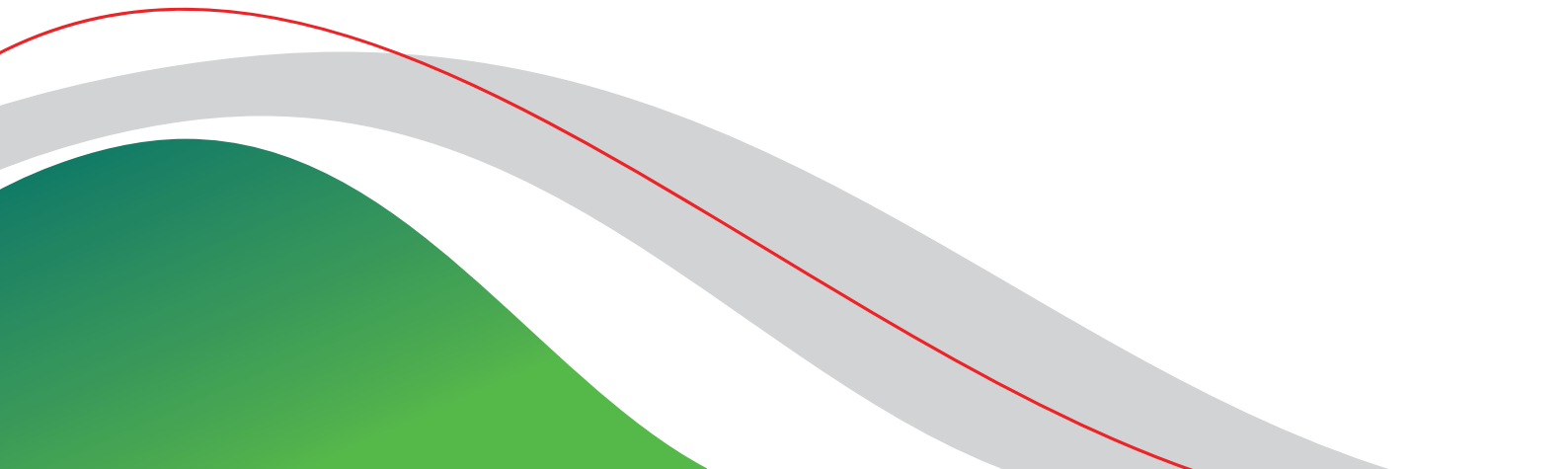




SHAMS DUBAI

# CHECKLIST TESTING AND INSPECTION WITHOUT INTERCONNECTION

VERSION 1.0 AUGUST 2015





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# TABLE OF CONTENTS

<b>1</b>	<b>SCOPE</b>	<b>5</b>
1.1	PV PLANT AND INSPECTION DATA	6
<b>2</b>	<b>TESTING EQUIPMENT</b>	<b>7</b>
<b>3</b>	<b>DOCUMENTS</b>	<b>8</b>
3.1	Reference documents and standards	8
3.2	PV plant design documents (Technical dossier)	8
<b>4</b>	<b>TESTS AND INSPECTIONS WITHOUT INTERCONNECTION TO THE NETWORK</b>	<b>9</b>
4.1	Mechanical inspections and Tests	9
4.1.1	PV plant General Assessment	9
4.1.2	Civil Works	10
4.1.3	Support Structures	11
4.1.4	Photovoltaic Modules	12
4.2	Inspections without interconnection	13
4.2.2	Protection of Assembled Components (IP degree)	14
4.2.3	String Combiner Boxes (DC string connections and AC auxiliary services)	15
4.2.4	Electrical Power Connections in Substations and Electrical Rooms	16
4.2.5	Bonding and Earthing System	17
4.2.6	Connections to earthing system of metal structures / equipment	18
4.3	Tests without interconnection	19
4.3.1	Insulation of LV connections DC and AC	19
4.3.2	Measurements on PV strings	20
4.3.3	Calibration of protections (Interface Protection)	21
	<b>ANNEX 1 – INSULATION TESTS</b>	<b>22</b>
	<b>ANNEX 2 – TESTS ON PV STRINGS</b>	<b>23</b>
	PV string open circuit voltage measurements	23
	PV string short-circuit current measurements	23
	Test insulation between earth and short-circuited strings	23
	Report of detailed test results	24



# 1 SCOPE

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This document reports the results of the Mechanical Completion inspection.

The inspection consists of visual checks and of the measurement of selected electrical characteristics. Most checks are required with reference to 100% of the installation, some checks and measures with reference to a minimum percentage of 15% of the installation.

At completion of the test, a Test report shall be prepared.

Participants shall take note of inspection checks and measures for their own record. The test engineer of the Applicant / Contractor shall prepare the draft Test Report that will be distributed to the participants for comments and approval.

The present Mechanical Completion inspection is related to testing without interconnection, a further on-site testing phase shall be carried out in the frame of the Final Inspection: the Mechanical Completion test report will be thus become part of the Final Inspection Report.

The checks to be performed in the Mechanical Completion inspection are described in the following paragraphs.

The testing instruments shall be provided by the Applicant / Contractor and have valid calibration certificates in order that valid on-site testing measures can be performed.

## 1.1 PV PLANT AND INSPECTION DATA

Name of the PV Plant	Nominal Power (kW)			Location of the Plant	
Type of installation	Rooftop	Flat rooftop	Ground	Pole	BIPV
Date of the inspection					

Name of Test Engineer <sup>(1)</sup>	Affiliation	Licence / Register ID
	Consultant	

TESTING AND INSPECTION WITHOUT INTERCONNECTION RESULT	PASSED
	REJECTED

Participant	Affiliation	Role
	Consultant	Designer
	Consultant	Test engineer
	Contractor	Installer
	DEWA	Inspector

1 Tests are to be carried out by a licensed engineer

## 2 TESTING EQUIPMENT

Test equipment						
Type of measure		Manufacturer	Model	SN	Calibration Certificate	Date of last calibration
<b>1</b>	<b>DC power</b>					
	Wattmeter					
	DC clamp meter					
<b>2</b>	<b>PV installation test equipment (*)</b>					
	VOC, ISC, insulation resistance (see Sect. 4.2.2)					
<b>3</b>	<b>Solar radiation</b>					
	Reference cell					
<b>4</b>	<b>Cell temperature</b>					
	Thermocouple / PT100					
<b>5</b>	<b>Checks on PV strings</b>					
	Inclinometer					
	Digital multimeter					
	Clamp Digital multimeter					
	Insulation resistance and continuity (Megger or equivalent instrument)					

(\*) It is recommended the use of equipment that can perform measurements in accordance to IEC 62446 (e.g. Seward PV150, HT-Instruments PVCHECK, Gossen Metrawatt PROFITEST).

# 3 DOCUMENTS

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## 3.1 Reference documents and standards

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- [1] DEWA Standards for Distributed Renewable Resources Generators Connected to the Distribution Network
- [2] DEWA Connection Guidelines for Distributed Renewable Resources Generators Connected to the Distribution Network
- [3] DEWA Inspection and Testing Guideline for Distributed Renewable Resources Generators Connected to the Distribution Network

## 3.2 PV plant design documents (Technical dossier)

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A list of documents provided by the Applicant to DEWA will be filled as in the proposed template here below.

### Data-sheets and catalogues

[1]	
[2]	
[3]	
....	

### Technical Reports

[1]	
[2]	
[3]	
....	

### Drawings

[1]	
[2]	
[3]	
....	



# 4 TESTS AND INSPECTIONS WITHOUT INTERCONNECTION TO THE NETWORK

## 4.1 Mechanical inspections and Tests

### 4.1.1 PV plant General Assessment

With reference to 100% of the installation, verify the correspondence to the drawings and design documents regarding the quantity, type, sizing, installation and integrity of components and materials. The following checks shall be performed.

General assessment of RRGU / RRGP									
		Doc. ref.	Result						Ref. to Note
1	Configuration of PV plant, separation subfields, verification of string layout on support frames		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
2	Orientation of the PV field: within the range of tolerances set out in the project design		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
3	Check the total number of modules		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
Following the verification of the number of modules installed, the total power is equal to: xxx.xx kWp									
4	Positioning of the structures		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
5	Number and position of the cabins		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
6	Position of main cable ways		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
7	Safe access to the rooftop and Exit plan		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
8	Condition of the internal roads		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
9	Drainage works and / or rainwater drainage		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
10	Cleanliness of the modules		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
11	Barriers and fences (path, type) and segregation of hazardous areas		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
12	Availability of warning signs (e.g. "WARNING DUAL SUPPLY")		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
13	Availability of single line diagram and PV modules layout in the cabin		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
Note:		1. ....							
		2.....							
		3.....							

## 4.1.2 Civil Works

The Inspections listed below will involve the concerned Authority (i.e. Dubai Municipality, Trakhees, etc.). A provisional description of the Inspection is given only to make the Applicant aware of the kind of checks that may be performed.

With reference to 100% of the installation, verify the compliance with the drawings and design documents regarding the quantity, type, sizing, installation and integrity of components and materials. The following checks shall be performed.

Civil works									
		Doc. ref.	Result						Ref. to Note
1	Foundations (state, breakage, deterioration of the surface)		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
2	Structural alignments: within the tolerances set by design		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
3	Placement of inserts and holes in foundations and precast		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
4	General conditions of the cabins and related foundations		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
5	Waterproofing of the cabins		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
6	Roof integrity and ingress protection (water proof) of mounting system to the roof		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
7	Access doors of the cabins		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
8	Ventilation grills / air conditioning of the cabins		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
9	Integrity and layout of cableways / conduits		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
Note:		1. ....							
		2. ....							
		3. ....							

### 4.1.3 Support Structures

The Inspections listed below will involve the concerned Authority (i.e. Dubai Municipality, Trakhees, etc.). A provisional description of the Inspection is given only to make the Applicant aware of the kind of checks that may be performed.

With reference to 100% of the installation, verify the compliance with the drawings and design documents regarding the quantity, type, sizing, installation and integrity of components and materials. The following checks shall be performed.

Support Structures									
		Doc. ref.	Result						Ref. to Note
1	Mounting of supporting structures and of fixation elements		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
2	Condition of the components (damages, defects, weld quality, loss of galvanic protection, corrosion)		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
3	Planarity of the PV modules supporting structures (arrows, sags)		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
4	Inclination of PV modules: within the tolerances set in the design		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
5	Bolts and tightening torque corresponding to design (sample check)		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
6	Support structures and fasteners are suitable to weather conditions and compatible with other materials to prevent corrosion		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
Note:	1. ....								
	2.....								
	3.....								

## 4.1.4 Photovoltaic Modules

With reference to 100% of the installation, verify the compliance with the drawings and design documents regarding the quantity, type, sizing, installation and integrity of components and materials. The following checks shall be performed.

Photovoltaic modules									
Visual inspection of PV modules		Doc. ref.	Result					Ref. to Note	
1	Mechanical integrity of the modules (faults, breakdowns or incomplete assembly)		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
2	Integrity functional parts of the modules (delamination, discoloration, dirt, etc.)		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
3	Labeling of modules		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
4	Fixation system		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
5	Bolts and tightening torques corresponding to design (on a sample basis)		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
6	No growing trees or bushes shadow any PV module		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
Quality of cabling		Doc. ref.	Result					Ref. to Note	
7	Tightening of cable glands		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
8	Correct installation of DC cables (clamps, sharp edges, folds too narrow, etc.).		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
9	Assembly and crimping of plug-in connectors		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
10	Plug-in connectors do not touch the ground or the roof surface		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
Note:	1. ....								
	2. ....								
	3. ....								

## 4.2 Inspections without interconnection

### 4.2.1 Electrical equipment

With reference to 100% of the installation, verify the compliance with the drawings and design documents regarding the quantity, type, sizing, installation and integrity of components and materials. The following checks shall be performed.

Electrical equipment									
		Doc. ref.	Result					Ref. to Note	
1	Positioning and fixation of string combiner boxes for connection of PV strings		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
2	Installation of raceways and/or cable sheaths string		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
3	Positioning in the cabins of the equipment: inverters, transformers, switchgear, etc.		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
4	Mechanical integrity of the said equipment (e.g. faults, breaks)		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
5	Switch-disconnectors on DC side visible and reachable (all buildings, switch position according to design)		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
6	Emergency remote control (manual call point) to disconnect a portion of PV plant (ordinary and higher hazard buildings, min. eight 1.1 m above floor)		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
Note:	1. ....								
	2.....								
	3.....								

## 4.2.2 Protection of Assembled Components (IP degree)

With reference to 100% of the installation, check the fulfilment of the design prescriptions.

Protection of assembled components (IP degree)									
Check the fulfilment of the design prescriptions									
		Doc. ref.	Result						Ref. to Note
1	IP degree of equipment, string combiner boxes, etc.		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
2	Installation of equipment, string combiner boxes, etc.		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
3	Installation of cable glands and connectors related to the above equipment		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
4	Positioning of cable ducts / conduits on metallic cableways / ladders		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
5	Protective provisions against rodents (polyurethane foam to obstruct inlets of conduits and of cabins) and insects (anti-insect grilles)		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
6	Labeling of cables, cable ducts and equipment		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
Note:	1. ....								
	2.....								
	3.....								

### 4.2.3 String Combiner Boxes (DC string connections and AC auxiliary services)

With reference to a percentage of the installed plant, ranging between the 15% and the 20%, check compliance of labels (cables, terminal blocks, and connectors) with drawings and design documents. Check the cables are tightened in their respective terminals.

String combiner boxes (DC string connections and AC auxiliary services)									
		Doc. ref.	Result						Ref. to Note
1	Execution of wiring and cable labeling according to cable lists		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
2	The cross section area and the type of cables (UV resistant, waterproof, etc.) fully comply with the design documents		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
3	Cable loops executed with a minimum open area in order to reduce the risk of lightning induced voltage surges		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
4	Termination of DC cables and control cables (including AC auxiliary services if applicable) into their respective clamp terminals		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
5	Route of signal cables among the string combiner boxes		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
6	Quantity and characteristics of DC circuit breakers, disconnect switches, and protections. Check their functionality		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
7	Quantity and characteristics of surge arresters		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
8	Assembly and wiring of blocking diodes		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
Note:		1. ....							
		2.....							
		3.....							

## 4.2.4 Electrical Power Connections in Substations and Electrical Rooms

With reference to 100% of the installation, check compliance of labels (cables, terminal blocks, and connectors) with drawings and design documents. Check the cables are tightened in their respective terminals.

Electrical power connections in substations and electrical rooms									
		Doc. ref.	Result						Ref. to Note
1	Execution of wiring according to cable lists (sample check)		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
2	Labeling of trays and cables according to cable lists (sample check)		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
3	LV and MV switchgears: check termination of LV and MV cables and control that all cables are tightened into their respective clamp terminals		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
4	LV and MV switchgears: quantity and characteristics of breakers, isolators and protections. Check their functionality		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
5	Inverter connected according to design		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
6	Systems for air conditioning and/or ventilation according to design		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
7	Connection of switchgears according to design		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
8	Connection of LV / MV transformers according to design		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
Note:	1. ....								
	2.....								
	3.....								



## 4.2.5 Bonding and Earthing System

With reference to 100% of the installation, do the following checks.

Bonding and earthing system									
		Doc. ref.	Result					Ref. to Note	
1	Earthing system of PV plant installed according to design; check bonding connections and connection to terminals of main existing earthing grid		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
2	Certification of correct execution / performance of main earthing grid (assess periodical verification tests of earth resistance according to local rules)		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
3	Connections to DEWA earthing network, if applicable		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
4	Earthing conductors terminate in the earthing busbar of the DRRG system		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
5	Earthing busbar is properly bonded with the local earthing of the site		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
6	Independent earth connection of main equipment to earthing busbar		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
7	Connection of earthing copper cables to aluminum structures via proper connectors (copper-aluminum, tin plated copper, stainless steel, ...) to prevent corrosion from dissimilar metals		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
Note:	1. ....								
	2.....								
	3.....								

## 4.2.6 Connections to earthing system of metal structures / equipment

With reference to 100% of the installation, check the connections to the terminals and the earthing grid.

Connections to earthing system of metal structures / equipment									
		Doc. ref.	Result					Ref. to Note	
1	Installation and test of the electrical continuity of the grounding connections of metal support structures and other metal parts (at least two points of each support structure shall be connected to the earthing system)		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
2	The earthing conductors are connected to the pre-drilled holes of PV modules marked with an earthing sign and with lugs of a proper material to avoid corrosion.		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
3	Test of the electrical continuity of the PV modules frames (if any) with the supporting structure or installation and test of bonding and earthing conductors on PV modules frames		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
4	In case of bonding and earthing conductors on PV modules frames the removal of any PV module(s) does not compromise the continuity of the grounding system		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
5	Installation and test of the electrical continuity of the grounding connections of surge arresters		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
6	Installation and test of the electrical continuity of the grounding connections of equipment and switchgear in the cabins		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
7	Installation of the grounding connection of MV cable shields		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
8	Installation or revision of the Lightning protection system (LPS) according to detailed design		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
Note:		1. ....							
		2.....							
		3.....							

## 4.3 Tests without interconnection

### 4.3.1 Insulation of LV connections DC and AC

The measurements are collected in Annex 1

Insulation test – Summary of test results									
Protection devices and electronic equipment that might be affected by the test voltage shall be disconnected during the performance of the measures.									
		Doc. ref.	Result						Ref. to Note
1	Test insulation of DC circuits, including clamps and terminals (max. 1000 VDC for 1 min.)		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
2	Check Insulation resistance of DC circuits higher than 1 MΩ (including clamps and terminals). Check Insulation resistance of PV strings higher than 5 MΩ (2 MΩ in the case of moisture on PV modules)		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
3	Test insulation of AC circuits, including clamps and terminals (max. 1000 VDC for 1 min.)		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>			
4	Check insulation resistance is higher than 1 MΩ for DC circuits including clamps and terminals		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
Note:	1. ....								
	2. ....								
	3. ....								

### 4.3.2 Measurements on PV strings

The measurements are collected in Annex 2

Measurements on PV strings – Summary of test results									
Protection devices and electronic equipment that might be affected by the test voltage shall be disconnected during the performance of the measures.									
		Doc. ref.	Result						Ref. to Note
1	Measure each single string voltage VOC (inverter switched off)		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
2	Measure each single string current ISC (inverter switched off)		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
3	Insulation test between short-circuited array and earth. Limit value of insulation resistance for acceptance of each string: 5 MΩ in dry conditions (2MΩ in wet conditions)		OK	<input type="checkbox"/>	NO	<input type="checkbox"/>	N/A	<input type="checkbox"/>	
Note:		1. ....							
		2.....							
		3.....							





# ANNEX 2 – TESTS ON PV STRINGS

## PV string open circuit voltage measurements

Operational notes (See Figure 1 in Annex 2)	
1.	Solar irradiance $\geq 600$ W/m <sup>2</sup> on PV module surface
2.	String voltage measured in open circuit, inverter switched off.
3.	Measure strings connected in parallel (e.g. to same combiner box) so that possible changes of solar radiation are minimized.
4.	For strings connected in parallel (e.g. to same combiner box) evaluate percentage difference of each measure from average (Voc_ave_strings).
5.	Check strings that show differences larger than $\pm 5\%$ .

## PV string short-circuit current measurements

Operational notes (See Figure 2 in Annex 2)	
1.	Solar irradiance $\geq 600$ W/m <sup>2</sup> on PV module surface
2.	Measure short-circuited strings, downstream e.g. the DC disconnect of combiner box, inverter switched off.
3.	Test each single short-circuited string, other strings in open. Before each new test open the DC disconnect, disconnect the last tested string and connect the following string to be tested. Finally close the DC disconnect, and test.
4.	Measure strings connected in parallel (e.g. to same combiner box) so that possible changes of solar radiation are minimized.
5.	For strings connected in parallel (e.g. to same combiner box) evaluate percentage difference of each measure from average (Voc_ave_strings).
6.	Check strings that show differences larger than $\pm 5\%$ .
NOTE: In case of DC disconnect embedded in the inverter, an external circuit shall be used. The safe connection/disconnection between (+) and (-) poles is thus made by means of a proper switch-disconnector	

## Test insulation between earth and short-circuited strings

Operational notes	
1.	Measure short-circuited strings, downstream e.g. the DC disconnect of combiner box, inverter switched off.
2.	Test each single short-circuited string, other strings in open. Apply the test voltage maximum 1000Vdc for 1 minute between earth and short-circuited string. Before each new test open the DC disconnect, disconnect the last tested string and connect the following string to be tested. Finally close the DC disconnect, and test.
3.	Surge protective devices shall be disconnected before testing.
4.	Insulation resistance for acceptance of test result 5 M $\Omega$ in dry conditions (2 M $\Omega$ in wet conditions).

## Report of detailed test results

VOC, ISC, Insulation resistance (1 of xx)						
Combiner Box	Start Time	Stop Time	Start Time	Stop Time	Start Time	Stop Time
String	Voltage		Current		Insulation resistance	
	VOC [V]	Difference between VOC_ave [%]	ISC [A]	Difference between ISC_ave [%]	[MΩ]	Resistance test result
1						OK <input type="checkbox"/>
2						OK <input type="checkbox"/>
3						OK <input type="checkbox"/>
4						OK <input type="checkbox"/>
5						OK <input type="checkbox"/>
6						OK <input type="checkbox"/>
7						OK <input type="checkbox"/>
8						OK <input type="checkbox"/>
9						OK <input type="checkbox"/>
10						OK <input type="checkbox"/>
11						OK <input type="checkbox"/>
12						OK <input type="checkbox"/>
13						OK <input type="checkbox"/>
14						OK <input type="checkbox"/>
15						
16						
VOC_ave [V]		Itot_strings				
		ISC_ave [A]				
<div style="background-color: #008000; color: white; padding: 5px;">Note:</div>						



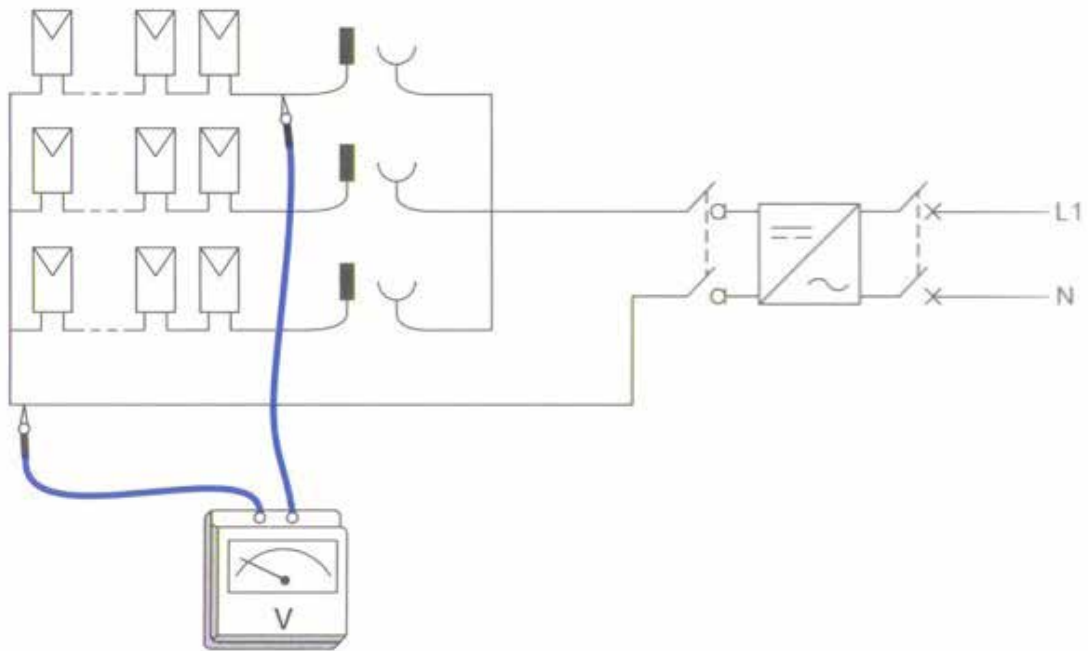
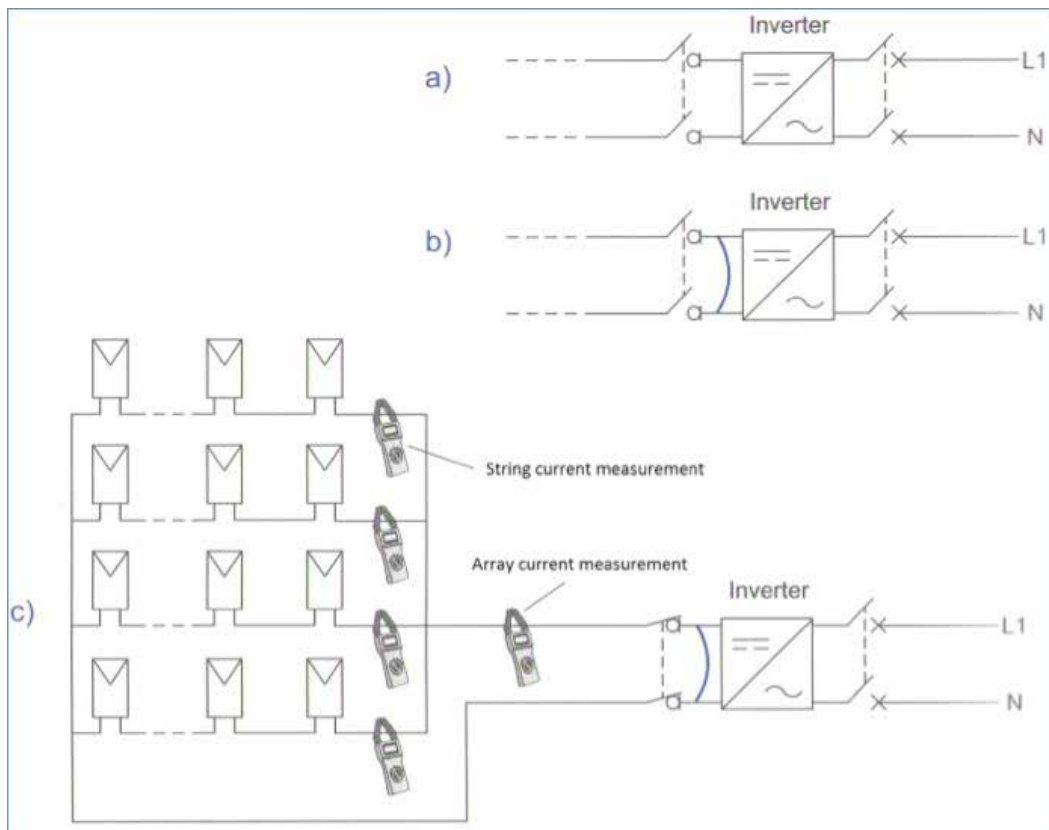


Figure 1 – Measurement of the open-circuit voltage of a string



- a) Circuit-break the inverter upstream and downstream
- b) Short-circuit the terminals not powered of the circuit-breaker upstream the inverter
- c) Close the circuit-breaker upstream the inverter and measure the current by means of a DC current clamp

Figure 2 – Procedure for the measurements of the current of strings and array:

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For generations to come

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