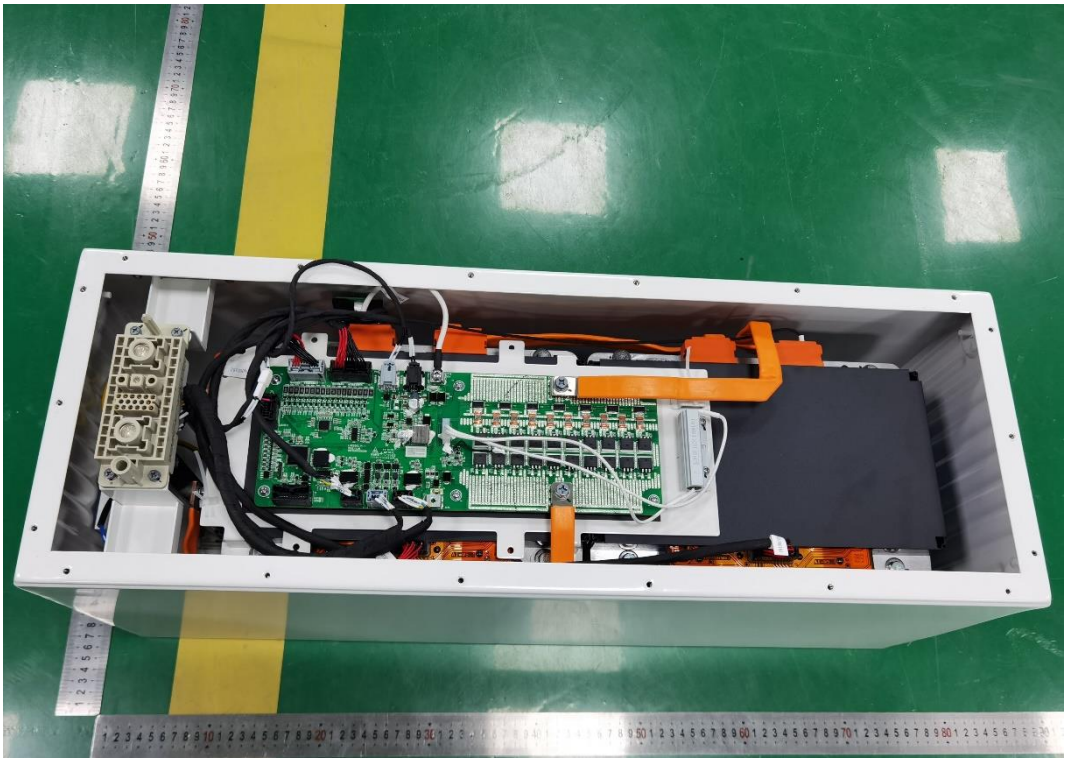
External view of battery system (For model: AI-W5.1-B)



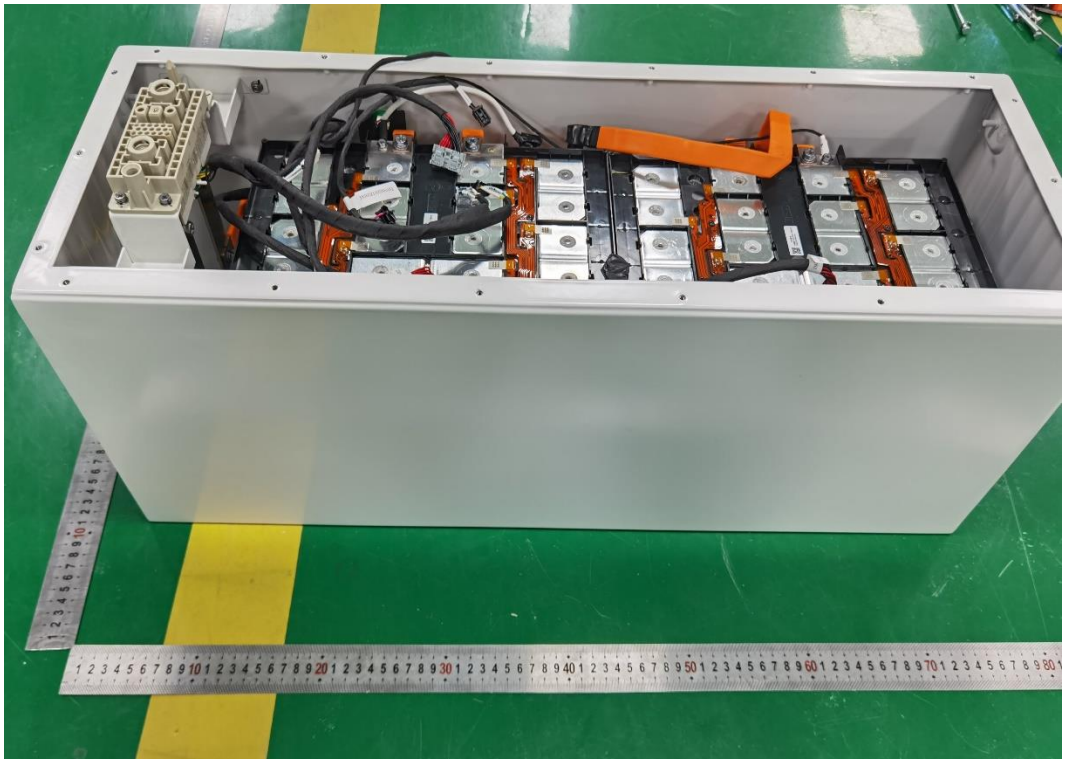
External view of battery module (For model: AI-W5.1)



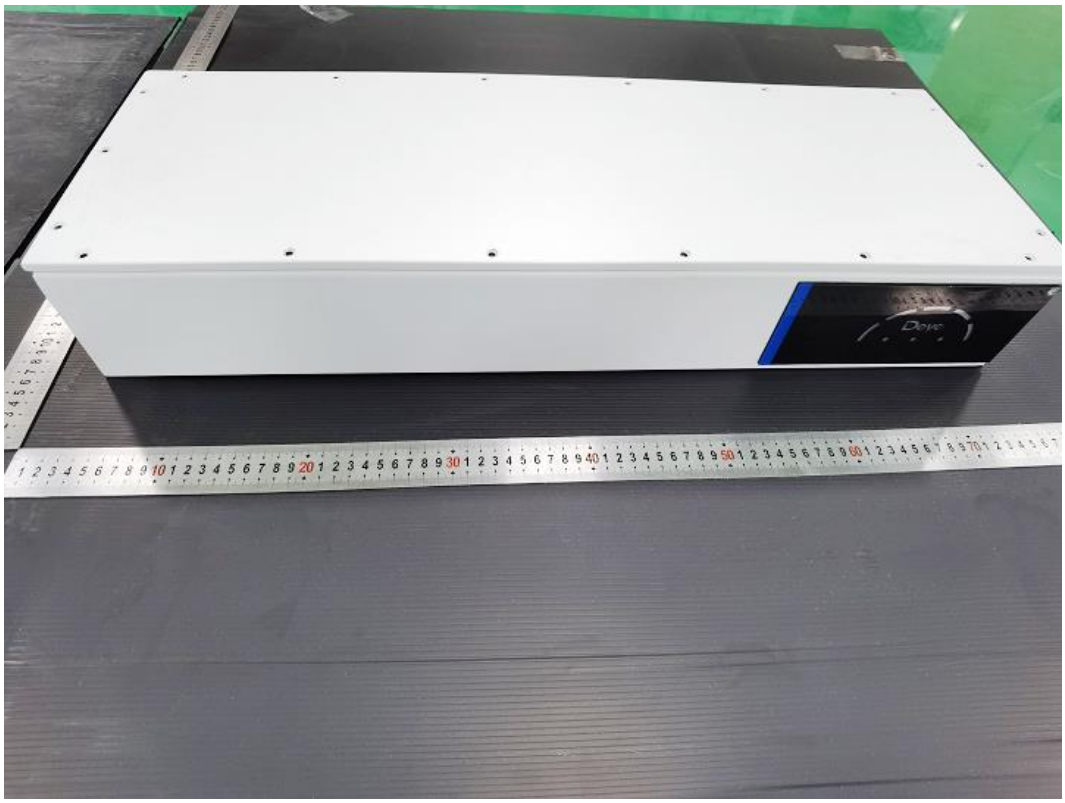
Internal view of battery module (For model: AI-W5.1)



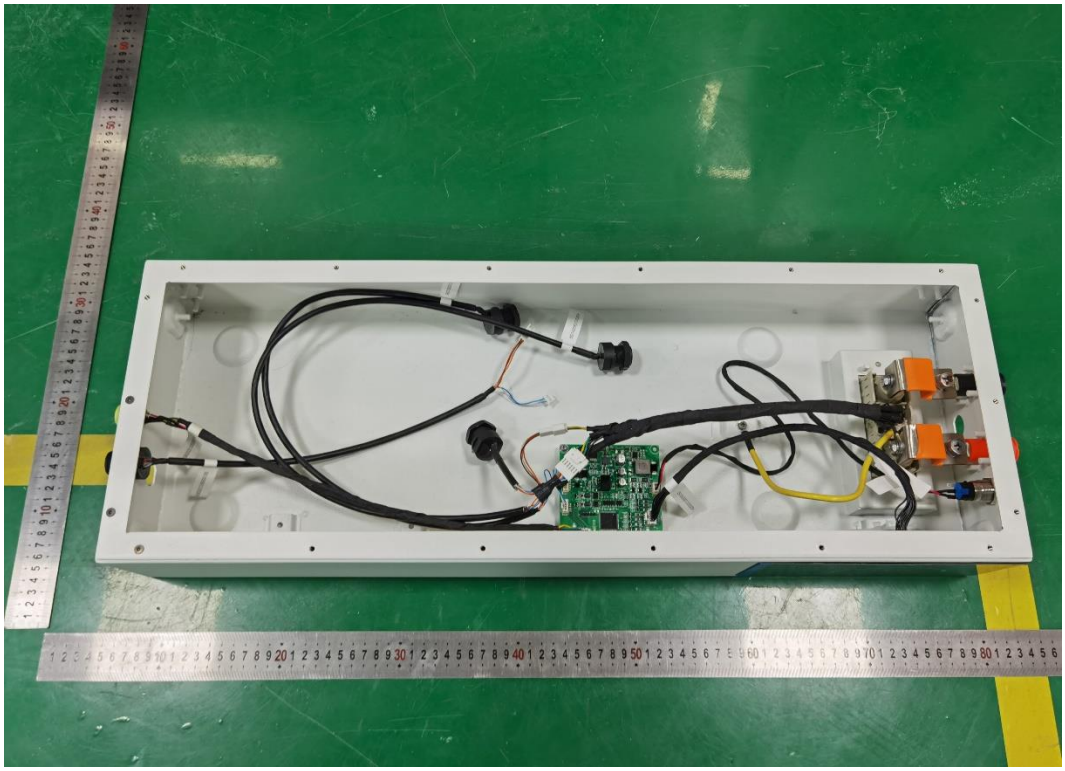
Internal view of battery module (For model: AI-W5.1)



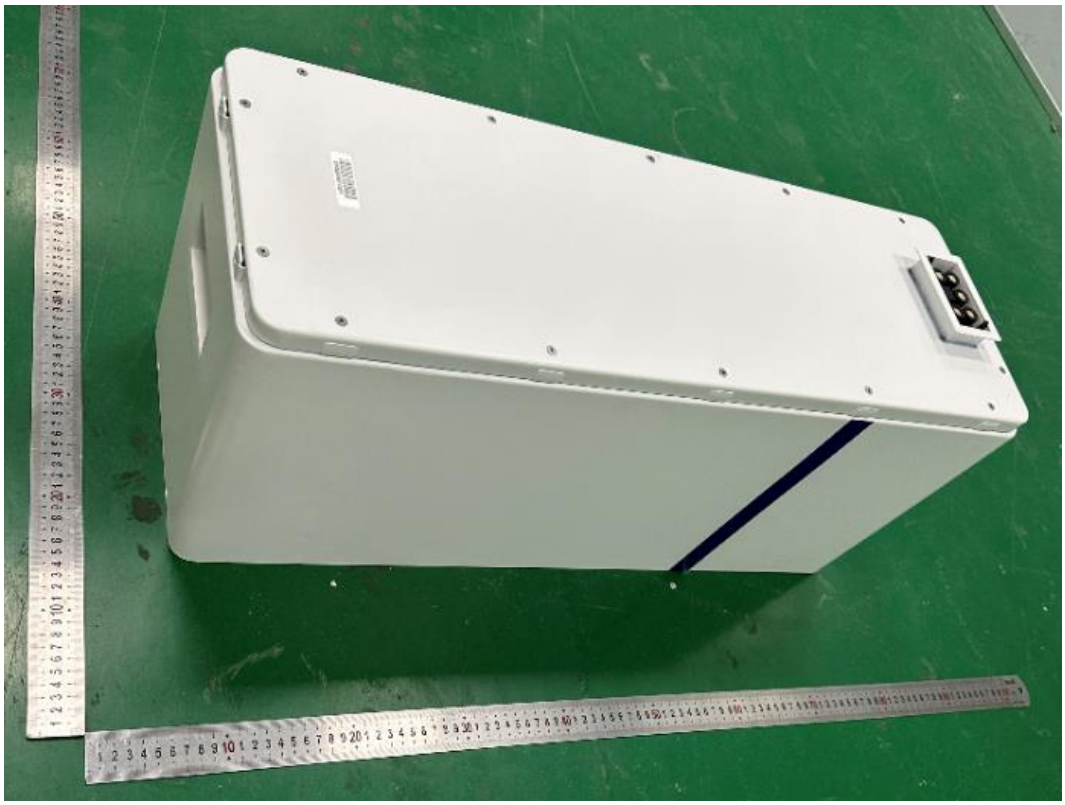
External view of PDU (For model: AI-W5.1)



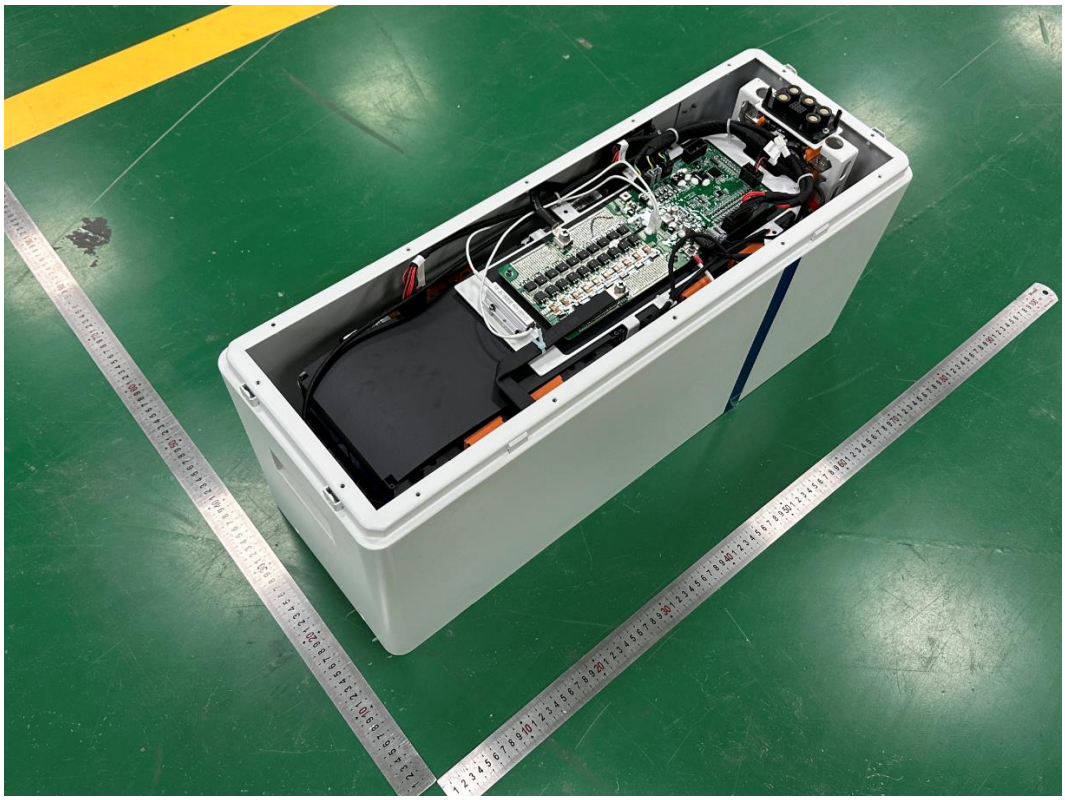
Internal view of PDU (For model: AI-W5.1)



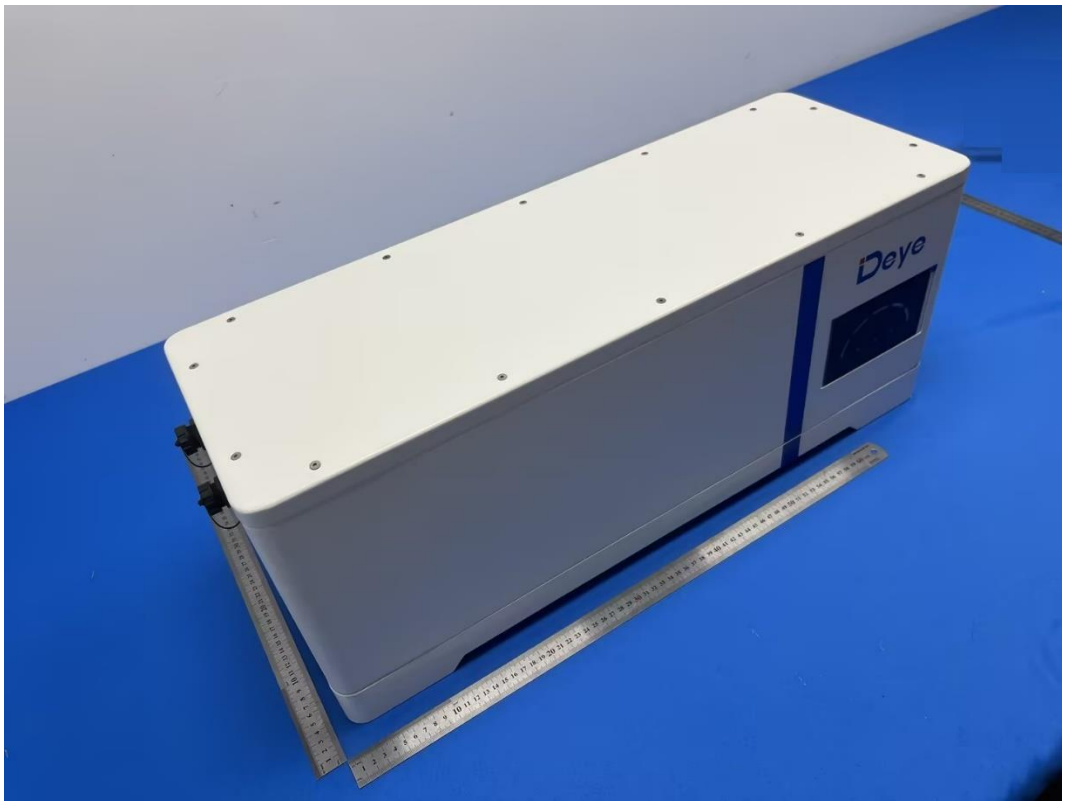
External view of battery module (For model: AI-W5.1-B)



Internal view of battery module (For model: AI-W5.1-B)

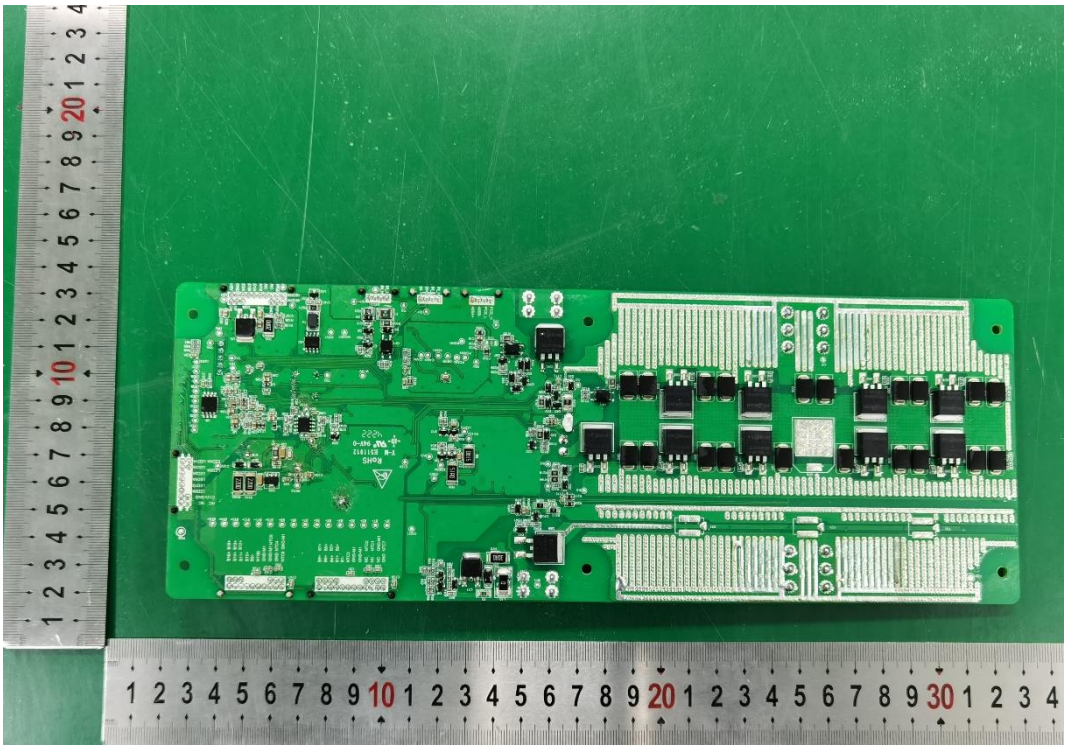


Internal view of battery module (For model: AI-W5.1-B)

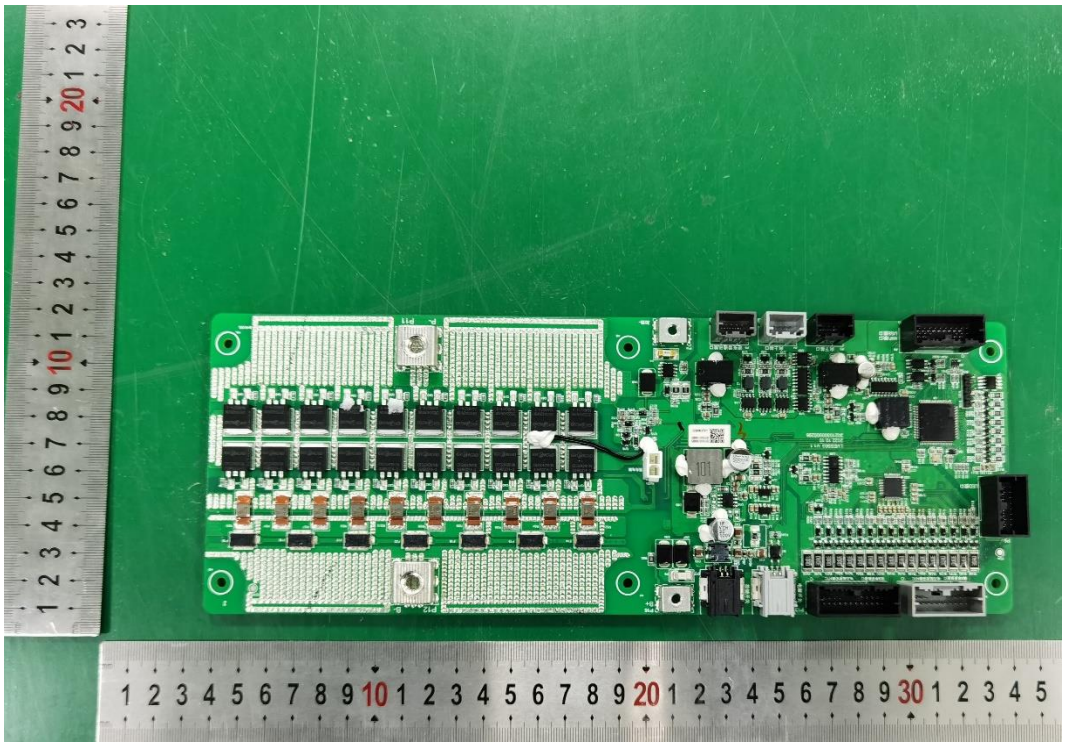


Internal view of PDU (For model: AI-W5.1-B)

PCB



PCB



---End of report---