SHAMS DUBAI

INSPECTION AND TESTING GUIDELINES FOR DISTRIBUTED RENEWABLE RESOURCES GENERATORS CONNECTED TO THE DISTRIBUTION NETWORK

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1 INTRODUCTION

1.1 Scope

These Guidelines provide information meant for Dubai Residents, Consultants and Contractors on the technical aspects which have to be taken into consideration in order to connect a Renewable Resources Generating Plant (RRGP) to the Low (230/400 V) or Medium Voltage (6.6, 11 or 33 kV) Distribution Network.

It applies to the inspection and testing of RRGPs, particularly to the Photovoltaic (PV) Generating Plants, also called Photovoltaic or Solar Plants.

Inspection and testing requirements related to the connection of RRGPs to the Low Voltage or Medium Voltage Distribution Network are provided in the **DEWA Standards For Distributed Renewable Resources Generators Connected to the Distribution Network** [1], (hereafter referred to as **"the Standards"),** which represents the main reference document for the definition of the requirements these generating facilities have to comply with in order to be connected to the Distribution Network. Additional details regarding the process for the connection of RRGPs are provided in the **DEWA Connection Guidelines For Distributed Renewable Resources Generators Connected to the Distribution Network [2],** (hereafter referred to as **"the Connection Guidelines").**

This document sets out the criteria and guidelines that need to be taken into account when performing the assessment, through on-site tests, of Solar PV plants to be connected to DEWA distribution network.

In particular, it focuses on the test methods that have to be applied by a certified Test Engineer appointed by the Applicant, in order to provide DEWA with all the documentation which certifies the correct execution of the installation and its correct working behaviour.

Figure 1 summarizes the timeline of the verification process, the inspection and other related activities according to the different roles:

- Applicant, in charge for carrying out the tests
- DEWA, in charge for carrying out Inspections, the meter installation and the connection
- Concerned Authority, in charge of issuing Building Permits/building completion certificates and for checking the Mechanical "civil works" and "support structures" (i.e. Dubai Municipality, Trakhees, etc.)

The role of the Applicant is then clear in the Test process.

As can be seen from the Figure 1, the assessment of a PV plant for its connection to the distribution network requires a number of Inspections and Tests that depend on the maximum capacity of the plant:

- PV plants below 100 kW;
- PV plants equal or above 100 kW.

In both cases, inspections and tests are to be performed before the connection to distribution network (which includes the inspection at the "Mechanical Completion" stage) and after the (temporary) connection to the distribution network. After the second round of Inspections and Tests has been carried out, everything is assembled correctly and the PV plant works properly, the authorization to start the production is given by DEWA.

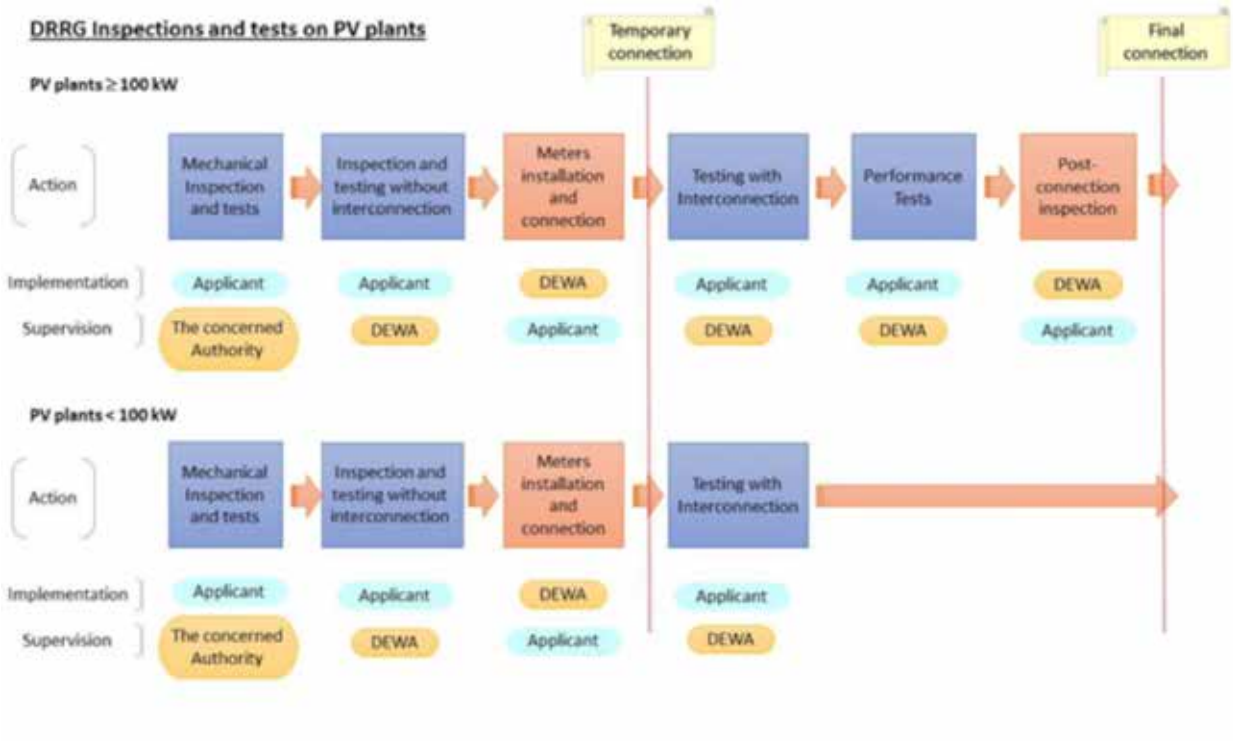


Figure 1 – Inspections to verify and test a DRRG Plant

The goal of the overall assessment is to verify the plant and its compliance with the technical standards in force, as specified in the Standards [1].

Depending on the maximum capacity of the PV plant, the Applicant shall carry out the following actions:

- Mechanical Tests
- Tests without interconnection
- Tests with interconnection
- Performance Tests

DEWA may supervise the above Inspections and Tests, except the Mechanical Tests that may involve the concerned Authority (i.e. Dubai Municipality, Trakhees, etc.).

After the Inspections and Tests specified for the given PV plant are successfully conducted with satisfactory results, DEWA issues the Connection Agreement, which certifies that the installation is compliant with DEWA rules and regulations and that the electricity production can start.

The requirements of the above described Inspection are in accordance with the requirements of the standard IEC 62446 "Grid connected photovoltaic systems – Minimum requirements for system documentation, commissioning tests and inspection" [3].

Particular care will be devoted, in this document, to the modalities to perform the tests, being the Inspection a task to be typically performed by the Engineers of DEWA, or by those of the concerned Authority as regard the Mechanical Inspection. However

- in order to make the Applicant aware of which Inspections DEWA, or other Authority, is due to perform,
- to allow her/him to ease and speed up the task of above said Engineers by adequately preparing the site for the Inspections,
- to autonomously carry out the same checks,

the lists of these Inspections will anyway be commented in these Guidelines.

1.2 Definitions

The most relevant definitions for the present Guidelines are listed below.

AC module - A PV module with an inverter mechanically secured to it so that the electrical output is a.c. and no d.c. plug/socket connections are in use between the module and the inverter.

Active Power - Active Power is the real component of the apparent power, expressed in watts or multiples thereof (e.g. kilowatts (kW) or megawatts (MW)). In the text this may be generically referred as P or Pn in case of rated active power of equipment.

Apparent Power - Is the product of voltage (in volts) and current (in amperes). It is usually expressed in kilovolt-amperes (kVA) or megavolt-amperes (MVA) and consists of a real component (Active Power) and an imaginary component (Reactive Power). In case of inverters, the rated apparent power corresponds to the maximum active power deliverable by the inverter at unity power factor.

Applicant: May be either the Consultant or the Contractor

NOC Application for Connection - is filled by an Applicant for a new RRG Connection. This application shall be made through the Distributed Generation Application Form in the prescribed format and shall contain the required information.

Connection Agreement - The agreement between DEWA and a RRG, which stipulates the terms and conditions for the connection and operation of the Electricity Generator into the Power Distribution System and its operation.

Connection Point - Is the location at which the Renewable Resource Generating Units, Renewable Resource Generating Plants as well as consumer loads are connected to the Network and where the Main Meter is installed. In the connection schemes this is also referred to as POC (Point Of Connection).

Consultant - A company enrolled with DEWA as electrical & DRRG Solar PV consultant, which carries out the design of electrical facilities of all types including design of solar PV plants.

Contractor - A company enrolled with DEWA as electrical & DRRG Solar PV contractor, which carries out electrical consulting/contracting works of all types including solar PV plants. The Contractor may also perform design, supply equipment and materials or labour, especially for constructing, building and installing Solar PV plants.

Converter - Also called Power Converter. See **Inverter**.

Current - Unless stated otherwise, current refers to the root-mean-square value of phase current.

Distribution System / Network - Is the medium (6.6, 11 or 33 kV) or low voltage (0.4 kV) electricity grid for supplying electricity to the end consumers.

DRRG - Distributed Renewable Resources Generation

DRRG NOC - A NOC for the purpose of constructing a DRRG plant.

Downstream - See: Upstream

Generating Unit / Plant - A Generating Unit is an indivisible set of installations which can generate electrical energy. A set of Generating Units, circuits and auxiliary services for the generation of electrical energy forms a Generating Plant. See also the definition of "Renewable Resource Generating Unit / Plant".

Grid Connection: The connection of a Renewable Resource Generating Plant (RRGP) to the electrical grid.

Grid Connection fee: The fee to be paid for the connection to the grid.

Interface Protection - The electrical protection required to ensure that either the Generating Plant or the Generating Unit is disconnected for any event that could impair the integrity or degrade the safety of the Distribution Network.

Inverter - Device which converts the direct current produced by the photovoltaic modules to alternating current in order to deliver the output power to the grid. The inverter is also capable of controlling the quality of output power.

Isolated inverter - An inverter with, at least, simple separation between the main power output circuits and PV circuits (usually by means of a transformer) and with leakage currents less than the limits required to be classified as an isolated inverter (IEC 62109-2). The separation/ isolation may be either integral to the inverter or provided externally, e.g. an inverter with an external isolation transformer.

Non-isolated inverter - An inverter without the minimum separation between the main power output and PV circuits or with leakage currents greater than the requirements for an isolated inverter.

Junction box - Closed or protected connecting device were one or several junctions are performed.

Low Voltage (LV) Network – A Network with nominal voltage lower than 1kV.

Maximum Capacity - The maximum continuous Active Power which a Generating Plant can feed into the Network as agreed between DEWA and the Plant Producer. This corresponds to the sum of the maximum active power deliverable by the inverters at the AC side, that is also the sum of the rated power of the inverters at unity power factor (to be noted that this latter may also be lower than the sum of the power at STC of the photovoltaic modules). In the text, this maximum capacity will also be indicated as P_{MC}.

Medium Voltage (MV) Network - A Network with nominal voltage included in the range from 1kV up to 33 kV. In Dubai, four voltage levels may be found on the MV distribution network, namely 6.6 – 11 – 22 – 33 kV. The 11 kV voltage level is the most used and diffused.

Main Electricity Meter - The main electricity meter installed at the Connection Point (DEWA side) and will perform the Net Metering of: i) the electricity delivered by the RRGP to the Distribution Network; and ii) the energy absorbed from the Distribution Network on a monthly basis.

Microinverter - An inverter that converts direct current produced by a single PV module to alternating current. The output from several microinverters is combined in order to deliver the output power to the grid.

RRGP Electricity Meter - also called **PV Generation Check-meter**: Electricity meter installed at the common output point of all the Generating Units, to measure the total energy produced by the RRGP.

Network - Plant and apparatus connected together and operated by DEWA in order to transmit or distribute electrical power.

Non-Synchronously - Connected Renewable Resource Generating Unit – A Renewable Resource Generating Unit that is not electromagnetically directly connected to the Network. All types of installations that are fully connected to the Network through Power Electronic Converters, for instance photovoltaic power generating Units, fall into this category.

Overall duration: Total amount of time needed for project development until PV plant starts operating.

Peak Power (Wp) - The output power achieved by a Photovoltaic Module under Standard Test Conditions (STC). It is measured in Wp (W peak). The sum of the peak power of the photovoltaic modules of either a string or an array determines the peak power of the string and the array respectively (usually measured in kWp). The peak power of a photovoltaic array at STC is conventionally assumed as the rated power of the array.

Permission: A license to carry out an act that, without such licence, would be considered unlawful.

Photovoltaic (PV) cell - The most elementary device that exhibits the photovoltaic effect, i.e. the direct non-thermal conversion of radiant energy into electrical energy.

Photovoltaic (PV) Module - Also called Photovoltaic (PV) panel. The smallest, complete, environmentally protected assembly of interconnected cells.

Photovoltaic (PV) string - A circuit of one or more series-connected modules.

Photovoltaic (PV) string (array) combiner box - A junction box where PV strings (sub-arrays) are connected which may also contain overcurrent protection devices and/or switch-disconnectors.

Photovoltaic (PV) array - Assembly of electrically interconnected PV modules, PV strings or PV sub-arrays.

Photovoltaic (PV) sub-array - An electrical subset of a PV array formed by parallel-connected PV strings.

Power Factor - Is the ratio of Active Power to Apparent Power.

Protective earthing - Earthing of a point in equipment or in a system for safety reasons.

Power Generating Plant (Power Plant) - Set of Generating Units, circuits and auxiliary services for the generation of electrical energy. In case of a Generating Plant made only of RRGU, a reference to RRGP will be made in this document.

P-Q-Capability Diagram - Describes the ability of a Generating Unit to provide Reactive Power in the context of varying Active Power and at the rated voltage.

Power Distribution System - The electrical network and its components which are owned and operated by DEWA with the main purpose of delivering electricity to consumers from the Power Transmission System. The 33kV and below voltage levels are considered a distribution system. The components of a Power Distribution system include all associated equipment including but not limited to interconnecting lines, electrical substations, pole mounted transformers, analogue electrical elements such as resistors, inductors, capacitors, diodes, switches and transistors.

Power Transmission System - The system belonging to DEWA which entirely or mainly comprises of the High-Voltage (> 33 kV) electricity cables, lines and electricity installations and facilities owned and/or operated by DEWA and used to transmit electricity from a power unit to a power substation or other electricity generation unit.

Process: A Process is one of the necessary functional procedures necessary to develop a PV system. A Process is described by a sequence of Process Steps (which may be of either administrative or technical nature).

Process Duration: The overall time needed to complete a specific process of the PV project lifecycle.

Process Step: A step is one of a sequential succession of actions that need to be executed in order to satisfy the legal-administrative and the other requirements of a process.

Producer: Any entity authorised by DEWA to produce electricity connected to the network in the Emirates. In other documents the term "Generator" may be used.

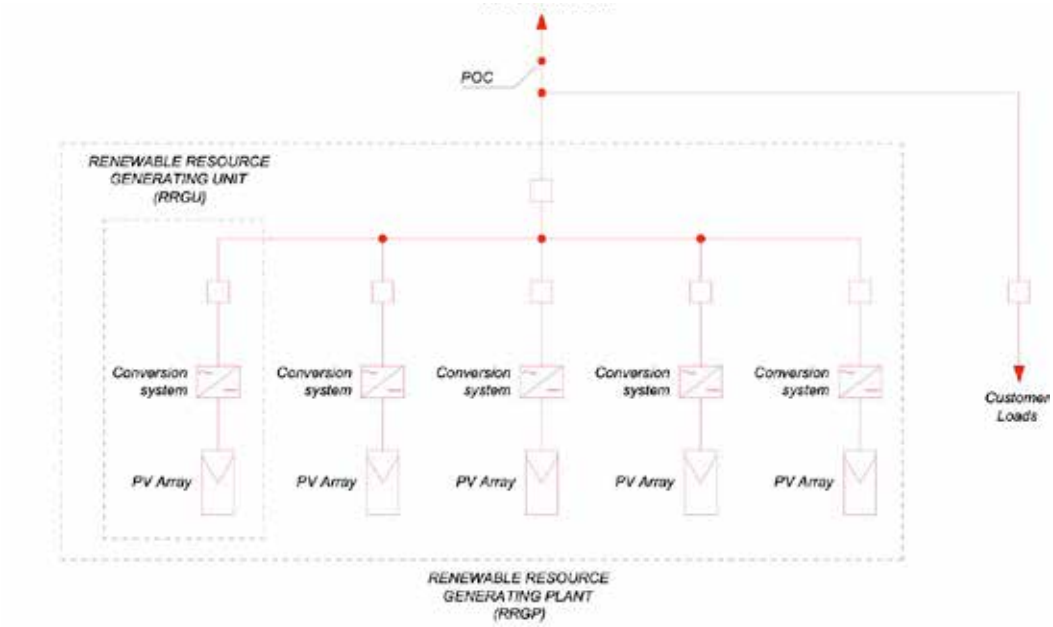
PV Project Lifecycle: All the procedures required to authorise, install and finally connect a PV system. The Project Lifecycle is defined as a sequential succession of Processes, each of them described by a sequence of Process Steps (either administrative or technical).

Reactive Power - Reactive Power is the imaginary component of the apparent power, usually expressed in kilovar (kVAr) or Megavar (MVAr).

Representative - Any person representing or mandated to represent a party, including, but not limited to its directors, members of management, officers, employees, or professional advisors.

Renewable Resource Generating Plant (RRGP) - Is a set of Renewable Resource Generating Units.

Renewable Resource Generating Unit (RRGU) - Is a Generating Unit that produces power exclusively from renewable primary resources. This Renewable Resource Generating Unit can be part of a Generating Plant that includes non-renewable resources. In this latter situation, the Renewable Resource Generating Unit mentioned in the Standards is the part of the Plant that is able to produce energy without input from non-renewable resource. The Photovoltaic Generating Plant is illustrated below:



RRGP Voltage - Unless stated otherwise, voltage refers to the root-mean-square value of phase-to-phase voltages.

Standard test conditions (STC) – A standard set of reference conditions used for the testing and rating of photovoltaic cells and modules. The standard test conditions are:

a) PV cell temperature of 25 °C;
b) Irradiance in the plane of the PV cell or module of 1000 W/m^2; and
c) Light spectrum corresponding to an atmospheric air mass of 1,5.

Switch-disconnector – Mechanical switching device capable of making, carrying and breaking currents in normal circuit conditions and, when specified, in given operating overload conditions. In addition, it is able to carry, for a specified time, currents under specified abnormal circuit conditions, such as short-circuit conditions. Moreover, it complies with the requirements for a disconnector (isolator).

Test Engineer – A Contractor or a Consultant or a Licensed Engineer who is skilled and qualified for testing photovoltaic DRRG installations as certified by DEWA.

Upstream – For a RRGP, "Upstream" means generator bound, e.g. towards the PV panel for a PV plant. "Downstream", instead, means towards the distribution network.

The below terms and definitions are taken form Section 3 of IEC 62446:

Verification – all measures by means of which compliance of the electrical installation to the relevant standards is checked (NOTE: it comprises inspection, testing and reporting).

Inspection – examination of an electrical installation using all the senses in order to ascertain correct selection and proper erection of electrical equipment.

Testing – implementation of measures in an electrical installation by means of which its effectiveness is proved (NOTE: it includes ascertaining values by means of appropriate measuring instruments, said values not being detectable by inspection).

Reporting – recording of the results of inspection and testing.

1.3 Reference documents

The following documents have been quoted in this document:

[1] DEWA Standards For Distributed Renewable Resources Generators Connected To The Distribution Network (in the following only "Standards") (*)

[2] DEWA Connection Guidelines For Distributed Renewable Resources Generators Connected To The Distribution Network (*)

[3] IEC 62446 "Grid connected photovoltaic systems – Minimum requirements for system documentation, commissioning tests and inspection"

[4] DEWA Safety of People: Recommendations for DRRG Solar PV Systems (*)

[5] Standard EN 50160, Voltage characteristics of electricity supplied by public distribution networks

(*) Available on DEWA website www.dewa.gov.ae

1.4 Acronyms and Terminology

The following acronyms will be used throughout the text of this document:

DRRG Distributed Renewable Resource Generation
PV Photovoltaic
RRGU Renewable Resource Generating Unit (see 1.2)
RRGP Renewable Resource Generating Plant (see 1.2)
NOC No Objection Certificate
MC Mechanical Completion
FI Final Inspection
CT Current Transformer
VT Voltage Transformer
MV Medium Voltage
LV Low Voltage
PPE Personal Protective Equipment

2 ON-SITE TESTING (AND INSPECTIONS) OF A RRGP

According to the Standards [1] the following on-site tests (and inspections) shall be performed on RRGUs / RRGPs before and after connection to the distribution network.

- Mechanical Testing (and inspection)
- Testing (and inspection) without interconnection to the network to check the consistency of the system.
- Testing (and inspection) with interconnection to the network for the verification of the features and the functionalities of the system (tests carried out by the Applicant for plants P_{MC} < 100kW and Performance Tests for plants with $P_{MC} \geq 100$ kW).

Inspection and tests at Mechanical Completion (MC) stage are required as a separate preliminary inspection. Performance tests and Post-connection inspection are required only in case of RRGPs with maximum capacity $P_{MC} \geq 100$ kW.

2.1 General Requirements

The general requirements for the performance of all the Tests are described in the following paragraphs.

The items subject to technical verifications are presented in this document. A checklist will also be delivered in advance to the Applicant so that s/he is aware of the requirements.

The general requirements for performing Testing (and Inspections) without interconnection to the network are listed below.

- The aim of Tests (and Inspections) is to assess the completion of the installation, and that this is compliant with applicable standards and rules.

- Before the Tests (and Inspections) can take place, the Consultant/Contractor shall ensure that the installations to be inspected or tested have been completed. Completion means:
  - Installation completed with reference to the items to be checked 100% by visual and mechanical Inspection and Test (for plants with $P_{MC} \geq 100$ kW these are the inspections and Tests to be performed at the Mechanical Completion stage).
  - Electrical Tests performed in advance by the Applicant to assess the performance of the different items is in accordance to the requirements set in the Standards [1]. In this way, if the measurements result is not adequate, the required corrective measures can be applied before the Inspection takes place.

After the Positive results of the Mechanical Completion Inspection, the construction of the PV plant can proceed up to the conclusion and successive connection to the network.

The general requirements for performing Testing (and Inspections) with interconnection to the network are listed below:

- The Tests (and Inspections) have the following aims:
  - Assess the overall functionality of the solar power generation plant and of the conventional equipment required for connecting the plant to the grid;
  - When required, assess the performance of the plant (efficiency of solar power generation); and
  - Issue the Technical Dossier of the PV RRGU / RRGP.
- Before the Tests can take place, the Consultant/Contractor shall ensure that the installations to be inspected have been completed.

2.2 Methodology of the Tests

The methodology of the Tests is outlined below:

1. The percentage of installation to be evaluated in the frame of each check is defined in the following sections.

2. The Consultant/Contractor will ensure the equipment required for all checks and verifications is available for the performance of the test.

3. A check or test yielding a negative result can be repeated in case an adequate correction measure can be applied (e.g. retest a PV string that was found not properly connected) and the result of the test repetition acknowledged; in case a negative result cannot be corrected, the check or test is to be considered failed.

4. In case of a negative result, the Applicant/Consultant/Contractor shall apply the agreed corrective measure before the checks and verifications that ended with a negative result are repeated, in the frame of a next site inspection, and a revision of the inspection report shall be issued.

5. In case of positive result, the installation will be approved and the RRGUs / RRGPs will be allowed to start the production.

2.3 Design Documents for the Inspection

The documents required for the Inspections and then to be submitted in advance to DEWA are those listed at point 3.4 of the Connection Guidelines [2] .

2.4 Test Engineer

All checks and technical verifications have to be performed by the Test Engineer delegated by the Applicant for this activity. The Test Engineer is to ensure the availability of the necessary test equipment.

2.5 The test engineer, delegated by the applicant, must be certified by DEWA.Reporting

For the testing (and inspection), both with interconnection and without interconnection, a number of checklists are available to guide the sequence of the checks and technical verifications. These checklists will have to be requested to DEWA or to the concerned Authority.

2.6 Safety Issues

As stated in 2.4, the performance of on-site tests, particularly of electrical tests, is the task and the responsibility of the Test Engineer. This must be aware of the main details of such electrical tests and the associated hazards, according to the description provided below. All what is located upstream of a circuit-breaker device on the DC section of a PV plant remains under voltage (during the day) even after the opening of this device.

All switchgears and boxes of the photovoltaic plant on DC side shall expose a warning, which indicates the presence of live parts even after the opening of the inverter circuit-breaker devices.

Figure 2 shows an example of warning sign to indicate the presence of danger.

All interventions on the live parts of PV strings are therefore to be considered an intervention under voltage. This difference is unusual for an installer who is accustomed to thinking that the plant is off-voltage when the general circuit breaker is switched off.

Only a qualified person, i.e. a professional with sufficient knowledge and experience can work safely on live parts and successfully carry out electric interventions under voltage.

The protection provisions and the proper PPE are specified in relevant international and local standards. However, it is worth mentioning that when working under voltage, the operator must wear (see Figure 3):

- A safety helmet made of insulating material with face shield (mainly to protect him against electric arcing);
- Flame-retardant clothing that does not leave uncovered parts of the trunk or limbs;
- Insulating gloves (of appropriate voltage class).

Insulated tools for electrical work are also to be used. An alternative to insulated tools is an insulating mat for electrical purposes, placed beneath the operator.

After the electric shock, arcing represents the main danger in electric interventions under voltage. The energy released by electric arcs may cause burns, damage to eyes and skin and this energy increases with the arcing current and the duration of the intervention.

In case of short-circuit, the arcing current in PV plants is lower than that in other electric plants supplied by the grid, but the duration is greater because it is more difficult to extinguish a DC arc.

Works under voltage carried out in open air spaces shall be avoided in case of:

- Fog, rain, snow or dust storm, mainly because of the scarce visibility.
- Very low temperatures or strong wind, because of the difficulty to grip and hold tools.
- Thunderstorms, because of the possible over voltages on circuits.

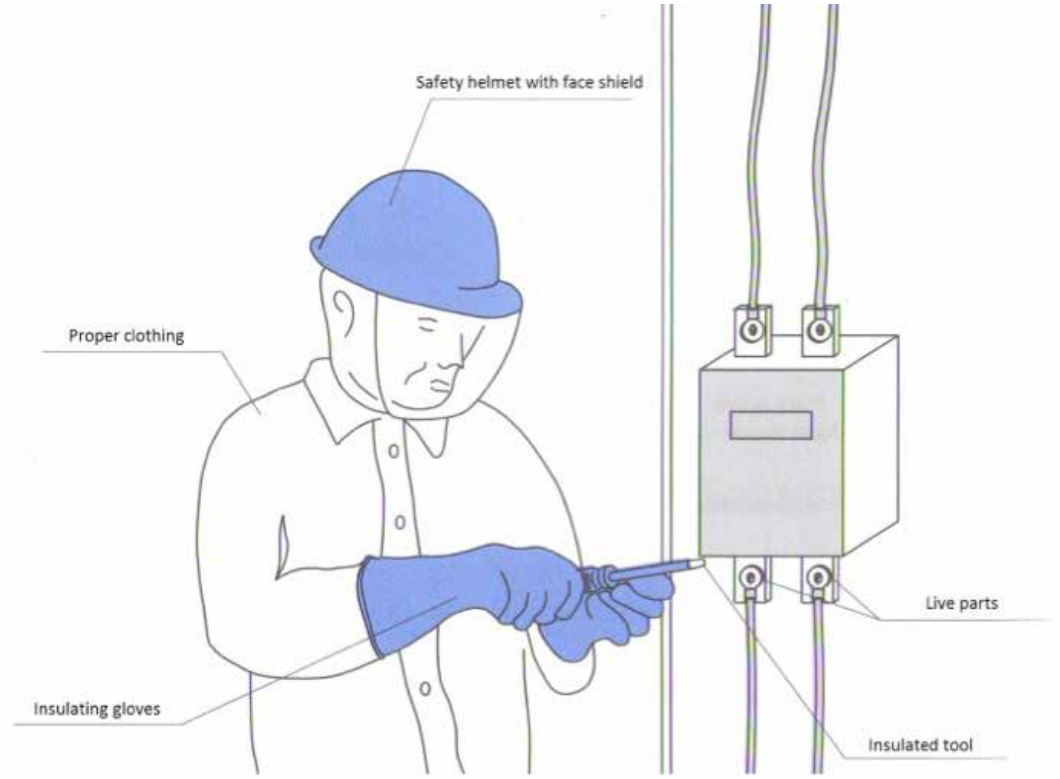


Figure 3 – Safety measures for works under voltage

Construction works of an ordinary electric plant do not present any risk of electrical nature, until the plant has been completed and connected to the grid.

However, this is not valid for the installation of a photovoltaic plant, because the exposure of a PV module to sunlight produces a voltage between the poles of the module itself. To avoid this, one may short-circuit both connectors of a PV module or of a series of modules (the short circuit current does not damage the PV modules because it is only slightly greater than the rated current).

Another possible expedient is shown in Figure 4, and consists of keeping the connectors of a module and the string circuit-breaker open during installation.

Figure 4 illustrates that a person with access to the positive (+) and negative (-) poles upstream or downstream of the circuit-breaker is **safe (case A)**. Alternatively, a person who touches two poles on the same branch is **not safe (cases B and C).**

In all cases, the work and interventions in construction and during inspection and maintenance of a PV array shall be considered works/ interventions under voltage.

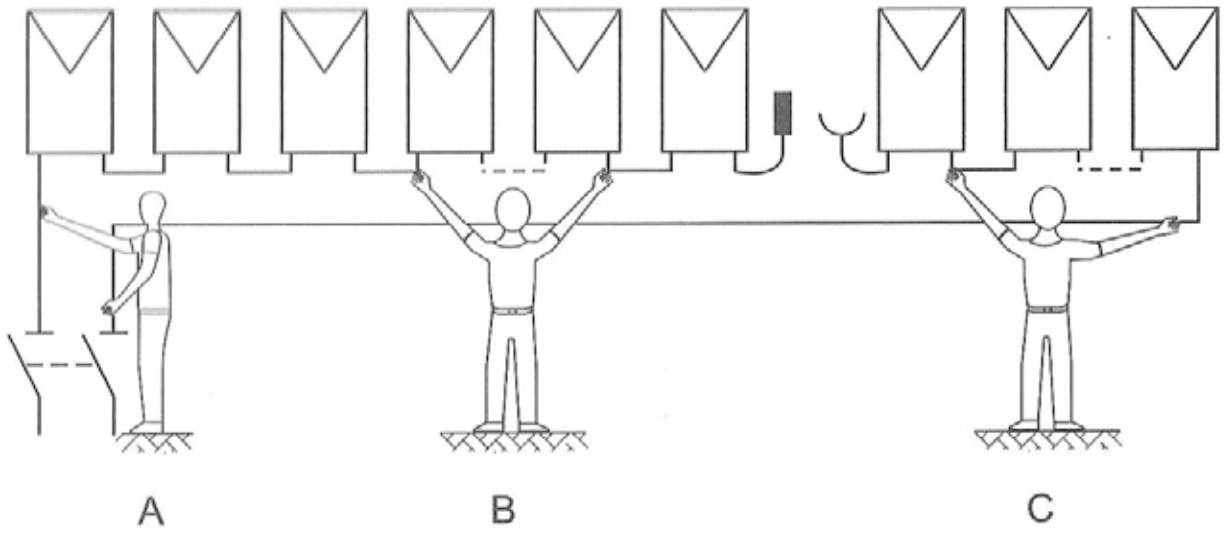


Figure 4 – The interruption of a string makes the worker A safe but keeps the workers B and C unsafe

Interventions on PV plants also involve non-electric risks, as follows:

- **Burning when touching PV modules.** If modules are exposed to sunrays, they may reach temperatures of almost 100 °C at the front and 80 °C at the rear. Operators are to wear work gloves resistant to up to 100 °C and proper clothing.

- **Risk of falling.** When the PV plant is installed on a roof, operators shall adopt the safety measures prescribed for the given circumstance, for instance a safety harness anchored with a carabineer to a stable element of the roof (hooks, safety ropes, pillars, etc.).

- **Insect stings.** Bees, hornets and other insects can nest behind a PV module or in another sheltered place.

More information about the possible hazards involved when working with Solar PV equipment is available in the document "Safety of People: Recommendations for DRRG Solar PV Systems" [4].

2.7 Information from Applicant about Specific Risks on-site and Safety Measures

A form indicating specific risks and on-site safety measures shall be filled and delivered by the Applicant / Contractor to DEWA or to the concerned Authority, before the respective Inspectors visit the site of the PV plant.

A template of the said form is provided in **ANNEX 1 – "SAFETY INFORMATION FORM TO BE FILLED BY THE APPLICANT"**

3 PART I – TESTS (AND INSPECTIONS) WITHOUT INTERCONNECTION TO THE NETWORK

3.1 Methodology

The Technical Tests (and Inspections) to be performed before the connection to the network are in accordance with the specifications in Appendix D of the Standards [1]. Particularly, the content of such tests is defined in "D.5.1.2 - Testing without interconnection to the network to check the consistency of the system".

As mentioned earlier, an intermediate phase termed "Mechanical Completion" is required. The main purpose of having an Inspection and Tests at this stage is to assess that the main portion of the PV plant equipment, including civil works and PV modules, has been installed properly and subsequently verified by the Contractor. It may also happen that interventions such as the laying of a DC connection cable and the fixation of the cables connecting PV modules in strings, have also been completed, therefore specific Electrical Tests (and Inspections) may also be performed during this first Inspection.

By means of Inspections and Tests it is possible to verify that works and installations have not only been completed but also that this was performed in accordance with design documents. In addition, the Inspection also verifies that the design and the installation have been performed to meet with the relevant standards and any other relevant local laws and regulations.

The Inspections and Tests will particularly focus on:

- Installation of PV modules support and/or fixation structures;
- Fixation of PV modules to the said structures;
- Electrical connection of all metallic masses and all the metallic parts to be earthed (e.g. PV module frames and support structures) to the earthing system; and
- Connection of PV modules in strings up to the first relevant switchboard.

It is also important that the earthing connection of PV modules, if it is required, is performed according to; the applicable standards and rules, the PV module specifications, and the detailed design. Accordingly, some Inspections and Tests in the Mechanical Completion Inspection are devoted to assessing the performance of the wiring that connect PV modules together in strings and to the earthing system. In case of a negative test result, corrective measures are to be defined and applied in order to complete the PV plant installation.

The Test is composed by the measurement of selected electrical quantities in order to assess the characteristics of a given circuit. Most checks are required with reference to 100% of the installation, some checks and measurements with reference to a minimum percentage of 15% of the installation.

3.1.1 Inspections

Inspections consist of the visual check of mechanical and electrical installations, components, equipment and systems (Table 1). The Inspection participants shall verify that the required equipment has been installed and that the installation is compliant with the As-Built documents.

Table 1: Testing without interconnection to Network: Visual and mechanical Inspection

Visual and mechanical inspection (*) (Appendix D.5.1.2.1 of ref. [1])
1. General assessment of RRGU / RRGP. The following subsets of tests / checks should be considered: a) Layout and total number of PV modules. b) Substations and main cable connections (if already finished); Internal roads; Fences or any other barriers required for segregation of hazardous areas; Warning signs. c) Availability of documents and drawings inside substations (if already finished) (PV modules/strings layout, single line diagrams, detailed diagrams, etc.).
2. Civil works (*).
3. Support Structures (*).
4. Photovoltaic modules. The following subsets of tests should be considered. a) Visual inspection of PV modules. b) Quality of cabling. c) Modules identification (on a sample basis).
5. Electrical equipment.
6. Protection of assembled components (e.g. IP degree).
7. Visual inspection of string combiner boxes (DC - string connections and AC – auxiliary services).
8. Visual inspection of electrical power connections in the substations and electrical rooms.
9. Bonding and earthing system.
10. Connections of metallic structures and equipment to earthing system (if required).

(*) Inspections that will involve the concerned Authority (i.e. Dubai Municipality, Trakhees, etc.). The information is provided for reference only. The applicant is to fulfill the requirements as requested by the concerened Authority.

Checks n° 4, 7 and 10 shall be performed for at least a 15% of the installation.

3.1.2 Tests

Tests and measurements (Table 2) are particularly devoted to assess the DC connections, and the earthing connections joining the PV modules and the (metal) support structures.

The Electrical Tests and measurements shall confirm that the electrical installations are being performed in a workmanlike manner. The aim of these tests is in fact to verify the quality of the installation; hence, they shall be performed for a minimum of 15% of the installation.

Table 2: Testing without interconnection to Network: Electrical Tests and Measurements

Electrical Tests and Measurements (Appendix D.5.1.2.2 of ref. [1])	
1.	Insulation of LV DC and AC connections Test performed by applying between live conductors and earth (structures) a test voltage 1000 Vdc for 1 minute. Limit value for acceptance of insulation resistance: 1 MΩ.
2.	Voltage and current measurements on photovoltaic strings
a)	Measure each single string voltage V_{OC} (inverter switched off).
b)	Measure each single string current I_{SC} (inverter switched off). Check average Voltage and Current of strings pertaining to each string combiner box: in case of strings with deviations higher than ± 5% from average, continuity of related circuits shall be verified first and strings voltage/current rechecked subsequently. Test the strings belonging to the same combiner box in rapid sequence to minimize effects due to variations of solar radiation.
3.	String insulation to earth Measure each single string with the poles (+) and (-) short-circuited and earth connected (with other strings open). Apply between short-circuit and earthing system a test voltage (1000 Vdc for 1 minute). Disconnect surge arresters prior to performing the test. The limit value of insulation resistance for acceptance of each string is ≥ 40 [MΩm²] / S (where S is the total surface of PV modules of the string in m²) with a minimum of 5 MΩ in dry conditions and 2MΩ in wet conditions. The above test may be made also by grouping 2 or more string in parallel, provided that the resulting power is ≤ 10 kW.
4.	Calibration of protections (Interface Protection). Checking/adjusting thresholds of equipment and protective devices, through simulated tests of intervention where possible (Off-grid tests)

It is worth noting that measuring string current I_{SC} (test n°2b) and testing string insulation to earth (test n°3) can be dangerous if not carried out properly and carefully; recommendations are highlighted in the following paragraphs.

The benefits expected from the performance of such tests are highlighted below:

- The Consultant/Contractor will have to check the quality of cable installations and of the electrical wirings and connections, well before all installations are brought to completion.
- DEWA inspectors will have the opportunity to assess the quality of the installations and if necessary request from the Consultant/Contractor to improve the quality.
- DEWA and the Owner will have feedback on the level of performance of the Consultant/Contractor.

The details of each verification envisaged within the Mechanical Completion Inspection as specified in the Standards [1] are described in the following paragraphs.

3.2 Mechanical Tests (and Inspection)*

3.2.1 General Assessment of RRGU / RRGP

With reference to 100% of the installation, in order to verify the compliance with the drawings and design documents regarding the quantity, type, sizing, installation and integrity of components and materials, the following verifications shall be performed:

a) Layout and total number of PV modules and related supporting structures.
   - Layout details:
     - Configuration of the system and the division into sub-arrays
     - Layout of the strings with reference to supporting structures / frames
   - Number of PV modules
     - Confirm total DC peak power
   - Positioning of supporting and fixing structures
   - Status of the surface of the PV modules

b) Substations and main cable ways and connections (if already finished); Safe access to the rooftop and Exit plan; Internal roads (for ground plants); Fences or any other barriers required for segregation of hazardous areas; Rainwater drainage; and Warning signs.

c) Availability of documents and drawings inside substations: single line diagrams, PV modules/strings layout, detailed diagrams, etc.

3.2.2 Civil Works

***Note:** 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, in order to verify the compliance with the drawings and design documents regarding the quantity, type, sizing, installation and integrity of components and materials, the following verifications shall be performed:

a) Foundations (state, breakage, deterioration of the surface)
b) Structural alignments: within the tolerances set by design
c) Placement of inserts and holes in foundations and precast
d) General conditions of the cabins and related foundations
e) Waterproofing of the cabins
f) Roof integrity and ingress protection (water proof) of mounting system to the roof
g) Access doors of the cabins
h) Ventilation grills / fans / air conditioning of the cabins
i) Integrity and layout of cableways / conduits

3.2.3 Support Structures

***Note:** 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, in order to verify the compliance with the drawings and design documents regarding the quantity, type, sizing, installation and integrity of components and materials, the following verifications shall be performed:

a) Mounting of supporting structures and of fixation elements
b) Condition of the components (damages, defects, weld quality, loss of galvanic protection, corrosion)
c) Planarity of the PV modules supporting structures (sags)
d) Inclination of PV modules: within the tolerances set in the design
e) Bolts and tightening torque corresponding to design (sample check)

3.2.4 Photovoltaic Modules

With reference to the percentage of the installed plant, ranging between 15% and 20%, in order to verify the compliance with the drawings and design documents regarding the quantity, type, sizing, installation and integrity of components and materials, the following subsets of tests can be considered:

a) Visual inspection of PV modules:
   1) Mechanical integrity of the modules (faults, breakdowns or incomplete assembly)
   2) Integrity functional parts of the modules (delamination, discoloration, dirt, etc.)
   3) Labeling of modules
   4) Fixation system
   5) Bolts and tightening torques corresponding to design (on a sample basis)

b) Quality of cabling:
   1) Tightening of cable glands
   2) Correct installation of DC cables (clamps, sharp edges, folds too narrow, etc.).
   3) Assembly and crimping of plug-in connectors

3.3 Inspection without interconnection

The following inspections and tests are necessary for all the plants, regardless the actual capacity of the plant.

3.3.1 Electrical Equipment

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

a) Positioning and fixation of string combiner boxes for connection of PV strings
b) Installation of cable trays and string cable sheaths
c) Positioning of the equipment: inverters, transformers, switchgears, etc.
d) Mechanical integrity of the said equipment (e.g. faults, breaks)
e) Switch-disconnectors on DC side visible and reachable
f) 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)

3.3.2 Protection of Assembled Components (e.g. IP degree)

With reference to 100% of the installation, verify the fulfilment of the design prescriptions:

a) IP degree of equipment, string combiner boxes, switchgears, etc.
b) Installation of equipment, string combiner boxes, switchgears, etc.
c) Installation of cable glands and connectors related to the above equipment
d) Positioning of cable ducts / conduits on cable trays
e) Protective provisions against rodents (polyurethane foam to obstruct inlets of conduits and of cabins) and insects (anti-insect grilles)
f) Labeling of cables, cable ducts and equipment

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

With reference to a percentage of the installed plant, ranging between 15% and 20%, verify the compliance of labels (cables, terminal blocks, and connectors) with drawings and design documents. Ensure that the cables are tightened in their respective terminals before performing this inspection.

a) Execution of wiring and cable labelling according to cable lists
b) Termination of DC cables and control cables (including AC auxiliary services if applicable) into their respective clamp terminals
c) Route of signal cables among the string combiner boxes
d) Quantity and characteristics of DC circuit breakers, disconnect switches, and protections. Check their functionality
e) Quantity and characteristics of surge arresters
f) Assembly and wiring of blocking diodes

3.3.4 Electrical Power Connections in Substations and Electrical Rooms

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

Execution of wiring according to cable lists (sample check)

a) Labelling of trays and cables according to cable lists (sample check)
b) LV and MV switchgears: check termination of LV and MV cables and verification that all cables are tightened into their respective clamp terminals
c) LV and MV switchgears: quantity and characteristics of breakers, disconnect switches, and protections. Check their functionality
d) Inverter connected according to design
e) Systems for air conditioning and/or ventilation according to design
f) Connection of switchgears according to design
g) Connection of LV / MV transformers according to design

3.3.5 Bonding and Earthing System

With reference to 100% of the installation, perform the following verifications:

a) Earthing system of PV plant installed according to design; check bonding connections and connection to terminals of the existing earthing system
b) Certification of correct execution / performance of main earthing grid (assessment and periodical verification tests of earth resistance according to local rules)
c) Connections to DEWA earthing network, if applicable
d) Earthing conductors terminate in the earthing busbar of the DRRG system
e) Earthing busbar is properly bonded with the local earthing of the site
f) Independent earth connection of main equipment to earthing busbar
g) Connection of earthing copper cables to aluminium structures via proper connectors (copper-aluminium, tin plated copper, stainless steel etc.) to prevent corrosion from dissimilar metals

3.3.6 Connections to Earthing System of Metal Structures / Equipment

With reference to 100% of the installation, verify the connections to the terminals and the earthing grid:

a) Installation and test of the electrical continuity of the earthing connections of metal support structures and other metal parts (at least two points of each support structure shall be connected to the earthing system)
b) Installation and test of the electrical continuity of the connections to earth of surge arresters
c) Installation and test of the electrical continuity of the earthing connections of equipment and switchgear in the cabins
d) Installation of the earthing connection of MV cable shields
e) Installation or revision of the Lightning protection system (LPS) according to detailed design

3.4 Tests without interconnection

The following tests shall be performed with reference to a percentage of the installed plant, ranging between 15% and 20%.

3.4.1 Insulation of LV connections DC and AC

Test to be performed by applying a test voltage of maximum 1000 Vdc for 1 minute between live conductors and earth (structures). Limit value for acceptance of insulation resistance: 1 MΩ.

Note: Protection devices and electronic equipment that might be affected by the test voltage shall be disconnected during the performance of the measurements.

a) Test Insulation of DC circuits, including clamps and terminals (max. 1000 Vdc for 1 min.)
b) Check insulation resistance of DC circuits is higher than 1 MΩ (including clamps and terminals); insulation resistance acceptance threshold shall be higher than 5 MΩ for strings (2 MΩ in the case of moisture on PV modules)
c) Test Insulation of AC circuits, including clamps and terminals (max. 500 Vdc for 1 min.)
d) Check insulation resistance is higher than 1 MΩ for AC circuits including clamps and terminals

3.4.2 Measurements on PV strings

NOTE: Measuring string current I_{SC} can be dangerous if not carried out properly and carefully. Particularly, connection and disconnection of (+) and (-) poles has to be performed by using a suitable DC switch-disconnector.

a) Measure each single string voltage V_{OC} (inverter switched off, see Figure 5)
b) Measure each single string current I_{SC} (inverter switched off, see Figure 6)

The aim of this test is to check that V_{OC} and I_{SC} of strings belonging to same combiner box are comparable within ± 5% tolerance; in case the difference is larger; the continuity of the related circuits should be verified before rechecking the string voltages and the currents.

Measurements on strings belonging to the same string combiner box must be made in a quick sequence (if necessary to minimize effects due to variations of solar radiation).

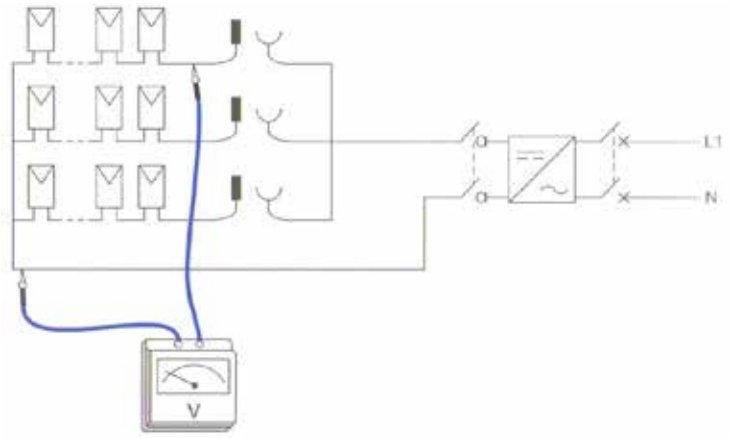
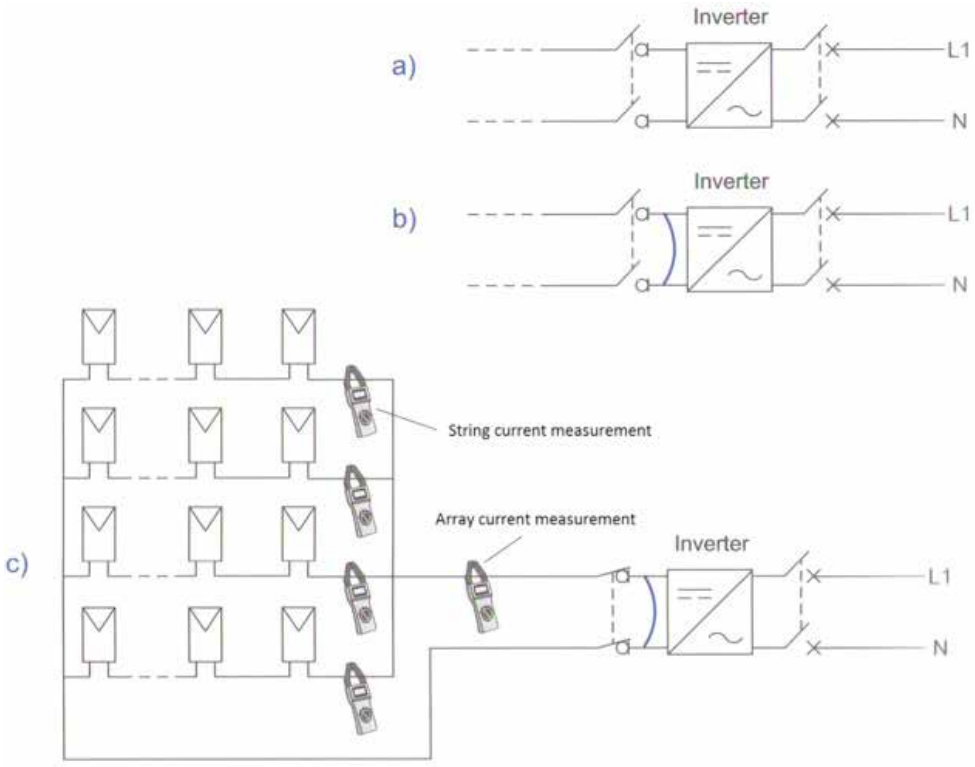


Figure 5 – Measurement of the open-circuit voltage of a string



a) Open both upstream and downstream inverter circuit breakers
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 6 – Procedure for the measurement of the current of strings and array

3.4.3 String Insulation to Earth

Test to be performed on each string with the poles (+) and (-) short-circuited and earth connected (other strings are open) by applying a test voltage of maximum 1000 Vdc for 1 minute. Disconnect surge arresters prior to the test.

Note: Protection devices and electronic equipment that might be affected by the test voltage should be disconnected during the performance of the measurements. Testing string insulation to earth can be dangerous if not carried out properly and carefully. Particularly, connection and disconnection of (+) and (-) poles has to be performed by using a suitable DC switch-disconnector. Alternatively, the test can be done in the dark or by covering the front of the PV modules.

Measure each single string in short-circuit and earth connected (other strings of the same combiner box shall be open). Limit value of insulation resistance for acceptance of each string: 5 MΩ in dry conditions (2MΩ in wet conditions).

3.4.4 Calibration of Protections (Interface Protection)

The Interface Protection(s) usually comes with predefined settings from the manufacturer. However, it is required that the settings are checked on-site and if necessary the said settings should be adjusted.

- Adjust – if required – the thresholds of equipment and protective devices; and
- Check the settings and the correct intervention of the Interface Protection(s) through simulated tests by means of the methods and equipment described in Appendix D.1.4 and D.2.5 of the Standards [1].

The RRGU / RRGP can have several protection equipment and devices. It is required that all such devices are checked and tested.

4 PART II - TESTING WITH INTERCONNECTION – PERFORMANCE TESTS AND POST-CONNECTION INSPECTION

4.1 Methodology

The overall aim of the test is the verification of the features and the functionalities of 100% of the system. The technical verifications to be performed in the frame of this part of the plant assessment shall be in accordance with the specifications defined in Appendix D of the Standards [1]. Particularly, the content of such inspection is defined in paragraph "D.5.1.3 - Testing with interconnection to the network for the verification of the features and the functionalities of the system".

For all the plants, the below described tests (Table 3, Table 4, and Table 5)

Verification of the technical dossier (Appendix D.5.1.3 of ref. [1])
1. Check: a) The Technical Dossier contains as-built design documents; and b) The certifications relevant to the system and its installation. c) The adequacy of such documentation in terms of both document availability; and d) Availability of the required information.

Table 5 shall be carried out by a Test Engineer or by another body recognized by DEWA. The outcomes of these tests will be collected into a Technical Dossier to be submitted to DEWA for approval. In case of a plant with $P_{MC} \geq 100$ kW, this approval will be a prerequisite to the execution of the Performance Tests.

A list of the tests, grouped according to functionalities, performance, and documentation is presented here.

Table 3: Final Inspection: Functionalities of RRGU / RRGP

Functionalities of RRGU / RRGP (Appendix D.5.1.3 of ref. [1])	
2.	Connection to grid and start-up of RRGU/RRGP
3.	Parallel with the grid
4.	Start-up tests on inverters. Tests performed separately on each inverter and progressively throughout the whole RRGU/RRGP
5.	Verification of connection of energy meters. a) Detect nameplate data of all voltage and current transducers. b) Check connection of meters to voltage/current transducers, and transformation settings. c) Check compliance off meter calibration certificates.
6.	Alarms and messages. Check the correct operation of alarms and messages through simulated tests of intervention (blank tests)
7.	Measurements. Check agreement and degree of accuracy of measurements.
8.	RRGU/RRGP Monitoring system. Check system operation, reliability of measurements, and agreement with requirements. a) Check calibration and certification of meteorological sensors. b) Remote monitoring functions
9.	Operation of electrical systems in each cabin.
10.	Security system. Checking installation operation of security system (if any)

Table 4: Verification of the technical dossier

Verification of the technical dossier (Appendix D.5.1.3 of ref. [1])
11. : Check a) The Technical Dossier contains as-built design documents; and b) The certifications relevant to the system and its installation. c) The adequacy of such documentation in terms of both document availability; and d) Availability of the required information.

Table 5: Measurements of the RRGU / RRGP performance

Measurements of the RRGU / RRGP performance (Appendix D.5.1.3 of ref. [1])
12. Measurement of PV generator performance. The test is performed for each inverter and related strings of PV modules. a) Measurement of power input to inverter by DC wattmeter (including voltage and current). b) Measurement of power output from inverter by AC wattmeter (single or three-phase electrical quantities) connected to inverter busbar. c) DC and AC measurements must be synchronized. Measurements shall be carried simultaneously or in fast sequence, for each subsection (inverter) of RRGU. Measurements of solar radiation from a reference solar cell or pyranometer.

4.2 Functionalities of RRGU / RRGP

The verifications described in the present section can be performed after the Inspection has been executed, the meter installed and the plant energized with the connection to the distribution network.

4.2.1 Connection to Grid and Start-up of RRGU/RRGP

The Test starts by connecting and energizing the equipment of the RRGU / RRGP. Each unit of the solar PV generator will receive power from the mains, allowing auxiliary services to supply switchboards and switchgears up to string combiner boxes.

4.2.2 Parallel with the grid

After the plant has been connected to the grid and powered, the following verifications shall be performed:

- Check the grid connection equipment and related protections are set up in accordance with the parameters defined in the Standards [1]; and
- Check the PV power generation and transformation equipment is working as expected.

Then perform the parallel with the grid so that the generated power can supply the loads located in the premises of the plant owner or be delivered to the distribution network.

4.2.3 Start-up Tests on Inverters

A sequence of Tests shall be performed separately on each inverter and progressively throughout the whole RRGP, to assess that inverters are working properly and set up in accordance with the parameters defined in the Standards [1]. The following verifications are envisaged:

- Cable connections.
- Voltage/current input/output values from inverter instruments.
- Start-up and shut-down tests.

4.2.4 Verification of Connection of Energy Meters

Installation and verification of energy meter(s) shall be under the responsibility of DEWA. It is recommended that during the Final Inspection the participants collect the information and data summarized below:

- Detect nameplate data of all voltage and current transducers (if any);
- Check connection of meters to voltage/current transducers, and transformation ratio settings; and
- Check compliance of meter calibration certificates.

During these checks the Inspectors shall assess the energy metering devices available in the plant, and in particular, check the readings of the instruments available in the inverter.

4.2.5 Alarms and Messages

Alarms and warning messages can help reliable and safe operation of any plant. According to the plant size, such messages shall be managed by the Consultant/Contractor, the Owner or by the entity appointed for the "Operation and Maintenance" service.

In any case, it is important to check the correct operation of alarms and messages through simulated tests of intervention.

4.2.6 Measurements

This part of the Tests is devoted to verifying the degree of accuracy of the measurements performed by the instruments aboard any equipment. This accuracy must be compliant with the equipment technical specifications.

4.2.7 RRGU/RRGP Monitoring System

With reference to the size of the DRRG, a monitoring system may be installed to facilitate the management of the PV plant. According to the plant size, such a monitoring system shall be managed by the Consultant/Contractor, the Owner or by the entity appointed for the "Operation and Maintenance" service.

The Test allows verification that the monitoring system is in accordance with the design, the operation of such system, and the reliability of the measurements. The following verifications shall be performed:

a) Verify the certification of the meteorological sensors: solar radiation (solar cell or pyranometer), wind, and humidity.
b) Verify the solar radiation sensors by comparing their readings with the readings of similar sensors. This test shall concern especially PV plants of Maximum Capacity larger than 100 kW, for which a performance test is required (see below). The verification of the solar sensors shall ensure that the sensors and instruments of the PV plants are reliable and ensure the PV plant performance can be evaluated any time in the frame of the operation of the PV plant.
c) Verify the correct measurement of the temperature of the backside of the module by the temperature probe.
d) Verify the remote monitoring functions available from the monitoring equipment and system.

4.2.8 Operation of Electrical Systems in each cabin

Suitable behaviour of the electrical systems in each cabin, both for power and auxiliary systems, are to be verified. The checks shall be performed by verifying the correct operation of such systems through their instruments, particularly to assess the absence of warning or error messages.

4.3 Verification of the Technical Dossier

After the Consultant/Contractor has performed the Tests with interconnection, s/he shall submit the Technical Dossier to DEWA.

DEWA verifies the completeness and the formal accuracy of the Technical Dossier relevant to the given RRGU / RRGP installation.

The aim of this verification is for DEWA to be sure that all the necessary Tests with Interconnection to the grid have been carried out and that the connection process may continue.

The availability of design documents updated to the as-built condition and of the documentation of the equipment (e.g. technical specifications, installation guides, user's manuals, certifications, etc.) is important for the operation of the PV plant, particularly for the technicians involved in the O&M activity.

DEWA will in particular have to perform the following verifications:
a) Presence of As-built design documents in the Technical Dossier;
b) Availability of the Certifications relevant to the system and its installation,
c) Adequacy of such documentation in terms of both document availability, and
d) Availability of the information required for the completion of the Technical Dossier.

In case of lack of one or more document in the Technical Dossier, DEWA requests the Applicant to produce the missing documents.

4.4 Performance Tests and Post Connection Inspection

This section applies only to PV plants of Maximum Capacity ≥ 100 kW.

Under the assumption that all preceding tests carried out during the Inspection without DEWA supervision, after the connection to the grid were successful, DEWA, having first verified the correctness of the latter tests by checking the Technical Dossier, issues a Preliminary Authorization to let the Applicant execute the Performance Tests. The tests will be carried out by a Contractor test engineer or by an appointed system integrator engineer.

4.4.1 Performance Tests

The Performance Test is divided into Energy Performance Test and Power Performance Test.

Energy Performance Test

The Performance Test is carried out for the whole plant, involving the following measurements:

a. Read active energy as measured by the production meter.
b. Measurements of the solar irradiance from a reference solar cell or pyranometer connected to a data logger in order to store them in the performance test time span.
c. Measurements of the PV module temperature by means of a temperature sensor located on the back surface. Values to be sent to the data logger

The active energy which may be produced by the modules, according to the actual operating conditions, is compared with the measured active energy (by the meter), in order to calculate the Energy Performance Ratio.

The aim is to calculate the following performance indicators:

Performance ratio without temperature correction (PR)

$$PR = \frac{E_{ac}}{P_{nom} * \Delta t_s \sum_j G_j} * 60 * 10^3$$

Performance ratio with temperature correction (PR_ϑ)

The temperature correction is useful for comparison among measurements of PR made in different periods. The STEC reference temperature REF = 25 °C is assumed in the formula.

$$PR_\vartheta = \frac{E_{ac}}{P_{nom} * \Delta t_s * \sum_j (G_j * [1+(\vartheta_{pvj} - \vartheta_{REF}) * \Upsilon/100])} * 60 * 10^3$$

The meaning of the symbols is the following:

- E_{AC} = AC active energy [kWh] at the output of inverter measured in the given period (accuracy ±2%)
- P_{nom} = Nominal power of PV generator [kW] (total nominal power of installed modules)
- Dt_s = Sampling interval [min]
- G = Solar Irradiance $[\frac{W}{m^2}]$ sensor coplanar to the surface of the modules (accuracy equal or better than ±5%)
- ϑ_{pv} = PV module temperature [°C]
- Υ = Power temperature coefficient of the module [%/°C] (this coefficient is usually negative)

The tests can be carried out after successful commissioning and shall last a rolling 10 Days duration accounting for the following criteria:

- at least five (5) days with irradiance (G) measured on the plane of the array greater than 600 W/m² for 3 contiguous hours
- for at least five (5) days, the daily total irradiation on the plane of the array exceeds 4.0 kWh/m² (these days may be the same as those indicated in the previous point).
- In the event that the five days are not reached with the required irradiation levels, the measurement period will be extended until the irradiation criteria are achieved.
- Availability of the PV Plant and the grid shall be 100%. In the event of unavailability, the testing period will be extended accordingly by the relevant number of days.
- The sampling interval Dts is constant and not larger than 15 min.

Power Performance Test

In principle the test is performed for each inverter and related strings of PV modules (array), and is based on the following measurements.

a. Measurement of power input to inverter by DC wattmeter (including voltage and current).

b. Measurement of power output from inverter by AC wattmeter (single or three-phase electrical quantities) connected to inverter busbar.

c. DC and AC measurements must be synchronized. Measurements shall be carried simultaneously or in fast sequence, for each subsection (inverter) of RRGU.

d. Measurements of the solar Irradiance from a reference solar cell or pyranometer.

e. Measurements of the PV module temperature by means of a temperature sensor located on the back surface

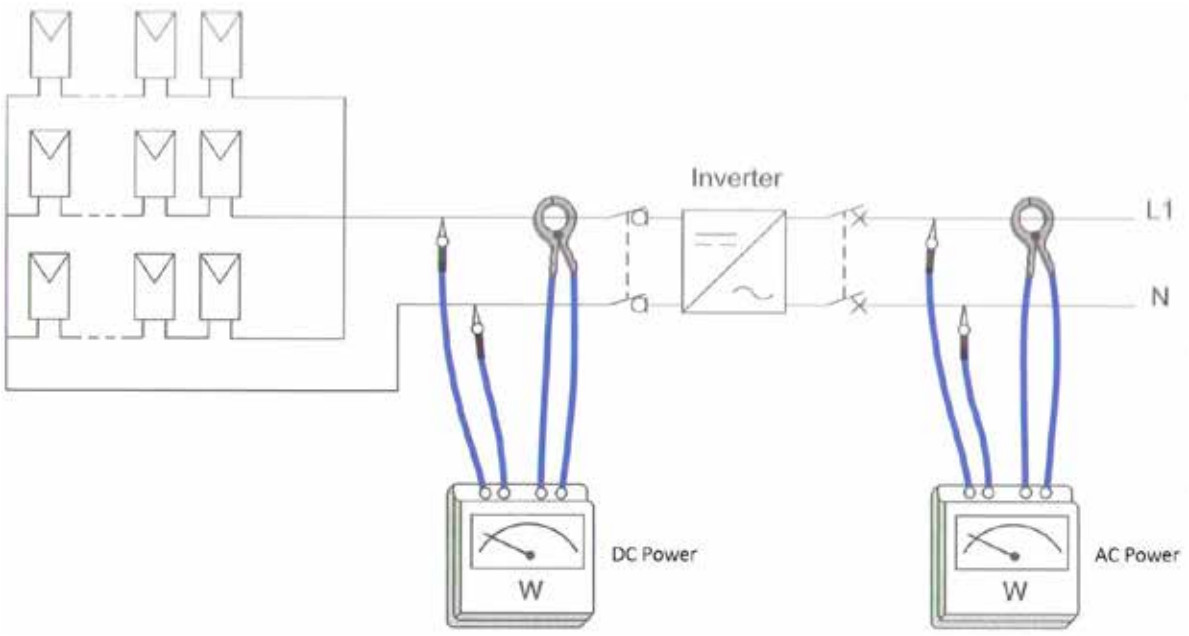


Figure 7 – Power Performance Test. Measurement of DC and AC power on a PV plant

Figure 8 – Measurement of the solar irradiance from a reference solar cell. Example of a solar cell oriented as PV modules

The aim is to calculate the following performance indicators:

Performance ratio on power without temperature correction (PR_p)

$$PR_p = \frac{P_{AC}}{G} * \frac{1000}{P_{nom}} \qquad \eta INV = \frac{P_{AC}}{P_{DC}}$$

Performance ratio on power with temperature correction ($PR_{p\vartheta}$)

The temperature correction is useful for comparison among measurements made in different periods. The STC reference temperature ϑ_{REF} = 25°C is assumed in the formula.

$$PR_p = \frac{P_{AC}}{G} * \frac{1000}{P_{nom}*[1+(\vartheta_{PV}-\vartheta_{REF})*\Upsilon/100]} \qquad \eta INV = \frac{P_{AC}}{P_{DC}}$$

Array efficiency (sunlight to electricity conversion efficiency of the PV array) (ηA)

$$\eta A = \frac{P_{DC}}{G * N_m * A_m} * 1000$$

The meaning of the symbols is the following:

- P_{DC} = DC power [kW] of the PV generator (accuracy ±2%) as measured at the inverter DC input
- P_{AC} = AC active power [kW] at the output of inverter (accuracy ±2%)
- P_{nom} = Nominal power of PV generator [kW] (total nominal power of installed modules) @ STC
- N_m = Number of PV modules
- A_m = Area of each PV module [m^2]
- G = Solar Irradiance ($\frac{W}{m^2}$) sensor coplanar to the surface of the modules (accuracy equal or better than ±5%)
- ϑ_{PV} = PV module temperature [°C]
- ϑ_{Air} = Air temperature [°C]
- Υ = Power temperature coefficient of the module [%/°C] (this coefficient is usually negative)

The tests are valid if Solar Irradiance G > 600 ($\frac{W}{m^2}$).

The results of the Performance Tests shall be described in a separate document and a copy of this Test will be made available to DEWA before the Post Connection Inspection can take place.

The Performance Test shall also include the following information:

- Information and data specifying location and technical characteristics of the plant.
- Name affiliation and signature of the person(s) undertaking the measurements, and those participating to the test (if any).
- List of the equipment used during the inspection.
- Description of the tests, the sections of the PV plant that were tested, and the results of the related performance tests.

After the positive conclusion of the Performance Tests, the Applicant notifies DEWA through the website and a Post-Connection inspection can be scheduled.

4.4.1.1 Harmonic Emissions

For RRGP greater than or equal to 100 kW the harmonic emissions generating from the plant shall be measured to allow DEWA to verify that network power quality is actually in line with the requirements reported in [1] and [5], and that the RRGP does not generate disturbances to other customers. In principle, the tests are performed for the whole power plant at POC. If the RRGP has different POCs, the tests must be performed at each POC.

The methodology of the tests is here summarised:

- Observation period of at least one week with fixed steps of 10 minutes.
- N = number of 10-minute intervals in which the supply voltage is within normal operating range.
- N1 = number of 10-minute intervals in which voltage harmonics level exceeds individual harmonic limit and the supply voltage is within normal operating range. Levels for individual harmonics limits are defined in [1].
- N2 = number of 10-minute intervals in which the THD value for one or more of the phase voltages exceeds the voltage limit defined in [1] and the supply voltage is within normal operating range.

The harmonic content on the voltage is acceptable whenever N1/N ≤ 5% for each individual harmonics and N2/N ≤5% for THD during the observation period.

The Harmonic Emissions Performance Tests may be performed indifferently using one of the following measurements methods:

- Taking advantage of the functionalities of the Smart Meter (if it is compliant with the above measurements requirements), by retrieving the measurements on a suitable time period.
- Installing and making use of specific instrumentation, compliant with the above requirements, to perform a dedicated test campaign.

The tests are deemed valid if they have been carried out considering operating conditions of the PV plant as specified in 4.4.1.1. In other words, it is advisable to measure the harmonic content in the voltages during the Performance Test campaign. The tests results and the measured values shall be clearly presented in tables for their analysis by DEWA engineers and their confrontation with DEWA planning levels or limits. In case some limits are exceeded, DEWA is entitled to ask the customer for additional measurements on current harmonics emissions in order to check the actual RRGP current emission spectrum and investigate whether the causes of such limits violations are to be attributed to the RRGP or to the interaction with other RRGPs.

4.4.1.1.1 Additional measurements

In case some voltage harmonics limits are exceeded, the following additional measurements are needed:

- background harmonic voltage of the existing grid at the Point of Connection, with the plant disconnected from the grid. The measurements with the methodology as described in the previous paragraph have to be carried out, after disconnection of the plant
- emission of current harmonics during continuous operation.

The current harmonic measurements have to be performed too with an observation period of at least one week with fixed steps of 10 minutes. The values of the individual current components and the total harmonic current distortion shall be given in tables in percentage of In and for operation of the RRGP within the active power ranges 0-25, 25-50, 50-75 and 75-100% of Pn.

The individual harmonic current components shall be specified as subgrouped values for frequencies up to 50 times the fundamental grid frequency, and the total harmonic current distortion shall be calculated as derived from these.

The current harmonics shall be measured for the RRGP operating with reactive power as close as possible to zero, i.e. if applicable the reactive set-point control shall be set to Q=0. If other operational mode is used, this shall be clearly stated.

4.4.2 Evaluation of the Performance Tests

Carrying out the Performance Tests is a mandatory step of the connection process however these tests are not intended as acceptance criteria.

The aim of these Performance Tests is to demonstrate the performance of the RRGP. Also, test results lower than the performance expected for instance according to the design data will not prevent in principle the completion of the connection process.

Nevertheless, if performance is not according to the design data, the Applicant will know that something is not properly installed or properly working in the plant. If this is the case, the Applicant shall take advantage of such warning to recheck and retest the RRGP until the performance is as close as possible to the expected rates.

The higher the Performance Ratio, the more efficiently the PV system is operating. Reasonable values of the PR may range between 75 % and 90 %.

4.4.3 Post-Connection Inspection

This Post-Connection site inspection is aimed to:

- Make the final checks on the installation, if necessary;
- Verify the proper behaviour of the meters, if necessary;
- Supervise the Power Performance Tests if repeated by the Applicant, on explicit request of DEWA, if considered necessary; and
- Obtain the reading of the meters in order to begin to consider the exports and net metering.

The results of checks related to the energy meters shall be noted in the appropriate section of the checklist “Testing and Inspection with interconnection”.

The results of the repetition of the Performance Tests could also be reported in the same document, if necessary.

ANNEX 1 – SAFETY INFORMATION FORM TO BE FILLED BY THE APPLICANT

The following form indicating specific risks and on-site safety measures shall be filled and delivered by the Applicant / Contractor to DEWA, before DEWA – or the concerned Authority – Inspectors visit the site of the PV plant.

On-site inspection of the DRRG installation Information on specific risks for the site and safety measures communicated by the Applicant
1. Reference applicant / customer 2. Site (Town, street and/or Geographical coordinates) 3. Activity (residential, commercial, industrial, school, health, etc.)
4. Location of the PV generator (slanted or plain rooftop, façade, ground, canopy, etc.) 5. Safety measures to be taken when accessing to the PV array
6. Location of the combiner boxes 7. Location of the inverters 8. Location to other switchgears 9. Safety measures to be taken when accessing to combiner boxes, inverters, switchgears
10. Circuit breaker to be opened during inspection and tests, with reference to the electric diagram
11. Interference with other works or plants
12. Location of fire hydrants and fire extinguishers

List of risks in the workplace and related prevention and protection measures		
Specific risk	**Collective protective measures and equipment**	**Personal protecting measures (PPE)**
Falling		
Dusts		
Slipping		
Harmful substances		

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