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PROJECT: LETHABO & KENDAL PV POWER PLANT								
<h1 style="text-align: center;">MAINTENANCE PLAN</h1>								
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## 1. OBJECTIVE

- The object of this procedure is to define the minimum general conditions that must be fulfilled to ensure adequate maintenance of the grid-connected photovoltaic solar energy facilities.
- This procedure is aimed at guaranteeing personal safety and preventing equipment malfunctions that could produce breakage thereof.
- LV photovoltaic maintenance shall refer to the cleaning, revision and electrical verification work performed on the part of the facility comprised between the capture system (photovoltaic panels) and the point of connection to the grid (transformation centre).  
This part of the facility comprises the photovoltaic modules, grid adaptation system (inverters), direct and alternating circuit lines and terminals and circuit breaker and protection devices (fuses, magneto-thermal switches, etc.).
- MV electrical preventive maintenance shall refer to the cleaning, revision and verification work performed on the part of the facility comprised between the MV cabinet (including line input/output terminals) and the connection line to the transformer.  
This part of the facility comprises MV cabinet input/output lines and terminals, MV cabinet, MV circuit breaker fuses, MV cable and terminals, MV distribution lines, MV circuit breaker fuses, transformer temperature sensors and circuit protection devices.

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## 2. SCOPE


- In order to perform this preventive maintenance work, the personnel in charge must have a working knowledge of the safety and protection equipment and must be qualified to perform work on live low and medium-voltage installations.
- Two action plans have been defined that encompass the necessary operations during the life of the installation and increase the reliability and extend the duration thereof: Supervision Plan and Preventive Maintenance Plan.

### 1. SUPERVISION PLAN.


- The supervision plan basically refers to those operations that will ensure the correctness of the operating values of the installation. It is a simple observation of the main functional parameters (energy, voltage, current, etc.) aimed at verifying the proper functioning of the installation, as well as recording meter readings.
- The supervision plan will include those visits made to the power plant for the purpose of supervision thereof or for obtaining production records.
- A record will be kept of each visit which will include installation details, identification of personnel and will reflect the status of the facilities and any incidents that may have occurred.

### 2. PREVENTIVE MAINTENANCE PLAN.

- The preventive maintenance plan encompasses visual inspection operations, verification of actions and others which, applied to the installation, should keep the operating conditions, characteristics, protection and durability of the installation within the permissible limits.
- The maintenance plan shall be implemented by qualified technical personnel authorised to perform electrical installations, commissioning and maintenance of photovoltaic power plants.
- Likewise, the executing personnel must have a working knowledge of safety and protection equipment and must be qualified to perform work on live low voltage installations.
- The preventive maintenance plan shall include all operations relative to the maintenance and replacement of consumable or worn elements necessary for ensuring proper functioning during its useful life.
- The preventive maintenance plan shall include, at least, a six-monthly revision during which the following activities will be carried out:
  - General verification of the mechanical status of cables and terminals (including earth cables and re-tightening of connection terminals), support structure, anchoring of modules, cleaning, etc.
  - Verification of module status (verification of the situation with regard to the original project, verification of connections and cleaning thereof).
  - Verification of inverter status (operation, signal lights, alarms, etc.).
  - Verification of electrical protection devices.


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- Verification of fiscal metering equipment operation.
- Verification of the solar farm safety systems.
- Verification of the weather station.
- Electrical revision of transformation centres, distribution centres and MV lines.

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## REFERENCES

- ABB Electrical Safety Guide.
- Electrical verifications prior to energize photovoltaic power plants.

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## 4. DEFINITIONS

- **Work procedure:**  
The sequence of operations for correctly executing work, including the material (work or protection) and human (qualification or training) means for such purpose.
- **Qualified worker:**  
A person who has been authorised in writing based on his/her specialised knowledge of electrical installations, due to having accredited, professional or university training or to having certified experience of two or more years.
- **Authorised worker:**  
A person who has been authorised in writing by his/her employer to perform certain work involving electrical hazard, based on his/her capacity for performing said work correctly, according to established procedures.
- **Work Supervisor:**  
A person designated by the company to assume responsibility for the work being executed.
- **Preventive maintenance:**  
The set of activities, actions, tests and/or analyses carried out routinely and with a pre-established periodicity, the object of which is the knowledge and/or verification of the general status of the different units and systems of the electrical infrastructures and proper functioning thereof, proceeding, where necessary, to replace components for the purpose of preventing anomalies or malfunctions.  
Anomaly shall be understood to be the status of a unit and/or systems which alters the proper functioning thereof and/or assembly wherein it is integrated.  
Preventive maintenance is based on the revision of equipment in accordance with certain maintenance procedures pre-established for each unit with a determined periodicity. These procedures are established based on the manufacturer's instructions and on the maintenance company's experience or operating procedures.
- **Corrective maintenance:**  
Set of activities and/or actions, including the repair and/or replacement of materials and components carried out in the different units or systems of the electrical infrastructures in the event of anomaly and/or malfunction, with the object of returning them to their adequate operating status.  
Unprogrammed corrective maintenance is understood to be that performed when a malfunction occurs unexpectedly and requires urgent intervention in order to resume the service in the shortest possible time.  
Programmed corrective maintenance is understood to be that the execution of which was previously planned.


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## 5. RESPONSIBILITIES

The following persons shall be responsible for implementing this procedure:

- **Site Quality Manager:**  
The Site Manager will take responsibility for Site Quality Control if this function has not been explicitly defined. He/she will ensure the correct application of this procedure and will inspect the work executed and issue the documentation listed under the RECORDS section of this procedure, keeping an onsite file of the generated records.
- **Site Supervisors:**  
Site Supervisors will coordinate the work teams and organise the human and material resources under their control for performing the operations mentioned herein.  
He/she will be responsible for ensuring observation of the adopted safety measures by the operators and the use of the envisaged prevention means for this activity, such as:
  - Approved safety harness.
  - Helmet.
  - Safety shoes.
  - Work gloves.
  - Insulating gloves.
  - Signalling units.
- **Work Supervisors:**  
Reporting to the Site Supervisors, Work Supervisors manage the teams under their control in order to conduct, record and approve the inspections and verifications indicated in this procedure.  
Check that work tools are in perfect use condition and have the corresponding calibration certificate.  
Execute installation shutdown/start-up operations following all the safety regulations.  
The results and acceptance of the inspections conducted and the measures implemented in this maintenance procedure shall be recorded using the formats provided in Annex 1.  
Likewise, all installation details and meter readings shall be recorded using the formats provided in Annex 2.
- **MV network energization and transformation centres team:**  
Composed of one Work Supervisor and several qualified or authorized assistants, with the function of performing all the required preliminary operations for correct energization of the MV grid and transformation centres of each installation, always under the supervision of the Site Supervisor.



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## 6. PREREQUISITES

The operation and maintenance of the photovoltaic facility or any of its systems must mandatorily be performed in accordance with the Safety Instructions set out in the following documents:

- Prior to starting the work, verification of fulfilment of the following requirements:
- The necessary equipment, tools, personnel and client relations are those defined in this procedure, as well as the contractual documentation:
- Proposals, contracts, etc.
- The verification tools used shall be duly calibrated in accredited laboratories or those capable of issuing certificates of calibration traceable to national standards.
- Upon arrival at the installation and prior to performing any operation, the person responsible for the installation shall be informed of the operation to be performed and will request authorisation to shut down the installation.
- All maintenance operations must be performed with the installation shut down and disconnected from the grid, unless the operation itself requires the installation to be powered up in order to verify functioning thereof.
- All maintenance operations shall ALWAYS require a minimum of two people.
- All operations requiring the use of chemical products must follow the Safety Specifications issued by the manufacturer of said products.
- Before performing any work on the DC photovoltaic field, the steps below shall be followed in the indicated order:
  - Stoppage of the inverter equipment and visible or effective disconnection of all possible AC voltage sources.
  - Visible or effective disconnection of all possible DC voltage sources.
  - Interlocking or blockage of disconnection devices and signalling thereof.
  - Verification of absence of voltage.
  - If the DC voltage source cannot be disconnected, short circuit all the possible DC voltage sources using an adequate device for this operation (short-circuiting device and/or capacitor discharge resistor).
- If the Transformation Centre cell must be manipulated, the worker shall be qualified or authorised under the supervision of a qualified person.
- All work that implies risk of electric shock shall be performed by personnel authorised in accordance with SANS requirements, and following the safety instructions established by the supplier for operating in each type of power box.
- Waste generated during maintenance shall be correctly managed and no waste shall be deposited outside of its corresponding container.



THE ELECTRICAL INSTALLATION SHALL BE SHUT DOWN BEFORE PERFORMING ANY WORK ENTAILING ELECTRICAL HAZARD THERETO OR TO THE SURROUNDING AREA, TAKING INTO ACCOUNT THE FIVE GOLDEN RULES WHICH SHALL ALWAYS BE APPLIED TO WORK PERFORMED IN BOTH HIGH-VOLTAGE AND LOW-VOLTAGE INSTALLATIONS.

➤ **FIVE GOLDEN RULES**

1. APERTURE OF CIRCUITS
2. BLOCKAGE OF CIRCUIT BREAKER DEVICES
3. VERIFICATION OF ABSENCE OF VOLTAGE
4. EARTHING AND SHORT-CIRCUITING
5. DELIMITATION AND SIGNALLING OF THE WORK AREA

## 6.1. MATERIAL MEANS

The material means most commonly used to perform maintenance work on photovoltaic facilities are listed below.

❖ **Metering devices:**

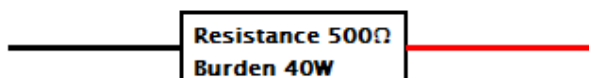
- Multimeter.
- 2 AC/DC ammeter clamps.
- 1000 VAC insulation meter.
- Pyranometer.
- Thermometer.
- Pt100 sensor with metal capsule or variable resistance verification device (potentiometer, resistor block, etc.).
- Flex meter.
- Direct/indirect relay testing equipment.
- Meter

❖ **Safety equipment:**

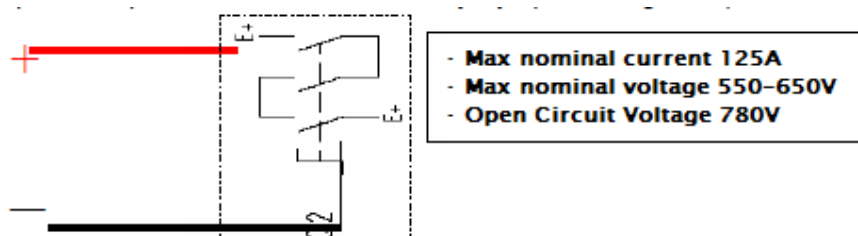
- Safety harness
- Helmet.
- Safety shoes.
- Insulating gloves.
- Disk danger signals.
- Insulating tape.
- Safety belts.
- Earthing and discharge equipment.
- Voltage detector poles.
- Operating/insulating pole.

❖ **Tools:**

- Inverter equipment user manual.
- Work procedures for performing preventive maintenance in photovoltaic power plants.
- Inspection records of preventive maintenance in photovoltaic power plants.
- Technical installation documentation.
- Single-line and series-parallel connection drawing of the installation.
- Laptop.
- Serial cable for communications.
- Insulated hand tool sets (screw drivers, fixed and ratchet wrenches, pliers, scissors, etc.).
- Suction device.
- Flashlight.
- Pressurised water unit.
- Terminal presses.
- Ammeter clamp for direct and alternating current.
- 1000 V multimeter.
- 1000 V insulation meter.
- Ladder.
- 8Nm-200Nm torque wrench.
- Communication transmitters.
- Passkey for opening power boxes.
- Discharge resistor for capacitors according to the diagram.



- Series-parallel box short-circuiting device according to diagram.



**❖ Cleaning equipment and consumable materials:**

- Paper and cleaning cloths.
- Rubber gloves.
- Different-sized screws.
- Insulating tape.
- Enamel paint.
- Cold-galvanising paint.
- Anti-corrosion protection (Tectyl 120 CGW or similar).
- Sealing tape.
- Water and non-abrasive cleaning products (soap, cloths, brushes, etc.).
- Multi-use cleaner.
- Contact spray or grease.
- Plastic flanges.
- Soft plastic bristle brush (300mm).
- Medium-sized paintbrush (70mm).
- Cylindrical soft bristle brush.
- Cleaning rod with extendable handle (diameter: 100 mm; handle: 1 m).
- Cloths and paper.
- Metal brushes.
- Enamel paint, paintbrushes and galvanised paint.
- Dielectric cleaning liquid.
- Rubber gloves.
- Different-sized connection screws.
- Insulating tape.
- Electrical contact grease (Molykote, Penetrox A13 or similar).
- Different-sized connection screws.
- Enamel paint and paintbrushes.
- LOCTITE® 5970 silicone.
- Paste for repairing cracks in MV cores (PACTAN).

**6.2. MAINTENANCE OPERATIONS SUMMARY**

The maintenance operations and time intervals shall be those shown in the summary table below:

Component	Operation	Interval	Operation
Inverter	Inspection and cleaning	six-monthly	<b>7.2</b>
	Electrical verifications		<b>7.2</b>
	Verification of functioning		<b>7.2</b>
	Verification of connections		<b>7.2</b>
Photovoltaic panels	Inspection	six-monthly	<b>7.6 and 7.7</b>
	Verification of connections		<b>7.8</b>
	Electrical verifications. Voc and Ioc		<b>7.4</b>
	Cleaning	six-monthly	<b>7.7</b>



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General junction boxes	Inspection	six-monthly	<b>7.4 and 7.8</b>
	Verification of connections		<b>7.8</b>
AC cables	Inspection	six-monthly	<b>7.10</b>
	Line meggering		<b>7.10</b>
	Verification of terminal torque settings		<b>7.10</b>
DC cables	Inspection	six-monthly	<b>7.8</b>
	Line meggering		<b>7.8</b>
	Verification of terminal torque settings		<b>7.8</b>
Structures	Inspection	six-monthly	<b>7.5</b>
	Verification of torque settings		<b>7.5</b>
Centralisation of meters	Inspection and cleaning	six-monthly	<b>7.9</b>
	Electrical tests		<b>7.9</b>
	Verification of connections		<b>7.9</b>
	Verification of meter functioning		<b>7.9</b>
General protection box	Inspection and cleaning	six-monthly	<b>7.9</b>
	Electrical tests		<b>7.9</b>
	Verification of connections		<b>7.9</b>
Installation of auxiliary services	Inspection and cleaning	six-monthly	<b>7.9</b>
	Electrical tests on protections		<b>7.9</b>
	Verification of electrical connections		<b>7.9</b>
Earthing network	Inspection	annually	<b>7.11</b>
	Verification of connections		<b>7.11</b>
	Metering of earthing resistance		<b>7.11</b>
	Metering of passthrough and contact		<b>7.11</b>
Prefabricated centres	Inspection	six-monthly	<b>7.12</b>
	Cleaning		<b>7.12</b>
Safety installation	Inspection and cleaning	six-monthly	<b>7.2</b>
	Verification of electrical connections		<b>7.2</b>
	Verification of conduits and support structures		<b>7.2</b>
	Verification of functioning		<b>7.2</b>
Weather tower	Inspection and cleaning of box dessicant	six-monthly	<b>7.6 and 7.7</b>
	Verification of connections		<b>7.8</b>
	Verification of sensor functioning		<b>7.4</b>
	Calibration and adjustment of sensors	annually	<b>7.7</b>
Transformation centres and MV lines	Visual inspection and cleaning	annually	<b>7.18-7.29</b>
	Verification of electrical connections		<b>7.18-7.29</b>
	Specific tests		<b>7.10-7.20</b>
	Regulatory inspection	tri-annually	<b>7.30</b>

## 7. MAINTENANCE OPERATIONS PROCEDURES

The common procedures used in the preventive maintenance of the infrastructures that comprise this photovoltaic facility, for both LV and MV installations, are summarised below.

### 7.1. PRELIMINARY VERIFICATIONS.

Prior to shutting down the installation and disconnecting the equipment from the power supply, the proper functioning of the installation shall be evaluated by means of the following verifications:

#### ❖ CURRENT METERING IN ALL DC SERIES

- Bearing in mind that the current injected by the panel depends directly on solar radiation intensity and that maintenance work will not always be performed under the same irradiation conditions, in order to verify that all the series inject approximately the same current intensity regardless of irradiation conditions while simultaneously verifying that there are no open panel series, said verification must be performed using two DC ammeter clamps (photo 1).

Considering that all the panels of an installation have the same characteristics, one ammeter clamp will be disposed on one of the series, taking its reading as a reference, while the rest of the series will be metered by the other ammeter clamp, comparing the instant readings of both clamps at a given time. This will allow detection of a possible problem within a series in the event of a considerable difference between the readings of the two clamps.



photo 1

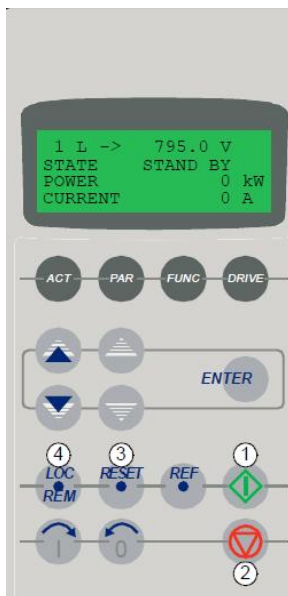


photo 2

In order to compare the instant current output reading between the two series housed in separate parallel boxes or different rows, communication transmitters will be used between the technicians (photo 2).

### ❖ EVALUATION OF INVERTER EQUIPMENT OPERATION.

The equipment shall be considered to function CORRECTLY when any of the following states are confirmed:




No.	Use
1	Start
2	Stop
3	Fault reset
4	Change between Local/Remote (external) control

**With a simple alternating voltage of 200-253 VAC and a frequency of 49-51 Hz in the installation:**

- **STATE 1:**  
There is insufficient panel voltage (see equipment specifications) and the unit's display screen is turned off.
- **STATE 2:**  
There is sufficient panel voltage (see equipment specifications) to turn on the display screen but not to start up the unit. In this state, the equipment will display all the menu parameters on pressing the corresponding key for each inverter unit model, but will not start up even if the start/stop key is pressed.
- **STATE 3:**  
There is sufficient panel voltage to start up the unit (see equipment specifications) and it could be generating current. If the unit is generating current, the unit's DC working voltage and the power being generated will be displayed on the screen.

At this point, the menu of the unit is accessible and the different parameters metered by the unit during operation will be displayed:

- Ucc (DC voltage).
- Pac (Power generated).
- Uac (AC working voltage).

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- Iac (Current generated).
- Frec (AC working voltage frequency).
- Pcc (power absorbed by the panels).
- Icc (current absorbed by the panels).

The equipment is considered to function INCORRECTLY when the following state is confirmed:

**There being sufficient panel voltage for startup, a simple grid voltage of 200-253 VAC and a grid frequency of 49-51 Hz:**

- **STATE 4:**  
In this state the following can occur:
  1. The display screen is turned off.
  2. The screen is turned on but no message is displayed.
  3. The screen is turned on and displays incoherent characters.
  4. The screen is turned on and alarm messages are displayed.

## 7.2. WORK ON INVERTER EQUIPMENT.

Prior to performing any intervention in the interior of an inverter unit, be sure to follow the instructions of the manufacturer's operating and maintenance manual, included in Annex 3 attached hereto, always taking the following precautions:

- Switch off the unit by pressing the start/stop key (photo 3).
- Press the emergency push-button (photo 4).
- Once the unit has stopped injecting, the panel circuit must be open via the circuit breaker, trip switch or breaker element that will prevent DC current from reaching the unit while we are working on it.
- After completing the previous step, the next step will be to cut off the AC voltage by actuating the main switch and/or differential switch of the installation (photo 5).



photo 3

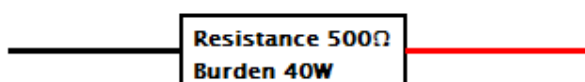
photo 4

photo 5

Operations inside the inverter must be performed with precaution due to the risk of electric shock, despite having disconnected the inverter from the grid and panels. It is therefore advisable, before



performing any intervention in the inverter equipment or junction boxes, to ensure that the inverter is disconnected from the panel AC/DC grid for, at least, 30 minutes so that the equipment capacitors are allowed to discharge or use a discharge resistor with the adequate calibre according to the diagram to carry out the discharge immediately prior to the intervention:



- Once this time has elapsed, check for the absence of both AC and DC voltage (photos 6 and 7) and perform the maintenance and verifications specified by the manufacturer of the equipment.



photo 6



photo 7

- Check, by means of gentle pulls, that the cables are firmly connected. If any of these are loose, tighten as required or reconnect them.
- If there are glands, check that these are adequately fixed to the device (well tightened and without slack and ensuring that they do not become twisted). If you observe loosening of the glands, tighten them as required.
- Check that the length of the cables in the interior of the device is sufficient so that connections are not subject to tensions.
- Check that the terminals are corrosion-free and that connections are electrically effective. In especially adverse environments, protect the connections with anti-corrosion protection (spray, grease, etc.).
- Check the state of the metal casing: lack of paint, rust, etc.
- Check fixation and connection points, screws and anchorings, re-tightening if necessary according to point 8 of this procedure.
- Check the functioning of the cooling motors.
- Check that the device does not have traces of dirt that can prevent visualisation of their indications or can affect the proper functioning thereof. Where necessary, remove the dirt using a cloth moistened with water or multi-use cleaner.
- Check, by means of visual inspection and small weight overloads, that the device is firmly secured and that its support surface does not show signs of deterioration (cracks, detachment of material, etc.). Where applicable, execute the necessary civil works to ensure the repair of the corresponding state of deterioration.
- Check the fuses, auxiliary relays and signal lights.



- Check the interlockings and control circuits.
- Check the state of the cables and connections.
- Once you have finished revising the equipment, disconnect it from both the AC and DC voltage to continue revising the rest of the photovoltaic installation.
- In the event that the installation has two sections (general parallel lines) with load break switches per section, it will not be necessary to disconnect the inverter equipment but rather it will be sufficient to open the switch of the section whereon work will be performed.
- Supply power to the equipment by firstly closing the AC and/or differential switch and then the DC and/or differential switch.
- Finally, start up the equipment by pressing the startup/stop button.

**WARNING:**

The radiator located on the power side of the inverter may reach high temperatures.

The parallel lines stemming from the panels can reach high voltages even with low irradiance levels.

In order to perform this verification, you will require a series and parallel connections drawing of the photovoltaic field.

- Before performing any type of operation on the DC field junction boxes, you must shut down the installation and disconnect the inverter equipment from the grid with the push-button activated, following the same procedure as that explained in point 7.2 “WORK ON INVERTER EQUIPMENT.”
- If the installation has two sections (general parallel lines) with load break switches per section, it will not be necessary to shut down the installation as indicated in the previous paragraph, but rather just open the switch of the section whereon work will be performed and, upon completion of the work, the switch will be re-established and the switch of the second line will be opened in order to continue the work.
- Before performing any operation on a series-parallel junction box, you must disconnect all the voltage sources entering the box in accordance with the following process:
- With the installation shut down and the general AC/DC break devices open, disconnect all the positive and negative terminals of the series by actuating the breakable fuses of all the parallel boxes of a same section (general parallel line). This will ensure the absence of DC voltage in the main parallel strips.
- In order to completely isolate the parallel box whereon work will be performed, you must break the input of the positive and negative poles from the generation fields (panel series), actuating the MULTI-CONTACT fast connections of the first and last panel in order to remove voltage from the cables of the series that enter the parallel box (photo 8).



photo 8

Never disconnect the MULTI-CONTACT connectors with the inverter started up as they could be destroyed by the voltage arc that would appear.

- If the panel model installed does not have MULTI-CONTACT devices and the connection between panels is performed directly by means of connections screwed to the panel box itself, it will be necessary to short-circuit the series that will be revised with the help of a device (switch, breaker, etc.) with load breaking capacity for voltages in excess of 700V AC/DC (photo 9), connected by means of clamps between the positive and negative poles (photos 10 and 11) of the first and last panels of the series to be revised. In this manner, the series will function in island mode and the voltage in the parallel box terminals will be negligible.



photo 9



photo 10



photo 11

- Once all the possible voltage sources have been removed, verify the absence of voltage using a multimeter. Subsequently, performance maintenance and verifications in accordance with the work procedures.
- Check, by means of gentle pulls, that the cables are firmly connected. If you observe any loose connections, tighten accordingly and re-connect the cables if necessary (photo 12).
- Check that the length of the cables in the interior of the boxes is sufficient in order to prevent cable tensioning.

- Check that the glands are adequately secured to the boxes (well tightened, without slack and do not become twisted). If you observe the presence of any loose cables, tighten these accordingly.
- Ensure that the terminals are rust-free and that the connections are electrically effective. In particularly adverse environments, protect the connections with anti-corrosion protection (spray, grease, etc.).
- Ensure that the boxes are adequately sealed and watertight. In case of doubt or presence of condensation in their interior, replace the watertightness gland or use special sealing tape to ensure the watertightness thereof.
- In installations with panels connected by means of screwed connections, check the tightness of the connection using an insulated screwdriver (photo 13).



photo 12



photo 13

**Warning! There is risk of indirect electrical contact when performing this work, due to which the use of a Class 2 insulated tool is necessary.**

- When you have finished revising the junction boxes, reconnect all the MULTI-CONTACT devices and close all the breakable fuses of the general parallel boxes.

### 7.3. VERIFICATION OF THE ELECTRICAL CHARACTERISTICS OF THE DC PHOTOVOLTAIC FIELD (VERIFICATION OF THE ENVISAGED VOLTAGE AND CURRENT VALUES).

These verifications shall be performed in the middle of the day on sunny days.

- These verifications are aimed at metering open circuit voltage and short-circuit current of the series, based on the  $V_{co}$  test (open circuit voltage) and  $I_{cc}$  test (short-circuit current) characteristics of a module, verifying that the values obtained correspond to the configuration of the series and the (approximate) irradiance and temperature values at the time of metering.
- In order to perform said metering, you must have a series-parallel connections drawing of the photovoltaic field and information relative to the technical characteristics of the modules used in the installation.
- Before performing any type of operation on the DC field connection boxes, the installation must be shut down with the inverter equipment disconnected from the

grid and the push-button activated, following the same procedure as that explained in point 7.2 “WORK ON INVERTER EQUIPMENT.”

- Once the DC section whereon work will be performed has been opened and the parallel boxes of said section are located, disconnect the positive and negative terminals, actuating the breakable fuses corresponding to the series to be verified (photo 14).



photo 14

**WARNING:** Never disconnect the DC current stemming from the panels with the inverter in operation and especially when these do not have load breaking capacity, otherwise it could cause destruction of the breaker devices due to the voltage arc that would be produced. In order to disconnect the panels from the inverter, stop the equipment and firstly disconnect the AC protections, followed by the DC protections.

## METERING OPEN CIRCUIT VOLTAGE V<sub>0</sub>:

**WARNING:** Cables stemming from the panels can reach high voltages even with low irradiance levels.

The process to be followed to perform this verification shall be the following:

- Disconnect the positive and negative terminals, actuating the protection and disconnection elements corresponding to the series to be verified.
- Prepare the polymeter to meter DC voltages and select the adequate scale, verifying the open circuit voltage under the technical characteristics of a panel and multiplying it by the number of panels that comprise the series.
- Dispose the polymeter sensors on the generator circuit positive/negative cable input terminals (panel series) inside the parallel box. Reversing the polarity will (simply) result in a negative reading.
- In order to verify that the V<sub>0</sub> voltage between the positive and negative terminals of each generator circuit (panel series) is correct for panel working conditions at the time of metering, taking into account that the readings obtained are highly

influenced by the temperature of the photovoltaic module cells at said time (photo 15).

- The cell reference temperature considered is approximately 25°C higher than ambient temperature. In order to verify that the reading is correct, a 1.8% reduction per 5°C increment in cell temperature shall be applied to the reference voltage obtained as the product of the open circuit voltage of a module under STC conditions multiplied by the number of modules that form the series, with respect to a temperature of 25°C corresponding to STC conditions.



photo 15

- Finally, the work procedures shall be recorded, including the metering results, temperature and irradiance value readings at the time of metering with the help of a thermometer and the pyranometer.

## METERING OF SHORT-CIRCUIT CURRENT:

The decision of whether or not to conduct this test shall depend solely on the results of current meterings performed during the preliminary verifications described in the point “CURRENT METERING IN ALL DC SERIES” during the preliminary verifications, conducting this test only on those panel series where the result of the meterings differ from the rest of the series.

The process to be followed for performing this verification shall be the following:

- Disconnect the positive and negative terminals, actuating the protection and disconnection elements corresponding to the series to be verified.
- Disconnect the MULTI-CONTACT fast connections of the first and last panel of the series to remove the voltage from the parallel box input cables (photo 17).





photo 16

**WARNING:** In order to perform this verification, you must short-circuit the panel series to be verified. Bearing in mind the high voltages that can be reached in a panel series, you must use a device (switch, breaker, etc.) with load-breaking capacity for AC/DC voltages in excess of 700 V (photo 16) in order to close and open in short-circuit the positive and negative pole of the series to be verified, avoiding possible damages to the equipment due to electric arc priming.



photo 17

Never disconnect the MULTI-CONTACT connectors with the inverter in operation as they could be destroyed by the voltage arc that would be produced. In order to disconnect the panels from the inverter, firstly disconnect the AC fuses and then the DC fuses.

- Once you have broken the series in the MULTI-CONTACT connectors and with the testing device open (switch or breaker), connect the parallel box positive/negative input cables to the ends of the switch (photo 18).
- Once you have connected the series to the device (with the device open), reconnect the MULTI-CONTACT connectors of the first and last panels of the series to close the circuit up to the switch.

**Warning! There is risk of indirect electrical contact when performing this work, due to which the use of a Class 2 insulated tool is necessary.**

- Prepare the ammeter clamp to meter DC voltage and select the adequate scale, verifying the short-circuit current of one of the panel series under the technical characteristics.
- Dispose the ammeter clamp on one of the poles of the series to be metered.
- Once you have disposed the clamp, close the device (switch or breaker), thereby closing the series in short-circuit.
- Verify, using the clamp, that the short-circuit current of each generator circuit (panel series) is the same and approximately equal to the test current of one of the panels. The temperature and irradiance value will depend on the time of metering (photo 18).



- After verifying the current of all the generator fields (series), verify that the main short-circuit current (parallel) is approximately equal to the testing current of a panel multiplied by the number of generator circuits (serially disposed branches). The temperature and irradiance value will depend on the time of metering.
- Once you have finished the electrical verifications, reconnect the positive and negative poles to the corresponding protection and disconnection elements, being sure to remove all voltage sources once again, as explained at the start of this point.
- Finally, the work procedures shall be recorded, including the metering results, temperature and irradiance value readings at the time of metering with the help of a thermometer and the pyranometer.

## 7.4. VERIFICATION OF SUPPORT STRUCTURES.

In order to perform this verification, you must have access to the mechanical assembly specifications of the structure, reviewing the following points:

- Check, by means of visual inspection, that the foundations of the structure and/or its bearing surface do not show signs of deterioration (cracks, detachment of material,



rust, etc.). Where necessary, repair it executing the necessary civil works to ensure the repair of the corresponding state of deterioration.

- Check that the joints and anchoring of the structure are not slack or loose, thereby causing vibrations due to the effect of the wind. Where necessary, apply the corresponding torque settings corresponding to the different screw sizes according to point 8 “VERIFICATION OF TORQUE SETTINGS.”
- Check, by means of visual inspection, that the structural elements have not suffered deformations (caused by the stress supported by these) not specified in the structural analysis carried out during the design phase.
- Check that there are no hydraulic leaks using T-bars, joint nuts and splices in the hydraulic circuit of each tracker.
- Revise the tightening of the anchoring shackles and the correct voltage of the cables (guy ropes).
- Check the state of the bolts and pins of the hydraulic pistons.



## 7.5. VERIFICATION OF PANEL STABILITY, RIGIDITY AND FIXATION.

Check that the panels are adequately secured to the support structure and that there is no slack or loosening of the fixations that could cause vibrations due to the wind. Tighten as required in accordance with point 8 “VERIFICATION OF TORQUE SETTINGS,” in order to ensure adequate panel stability, rigidity and fixation. This verification can be performed visually and observing what occurs on attempting to move the panels manually (photo 22).



photo 22

## 7.6. VERIFICATION OF PANEL CLEANLINESS.

Check for the presence of objects on the panels or dirt deposited on the module surfaces (particularly stemming from birds and small plants) which cannot be removed naturally. Their effects are similar to those of shading.

- When required, the modules must be cleaned manually, using water and non-abrasive products and without using scrubbers that could scratch the module surfaces. It is advisable to perform this operation when the panel is not hot.



Check that there is no unplanned shading of the photovoltaic modules due to variations in the surrounding vegetation or due to the positioning of objects near the modules. This shading can considerably decrease the production of electrical energy and, therefore, the characteristics of the photovoltaic facility.

## 7.7. VERIFICATION OF CABLES IN THE DC FIELD.

- Check that the protection ducts and conduits are in perfect state, without signs of damage or insulation or watertightness defects. Where necessary, replace or repair the affected element, in accordance with the extent or importance of the damage.
- Check that the fixation flanges of the aerial conductors, protection ducts and conduits are in good condition.
- Visually check that the MULTI-CONTACT connector devices are in good condition.
- Visually check ditch layout signalling and the state of the inspection boxes.
- Check the fixations of supports and trays and the state of cleanliness or deterioration thereof.

- Check that the visible parts of the cable sheathing is not pierced, cut or mechanically damaged due to friction against edges.
- Check that the cables are identified according to pole polarity.
- Check insulation resistance (meggering), if applicable, in accordance with point 9 of this procedure.
- Applied voltage testing (dielectric rigidity), if applicable, in accordance with point 9 of this procedure.

## 7.8. REVISION OF METER CENTRALISATION AND GENERAL PROTECTION BOXES.

In order to perform this verification, you must have a connections drawing of the AC side of the installation. Before performing any type of operation on the AC installation connections, you must shut down the installation, disconnect the inverter equipment from the grid and activate the push-button, following the same procedure as that explained in the point “WORK ON INVERTER EQUIPMENT,” as well as breaking the general AC evacuation line stemming from the general protection box (CGP) as set out below.

Once extracted, verify the live side of the fuse holder using a multimeter, placing a sign indicating the presence of voltage at that point. Perform the maintenance work and verifications on the rest of the discharged AC installation in accordance with the maintenance procedures:

- With the installation shut down and the master AC breaker switch open in the meter centralisation, disconnect the three blade fuses of the general protection box. To this end, the technician in charge shall use insulating gloves and an approved tool for manipulating this type of fuses (photo 24).



photo 24

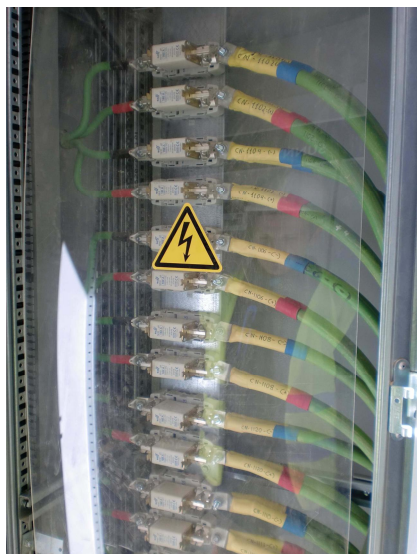


photo 25

Never disconnect the blade fuses with the inverter coupled to the grid, as it could seriously damage the box as a consequence of the electrical arc.

Warning: after extracting the blade fuses from the general protection boxes, there is still voltage in the connection of the line stemming from the transformation centre. In order to remove the voltage, open the line from the transformation centre itself.

Disconnection of the blade fuses without insulating gloves and an approved device for performing this operation is prohibited (photo 26).



photo 26



- Check the torque settings of the connections with the help of a dynamometric wrench, according to point 8 of this procedure.
- Check that the cable and the connections are not hot.
- Check the earthing of metal parts.
- Check the correct curvature of the cables.
- Check the correct fixation of the modules.
- Check the distances between the connections.
- Check the identification of phases by colours.
- Check the identification of the meter boxes and modules.
- Re-tighten the connections in accordance with the torque settings, as indicated in point 8 of this procedure).
- Check the state of cleanliness of the fuses and bases.
- Check the pressure of the clamps.
- Check that the fiscal metering devices (meters) function correctly.

## 7.9. REVISION OF AC CABLES.

- Visually check ditch layout signalling and the state of the inspection boxes.
- Check the fixations of supports and trays and the state of cleanliness or deterioration thereof.
- Check that the protection ducts and conduits are in perfect state, without signs of damage or insulation or watertightness defects. Where necessary, replace or repair the affected element, in accordance with the extent or importance of the damage.
- Check that the visible parts of the cable sheathing are not pierced, cut or mechanically damaged.
- Check that aerial conductors, protection ducts and conduits are adequately secured (in form and number).
- Check that the phases are identified according to the phase sequence.
- Check insulation resistance (meggering), if applicable, in accordance with point 9 of this procedure.
- Applied voltage testing (dielectric rigidity), if applicable, in accordance with point 9 of this procedure.

## 7.10. REVISION OF THE WEATHER STATION.

In order to perform this verification, you will need the operation and maintenance manual of the weather station included in Annex IV attached hereto, as well as the mechanical assembly specification of the different system devices, reviewing the following points:

- Check that the sensors do not show signs of dirt or obstacles which can could cause shading and affect metering. Where necessary, remove any dirt or possible obstacles.



- Check, by means of visual inspection and small weight overloads, that the fixation of the sensor and bearing surface thereof do not show signs of deterioration (ground movement, cracks, etc.). Where applicable, execute the necessary civil works to ensure the repair of the corresponding state of deterioration.
- Check that the joints and anchoring of the structure do not show signs of slack or loosening that can cause vibrations due to the effect of the wind. Where applicable, apply the torque corresponding to the size of the screw in accordance with point 8 “VERIFICATION OF TORQUE SETTINGS.”
- Visually check that the structural elements do not show signs of deformation (caused by the stress supported) not specified in the structural analysis carried out during the design phase.
- Check fixation and connection points, screws and anchoring, re-tightening if necessary according to point 8 of this procedure.
- Prior to revising the electrical connections, remove any voltage source and disconnect the installation in order to avoid accidents and damages to the system equipment.
- Once all the possible voltage sources have been removed verify the absence of voltage using a multimeter, as well as performing the maintenance and verifications in accordance with the work procedures.
- Check, by means of gentle pulls, that the cables are firmly connected. If there are any loose connections, tighten as required and reconnect the cables if necessary.
- Check that the length of the cables in the interior of the boxes is sufficient to prevent the connections from being subject to stress.
- Check that the glands are adequately fixed to the boxes (adequately tightened, without slack and not twisted). If any gland is loose, tighten as required.
- Ensure that the terminals are free of corrosion and that the connections are electrically effective. In particularly adverse environments, protect the connections with anti-corrosion protection (spray, grease, etc.).
- Ensure that the boxes are adequately closed and watertight. In the event of doubt or presence of condensation in their interior, replace the gasket or use special sealing tape to ensure water tightness thereof.
- Once you have finished revising the junction boxes, re-establish the power supply and continue the revision work on the safety system equipment.
- Check the state of video cables and connections.

**Warning! There is risk of indirect electrical contact when performing this work, due to which the use of a Class 2 insulated tool is necessary.**

## 7.11. GENERAL REVISION OF THE PREFABRICATED CENTRES.

- Check the paint on the walls and the existence of deficient structures.
- Check the existence of accumulated dust.
- Check the existence of stored materials.
- Check the existence of sufficient lighting.
- Check the existence of inadequate dimensions between inverters and corridors.
- Check for signs of rodents.



- Check the existence of emergency lighting.
- Check the existence of fire extinguishers.
- Check the existence of personal protection grids and screens.

## 7.12. REVISION OF THE AUXILIARY SERVICES CABINET.

In order to perform this verification, you will need a connections drawing of the auxiliary services part of the installation.

- With the installation shut down and the master AC cut-off switch open in the meter centralisation, disconnect the three blade fuses of the central protection box.
- Once extracted, verify that the fuse holder side has voltage using a multimeter, placing a sign indicating the presence of voltage at that point and performing the maintenance work and verifications on the rest of the discharged AC installation, in accordance with the maintenance procedures.
- Check the torque settings of the connections using a dynamometric wrench, in accordance with point 8 of this procedure.
- Check that the cable and connections are not hot.
- Check the earthing of the metal parts.
- Check for correct cable curvature.
- Check for correct module fixation.
- Check the distances between connections.
- Verify the identification of phases by colours.
- Check the identification of meter boxes and modules.
- Re-tighten the connections using a torque wrench (as indicated in point 8 of this procedure).
- Check the state of cleanliness of the fuses and bases.
- Check the pressure of the clamps.
- Check that the fiscal metering devices (meters) function correctly.



photo 27



### 7.13. REVISION OF THE SAFETY SYSTEM.

In order to perform this verification, you will need a control and power supply connections drawing of the safety system, as well as the mechanical assembly specifications of the different system devices, revising the following points:

- Check that the cameras do not show signs of dirt or obstacles which hamper visualisation or can affect functioning thereof. Where necessary, remove the dirt or possible obstacles.
- Check, by means of visual inspection and applying small weight overloads, that the cameras and movement detectors are firmly secured and that the bearing surface thereof does not show signs of deterioration (ground movement, cracks, etc.). Where applicable, execute the necessary civil works for repairing the corresponding state of deterioration.
- Check that the joints and anchoring of the structure do not show signs of slack or loosening that could cause vibrations due to the effect of the wind. Where applicable, apply the torque setting corresponding to the size of the screw as specified in point 8 “VERIFICATION OF TORQUE SETTINGS.”
- Check, by means of visual inspection, that the structural elements have not suffered deformations (caused by the stress supported) not specified in the structural analysis carried out during the design phase.
- Check fixation and connection points, screws and anchoring, re-tightening if necessary according to point 8 of this procedure.
- Before revising electrical connections, in order to avoid accidents and damages in the equipment of the system, remove any voltage source and disconnect the installation.
- Once all the possible voltage sources have been removed, verify the absence of voltage using a multimeter and perform maintenance and verifications in accordance with the work procedures.
- Check, by means of gentle pulls, that the cables are firmly connected. If you observe any loose connections, tighten accordingly and re-connect the cables if necessary.
- Check that the length of the cables in the interior of the boxes is adequate to prevent the connections from being subject to stress.
- Check that the glands are adequately fixed to the boxes (correctly tightened, without slack and are not twisted). If you observe any loose glands, tighten these as required.
- Ensure that the terminals are rust-free and that the connections are electrically effective. In particularly adverse environments, protect the connections with anti-corrosion protection (spray, grease, etc.).
- Ensure that the boxes are adequately closed and watertight. In the event of doubt or the presence of condensation in their interior, replace the gasket or use special sealing tape to ensure the water tightness thereof.

When performing this work there is risk of indirect electrical contact, due to which the use of a Class 2 insulated tool is necessary.



- Once you have finished revising the connection boxes, re-establish the power supply and continue revising the safety system equipment.
- Check the functioning of the cooling motors.
- Check the fuses, auxiliary relays, signal lights and sirens.
- Check the exterior lighting system
- Check actuations and control circuits.
- Check the state of video cables and connections.



#### 7.14. RE-ESTABLISH THE VOLTAGE AND START UP THE INSTALLATION.

In order to re-establish the voltage and start up the photovoltaic installation, the steps below shall be followed:


- After revising the AC side, reconnect all the blade fuses by activating the disconnected master AC switch, to which end the technician in charge will use insulated gloves and the approved tool for manipulating this type of fuses.
- Provide power supply to the inverter equipment by firstly closing the general AC circuit protection devices (magneto-thermal, differential).
- Next, we will close the protection and general breaker devices of the panel DC circuit.
- Using a polimeter, we will check AC/DC voltages, verifying that these are correct and that a change in polarity has not occurred in the DC circuit (photos 29 and 30).



photo 29



photo 30

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- Finally, we will start up the equipment and ensure that the installation is correctly coupled to the grid, verifying that the P, V and I parameters are correct.

*It is advisable to firstly shut off the AC power supply of the equipment and then the DC power supply, in order to avoid possible damages to the inverter.*

## 7.15. VERIFICATION OF COOLING IN BUILDING.

Once grid voltage has been re-established, we will check the proper functioning of the cooling system by performing the following verifications:

### VERIFICATION OF THE PROPER FUNCTIONING OF THE ROOM EXTRACTOR FAN.

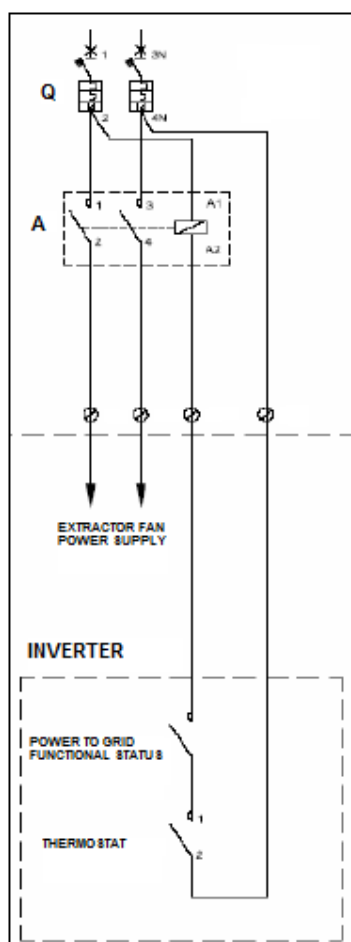
- Check the proper functioning of the room extractor fan, varying the setting of the prefabricated centre thermostat to below ambient temperature.
- We will check that the consumption of the extractor fan is appropriate to the technical characteristics of the motor using the ammeter clamp.
- We will check that the extractor fan extracts the air towards the exterior of the building.
- Finally, we will leave the thermostat setting at 35°C.

### VERIFICATION OF THE PROPER FUNCTIONING OF THE AIR CONDITIONING SYSTEM.

- Check the proper functioning of the air conditioning equipment, lowering the temperature setting of the thermostat to below ambient temperature.
- We will check that the consumption of the machine is appropriate to the technical characteristics thereof using the ammeter clamp.
- Finally, we will leave the thermostat setting at 30°C.

### VERIFICATION OF THE PROPER FUNCTIONING OF THE INVERTER EXTRACTOR FAN.

- With the inverter in operation, we will lower the setting of the thermostat installed in the interior of the equipment until the extractor starts working.
- We will check that the operation of the extractor fan is conditioned by the simultaneous state of the coupled inverter and actuation of the thermostat (see diagram), verifying that the extractor fan stops working on stopping the equipment.
- We will check, using the ammeter clamp, that consumption of the extractor fan is appropriate to the technical characteristics of the motor.
- We will check that the extractor fan extracts the air from the interior of the equipment towards the exterior of the prefabricated centre.
- Finally, we will leave the thermostat setting at 40°C.



## 7.16. VERIFICATION OF VOLTAGE DROP IN THE DC PHOTOVOLTAIC FIELD.

In order to perform this verification you will need the general wiring drawing of the photovoltaic installation. This verification should be performed in the middle of the day on a sunny day and with the photovoltaic installation in operation:

- Check, using the ammeter clamp, that the DC-side current of the inverter equipment is approximately the same as the expected maximum current for the installed power and verify, using the polimeter, that the difference between the voltage in the terminals of the main circuit of the parallel connection boxes and the voltage in the DC terminals of the inverter equipment fall within the permissible range of a 1.5% voltage drop (photos 31, 32 and 33).



photo 31


photo 32

photo 33

## 7.17. VERIFICATION OF THE VOLTAGE DROP BETWEEN THE INVERTER EQUIPMENT AND THE POINT OF CONNECTION OF THE TRANSFORMER.

In order to perform this verification you will need the general wiring drawing of the photovoltaic installation. This verification should be performed in the middle of the day on sunny days and with the photovoltaic installation in operation.

Verify, using the ammeter clamp, that the AC output current of the inverter is approximately the same as the maximum current envisaged for the installed power and verify, using the polymeter, that the difference between the voltage in the inverter output terminals and the voltage at the point of connection to the grid falls within the permissible margin of a 1.5% voltage drop.

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## 7.18. SIGNALLING OF PERSONNEL INSIDE THE WORK AREA.

Indicate the presence of men at work by placing a signal at the access door to the work area, indicating the prohibition of entry by unauthorised personnel and the risks assumed if said prohibition is ignored.

Each work team will carry a signalling system, placing it at the door to the work area whenever they access it, prohibiting the entry of unauthorised personnel and warning of the risks they could encounter.

## 7.19. BLOCKAGE OF ELECTRICAL EQUIPMENT.

All work that implies risk of electric shock shall be performed by authorised personnel in accordance with SANS requirements, following the safety instructions established by the supplier for operating with each type of power box.

In order to block electrical equipment, the instructions provided in document P-U08025-1-TQ013 shall be followed.

## 7.20. SHUTTING DOWN THE PHOTOVOLTAIC INSTALLATION.

Before performing any intervention and discharging the transformation centre, follow the sequence below to shut down the photovoltaic installation:


- Switch off the equipment by pressing the start/stop button.
- Press the emergency push-button.
- Once the equipment is no longer injecting, cut the panel circuit by actuating the circuit breaker, trip switch or breaker element that will prevent DC voltage from reaching the equipment while we are working on it.
- After completing the previous step, cut off the AC voltage by actuating the master cut-off and/or differential switch of the installation.

## 7.21. REMOVE VOLTAGE AND DISCHARGE THE TRANSFORMER.

Once the photovoltaic installation has been shut down, discharge the transformer by closing the earth circuit breaker.

**In order to manipulate MV cells at the Transformation Centres, the worker must be qualified or authorised under the supervision of a qualified technician.**

The permission of the installation manager and THE OWNER shall be requested via the “Transformation Centre Cell Manipulation Authorisation.” Once these two initial conditions have been fulfilled, the following sequence of steps shall be followed to cut off the voltage:

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1. Open the MV main switch of the transformation centre by actuating the aperture device.
2. Discharge the trigger springs.
3. Cut off the voltage by actuating the breaker.
4. Discharge the transformer by closing the earth circuit breaker **(in the case of outdoor transformation centres, earthing of the transformer shall be performed using portable earthing equipment)**.
5. Prevent any possible feedback by removing the key prepared for such purpose.
6. Verify the absence of voltage.
7. Signal the work area using labels designed for such purpose.

Protect the MV cabinet switch with a lock and signal its presence in order to avoid accidental activation when personnel are performing work on the transformation centre.

As transformation centre is equipped with an Uninterrupted Power Supply (SAI/UPS), the voltage shall be cut off not only at the cell, but also by actuating the main auxiliary services cut-off switch, blocking the main switch before performing any operation on the transformation centre. Take into account that there can still be a voltage of 230 VAC in the control area even after discharging the transformation centre or opening the main cut-off switches.

In order to ensure that the transformer has been discharged, as well as visually checking that the voltage detectors are not flashing, meter the voltage in the terminals of the flashing indicators. The maximum voltage at this point is approximately 220 VAC.

With the operations performed up to now we have discharged the transformation centre, but there is still voltage in the MV cabinet input cables. In order to remove the voltage from this point we will request discharge from the power supply company to which it is connected. If we are unsure of how to proceed due to unawareness of line distribution we will consult the single-line diagram.


In the case of outdoor transformation centres, the transformer must be visibly earthed.

In order to visibly earth the transformer we will follow the steps below:

- Visible earthing will be performed using the 50 mm<sup>2</sup> portable earth set, connecting the 20 Kv terminals of the transformer to the earthing fittings.
- We will firstly connect the portable earthings to the earthing fittings.
- We will then check for the presence of voltage in the MV terminals using the detector rod.
- Finally, we will successively earth the 1U” 1V” and 1W terminals, disposing the earthing clamp on the connection between the MV terminals and the transformer.

This operation shall obligatorily be performed using an insulating rod.

The installation shall be considered to be discharged and therefore suitable for working thereon without risk of electric shock, once all of these steps have been followed and the substation has been alerted of the operation performed, confirming this through a number that will be recorded in the manipulation authorisation and on the duly installed signs.

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## 7.22. REVISION OF THE POWER TRANSFORMER.

**Be careful with the temperature of the flanges and coils. Protect your hands with gloves. It is advisable to wait for at least 20 minutes after discharging before entering the housing in order to allow the transformer to cool down.**

The data and readings obtained during the revision of the transformer shall be recorded in the work procedure of ANNEX 1 attached hereto.

### 1. CLEANING THE TRANSFORMER.

**Do not use any type of solvent or degreaser to clean the equipment or pour water directly thereon.**

In order to clean the equipment, we will use the soft bristle brush and cloths to remove the dirt. If the dirt adhered to the equipment does not come off, it may be rubbed with a cloth slightly moistened in water, subsequently removing the moisture from the area with a dry cloth.

### 2. VERIFICATION OF ELECTRICAL CONNECTIONS

**The torque settings of those screws and bolts which are not wax-sealed or marked and conserve their original position shall not be verified. All those screws or bolts which are not factory-marked shall be wax-sealed or marked in YELLOW after verifying their torque settings.**

- MV cable: The torque settings of all the terminals shall be verified, provided that they are not previously marked:

**Never grease the MV terminals.**

LV cables:

- In dusty, corrosive or saline environments, the joint between the edge of the LV cable terminal and aluminium fuse plate shall be sealed using LOCTITE® 5970 silicone once the terminal has been installed and secured.
- In the event of having to disassemble any of the terminals, the plate faces shall be polished using a fine-grade abrasive, removing the dust with a clean cloth. Gently polish the cable terminal until the tin recovers its original shine.

Apply conductive grease on all the electrical connections:

- Copper-to-copper connections: PENETROX E
- Aluminium-to-copper connections: PENETROX A-13
- Curvature: the minimum curvature radius of the cables must be five times its outer diameter.





### 3. VERIFICATION OF ELECTRICAL DISTANCES.

- **Verification of MV distances**

The distances from any live part of the transformer to the earth (including LV cables) shall be:

Trafos up to 12kV 120mm

Trafos up to 24kV 220mm

Trafos up to 36kV 320mm

- **Verification of LV distances**

Verify that the distances indicated below are less than 50 mm.

### 4. VERIFICATION OF THE TEMPERATURE SENSORS.

- Check the wiring and connection of the temperature sensors.
- Check the temperature sensors by measuring the value in ohms and check that this value is appropriate to the temperature of the transformer according to Table 1.
- **Table 1. Resistance of the P.T 100 sensor according to Standard IEC 751**  
In addition to the points to be reviewed in accordance with the procedure, we will also perform the following verifications:

T (°C)	0	1	2	3	4	5	6	7	8	9	10
0	100,000	100,391	100,781	101,172	101,562	101,953	102,343	102,733	103,123	103,513	103,902
10	103,902	104,292	104,681	105,071	105,460	105,849	106,238	106,627	107,016	107,404	107,793
20	107,793	108,181	108,570	108,958	109,346	109,734	110,122	110,509	110,897	111,284	111,672
30	111,672	112,059	112,446	112,833	113,220	113,607	113,994	114,380	114,767	115,153	115,539
40	115,539	115,925	116,311	116,697	117,083	117,469	117,854	118,240	118,625	119,010	119,395
50	119,395	119,780	120,165	120,550	120,934	121,319	121,703	122,087	122,471	122,855	123,239
60	123,239	123,623	124,007	124,390	124,774	125,157	125,540	125,923	126,306	126,689	127,072
70	127,072	127,454	127,837	128,219	128,602	128,984	129,366	129,748	130,130	130,511	130,893
80	130,893	131,274	131,656	132,037	132,418	132,799	133,180	133,561	133,941	134,322	134,702
90	134,702	135,083	135,463	135,843	136,223	136,603	136,982	137,362	137,741	138,121	138,500
100	138,500	138,879	139,258	139,637	140,016	140,395	140,773	141,152	141,530	141,908	142,286
110	142,286	142,664	143,042	143,420	143,797	144,175	144,552	144,930	145,307	145,684	146,061
120	146,061	146,438	146,814	147,191	147,567	147,944	148,320	148,696	149,072	149,448	149,824
130	149,824	150,199	150,575	150,950	151,326	151,701	152,076	152,451	152,826	153,200	153,575
140	153,575	153,950	154,324	154,698	155,072	155,446	155,820	156,194	156,568	156,941	157,315
150	157,315	157,688	158,061	158,435	158,808	159,180	159,553	159,926	160,298	160,671	161,043
160	161,043	161,415	161,787	162,159	162,531	162,903	163,274	163,646	164,017	164,388	164,760
170	164,760	165,131	165,501	165,872	166,243	166,614	166,984	167,354	167,724	168,095	168,465
180	168,465	168,834	169,204	169,574	169,943	170,313	170,682	171,051	171,420	171,789	172,158
190	172,158	172,527	172,895	173,264	173,632	174,000	174,368	174,736	175,104	175,472	175,840
200	175,840	176,207	176,575	176,942	177,309	177,676	178,043	178,410	178,777	179,143	179,510





- Check for the presence of oil leaks through terminal joints, cover joints, etc.
- Check the insulating oil level on the level indicator.
- Check silica gel colour, replacing it if necessary.
- Conduct function tests on the transformer protections (Buchholz, thermometer, thermostat, etc.), verifying the functioning thereof and generation of alarms.
- Conduct insulation tests, as indicated in point 8 of this procedure.
- Conduct dielectric rigidity tests on the oil and take samples for physical and chemical testing if necessary, as indicated in point 9 of this procedure.
- Conduct transformation ratio tests if necessary.

Once these verifications have been made, conduct the meggering tests following the steps below:

- In order to save time when performing preventive maintenance and avoid having to remove the transformer from the terminal, megger the transformer and its MV/LV lines simultaneously.
- To this end, we will firstly remove the fuses from the MV cabinet and then open the earth circuit breaker of the transformer position (always ensuring that there is no risk before performing this operation), simultaneously meggering the MV transformer winding and MV bridges.
- Disconnect the LV main switches.
- Release the cable that joins the neutral to the transformer star.
- Apply 5000 V for at least 30 seconds between the primary trafo winding phases. The metered insulation resistance must be greater than 30 mOhm.
- Apply 5000 V for at least 30 seconds between each phase of the primary winding and main earth. Insulation resistance must be greater than 30 mOhm.
- Apply 5000 V for at least 30 seconds between each phase of the primary and secondary LV winding. Insulation resistance must be greater than 30 mOhm.
- Apply 1000 V for at least 30 seconds between the secondary LV winding and the main earth. Insulation resistance before time must be greater than 10 mOhm.
- Repeat the same tests for at least 60 seconds.

If any of the insulation value readings fall outside of the limits, the transformer cables shall be released and tested individually in order to discover which part of the installation has lack of insulation.

**The transformer coils must be immediately discharged after the reading in order to prevent possible electrical discharges.**

## 7.23. MV AND LV CABLES.

The data and readings obtained during the revision on the underground MV lines shall be recorded in the work procedure, in accordance with ANNEX 2 attached hereto.

- Visually check ditch layout signalling and state of the inspection boxes.
- Check fixation of supports, insulators and cleaning or deterioration thereof.




- Check that the cable sheathing is not pierced, cut or mechanically damaged.
- Check the torque settings of the connections with the help of a dynamometric wrench according to point 7 of this procedure.
- Check that the cable and connections are not hot.
- Check the state of the terminal boxes.
- Check that the cable curvatures are correct.
- Check that the MV cable screens are all earthed, at least at one end of the cable.
- Check that the phases are identified according to the phase sequence.
- Check insulation resistance (meggering), according to point 8 of this procedure.
- Conduct an applied voltage (dielectric rigidity) test, if necessary.

## 7.24. REVISION OF THE MV CABINET AND POWER FUSES.

We will firstly check the cell trigger by actuating the TRIGGER BUTTON of the cell and then we will earth the cell in order to revise said cell. Once the cell has been earthed, we will perform the following verifications:

- Open the fuse compartment, remove the fuses from their compartments and leave them outside of the cabinet; finally, close the compartments without the fuses in order to perform several manual cell opening and closing operations, thereby avoiding subjecting the transformer and earthing to rush currents upon closing the contact breaker.
- After removing the fuses and closing the door of their compartments, open the earth circuit breaker and, finally, close the switch. Once the switch has been closed without fuses, verify the cell trigger by actuating the TRIGGER BUTTON of the cell itself and repeat the operation up to five times in order to verify the proper functioning of the trigger and spring reclosing mechanisms.
- If the cell has a current protection relay, check that it marks an external trigger when we cause temperature-based triggering.
- We will also verify the correct interlocking between the cell and the transformer through the lock disposed on the fuse compartment, in such a manner that it must be open to be able to release the access key to the transformer housing (the key can only be extracted once the operations indicated on the plate adjacent thereto have been performed).
- Finally, in those cells which have a gas pressure control device, we will check that the pressure is within the green zone of the manometer; in the event of finding any cell wherein the gas pressure is within the orange or red zone, the cabinet will be discharged pending revision by the manufacturer, duly informing the person in charge of the installation.

The data and readings obtained during the revision of the underground MV lines shall be recorded in the work procedure, in accordance with ANNEX 3 attached hereto.

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## ANNUAL REVISION:

- Check the state of the metal casing: lack of paint, rust, etc.
- Check the state of the busbar, state of cleanliness of the cell, rods and insulating elements with a dry cloth.
- Check points of fixation and connection, screws and anchorings, re-tightening these if necessary in accordance with point 7 of this procedure.
- Check heat resistance functioning.
- Check the fuses, auxiliary relays and signal lights.
- Check the state of the cables and terminal boxes.
- Clean the interior and exterior, removing accumulating dust. To this end, use the suction device and, in the most conflictive zones, use brushes, paintbrushes and clean dry cloths.
- Check the state of the terminal boxes and connection terminals, verifying that they are not damaged or broken. Test the degree of tightening of the connections.
- Check the state of the flexible copper braids that join the doors to the structure, as well as the anchorings and constituent parts of the cabinet.
- Check the metering devices, checking that these are in perfect state and that they function correctly within their ranges and scales.
- Check the adjustment and fitting of the protections.
- Verify the insulation and resistance of the closing/opening coils. Check the closing and trigger circuits, the coil excitation voltages and their signalling and locks.
- Check the state and functioning of the magneto-thermal switches, contactors, auxiliary relays and other elements of the control circuits.
- Clean and grease the articulations of mobile elements such as line and earthing circuit breakers. Perform opening/closing operations, checking for seizure, pressure and the state of the contacts.
- Check the blocking devices or mechanical locks, following the opening/closing guidelines, extraction of keys, etc., indicated in the installation manual.

## TRI-ANNUAL REVISION:

- Perform the complete annual revision.
- Check synchronisation of actuation movements.
- Measurement of the closing/opening time of each arc chute, recording the times according to point 10 of this procedure.
- Check synchronisation between chutes according to point 10 of this procedure.
- Meter contact and insulation resistances according to point 10 of this procedure.
- Check the actuation contactors and coils according to point 10 of this procedure.
- Conduct functional tests in local and remote control mode, checking actuation and signalling.
- Conduct insulation tests following the steps below:
- In order to ensure that there is no voltage at the cabinet input and visually checking that the voltage detectors are not flashing, measure the voltage in the terminals of the flashing indicators using a polymeter (at least 1000 V). The maximum voltage at this point is approximately 220 VAC.



- In order to megger the input/output lines, together with the cabinet without need to remove the terminals in all the transformation centres, open the incoming earth circuit breakers of the transformation centre, close the line breakers (always ensuring that there is no risk of electric shock before conducting the test) and release the MV terminals at one end of the line in order to perform the measurement from this position.
- Apply 5000 V for at least 30 s between phases. The insulation resistance measured must be greater than 30 mOhm.
- Apply 5000 V for at least 30 s between each phase and earth. The insulation resistance measured must be greater than 30 mOhm.
- Repeat the same tests for at least 60 s.

If the insulation values fall outside of the limits in any of the measurements, release the cabinet lines and conduct the test individually thereon in order to locate the part of the installation with lack of insulation.

The lines must be discharged immediately after performing the metering in order to prevent possible electric shock.

## 7.25. REVISION OF METERING TRANSFORMERS.

- The data and readings obtained during revision of the transformers shall be recorded in the work procedure, in accordance with ANNEX 4 attached hereto.

### ANNUAL REVISION:

- Clean the supports, removing rust where necessary.
- Clean the insulating elements using a dry cloth.
- Check the state of the terminal box and cleanliness thereof.
- Check the connection terminals and screws, re-tightening these if necessary according to point 8 of this procedure.
- Check the oil level.
- Check for oil leaks.
- Check support anchorings, re-tightening if necessary according to point 7 of this procedure.
- Check the earthing of metal parts.

### TRI-ANNUAL REVISION:

- Perform the complete annual revision.
- Check transformation ratios:  
**Current trafo: transformation ratio and meggering according to point 8.**  
**Voltage trafo: transformation ratio and meggering according to point 8.**



## 7.26. EARTHING NETWORK.

- The data and readings obtained during the general revision of the earthing network shall be recorded in the work procedure, in accordance with ANNEX 5 attached hereto.
- Check that all the metal points (supports, coatings, doors, etc.) are joined to the main earth of the transformation centre.
- Check the resistance value of those parts of the earthing system that you consider should be inspected. The measurements made shall be considered satisfactory if they fulfil the technical specifications of the project or those defined by the client.
- Once the measurement has been made, annotate it in the record, identifying the equipment to which said measurement corresponds.

## 7.27. AUTOVALVE LIGHTNING CONDUCTORS.


The data and readings obtained during revision of the autovalves shall be recorded in the work procedure, in accordance with ANNEX 6 attached hereto.

- Clean the supports, removing rust where necessary.
- Clean the insulating elements using a dry cloth.
- Check the connection terminals, screws and anchorings, re-tightening if necessary according to point 8 of this procedure.
- Check earthing of metal parts.
- Annotate the reading of the discharge meter.
- Check leakage currents (maximum 5 ma), if necessary.

## 7.28. ANNUAL REVISION OF BOXES, RECTIFIERS AND DC BATTERIES.

The data and readings obtained during revision of the rectifier equipment and batteries shall be recorded in the work procedure, in accordance with ANNEX 7 attached hereto.

- Check electrolyte density and level in the batteries between the maximum and minimum, replacing if necessary with distilled water.
- Check the general state of cleanliness of the boxes.
- Check the state of rectifier fuses.
- Check the functioning and cleanliness of the ventilation system.
- Check earthing of the box.
- Check the degree of tightening of the connections.
- Check rectifier input voltage, rectifier output voltage and battery output voltage.
- Check metering instruments, alarms and equipment signalling.
- Check functioning of floatation, functioning under fast load and functioning under exceptional load.
- Check output voltage under exceptional load.
- Check over-voltage varistor.

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## 7.29. GENERAL VERIFICATION OF THE TRANSFORMATION CENTRE.

The data and readings obtained during the general revision of the transformation centre shall be recorded in the work procedure, in accordance with ANNEX 8 attached hereto.

- Check paint on walls and the existence of deficient structures.
- Check the existence of dust.
- Check the existence of stored materials.
- Check the existence of sufficient lighting.
- Check the existence of inadequate dimensions of cells and corridors.
- Check the existence of access doors for personnel and equipment.
- Check for signs of rodents.
- Check the existence of emergency lighting.
- Check the existence of spare fuses.
- Check the existence of fire extinguishers.
- Check the existence of personal protection grids and screens.
- Check the existence of insulating stools.
- Check the existence of voltage detector rods.
- Check the existence of operation rods and earthing.
- Check the existence of rescue rods.
- Check the existence of a first-aid instruction poster.
- Check the existence of standard signalling.

## 7.30. TRI-ANNUAL REGULATORY INSPECTION OF THE TRANSFORMATION CENTRE.

- Regulatory Substation Inspection by a certified OCA (Authorised Control Body) company.
- Certification of passthrough and contact voltages of the substation in accordance with the applicable standard.

## 7.31. OTHER

- Revision of the auxiliary services transformer.
- Revision of the auxiliary services box.
- Revision of the park control box.
- Revision of outdoor park lighting.

## 7.32. WASTE MANAGEMENT.

The waste generated during the maintenance operations shall be correctly managed and no waste shall be deposited outside of its corresponding container.



### 7.33. RE-ESTABLISH VOLTAGE AND COMMISSION THE TRANSFORMER.

In order to manipulate the MV cells in the transformation centre, the worker shall be qualified or authorised under the supervision of a qualified technician.

Upon completing the electrical maintenance, conduct a final inspection to confirm readiness for energising the transformation centre.

You must request the permission of the owner of the installation and the proprietor via the “Transformation Centre Cell Manipulation Authorisation” format. Once these two initial conditions have been fulfilled, complete the following sequence of steps to re-establish the voltage.

In order to re-establish the voltage in the transformation centre and subsequently in the photovoltaic installation, follow the sequence below:

- Firstly, open the earthing circuit breaker of the transformer (in the case of outdoor transformation centres, remove the portable earthing).
- Next, close the line breaker.
- Next, energise the transformer by closing the circuit breaker.
- Once you have checked the voltage in the main LV panel, close the main protection or protections of the LV circuit.
- Once the installation has been energised, commission the inverter equipment by starting these up and checking that they are coupled to the grid.
- Supply power to the inverter equipment by firstly closing the general protection devices (magneto-thermal, differential) of the AC circuit.
- Next, close the protection and general circuit breaker devices of the DC circuit of the panels.
- Finally, start up the equipment and check that the installation is correctly coupled to the grid, verifying that the P, V and I parameters are correct.

It is advisable to firstly cut off the AC power supply of the equipment, followed by the DC power supply, in order to avoid damages to the inverter.

In the mechanical manipulations of the breaker, use an insulating stool or mat, facial protection screen and high-voltage insulating gloves.

### 7.34. PANEL THERMOGRAPHY.

- Perform thermograph on the panels that comprise the park and which are in operation with the object of detecting hot spots and anomalies in the functioning thereof.
- Said thermograph shall be performed annually in accordance with the preventive maintenance plan of the installation.
- The methodology used to perform the thermograph shall consist of taking samples of % of the park and issuing the corresponding report.





## 8. VERIFICATION OF TORQUE SETTINGS

### 8.1. VERIFICATION METHOD.

As a general rule, before verifying the torque settings of a connection, check:

- The internal state of bolts and washers, replacing these if damaged.
- The state of cleanliness of the elements to be connected, removing any traces of dust, smut, moisture or any other agent that could damage the connection.
- Clean using a bristle brush, brushing the connector necks and the contact area with the conductors, along a length greater than that which will cover the connector. Apply a layer of contact grease with a dropping point of no less than 60° to the aluminium connections.
- Establish the connection, ensuring adequate sliding of the screw or stud over the bolt, without forcing its path at any point thereof. To this end, use fixed wrenches, avoiding the use of any type of clamps.
- The indicated torque setting shall be applied using the corresponding dynamometric wrench, which will have previously been verified or, if calibrated, will still be within its validity period.
- When having to tighten a part containing several screws, it will always be tightened in a symmetrically staggered manner on lids with four or more screws and alternatively on parts with two screws. Firstly, perform an approximation tightening (50%) verifying that the lids are disposed symmetrically; next, perform a second tightening of approximately 75% in order to subsequently tighten it 100%, always in the described order, which we have represented below.



## 8.2. TORQUE SETTING TABLES.

The following torque setting tables shall be applied in accordance with the nature of the connection elements:

COPPER TERMINAL AND STEEL SCREW		
BOLT (mm)	SCREW / STUD Ø (mm)	TORQUE SETTING (Kg.m/N.m)
13	8	1/10
17	10	2/20
19	12	3,5/35
22	14	3,5/35
24	16	4/40

ALUMINIUM TERMINAL AND STEEL SCREW		
BOLT (mm)	SCREW / STUD Ø (mm)	TORQUE SETTING (Kg.m/N.m)
13	8	3,5/35
17	10	3,5/35
19	12	5,5/55
22	14	5,5/55
24	16	7/70

GENERAL SCREWS		
BOLT (mm)	SCREW / STUD Ø (mm)	TORQUE SETTING (Kg.m/N.m)
6	4	0,15
8	5	0,30
10	6	0,50
13	8	1,25
17	10	2,45
19	12	4,20
22	14	6,80
24	16	10,5
27	18	14,5
30	20	20
32	22	26,5
36	24	34,5
41	27	51
46	30	68



## 9. INSULATION TEST (meggering)

In addition to the tests specified in this procedure, insulation tests, at least, shall be conducted on all the devices detailed below:

- AC cables with a rated voltage of 400 VAC, 06/1KV of insulation: an insulation test will be conducted for 1 minute at 1 Kv of DC voltage current.
- DC field cables <1000 Vc.c of rated voltage, 06/1KV of insulation: an insulation test will be conducted for 1 minute at 1 Kv of DC voltage current.

### 9.1. MINIMUM INSULATION VALUES.

- Minimum insulation values shall be calculated using the following formula:

$$R_m = \frac{10,000 \times V}{L}$$

being:

R<sub>m</sub> = minimum resistance in ohms.

V = maximum service voltage in volts.

L = conductor length in metres.

In any case, according to Standard IEC 60364-6-61, Table 61A, the minimum insulation value in LV cables is 0.25 Megaohms.

Insulation resistance values shall be annotated on the checklist, indicating the corresponding line and environmental conditions at the time of metering (temperature, weather, etc.).

### 9.2. TEST METHOD.


The test voltages for general insulation resistance measurements shall be comprised between 500 V and 1000 V, as specified in each case.

Unless indicated otherwise, the test will have the necessary duration to stabilise the measurement and will never be less than 1 minute.


Whenever possible, the safety earth terminal of the device shall be used to avoid fictitious leakage currents and eliminate the insulation associated with certain terminals of the tested circuit from the measurement.

The meter must be in a horizontal position during the time of metering.

The manner in which insulation tests must be conducted on cables shall be determined by the type of cable:

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- In the case of screened unipolar conductors, the test shall be conducted between the conductor and the earth screen.
- In the case of multi-polar cables with individual screens for each conductor, the tests shall be made for each conductor between said conductor and the corresponding screen.
- In the case of multi-polar cables without individual screens but having external metal protection, the tests shall generally be conducted on each conductor and all the rest shall be joined to the earthing protection. This is also applicable to multi-polar cables with screens external to the set of conductors. When the insulation between the different conductors and between each conductor and the earthing protection or screen must be individually tested, the safety earth terminal shall be used to connect the other conductors thereto.

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## 10. TRANSFORMER INSULATING OIL TESTING (NA)

In addition to sample taking, which will be performed annually for oil dielectric rigidity field testing with the help of a glow plug igniter, oil samples will be taken from the transformers at the client's request for physical/chemical and dissolved gas analysis, for monitoring and detecting possible internal defects therein (thermal, partial discharges, arcs, etc.). Sample taking and analysis shall be carried out in accordance with standards recommended by the manufacturer.

The following characteristics will be analysed in the physical and chemical analysis:

- Appearance according to recommended by the manufacturer or specified by the client.
- Rupture voltage or dielectric rigidity according to recommended by the manufacturer or specified by the client.
- Loss-angle tangent according to recommended by the manufacturer or specified by the client.
- Water content according to recommended by the manufacturer or specified by the client.
- Neutralisation index according to ASTM D 664/89 (acidity) or standard specified by the client.

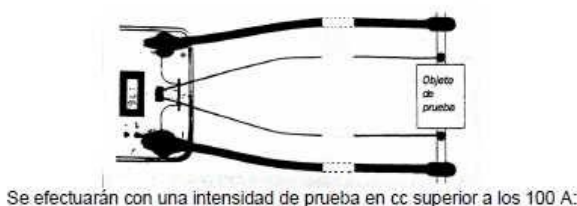
This type of analysis provides information relative to the state of the dielectric medium. If one or several of these parameters exceeds the limits considered normal could cause premature ageing of the insulation (paper or oil). The excessive deviation of parameter values from that considered normal will pose a risk to the installation that must be notified to the client.

## 11. AUTOMATIC CUT-OFF SWITCHES (CIRCUIT BREAKERS)

### 11.1. POLE CONTACT RESISTANCE.

The metering method used to conduct this test consists of metering the voltage drop at the ends of the contact when current is made to flow there through.

The use of a micro-ohm meter will allow detection of possible increases in switch contact resistance, in such a manner that these can be rectified before causing problems.



Object being tested. Tests will be conducted with a DC test current >100A:

- In switches with more than two cut-off Cameras per phase, metering shall be performed between camera input/output and total per phase (determination of resistance of interconnection between Cameras).
- The resistance of the entire phase shall firstly be metered and, if the value is appropriate to the sum of permitted value, metering per cut-off camera will not be necessary.


### 11.2. DISPLACEMENT CHARTS.

These will be created during closing/opening operations and fault closing (O-CO) operations, simultaneously recording the pole and/or cut-off camera times. The following data shall be obtained:

- Total travel path. Difference between the initial position and final position.
- Penetration of contacts.
- Opening/closing speed.
- Buffering, overflow and rebound.

### 11.3. OPERATION TIMES.

The resulting values shall always be adjusted within the tolerance of each cut-off switch. A lower opening time value will cause a higher short-circuit current asymmetry percentage in the cut-off switch than that tested, which could prevent cut-off and therefore explosion thereof.

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The following operations shall be performed:

- Metering of closing/opening times of each cut-off camera
- The same in the fault closing operation (O-CO) in order to analyse the dynamic behaviour of the cut-off switch.
- References will be taken of times and the presence of voltage in the power supply terminals of the closing/opening circuits in the cut-off switch terminal box.

#### 11.4. ASYNCHRONISM BETWEEN CAMERAS.

This test is aimed at locating the poles that firstly separate the contacts, in order to adequately maintain the poles that open or close first.


The test shall be conducted between the cameras of a single phase (longitudinal) and between phases (transverse), considering each phase as though it were a camera in the second case.

- Longitudinal synchronism: cameras will be synchronised when there is more than one, comparing the aperture of the first camera that opens to the last camera that opens, and comparing the closing of the first camera that closes to the last camera that closes.
- Transverse synchronism: On opening, the difference between the first camera that opens in the fastest phase is compared to the first camera that opens in the slowest phase. On closing, the difference between the first camera that closes in the fastest phase is compared to the first camera that closes in the slowest phase.

#### 11.5.- COIL CONSUMPTION.

Finally, opening/closing coil feed current and voltage will be metered. These values will be compared to earlier values and/or cut-off switches of the same type.



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## 12.- RECORDS

The data and values obtained during the course of the work shall be recorded.

To this end, each of the work procedure formats shall be completed, reflecting the state of each of the revised elements, as well as the values obtained from the different readings.


If any of the sections of the report were not applicable to the equipment being inspected, this shall be indicated with the initials N/A. The formats included under ANNEXES below shall be applicable to all the elements of a photovoltaic power plant that fall within the scope of this procedure.

## 13- ANNEXES:


The Site Quality Manager shall file the following records generated by the application of this document:

ANNEX 1: Photovoltaic power plant surveillance plan record.

ANNEX 2: Photovoltaic power plant preventive maintenance record.

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## ANNEX 1: PHOTOVOLTAIC POWER PLANT SURVEILLANCE PLAN RECORD

	SERVICE REPORT NO.	OT NO.	Type of work:		
	Signature of technicians:		Preventive maintenance Readings and monitoring Corrective Predictive Modifications / Improvements Startup		
Project:		Date:		Location:	
Installation:		Element:		Structure model:	

Reason for intervention:

Work executed:


PHOTOVOLTAIC PLANT STOPPAGE TIME						
Stoppage Date	Stoppage Time	Startup Date	Startup Time	Stoppage Time		

LABOUR						
Subcontractor	Technician	Date	Start time	Completion date	Completion time	Rate/Hour

SERIALISABLE MATERIALS						
Date	Quantity	Spare part Reference	Serial no.	Defective Reference	Serial no.	Description

CONSUMABLE and NON-SERIALISABLE MATERIALS								
Date	Quantity	Ref.	Description	Sto.	Date	Quantity	Ref.	Description

INSPECTION AND TESTING EQUIPMENT					
Tool	Serial No. Identification	Date last calibration	Tool	Serial No. Identification	Date last calibration

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Annotations					
Inv. equipment model			Model		No. panels per series
Idc	Vdc	Iac	Vac	Total consumed power Kwh	Total output power Kwh
Comments:					



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**B.doc**

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**ANNEX 2: PHOTOVOLTAIC POWER PLANT PREVENTIVE MAINTENANCE PLAN  
RECORD**

<u>GENERAL INSTALLATION DETAILS</u>					
PROJECT					
INSTALLATION OWNER					
CONTACT PERSON		TELEPHONE			
LOCATION	ADDRESS				
CITY/TOWN	POSTCODE		PROVINCE		
<u>GENERAL DESCRIPTION OF INSTALLATION</u>					
<u>PHOTOVOLTAIC GENERATOR</u>					
LOCATION	ACCESSIBILITY				
INCLINATION	ORIENTATION (SOUTH: 0°, EAST: -90°, WEST: +90°)				
MODULE MANUFACTURER	MODEL		DOCUMENTATION		
MODULE OUTPUT POWER (Wp)	NO. OF MODULES		INSTALLED POWER (Wp)		
ELECTRICAL CONFIGURATION					
<u>INVERTER EQUIPMENT</u>					
LOCATION	ACCESSIBILITY				
INVERTER MANUFACTURER	MODEL		DOCUMENTATION		
RATED INVERTED OUTPUT POWER (Wp)	NO. OF INVERTERS		RATED OUTPUT POWER (KW)		
INCOMING DC VOLTAGE	INCOMING DC VOLTAGE (Vac)				
OUTGOING AC VOLTAGE (V)	MONOPHASIC		TRIPHASIC		
SERIAL NO.					
<u>OTHER DETAILS</u>					
SOLAR TRACKER	TYPE				
TRACKER MANUFACTURER	MODEL				
TRACKER OUTPUT POWER	MONITORISATION				
TYPE OF GRID CONNECTION	DISTRIBUTION COMPANY				

GES	GENERAL SPECIFIC PROCEDURE	PE.GES-000
		S: 74 OF: 84
REF. PE.GES-000	GENERAL PHOTOVOLTAIC INSTALLATION REVISION PROCEDURE	REV.0

<u>1</u>	<u>PRELIMINARY VERIFICATIONS</u>	<u>RESULTS</u>	<u>COMMENTS</u>
1.1	Check for the existence of unplanned shading of the photovoltaic modules (vegetation, surrounding objects, etc.).		
1.2	Check that the grid frequency value variation does not exceed 50 Hz by more than 2%.	Hz	
1.3	Check that AC grid voltage variation does not exceed the rated installation voltage by more than 15%.	V	
1.4	Check that there is sufficient DC voltage in the panels to start up the inverter and P, V and I parameters are correct	V <sub>pico</sub> W <sub>sal</sub>	



	according to the technical specifications of the installation	$V_{sal}$ $i_{sal}$	
1.5	Check the current of the series by placing an ammeter clamp on one of the series, using the reading thereof as a reference and, with a second ammeter clamp, meter the current of the rest of the series, comparing the instant readings of both clamps at given times.	$V_{ref}$ <input type="checkbox"/>	
<b><u>2</u></b>	<b><u>VERIFICATION OF INVERTER EQUIPMENT</u></b>	<b><u>RESULTS</u></b>	<b><u>COMMENTS</u></b>
2.1	Before performing any type of operation on the inverter equipment, follow the instructions set out in point 7.2 of the photovoltaic power plant maintenance procedure	<input type="checkbox"/>	
2.2	Check that cables are correctly connected	<input type="checkbox"/>	
2.3	Check that the connections are not subject to stress.	<input type="checkbox"/>	
2.4	Check that the device does not have traces of dirt that hampers the visualisation of its indications or can affect the proper functioning thereof.	<input type="checkbox"/>	
2.5	Check, by means of visual inspection and small weight overloads, that the device is firmly secured and that its bearing surface does not show signs of damage.	<input type="checkbox"/>	
2.6	Ensure that the equipment is adequately closed or watertight	<input type="checkbox"/>	
2.7	Check the earthing of the inverter equipment.	<input type="checkbox"/>	
2.8	Check the state of paint and rust of the inverter.	<input type="checkbox"/>	
2.9	Clean and check the outer casing and interior of the inverter.	<input type="checkbox"/>	
2.10	Check the inverter signalling indicators	<input type="checkbox"/>	
<b><u>3</u></b>	<b><u>VERIFICATION OF DC FIELD JUNCTION BOXES</u></b>	<b><u>RESULTS</u></b>	<b><u>COMMENTS</u></b>
3.1	Before performing any type of operation on the DC field junction boxes, follow the instructions set out in point 7.3 of the photovoltaic power plant maintenance procedure	<input type="checkbox"/>	
3.2	Check, by means of gentle pulls, that the cables are firmly connected. If any loose connections are observed, tighten accordingly and re-establish the connection if necessary.	<input type="checkbox"/>	
3.3	Check that the length of the cables in the interior of the boxes is sufficient to prevent the cables from being subject to stress.	<input type="checkbox"/>	
3.4	Check that the glands are adequately fixed to the boxes (well tightened, without slack and are not twisted). If any loose glands are observed, tighten these accordingly	<input type="checkbox"/>	



3.5	Ensure that the terminals are rust-free and the connections are electrically effective	<input type="checkbox"/>	
3.6	Ensure that the boxes are adequately closed and watertight.	<input type="checkbox"/>	
3.7	Upon completion of the junction boxes, reconnect all the MULTI-CONTACT devices and close all the breakable fuses of the general parallel boxes.	<input type="checkbox"/>	
<b>4</b>	<b><u>VERIFICATION OF ELECTRICAL EQUIPMENT</u></b>	<b><u>RESULTS</u></b>	<b><u>COMMENTS</u></b>
4.1	Ambient conditions.	Sunny <input type="checkbox"/> Clouded <input type="checkbox"/> Temp.....°C Irrad.....W/m2	
4.2	Before performing any type of operation on the DC field junction boxes, follow the instructions set out in point 7.4 of the photovoltaic power plant maintenance procedure.	<input type="checkbox"/>	
	<b><u>Metering of open circuit voltage</u></b>		
4.3	Before metering, follow the instructions relative to this verification set out in point 7.4 of the photovoltaic power plant maintenance procedure.	<input type="checkbox"/>	
4.4	Check that the Vo voltage between the positive and negative terminals of each generator circuit (panel series) is adequate for the configuration and working conditions of the panels when metering as indicated in point 7.4 of the maintenance procedure.	Panel N° Panel V <sub>oc</sub> .....V Circuit V <sub>oc</sub> .....V	
	<b><u>Metering of short-circuit current</u></b>		
4.5	Before metering, follow the instructions relative to this verification set out in point 7.4 of the photovoltaic power plant maintenance procedure.	<input type="checkbox"/>	
4.6	Check, using the clamp, that the short-circuit current of each generator circuit (panel series) is the same and approximately equal to the test current of one of the modules; this value will depend on temperature and irradiance at the time of metering.	Icc M.....A Icc N.....A	
4.7	Check that the main short-circuit current (parallel) is approximately equal to the test current of a panel multiplied by the number of generator circuits (serially disposed branches); this value depends on temperature and irradiance at the time of metering.	Circuits N°..... Icc S.....A Icc P.....A	
<b>5</b>	<b><u>VERIFICATION OF THE SUPPORT STRUCTURE</u></b>	<b><u>RESULTS</u></b>	<b><u>COMMENTS</u></b>
5.1	Check, by means of visual inspection, that the foundations of the structure and/or its bearing surface do not show signs of deterioration (cracks, detached material, rust, etc.). Where necessary, repair the structure executing the necessary civil works to ensure the repair of the corresponding state of deterioration.	<input type="checkbox"/>	
5.2	Check that the joints and anchoring of the structure do not	<input type="checkbox"/>	



	show signs of slack or loosening that can cause vibrations due to the effect of the wind. Where necessary, apply the torque setting corresponding to the size of the screw in accordance with point 8 of the photovoltaic power plant maintenance procedure		
5.3	Check, by means of visual inspection, that the elements of the structure do not suffer deformations (caused by the stress supported) not specified in the structural analysis carried out during the design phase.	<input type="checkbox"/>	
6	<b>VERIFICATION OF THE PHOTOVOLTAIC PANELS</b>	<b><u>RESULTS</u></b>	<b><u>COMMENTS</u></b>
6.1	Before performing any type of operation on the panel junction boxes, follow the instructions set out in point 7.3 of the photovoltaic power plant maintenance procedure.	<input type="checkbox"/>	
6.2	Check that the cables are correctly connected in the panel junction boxes.	<input type="checkbox"/>	
6.3	Check that the connections are not subject to stress.	<input type="checkbox"/>	
6.4	Check that the glands are adequately secured to the boxes.	<input type="checkbox"/>	
6.5	Ensure that the terminals are rust-free and that the connections are electrically effective.	<input type="checkbox"/>	
6.6	Ensure that the junction boxes are adequately closed and watertight.	<input type="checkbox"/>	
6.7	Check that the panels are adequately fixed to the support structure and that there is no slack or loosening in the fixations that could cause vibrations due to the effect of the wind.	<input type="checkbox"/>	
6.8	Check that the modules are clean.	YES <input type="checkbox"/> NO <input type="checkbox"/>	
6.9	Clean the modules.	YES <input type="checkbox"/> NO <input type="checkbox"/>	
7	<b>VERIFICATION OF DC CABLING</b>	<b><u>RESULTS</u></b>	<b><u>COMMENTS</u></b>
7.1	Check that the protection ducts and conduits are in perfect condition, without signs of deterioration or insulation or watertightness defects. Where necessary, replace or repair the affected element in accordance with the extent or importance of the damage.	<input type="checkbox"/>	
7.2	Check that the fixation flanges of aerial conductors, protection ducts and conduits are in good condition.	<input type="checkbox"/>	
7.3	Visually check that the MULTI-CONTACT connector devices are in good condition.	<input type="checkbox"/>	
7.4	Visually check ditch layout signalling and state of the inspection boxes.	<input type="checkbox"/>	
7.5	Check support and tray fixations and the state of cleanliness or deterioration thereof.	<input type="checkbox"/>	
7.6	Check that the visible parts of the cable sheathing are not pierced, cut or mechanically damaged due to friction against edges.	<input type="checkbox"/>	
7.7	Check that the cables are identified according to pole polarity.	<input type="checkbox"/>	
7.8	Check insulation resistance (meggering), if applicable, according to point 9 of the photovoltaic installation maintenance procedure.	<input type="checkbox"/>	
8	<b>VERIFICATION OF METER AND GPB CENTRALISATION</b>	<b><u>RESULTS</u></b>	<b><u>COMMENTS</u></b>
8.1	Before performing any type of operation on the connections of the AC installation, follow the instructions	<input type="checkbox"/>	





	set out in point 7.9 of the photovoltaic installation maintenance procedure.		
8.2	Check the torque setting of the connections using a dynamometric wrench according to point 8 of the photovoltaic installation maintenance procedure.	<input type="checkbox"/>	
8.3	Check that the cable and connections are not hot.	<input type="checkbox"/>	
8.4	Check the correct cable curvature.	<input type="checkbox"/>	
8.5	Check the correct fixation of the modules.	<input type="checkbox"/>	
8.6	Check distances between connections.	<input type="checkbox"/>	
8.7	Check identification of phases by colours.	<input type="checkbox"/>	
8.8	Check identification of meter boxes and modules.	<input type="checkbox"/>	
8.9	Re-tighten the connections applying the torque setting indicated in point 8 of this procedure.	<input type="checkbox"/>	
8.10	Check the state of cleanliness of the fuses and bases.	<input type="checkbox"/>	
8.11	Check clamp pressure.	<input type="checkbox"/>	
8.12	Check the proper functioning of the fiscal metering devices (meters).	<input type="checkbox"/>	
9.	<b>VERIFICATION OF AC CABLING</b>	<b><u>RESULTS</u></b>	<b><u>COMMENTS</u></b>
9.1	Before performing any type of operation on the connections of the AC installation, follow the instructions set out in point 7.9 of the photovoltaic installation maintenance procedure.	<input type="checkbox"/>	
9.2	Visually check ditch layout signalling and state of the inspection boxes.	<input type="checkbox"/>	
9.3	Check support and tray fixations and the state of cleanliness or deterioration thereof.	<input type="checkbox"/>	
9.4	Check that the protection ducts and conduits are in perfect state, without signs of deterioration or insulation or watertightness defects. Where necessary, replace or repair the affected element, in accordance with the extent or importance of the damage.	<input type="checkbox"/>	
9.5	Check that the visible parts of the cable sheathing are not pierced, cut or mechanically damaged.	<input type="checkbox"/>	
9.6	Check that the fixation of aerial conductors, protection ducts and conduits are adequate.	<input type="checkbox"/>	
9.7	Check that the phases are identified in accordance with the phase sequence.	<input type="checkbox"/>	
9.8	Check the insulation resistance (meggering) in accordance with point 9 of the photovoltaic installation maintenance procedure.	<input type="checkbox"/>	
10	<b>VERIFICATION OF THE EARTHING NETWORK</b>	<b><u>RESULTS</u></b>	<b><u>COMMENTS</u></b>
10.1	Check that all metal points (supports, sheathing, trays, etc.) are joined to the main earthing of the prefabricated centres.	<input type="checkbox"/>	
10.2	Check the resistance reading of those parts of the earthing system that must be inspected. The metering performed shall be considered satisfactory if it fulfils the technical specifications of the project or those defined by the client.	<input type="checkbox"/>	
10.3	Once metering has been performed, annotate the value in the record, identifying the equipment to which it corresponds.	<input type="checkbox"/>	
11	<b>GENERAL VERIFICATION OF THE PREFABRICATED CENTRE</b>	<b><u>RESULTS</u></b>	<b><u>COMMENTS</u></b>
11.1	Check paint on walls and the existence of deficient structures.	<input type="checkbox"/>	



11.2	Check the existence of accumulated dust.	<input type="checkbox"/>	
11.3	Check the existence of stored materials.	<input type="checkbox"/>	
11.4	Check the existence of adequate lighting.	<input type="checkbox"/>	
11.5	Check the existence of inadequate distances between inverters and corridors.	<input type="checkbox"/>	
11.6	Check for signs of rodents.	<input type="checkbox"/>	
11.7	Check the existence of emergency lighting.	<input type="checkbox"/>	
11.8	Check the existence of fire extinguishers.	<input type="checkbox"/>	
11.9	Check the existence of personal protection grids and screens.	<input type="checkbox"/>	
11.10	Revise the auxiliary services cabinet.	<input type="checkbox"/>	
11.11	Revise the control and monitoring cabinet.	<input type="checkbox"/>	
11.12	Revise installation lighting.	<input type="checkbox"/>	
11.13	Revise the safety installation.	<input type="checkbox"/>	
12	<b>VERIFICATION OF COOLING</b>	<b><u>RESULTS</u></b>	<b><u>COMMENTS</u></b>
	Verification of room extractor fan operation		
12.1	Check the operation of the room extractor fan, lowering the thermostat setting of the prefabricated centre to below ambient temperature.	<input type="checkbox"/>	
12.2	Check, using the ammeter clamp, that extractor fan consumption is appropriate to the technical characteristics of the motor.		
12.3	Check that the extractor extracts air towards the exterior of the prefabricated centre.	<input type="checkbox"/>	
12.4	Finally, adjust the thermostat setting to 35°C.	<input type="checkbox"/>	
13	<b>Verification of air conditioning operation</b>	<b><u>RESULTS</u></b>	<b><u>COMMENTS</u></b>
13.1	Check the proper functioning of the air conditioning systems, lowering the temperature setting of the thermostat of the equipment to below ambient temperature.	<input type="checkbox"/>	
13.2	Check, using the ammeter clamp, that the consumption of the machine is appropriate to the technical characteristics thereof.	P <sub>motor</sub> .....W I <sub>ac</sub> .....A	
13.3	Finally, adjust the temperature setting to 30°C.	<input type="checkbox"/>	
14	<b>Verification of inverter extractor fan operation</b>	<b><u>RESULTS</u></b>	<b><u>COMMENTS</u></b>
14.1	With the inverter in operation, lower the temperature setting of the thermostat installed in the interior of the equipment until the extractor fan starts working.	<input type="checkbox"/>	
14.2	Check that extractor fan operation is appropriate to the simultaneous state of the coupled inverter and the actuation of the thermostat (see diagram), verifying that the extractor fan stops working when the equipment is stopped.	<input type="checkbox"/>	
14.3	Check, using the ammeter clamp, that extractor consumption is appropriate to the technical characteristics of the motor.	P <sub>motor</sub> .....W I <sub>ac</sub> .....A	
14.4	Check that the extractor fan extracts the air from the interior of the equipment towards the exterior of the prefabricated centre.	<input type="checkbox"/>	
14.5	Finally, leave the temperature setting of the thermostat at 40°C.	<input type="checkbox"/>	
15	<b>VERIFICATION OF VOLTAGE DROP</b>	<b><u>RESULTS</u></b>	<b><u>COMMENTS</u></b>



15.1	Check, using the ammeter clamp, that the current on the AC side of the inverter equipment is approximately equal to the maximum envisaged for installed power, and verify, using the polimeter, that the difference between the voltage in the terminals of the main circuit of the parallel connection boxes and voltage in the DC terminals of the inverter equipment fall within the permissible margin of a 1.5% voltage drop.	$I_{max} \dots\dots\dots A$ $V_{inv} \dots\dots\dots V_{dc}$ $V_{red} \dots\dots\dots V_{dc}$	
15.2	Check, using the ammeter clamp, that the outgoing AC current of the inverter is approximately equal to the maximum envisaged for installed power, and verify, using the polimeter, that the difference between the voltage in the output terminals of the inverter and voltage at the point of connection to the grid falls within the permissible margin of a 1.5% voltage drop.	$I_{max} \dots\dots\dots A$ $V_{inv} \dots\dots\dots V_{dc}$ $V_{red} \dots\dots\dots V_{dc}$	