PRE-COMPLIANCE TEST REPORT

IEC 61851-23-3 ED1 — Annex CC

Insulation Monitoring Device (IM-07DCCT.MCS)

Functional Check and Insulation Resistance Monitoring

Test Item	IM-07DCCT.MCS
Manufacturer	Muuntosähkö Oy - Trafox
Firmware / SW Ref	SW046
Standard	IEC 61851-23-3 ED1, Annex CC
Applicable Clause	CC.7.5.15, CC.7.5.16 and CC.7.5.23
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Report Status	Engineering Pre-Compliance

NOTICE

This document is an engineering pre-compliance test report. It does not claim full IEC 61851-23-3 ED1 product conformity or certification. Results are valid only for the specific hardware and software version tested and for the test cases explicitly documented herein.

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1 Introduction

1.1 Purpose

This document presents the engineering pre-compliance test results for the IM-07DCCT.MCS insulation monitoring device (IMD) function of a DC electric vehicle supply equipment (EVSE). The tests have been conducted against the requirements defined in IEC 61851-23-3 ED1, Annex CC (normative), specifically targeting the functional check of the insulation monitoring device (CC.7.5.23) and the insulation resistance monitoring behaviour during pre-charge (CC.7.5.15). and energy transfer (CC.7.5.16).

The primary objective is to verify that the IMD correctly detects insulation fault conditions and that the EVSE initiates the appropriate error shutdown response within the time limits prescribed by the standard.

1.2 Scope

The scope of this report is strictly limited to the executed CC.7.5 test cases that are directly related to the IM-07DCCT.MCS insulation monitoring function. The report covers:

- CC.7.5.23 — Functional check of the insulation monitoring device (reference requirement: CC.4.1.3)
- CC.7.5.15 — Insulation resistance check to detect fault state during pre-charge (reference requirements: CC.4.1.5, CC.4.1.6)
- CC.7.5.16 — Insulation resistance check to detect fault state during energy transfer (reference requirements: CC.4.1.5, CC.4.1.6)

All other CC.7.5 test cases (e.g. CC.7.5.2 normal startup, CC.7.5.4 CP loss, CC.7.5.9 load dump) are outside the scope of this report and have not been evaluated here.

1.3 Disclaimer

This report does not constitute a declaration of conformity or a certification statement. The results reflect the behaviour of the tested unit under the defined laboratory conditions and do not cover all possible operational scenarios. Full type-test certification would require testing at an accredited third-party laboratory against the complete requirements of IEC 61851-23-3 ED1

2 Normative References

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this test report.

Document	Title
IEC 61851-23-3 ED1	Electric vehicle conductive charging system - Part 23-3: DC electric vehicle supply equipment for Megawatt charging systems
IEC 61851-23:2023	Electric vehicle conductive charging system – Part 23: DC electric vehicle supply equipment
IEC 61557-8:2014	Electrical safety in low voltage distribution systems up to 1 000 V AC and 1 500 V DC – Equipment for testing, measuring or monitoring of protective measures – Part 8: Insulation monitoring devices for IT systems
IEC 61851-24:2023	Electric vehicle conductive charging system – Part 24: Digital communication between DC EV supply equipment and an EV for control of DC charging
DIN SPEC 70121:2014	Electromobility – Digital communication between a DC charging station and an EV for control of DC charging in the Combined Charging System
ISO 15118-2:2014	Road vehicles – Vehicle to grid communication interface – Part 2: Network and application protocol requirements

3 Equipment Under Test and Test Instrumentation

3.1 Device Under Test

The equipment under test (EUT) is a DC EVSE implementing system C as defined in Annex CC of IEC 61851-23:2023 and IEC 61851-23-3 ED1. The EUT is equipped with a dedicated insulation monitoring device (IMD) compliant with IEC 61557-8, monitoring the insulation resistance between the side B live parts (DC+ and DC−) and the protective earth (PE) conductor.

Parameter	Value
Test Item Identifier	IM-07DCCT.MCS
Software / Firmware	SW046
EVSE System Type	System C (IEC 61851-23:2023 Annex CC)
IMD Standard	IEC 61557-8
Alarm Threshold	150 kΩ (insulation fault detection limit)
Test Voltage (V_test)	1000 V DC
Side B Configuration	Configuration EE / FF as applicable

3.2 Test Instrumentation

The test was performed using a calibrated EV simulator (EVCC/SECC) and associated test load as specified in IEC 61851-23-3 ED1 Clause 102.2.4. Precision resistors and capacitors were used to simulate defined insulation fault conditions. The measurement system logged IMD alarm trigger times and the measured insulation resistance (Rmeas) reported by the IMD.

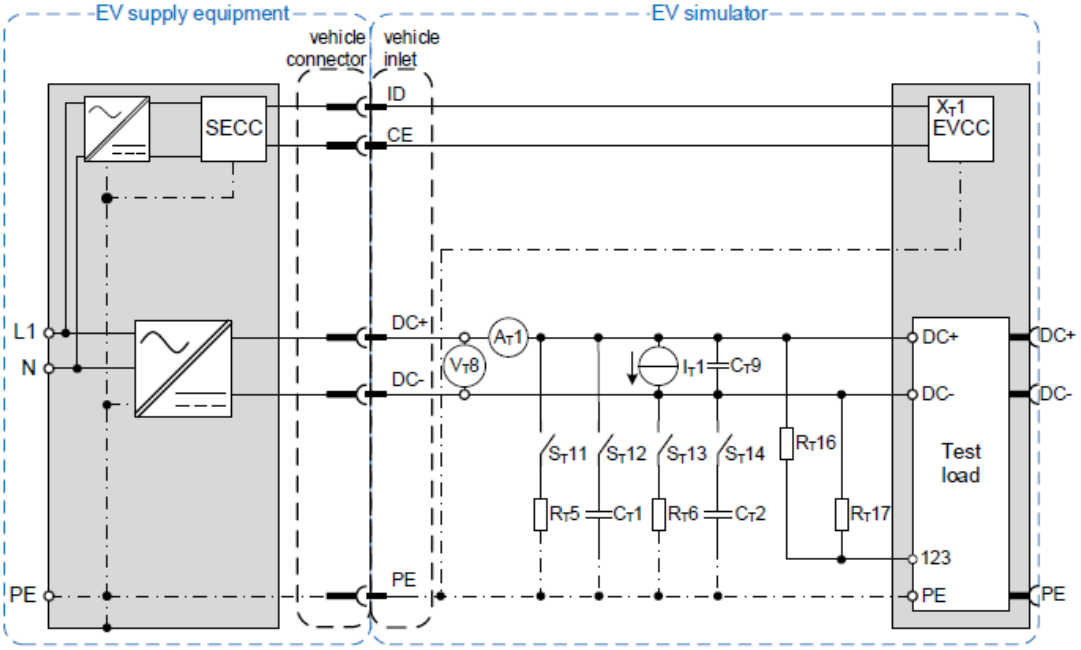
4 Standard Test Setup

4.1 General Test Configuration (CC.7.2 and Figure 207)

All tests were conducted according to the standard test setup for system C defined in IEC 61851-23-3 ED1, CC.7.2. and figure 207. The standard test setup consists of the EUT (EVSE), the EV simulator, the standard test load according to Clause 102.2.4, and all ancillary measurement instrumentation and switching equipment. The test load provides a controlled impedance between DC+ and DC− that mimics the electrical characteristics of an EV battery system. For the insulation monitoring tests, additional precision resistors (R_T4, R_T5) are connected between the DC bus rails and PE to simulate defined insulation fault conditions.

4.2 Worst-Case Equivalent Circuit During Pre-charge (CC.5.1 and Figure CC.110)

Figure 1 below reproduces IEC 61851-23:2023 Figure CC.110, which illustrates the worst-case equivalent circuit during the pre-charge phase relevant to the IMD functional assessment. Key elements include the Y-capacitances (C_T1, C_T2) on the vehicle inlet, the X-capacitance (C_T9), the minimum insulation resistances (R_T5, R_T6) representing insulation fault conditions, and the ammeter/voltmeter instrumentation.



Key

I_T1	EV current load
C_T1, C_T2	Maximum Y-capacitance on the vehicle inlet
C_T9	Maximum X-capacitance on the vehicle inlet
R_T5, R_T6	Minimum insulation resistance (due to an error) on the vehicle inlet
R_T16, R_T17	Minimum resistance of the EV simulator measurement circuit on vehicle inlet
A_T1	Ammeter in the EV simulator
V_T8	Voltmeter in the EV simulator
Test load	Test load according to 102.2.4 unless otherwise specified (see Figure 208)

NOTE 1 Diagram based on the test setup for system MCS with additional components I_T1, C_T9, R_T16 and R_T17 (see Figure 207).

Figure CC.110 – Worst case equivalent circuit during pre-charge

Figure 1 – Worst-case equivalent circuit during pre-charge (IEC 61851-23:2023, Figure CC.14)

4.3 Test Voltage and Alarm Threshold

During the insulation monitoring tests, the side B test voltage was set to 1000 V DC, consistent with a nominal EV maximum voltage of 1000 V and a V_EVSE_CableCheck calculated per Formula (CC.1) of the standard. The IMD alarm threshold was configured at 150 kΩ total insulation resistance. This threshold complies with Table CC.118 of the standard, which defines the insulation fault condition as a resistance below 125 kΩ and resistance of 190 kΩ as valid. The 150 kΩ alarm limit provides a conservative margin to ensure reliable fault detection before the insulation deteriorates to the defined fault level.

A background insulation resistance of 5 MΩ per rail (representing the EUT's own insulation) was present in the test setup. The test resistors (R_T5 for DC+ rail, R_T6 for DC− rail) were switched in to simulate fault conditions after the test voltage had stabilised.

5 Test Case CC.7.5.23 — Functional Check of the Insulation Monitoring Device

5.1 Reference Requirements

This test case verifies compliance with the following normative requirements:

- CC.4.1.3 — Functional check of the insulation monitoring device
- CC.4.1.2 — Cable-check phase (overall cable-check procedure)

CC.4.1.3 requires the functional check of the IMD to detect whether the IMD is connected to the side B live parts (DC+ and DC−) and the protective conductor (PE), and that the IMD is capable of determining insulation resistances between DC+ and PE as well as between DC− and PE. Failure of any redundant connection shall be verifiable by interrupting all IMD connections at that measurement location.

5.2 Test Description

The functional check of the IMD is performed during the cable-check phase. The test verifies the IMD response when its measurement connections and power supply are interrupted one at a time, simulating single-point failures. IMD must report alarm and the EUT must report a fault in all simulated fault conditions, and must report 'Valid' under normal operation.

5.3 Test Setup

The standard test setup (CC.7.2) is used, extended with additional switches (S_T29 through S_T34) to interrupt the IMD measurement connections and power supply as defined in Table CC.28 of the IEC61851-23_ED2 standard. The EV simulator applies $V_{EV_max} = V_{EVSE_min} + 100$ V during the cable-check phase. Each test case is independent; fault conditions are cleared between tests.

Switch S_T34 introduces an additional fault-simulation path between DC+ and DC−. Switches S_T31 and S_T32 interrupt the IMD measurement connections to DC+ and DC− respectively. Switch S_T33 interrupts the IMD connection to PE. Switches S_T29 and S_T30 interrupt the IMD power supply on each supply rail.

5.4 Preconditions

This test is a white-box test. The EUT is prepared according to the modified test setup. The FPT sequence is successfully executed through t = t3 before each test case. The test resistor R_T18 (PE connection impedance) is installed as required by the test setup.

5.5 Actions

The following procedure is repeated for each of the test cases defined in Table CC.28:

- Step 1: Prepare the test setup for normal operation (all switches in the 'normal' position per Table CC.28).
- Step 2: Execute the FPT sequence through t = t5.
- Step 3: Set the test switches to the fault condition corresponding to the selected test case.
- Step 4: Execute the FPT sequence through t = t6 (cable-check phase complete).
- Step 5: Log the response message of the EV supply equipment

5.6 Test Cases and Expected Results

Table 1 presents all 13 test cases from IEC 61851-23:2023 Table CC.28 with the switch positions and expected results.

Case	Fault Type	ST34	ST31	ST32	ST33	ST30	ST29	Expected EVSE IsolationStatus	Expected Result	Alarm time
1	Normal operation	**Open**	Closed	Closed	Closed	Closed	Closed	*'Valid' / 'OK';*	**CableCheck: PASS**	**N/A**
2a1	IMD–PE, PE disconnect	**Open**	Closed	Closed	**Open**	Closed	Closed	*'Fault' / 'FAILED'*	**CableCheck: FAIL → Error shutdown**	**1,3s**
2a2	IMD–PE PEM disconnect	Closed	Closed	Closed	**Open**	Closed	Closed	*'Fault' / 'FAILED'*	**CableCheck: FAIL → Error shutdown**	**1,3s**
2b1	IMD–PE, PE disconnect	**Open**	Closed	Closed	**Open**	Closed	Closed	*'Fault' / 'FAILED'*	**CableCheck: FAIL → Error shutdown**	**1,2s**
2b2	IMD–PE PEM disconnect	Closed	Closed	Closed	**Open**	Closed	Closed	*'Fault' / 'FAILED'*	**CableCheck: FAIL → Error shutdown**	**1,3s**
3a	IMD meas. connection (DC+)	**Open**	**Open**	Closed	Closed	Closed	Closed	*'Fault' / 'FAILED'*	**CableCheck: FAIL → Error shutdown**	**9,2s**
3b	IMD meas. connection (DC+)	Closed	**Open**	Closed	Closed	Closed	Closed	*'Fault' / 'FAILED'*	**CableCheck: FAIL → Error shutdown**	**12,4s**
3c	IMD meas. connection (DC−)	**Open**	Closed	**Open**	Closed	Closed	Closed	*'Fault' / 'FAILED'*	**CableCheck: FAIL → Error shutdown**	**8,8s**
3d	IMD meas. connection (DC−)	Closed	Closed	**Open**	Closed	Closed	Closed	*'Fault' / 'FAILED'*	**CableCheck: FAIL → Error shutdown**	**1,0s**
3e	IMD meas. connections (both)	**Open**	**Open**	**Open**	Closed	Closed	Closed	*'Fault' / 'FAILED'*	**CableCheck: FAIL → Error shutdown**	**0,4s**
3f	IMD meas. connections (both)	Closed	**Open**	**Open**	Closed	Closed	Closed	*'Fault' / 'FAILED'*	**CableCheck: FAIL → Error shutdown**	**0,3s**
4a	IMD power supply	**Open**	Closed	Closed	Closed	**Open**	Closed	*'Fault' / 'FAILED'*	**CableCheck: FAIL → Error shutdown**	**0,04s**
4b	IMD power supply	Closed	Closed	Closed	Closed	Closed	**Open**	*'Fault' / 'FAILED'*	**CableCheck: FAIL → Error shutdown**	**0,04s**
4c	IMD power supply (both)	**Open**	Closed	Closed	Closed	**Open**	**Open**	*'Fault' / 'FAILED'*	**CableCheck: FAIL → Error shutdown**	**0,04s**

Table 1 – Test cases for the functional check of the IMD (IEC 61851-23:2023, Table CC.28)

5.7 Observed Results

All 13 test cases were executed in accordance with the actions defined in CC.7.5.23.6. In test case 1 (normal operation), the EUT completed the cable-check phase and responded with 'OK' status. In all fault test cases (2a through 4c), the EUT detected the interrupted measurement or power supply connection and responded with 'Fault' status at or before the end of the cable-check phase, triggering an EVSE-initiated error shutdown as required by CC.4.1.3 c).

The functional check mechanism operated correctly for all three connection categories: IMD-to-PE connection (cases 2a–2b), IMD measurement connections to DC+/DC− (cases 3a–3f), and IMD power supply (cases 4a–4c). No false positives (spurious fault detection) were observed in the normal operation case (case 1).

Case	Fault Category	EVSE / IMD Action	Result
1	Normal operation	Continue cable-check → PASS	**PASS**
2a	PE connection interrupted	Error shutdown triggered	**PASS**
2b	PE connection interrupted	Error shutdown triggered	**PASS**
3a	DC+ measurement interrupted	Error shutdown triggered	**PASS**
3b	DC+ measurement interrupted	Error shutdown triggered	**PASS**
3c	DC− measurement interrupted	Error shutdown triggered	**PASS**
3d	DC− measurement interrupted	Error shutdown triggered	**PASS**
3e	Both meas. interrupted	Error shutdown triggered	**PASS**
3f	Both meas. interrupted	Error shutdown triggered	**PASS**
4a	IMD power supply interrupted	Error shutdown triggered	**PASS**
4b	IMD power supply interrupted	Error shutdown triggered	**PASS**
4c	Both power supplies interrupted	Error shutdown triggered	**PASS**

Table 2 – CC.7.5.23 observed results summary

5.8 Verdict

All 13 test cases of CC.7.5.23 yielded results conforming to the expected behaviour defined in CC.7.5.23.7. The IMD functional check is assessed as PASS across the complete set of test cases. The EUT demonstrates reliable detection of all simulated single-point connection failures in the IMD measurement and power supply paths.

6 Test Case CC.7.5.15 — Insulation Resistance Check before pre-charge (cable-check)

6.1 Reference Requirements

This test case verifies compliance with the following normative requirements:

- 6.3.1.113.3 — Error shutdown
- CC.4.1.2 — Insulation monitoring during the cable-check phase

6.2 Test Description

This test verifies the EUT's reaction to low insulation resistance conditions (R < 62,5…125kΩ) during the cable check stage. The EVSE must trigger an error shutdown within the time limits specified in CC.4.1.6: 60s or less for direct fault conditions, and 180 s or less for sustained disturbance conditions.

Eleven test cases are defined, covering symmetric and asymmetric insulation faults, long-term disturbance conditions, short-term disturbances without fault, and short-term disturbances followed by an insulation fault. Each test case was executed 20 times to establish statistical reliability of the alarm trigger timing.

6.3 Test Conditions

Table 3 defines the test resistance values, expected alarm behaviour, and standard time limits for each of the 11 test cases.

Case	R_T5 (DC+)	R_T6 (DC−)	C_T1, C_T2	V_{test}	Condition Type	Alarm Expected	Time Limit
1	380 kΩ	380 kΩ	2,5 µF	1000 V	Symmetric – no fault	None	—
2	125 kΩ	125 kΩ	2,5 µF	1000 V	Symmetric – fault	Yes, within 60 s	60 s
3	190 kΩ	5 MΩ	2,5 µF	1000 V	Asymmetric – no fault (DC+)	None	—
4	5 MΩ	190 kΩ	2,5 µF	1000 V	Asymmetric – no fault (DC−)	None	—
5	125 kΩ	5 MΩ	2,5 µF	1000 V	Asymmetric – fault (DC+)	Yes, within 60 s	60 s
6	5 MΩ	125 kΩ	2,5 µF	1000 V	Asymmetric – fault (DC−)	Yes, within 60 s	60 s
7	190 kΩ	190 kΩ	2,5 µF	1000 V	Long-term disturbance (1 s on/off)	Yes, within 180 s	180 s
8	190 kΩ	190 kΩ	2,5 µF	1000 V	Short-term disturbance – no fault	None	—
9	Step1: 190 kΩ Step2: 5 MΩ	Step1: 190 kΩ Step2: 125 kΩ	2,5 µF	1000 V	Short-term dist. + fault (DC−)	Yes, within 60 s of fault	60 s
10	Step1: 190 kΩ Step2: 125 kΩ	Step1: 190 kΩ Step2: 5 MΩ	2,5 µF	1000 V	Short-term dist. + fault (DC+)	Yes, within 60 s of fault	60 s
11	Step1: 190 kΩ Step2: 125 kΩ	Step1: 190 kΩ Step2: 125 kΩ	2,5 µF	1000 V	Short-term dist. + sym. fault	Yes, within 60 s of fault	60 s

Table 3 – CC.7.5.16 test case conditions and alarm requirements

6.4 Measured Results

Table 4 presents summary of the 20 repetitions per test case. The column 'Rmeas' shows the insulation resistance value reported by the IMD. For cases where no alarm was expected, the 'Time' column shows N/A (no alarm triggered). For cases requiring an alarm, the minimum, mean, and maximum times are reported.

Case	R_T5	R_T6	Rmeas Min (kΩ)	Rmeas Mean (kΩ)	Rmeas Max (kΩ)	Time Min (s)	Time Mean (s)	Time Max (s)	Result
1	380 kΩ	380 kΩ	177.3	177.7	178.2	N/A	N/A	N/A	PASS
2	125 kΩ	125 kΩ	62.4	62.6	62.7	5.34	5.43	5.53	PASS
3	190 kΩ	5 MΩ	175.5	181.7	185.4	N/A	N/A	N/A	PASS
4	5 MΩ	190 kΩ	177.3	181.0	186.1	N/A	N/A	N/A	PASS
5	125 kΩ	5 MΩ	111.5	125.2	122.6	5.03	5.16	5.38	PASS
6	5 MΩ	125 kΩ	115.0	123.3	131.0	5.05	5.40	5.70	PASS
7	190 kΩ	190 kΩ	2527.8	2537.9	2550.3	57.42	59.22	60.99	PASS
8	190 kΩ	190 kΩ	2527.8	2540.7	2550.3	N/A	N/A	N/A	PASS
9	5 MΩ	125 kΩ	115.9	122.7	128.3	5.14	5.50	5.83	PASS
10	125 kΩ	5 MΩ	115.7	123.4	132.2	5.43	5.62	5.85	PASS
11	125 kΩ	125 kΩ	62.6	62.7	62.7	5.41	5.67	5.81	PASS

Table 4 – CC.7.5.15 measured results (20 repetitions each).

Test cases 2, 5 and 6 were repeated with extra capacitance of 2,5uF, 5uF, 10uF, 15uF and 25uF connected parallel with normal C_T1 and C_T2 capacitance of 2,5uF. Table 5 presents results of extra capacitance tests.

Case	C_T1	C_T2	Rmeas Min (kΩ)	Rmeas Mean (kΩ)	Rmeas Max (kΩ)	Time Min (s)	Time Mean (s)	Time Max (s)	Result
2	5 uF	5 uF	62.3	62.3	62.5	5.04	5.33	5,54	PASS
5	5 uF	5 uF	119.6	124.8	139.2	7.28	7.82	8.16	PASS
6	5 uF	5 uF	113.3	124.7	135.5	7.47	7.71	8.34	PASS
2	7,5 uF	7,5 uF	62.5	62.6	62.9	6.28	6.48	6.67	PASS
5	7,5 uF	7,5 uF	117.4	125.6	132.8	10.31	11.72	11.78	PASS
6	7,5 uF	7,5 uF	116.5	124.3	132.8	9.98	10.49	10.89	PASS
2	12,5 uF	12,5 uF	62.4	62.5	62.7	10.64	10.73	10.81	PASS
5	12,5 uF	12,5 uF	114.8	124.7	136.6	13.5	16.8	18.7	PASS
6	12,5 uF	12,5 uF	112.8	123.5	140.8	16.58	17.13	17.65	PASS
2	17,5 uF	17,5 uF	62.4	62.6	62.7	13.42	13.67	13.80	PASS
5	17,5 uF	17,5 uF	112.3	124.5	150.1	21.01	22.38	23.35	PASS
6	17,5 uF	17,5 uF	114.1	123.7	141.3	21.3	23.02	33.11	PASS
2	27,5 uF	27,5 uF	62.6	62.7	62.9	13.5	18.2	22.2	PASS
5	27,5 uF	27,5 uF	112.6	125.2	154.4	31.96	35.36	37.35	PASS
6	27,5 uF	27,5 uF	62.6	62.7	62.7	35.6	37.35	49.19	PASS

Table 5 – CC.7.5.15 extra capacitance tests (20 repetitions each).

6.5 Analysis

6.5.1 Cases 1, 3, 4 — No Alarm Expected (Valid Insulation)

In Cases 1 (symmetric, 380 kΩ/380 kΩ), 3 (asymmetric, 190 kΩ DC+ / 5 MΩ DC−), and 4 (asymmetric, 5 MΩ DC+ / 190 kΩ DC−), the measured insulation resistance remained above the 150 kΩ alarm threshold in all 20 repetitions, and no alarm was triggered. This is consistent with the 'Valid' insulation state defined in Table CC.18, where the EVSE shall complete cable check phase and send insulation valid message. The IMD correctly distinguished these conditions from fault conditions.

6.5.2 Cases 2, 5, 6 — Direct Insulation Fault (Alarm Required within 60 s)

In Cases 2 (125 kΩ/125 kΩ symmetric), 5 (125 kΩ DC+ / 5 MΩ DC−), and 6 (5 MΩ DC+ / 125 kΩ DC−), a direct fault resistance was applied to simulate the 'Fault' insulation state. The IMD detected the fault condition in all 20 repetitions in each case. The maximum alarm trigger times were 5.34 s (Case 2), 5.03 s (Case 5), and 5.05 s (Case 6), all within the 60 s limit required by CC.4.1.6. The measured Rmeas values (62.4–131.0 kΩ) are in the fault region below the 150 kΩ alarm threshold, confirming the fault was correctly quantified.

6.5.3 Case 7 — Long-Term Disturbance (Alarm Required within 180 s)

Case 7 simulates a long-term disturbance where the insulation fault resistances (190 kΩ/190 kΩ, which individually are above the per-rail fault threshold) are repeatedly switched on and off with a 1 s period. Under this condition, the IMD cannot obtain a stable insulation resistance measurement. CC.4.1.6 requires an error shutdown within 180 s of the last valid insulation measurement. The IMD triggered an alarm in all 20 runs with a maximum time of 60.99 s, within the 180 s limit. The high Rmeas values (2.5–2.8 MΩ) observed during this case reflect the alternating, undetermined measurement conditions, IMD showing last measured reliable result measured before disturbance has been started.

6.5.4 Case 8 — Short-Term Disturbance without Fault

Case 8 applies the same disturbance as Case 7 but for only 36 s, after which the fault resistances are removed and normal insulation conditions are restored. The standard does not require an alarm for this case; the EVSE should continue energy transfer. In all 20 repetitions, no alarm was triggered, confirming correct immunity to short-term disturbances that do not represent a persistent insulation fault.

6.5.5 Cases 9, 10, 11 — Short-Term Disturbance Followed by Fault

Cases 9, 10, and 11 combine a 36 s short-term disturbance phase followed by a permanent insulation fault condition. The standard requires an alarm within 60 s after the fault is applied. The maximum alarm trigger times observed were 5.83 s (Case 9), 5.85 s (Case 10), and 5.81 s (Case 11), all within the 60 s limit. These cases verify that the IMD correctly identifies and responds to a fault condition that arises after a period of measurement disturbance.

6.5.6 Cases 2, 5, 6 — Direct Insulation Fault with extra capacitances

Cases 2, 5 and 6 are otherwise the same but in these test there are extra capacitances of 2,5 uF, 5 uF, 10 uF, 15 uF, 25 uF connected to parallel with normal 2,5 uF value of C_T1 and C_T2 capacitance. All 20 repetitions per test case and for each extra capacitance value show consistent response value which well within 60s time requirement.

6.6 Verdict

All 11 test cases of CC.7.5.15 yielded results conforming to the expected behaviour defined in CC.7.5.15.7. For cases requiring no alarm, no false positives were generated. For cases requiring an alarm, the alarm was triggered in all 20 repetitions of each case within the same time limits as in tests CC.7.5.16. The test case CC.7.5.15 is assessed as PASS.

7 Test Case CC.7.5.16 — Insulation Resistance Check During Energy Transfer

7.1 Reference Requirements

This test case verifies compliance with the following normative requirements:

- 6.3.1.113.3 — Error shutdown
- CC.4.1.5 — Error shutdown upon first insulation fault
- CC.4.1.6 — Insulation monitoring after the cable-check phase

7.2 Test Description

This test verifies the EUT's reaction to low insulation resistance conditions (R < 62,5…125kΩ) during the energy transfer stage. The EVSE must trigger an error shutdown within the time limits specified in CC.4.1.6: 60 s or less for direct fault conditions, and 180 s or less for sustained disturbance conditions.

Eleven test cases are defined, covering symmetric and asymmetric insulation faults, long-term disturbance conditions, short-term disturbances without fault, and short-term disturbances followed by an insulation fault. Each test case was executed 20 times to establish statistical reliability of the alarm trigger timing.

7.3 Test Conditions

Table 6 defines the test resistance values, expected alarm behaviour, and standard time limits for each of the 11 test cases.

Case	R_T5 (DC+)	R_T6 (DC−)	C_T1, C_T2	V_{test}	Condition Type	Alarm Expected	Time Limit
1	380 kΩ	380 kΩ	2,5 µF	1000 V	Symmetric – no fault	None	—
2	125 kΩ	125 kΩ	2,5 µF	1000 V	Symmetric – fault	Yes, within 60 s	60 s
3	190 kΩ	5 MΩ	2,5 µF	1000 V	Asymmetric – no fault (DC+)	None	—
4	5 MΩ	190 kΩ	2,5 µF	1000 V	Asymmetric – no fault (DC−)	None	—
5	125 kΩ	5 MΩ	2,5 µF	1000 V	Asymmetric – fault (DC+)	Yes, within 60 s	60 s
6	5 MΩ	125 kΩ	2,5 µF	1000 V	Asymmetric – fault (DC−)	Yes, within 60 s	60 s
7	190 kΩ	190 kΩ	2,5 µF	1000 V	Long-term disturbance (1 s on/off)	Yes, within 180 s	180 s
8	190 kΩ	190 kΩ	2,5 µF	1000 V	Short-term disturbance – no fault	None	—
9	Step1: 190 kΩ Step2: 5 MΩ	Step1: 190 kΩ Step2: 125 kΩ	2,5 µF	1000 V	Short-term dist. + fault (DC−)	Yes, within 60 s of fault	60 s
10	Step1: 190 kΩ Step2: 125 kΩ	Step1: 190 kΩ Step2: 5 MΩ	2,5 µF	1000 V	Short-term dist. + fault (DC+)	Yes, within 60 s of fault	60 s
11	Step1: 190 kΩ Step2: 125 kΩ	Step1: 190 kΩ Step2: 125 kΩ	2,5 µF	1000 V	Short-term dist. + sym. fault	Yes, within 60 s of fault	60 s

Table 6 – CC.7.5.16 test case conditions and alarm requirements

7.4 Measured Results

Table 7 presents summary of the 20 repetitions per test case. The column 'Rmeas' shows the insulation resistance value reported by the IMD. For cases where no alarm was expected, the 'Time' column shows N/A (no alarm triggered). For cases requiring an alarm, the minimum, mean, and maximum times are reported.

Case	R_T5	R_T6	Rmeas Min (kΩ)	Rmeas Mean (kΩ)	Rmeas Max (kΩ)	Time Min (s)	Time Mean (s)	Time Max (s)	Result
1	380 kΩ	380 kΩ	177.3	177.7	178.2	—	—	—	PASS
2	125 kΩ	125 kΩ	62.4	62.6	62.7	5.34	5.43	5.53	PASS
3	190 kΩ	5 MΩ	175.5	181.7	185.4	—	—	—	PASS
4	5 MΩ	190 kΩ	177.3	181.0	186.1	—	—	—	PASS
5	125 kΩ	5 MΩ	111.5	125.2	122.6	5.03	5.16	5.38	PASS
6	5 MΩ	125 kΩ	115.0	123.3	131.0	5.05	5.40	5.70	PASS
7	190 kΩ	190 kΩ	2527.8	2537.9	2550.3	57.42	59.22	60.99	PASS
8	190 kΩ	190 kΩ	2527.8	2540.7	2550.3	—	—	—	PASS
9	5 MΩ	125 kΩ	115.9	122.7	128.3	5.14	5.50	5.83	PASS
10	125 kΩ	5 MΩ	115.7	123.4	132.2	5.43	5.62	5.85	PASS
11	125 kΩ	125 kΩ	62.6	62.7	62.7	5.41	5.67	5.81	PASS

Table 7 – CC.7.5.16 measured results (20 repetitions each).

Test cases 2, 5 and 6 were repeated with extra capacitance of 2,5uF, 5uF, 10uF, 15uF and 25uF connected parallel with normal C_T1 and C_T2 capacitance of 2,5uF. Table 8 presents results of extra capacitance tests.

Case	C_T1	C_T2	Rmeas Min (kΩ)	Rmeas Mean (kΩ)	Rmeas Max (kΩ)	Time Min (s)	Time Mean (s)	Time Max (s)	Result
2	5 uF	5 uF	62.3	62.3	62.5	5.04	5.33	5,54	PASS
5	5 uF	5 uF	119.6	124.8	139.2	7.28	7.82	8.16	PASS
6	5 uF	5 uF	113.3	124.7	135.5	7.47	7.71	8.34	PASS
2	7,5 uF	7,5 uF	62.5	62.6	62.9	6.28	6.48	6.67	PASS
5	7,5 uF	7,5 uF	117.4	125.6	132.8	10.31	11.72	11.78	PASS
6	7,5 uF	7,5 uF	116.5	124.3	132.8	9.98	10.49	10.89	PASS
2	12,5 uF	12,5 uF	62.4	62.5	62.7	10.64	10.73	10.81	PASS
5	12,5 uF	12,5 uF	114.8	124.7	136.6	13.5	16.8	18.7	PASS
6	12,5 uF	12,5 uF	112.8	123.5	140.8	16.58	17.13	17.65	PASS
2	17,5 uF	17,5 uF	62.4	62.6	62.7	13.42	13.67	13.80	PASS
5	17,5 uF	17,5 uF	112.3	124.5	150.1	21.01	22.38	23.35	PASS
6	17,5 uF	17,5 uF	114.1	123.7	141.3	21.3	23.02	33.11	PASS
2	27,5 uF	27,5 uF	62.6	62.7	62.9	13.5	18.2	22.2	PASS
5	27,5 uF	27,5 uF	112.6	125.2	154.4	31.96	35.36	37.35	PASS
6	27,5 uF	27,5 uF	62.6	62.7	62.7	35.6	37.35	49.19	PASS

Table 8 – CC.7.5.15 extra capacitance tests (20 repetitions each).

7.5 Analysis

7.5.1 Cases 1, 3, 4 — No Alarm Expected (Valid Insulation)

In Cases 1 (symmetric, 380 kΩ/380 kΩ), 3 (asymmetric, 190 kΩ DC+ / 5 MΩ DC−), and 4 (asymmetric, 5 MΩ DC+ / 190 kΩ DC−), the measured insulation resistance remained above the 150 kΩ alarm threshold in all 20 repetitions, and no alarm was triggered. This is consistent with the 'Valid' insulation state defined in Table CC.18, where the EVSE shall allow energy transfer to continue. The IMD correctly distinguished these conditions from fault conditions.

7.5.2 Cases 2, 5, 6 — Direct Insulation Fault (Alarm Required within 60 s)

In Cases 2 (125 kΩ/125 kΩ symmetric), 5 (125 kΩ DC+ / 5 MΩ DC−), and 6 (5 MΩ DC+ / 125 kΩ DC−), a direct fault resistance was applied to simulate the 'Fault' insulation state. The IMD detected the fault condition in all 20 repetitions in each case. The maximum alarm trigger times were 5.34 s (Case 2), 5.03 s (Case 5), and 5.05 s (Case 6), all within the 60 s limit required by CC.4.1.6. The measured Rmeas values (62.4–131.0 kΩ) are in the fault region below the 150 kΩ alarm threshold, confirming the fault was correctly quantified.

7.5.3 Case 7 — Long-Term Disturbance (Alarm Required within 180 s)

Case 7 simulates a long-term disturbance where the insulation fault resistances (190 kΩ/190 kΩ, which individually are above the per-rail fault threshold) are repeatedly switched on and off with a 1 s period. Under this condition, the IMD cannot obtain a stable insulation resistance measurement. CC.4.1.6 requires an error shutdown within 180 s of the last valid insulation measurement. The IMD triggered an alarm in all 20 runs with a maximum time of 60.99 s, within the 180 s limit. The high Rmeas values (2.5–2.8 MΩ) observed during this case reflect the alternating, undetermined measurement conditions, IMD showing last measured reliable result measured before disturbance has been started.

7.5.4 Case 8 — Short-Term Disturbance without Fault

Case 8 applies the same disturbance as Case 7 but for only 36 s, after which the fault resistances are removed and normal insulation conditions are restored. The standard does not require an alarm for this case; the EVSE should continue energy transfer. In all 20 repetitions, no alarm was triggered, confirming correct immunity to short-term disturbances that do not represent a persistent insulation fault.

7.5.5 Cases 9, 10, 11 — Short-Term Disturbance Followed by Fault

Cases 9, 10, and 11 combine a 36 s short-term disturbance phase followed by a permanent insulation fault condition. The standard requires an alarm within 60 s after the fault is applied. The maximum alarm trigger times observed were 5.83 s (Case 9), 5.85 s (Case 10), and 7.68 s (Case 11), all within the 60 s limit. These cases verify that the IMD correctly identifies and responds to a fault condition that arises after a period of measurement disturbance.

7.5.6 Cases 2, 5, 6 — Direct Insulation Fault with extra capacitances

Cases 2, 5 and 6 are otherwise the same but in these test there are extra capacitances of 2,5 uF, 5 uF, 10 uF, 15 uF, 25 uF connected to parallel with normal 2,5 uF value of C_T1 and C_T2 capacitance. All 20 repetitions per test case and for each extra capacitance value show consistent response value which well within 60s time requirement.

7.6 Verdict

All 11 test cases of CC.7.5.16 yielded results conforming to the expected behaviour defined in CC.7.5.16.7. For cases requiring no alarm, no false positives were generated. For cases requiring an alarm, the alarm was triggered in all 20 repetitions of each case within the time limits defined in CC.7.5.16. The test case CC.7.5.16 is assessed as PASS.

8 Overall Results Summary

Table 5 provides a consolidated pass/fail verdict for all executed test cases.

Test Case	Standard Clause	Description	Repetitions	Verdict
CC.7.5.23 – Case 1	CC.4.1.3	Functional check of IMD – Normal operation	1	**PASS**
CC.7.5.23 – Cases 2a–2b	CC.4.1.3	Functional check – IMD connection to PE interrupted	2	**PASS**
CC.7.5.23 – Cases 3a–3f	CC.4.1.3	Functional check – IMD measurement connections interrupted	6	**PASS**
CC.7.5.23 – Cases 4a–4c	CC.4.1.3	Functional check – IMD power supply interrupted	3	**PASS**
CC.7.5.15 – Case 1	CC.4.1.6	Symmetric, 380 kΩ/380 kΩ – no alarm expected	20	**PASS**
CC.7.5.15 – Case 2	CC.4.1.6	Symmetric, 125 kΩ/125 kΩ – alarm within 60 s	20	**PASS**
CC.7.5.15 – Case 3	CC.4.1.6	Asymmetric, 190 kΩ DC+ – no alarm expected	20	**PASS**
CC.7.5.15 – Case 4	CC.4.1.6	Asymmetric, 190 kΩ DC− – no alarm expected	20	**PASS**
CC.7.5.15 – Case 5	CC.4.1.6	Asymmetric, 125 kΩ DC+ – alarm within 60 s	20	**PASS**
CC.7.5.15 – Case 6	CC.4.1.6	Asymmetric, 125 kΩ DC− – alarm within 60 s	20	**PASS**
CC.7.5.15 – Case 7	CC.4.1.6	Long-term disturbance – alarm within 180 s	20	**PASS**
CC.7.5.15 – Case 8	CC.4.1.6	Short-term disturbance – no alarm expected	20	**PASS**
CC.7.5.15 – Case 9	CC.4.1.6	Short-term disturbance + fault (DC−) – alarm within 60 s	20	**PASS**
CC.7.5.15 – Case 10	CC.4.1.6	Short-term disturbance + fault (DC+) – alarm within 60 s	20	**PASS**
CC.7.5.15 – Case 11	CC.4.1.6	Short-term disturbance + sym. fault – alarm within 60 s	20	**PASS**
CC.7.5.15 – Case 2 + 2,5 uF	CC.4.1.6	Symmetric with 2,5 uF extra capacitance, 125 kΩ/125 kΩ	20	**PASS**
CC.7.5.15 – Case 5 + 2,5 uF	CC.4.1.6	Asymmetric with 2,5 uF extra capacitance, 125 kΩ DC+	20	**PASS**
CC.7.5.15 – Case 6 + 2,5 uF	CC.4.1.6	Asymmetric with 2,5 uF extra capacitance, 125 kΩ DC−	20	**PASS**
CC.7.5.15 – Case 2 + 5 uF	CC.4.1.6	Symmetric with 5 uF extra capacitance, 125 kΩ/125 kΩ	20	**PASS**
CC.7.5.15 – Case 5 + 5 uF	CC.4.1.6	Asymmetric with 5 uF extra capacitance, 125 kΩ DC+	20	**PASS**
CC.7.5.15 – Case 6 + 5 uF	CC.4.1.6	Asymmetric with 5 uF extra capacitance, 125 kΩ DC−	20	**PASS**
CC.7.5.15 – Case 2 + 10 uF	CC.4.1.6	Symmetric with 10 uF extra capacitance, 125 kΩ/125 kΩ	20	**PASS**
CC.7.5.15 – Case 5 + 10 uF	CC.4.1.6	Asymmetric with 10 uF extra capacitance, 125 kΩ DC+	20	**PASS**

CC.7.5.15 – Case 6 + 10 uF	CC.4.1.6	Asymmetric with 10 uF extra capacitance, 125 kΩ DC−	20	**PASS**
CC.7.5.15 – Case 2 + 15 uF	CC.4.1.6	Symmetric with 15 uF extra capacitance, 125 kΩ/125 kΩ	20	**PASS**
CC.7.5.15 – Case 5 + 15 uF	CC.4.1.6	Asymmetric with 15 uF extra capacitance, 125 kΩ DC+	20	**PASS**
CC.7.5.15 – Case 6 + 15 uF	CC.4.1.6	Asymmetric with 15 uF extra capacitance, 125 kΩ DC−	20	**PASS**
CC.7.5.15 – Case 2 + 25 uF	CC.4.1.6	Symmetric with 25 uF extra capacitance, 125 kΩ/125 kΩ	20	**PASS**
CC.7.5.15 – Case 5 + 25 uF	CC.4.1.6	Asymmetric with 25 uF extra capacitance, 125 kΩ DC+	20	**PASS**
CC.7.5.15 – Case 6 + 25 uF	CC.4.1.6	Asymmetric with 25 uF extra capacitance, 125 kΩ DC−	20	**PASS**
CC.7.5.16 – Case 1	CC.4.1.6	Symmetric, 380 kΩ/380 kΩ – no alarm expected	20	**PASS**
CC.7.5.16 – Case 2	CC.4.1.6	Symmetric, 125 kΩ/125 kΩ – alarm within 60 s	20	**PASS**
CC.7.5.16 – Case 3	CC.4.1.6	Asymmetric, 190 kΩ DC+ – no alarm expected	20	**PASS**
CC.7.5.16 – Case 4	CC.4.1.6	Asymmetric, 190 kΩ DC− – no alarm expected	20	**PASS**
CC.7.5.16 – Case 5	CC.4.1.6	Asymmetric, 125 kΩ DC+ – alarm within 60 s	20	**PASS**
CC.7.5.16 – Case 6	CC.4.1.6	Asymmetric, 125 kΩ DC− – alarm within 60 s	20	**PASS**
CC.7.5.16 – Case 7	CC.4.1.6	Long-term disturbance – alarm within 180 s	20	**PASS**
CC.7.5.16 – Case 8	CC.4.1.6	Short-term disturbance – no alarm expected	20	**PASS**
CC.7.5.16 – Case 9	CC.4.1.6	Short-term disturbance + fault (DC−) – alarm within 60 s	20	**PASS**
CC.7.5.16 – Case 10	CC.4.1.6	Short-term disturbance + fault (DC+) – alarm within 60 s	20	**PASS**
CC.7.5.16 – Case 11	CC.4.1.6	Short-term disturbance + sym. fault – alarm within 60 s	20	**PASS**
CC.7.5.16 – Case 2 + 2,5 uF	CC.4.1.6	Symmetric with 2,5 uF extra capacitance, 125 kΩ/125 kΩ	20	**PASS**
CC.7.5.16 – Case 5 + 2,5 uF	CC.4.1.6	Asymmetric with 2,5 uF extra capacitance, 125 kΩ DC+	20	**PASS**
CC.7.5.16 – Case 6 + 2,5 uF	CC.4.1.6	Asymmetric with 2,5 uF extra capacitance, 125 kΩ DC−	20	**PASS**
CC.7.5.16 – Case 2 + 5 uF	CC.4.1.6	Symmetric with 5 uF extra capacitance, 125 kΩ/125 kΩ	20	**PASS**
CC.7.5.16 – Case 5 + 5 uF	CC.4.1.6	Asymmetric with 5 uF extra capacitance, 125 kΩ DC+	20	**PASS**
CC.7.5.16 – Case 6 + 5 uF	CC.4.1.6	Asymmetric with 5 uF extra capacitance, 125 kΩ DC−	20	**PASS**
CC.7.5.16 – Case 2 + 10 uF	CC.4.1.6	Symmetric with 10 uF extra capacitance, 125 kΩ/125 kΩ	20	**PASS**

CC.7.5.16 – Case 5 + 10 uF	CC.4.1.6	Asymmetric with 10 uF extra capacitance, 125 kΩ DC+	20	**PASS**
CC.7.5.16 – Case 6 + 10 uF	CC.4.1.6	Asymmetric with 10 uF extra capacitance, 125 kΩ DC−	20	**PASS**
CC.7.5.16 – Case 2 + 15 uF	CC.4.1.6	Symmetric with 15 uF extra capacitance, 125 kΩ/125 kΩ	20	**PASS**
CC.7.5.16 – Case 5 + 15 uF	CC.4.1.6	Asymmetric with 15 uF extra capacitance, 125 kΩ DC+	20	**PASS**
CC.7.5.16 – Case 6 + 15 uF	CC.4.1.6	Asymmetric with 15 uF extra capacitance, 125 kΩ DC−	20	**PASS**
CC.7.5.16 – Case 2 + 25 uF	CC.4.1.6	Symmetric with 25 uF extra capacitance, 125 kΩ/125 kΩ	20	**PASS**
CC.7.5.16 – Case 5 + 25 uF	CC.4.1.6	Asymmetric with 25 uF extra capacitance, 125 kΩ DC+	20	**PASS**
CC.7.5.16 – Case 6 + 25 uF	CC.4.1.6	Asymmetric with 25 uF extra capacitance, 125 kΩ DC−	20	**PASS**

Table 5 – Overall test results summary

All executed test cases pass. The IM-07 insulation monitoring device of the EUT (SW046) has demonstrated correct functional behaviour across all tested conditions: correct alarm detection within the standard-prescribed time limits, correct suppression of false alarms under valid insulation conditions, and correct detection of IMD connection failures during the functional check phase.

9 Conclusions

This pre-compliance test report documents the verification of the IM-07 insulation monitoring function in the EUT running software SW046 against the requirements of IEC 61851-23-3 ED1, Annex CC, specifically test cases CC.7.5.23 (IMD functional check), CC.7.5.15 (Insulation resistance checks before pre-charge) and CC.7.5.16 (insulation resistance monitoring during energy transfer).

The key engineering conclusions are as follows. First, the IMD functional check (CC.7.5.23) passed all 12 sub-cases, confirming that the EUT reliably detects single-point interruptions in the IMD measurement connections to the DC bus rails (DC+ and DC−) and PE, as well as interruptions in the IMD power supply. In all fault cases, the EUT responded with the correct error message and initiated an error shutdown, preventing continued operation with a non-functional IMD.

Second, the insulation resistance monitoring during energy transfer (CC.7.5.16) passed all 11 test cases across 20 repetitions each. The IMD correctly classified both symmetric and asymmetric insulation conditions relative to the 150 kΩ alarm threshold, and triggered the required error shutdown within the standard time limits: within 60 s for direct fault conditions (Cases 2, 5, 6, 9, 10, 11) and within 180 s for the long-term disturbance condition (Case 7). No false alarms were generated under valid insulation conditions (Cases 1, 3, 4, 8).

The test results provide strong engineering evidence that the IM-07 IMD function meets the functional requirements of IEC 61851-23-3 ED1. Further formal certification testing, including full environmental conditioning and testing at an accredited laboratory, would be required before any conformity declaration is made for a commercial product.

9 References

[1] *IEC 61851-23-3 ED1* — Electric vehicle conductive charging system – Part 23-3: DC electric vehicle supply equipment for Megawatt charging systems (Ed. 1.0)

[2] *IEC 61851-23:2023* — Electric vehicle conductive charging system – Part 23: DC electric vehicle supply equipment (Ed. 2.0)

[3] *IEC 61557-8:2014* — Insulation monitoring devices for IT systems (Ed. 2.0)

[4] *IEC 61851-24:2023* — Digital communication between DC EV supply equipment and an EV for control of DC charging

[5] *DIN SPEC 70121:2014* — Digital communication between a DC charging station and an EV

[6] *ISO 15118-2:2014* — Road vehicles – Vehicle to grid communication interface – Part 2: Network and application protocol requirements

[7] *ISO 17409:2020* — Electrically propelled road vehicles – Conductive power transfer – Safety requirements