PVTRIN Training course
Checklist & Practical Tips on PV/BIPV installations
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SUMMARY

This document aims to present, as an example, the parameters needed to verify, once installation has been completed, to check how the system is running; and the action should be taken in a maintenance operation in order to ensure a proper performance of a PV system.

The installation and maintenance checklist may vary depending on the type and features of the installation: for stand-alone and grid connected PV systems.

Practical tips are also provided to support the installer in completing a high quality installation, safely, within a reasonable time. Practical tips are listed in five categories according to the implementation phase of the project: 1. on site visit, 2. sizing / design, 3. Installation, 4. Maintenance/Inspection, 5. Operation & maintenance manual /customer needs.

This document is not intended to present an exhaustive or definitive list and cannot guarantee to cover all possible situations in depth. Technicians are advised to exercise their own professional judgment and to consult all current building regulations, health and safety codes, standards and other applicable guidelines, as well as the technical manual of the equipment used.
1. **CHECKLISTS**

1.1. **Installation checklist**

**TABLE 1. PV COMMISSIONING TEST SHEETS. Source:(DTI, 2006)**

**PV system – Installation Check List**

<table>
<thead>
<tr>
<th>Installation address</th>
<th>Inspection by:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Date: Reference:</td>
</tr>
</tbody>
</table>

**General installation (electrical – ref IEC60364-6-61)**

- [ ] Equipment compliant with standards, correctly selected & no damaged
- [ ] Equipment accessible for operation, inspection & maintenance
- [ ] Equipment and accessories correctly connected
- [ ] Particular protective measures for special location
- [ ] Equipment and protective measures appropriate to external influences
- [ ] System installed to prevent mutual detrimental influence
- [ ] Conductors connected and identified
- [ ] Conductors selected for current carrying capacity and voltage drop
- [ ] Conductors routed in safe zone or protected against mechanical damage
- [ ] Sunlight-resistant and wet-rated conductors are used in exposed locations
- [ ] Cables properly terminated with terminals listed for such conductors
- [ ] Presence of fire barriers, seals and protection against thermal effects

**General installation (mechanical)**

- [ ] Ventilation provided behind array to prevent overheating / fire risk
- [ ] Array frame & material corrosion proof
- [ ] Array frame correctly fixed and stable;
- [ ] Roof penetrations secure and weather tight
- [ ] Modules attached to the mounting structure according to the manufacturer’s instructions
- [ ] Cable entry weatherproof

**Protection against overvoltage/electric shock**

- [ ] Live parts insulated, protected by barrier/enclosure, placed out of reach or Class II
- [ ] Overcurrent devices in the D.C. circuits listed for dc operation? If device not marked D.C, verify D.C. listing with manufacturer
- [ ] Each module or series string of modules have an overcurrent device protecting the module (only relevant if required)
- [ ] Array frame equipotential bonding present (only relevant if required)
- [ ] Surge protection devices present (only relevant if required)
- [ ] RCD provided (only relevant if required)
- [ ] Properly sized equipment-grounding conductors routed with the circuit conductors
- [ ] Frame correctly integrated with existing LPS installation
- [ ] User-accessible fuses in “touch-safe” holders or fuses capable of being changed without touching live contacts

**D.C. System**

- [ ] Physical separation of A.C. and D.C. cables
☐ D.C. switch disconnector fitted (to IEC60364-712.536.2.2)
☐ D.C. cables – protective and reinforced insulation (only relevant if required)
☐ All D.C. components rated for operation at max. D.C. system voltage (Voc stc x 1,25)
☐ PV strings fused or blocking diodes fitted (only relevant if required)

A.C. System
☐ A.C. isolator lockable in off position only
☐ Inverter protection settings to local regulations

Charge Controller (if exists)
☐ Exposed energized terminals not readily accessible
☐ Diversion controller has an independent backup control method
☐ PV system schematic displayed on site

Batteries (if exist)
☐ Limited access
☐ Installed in well ventilated areas

Junction boxes
☐ Appropriate type and size and allow the conductors within to be accessible

Labelling & identification
☐ General labeling of circuits, protective devices, switches and terminals (to IEC60364-6-61
☐ PV system schematic displayed on site
☐ Protection settings & installer details displayed on site
☐ Emergency shutdown procedure displayed on site
☐ A.C. isolator clearly labeled
☐ D.C. isolator / junction boxes suitably labeled
☐ Signs & labels suitably affixed and durable

Owner’s Documentation.
☐ warranty,
☐ component warranties,
☐ owner’s manuals,
☐ Utility interconnection agreement,
☐ instructions for operation and maintenance.
### 1.2. Maintenance checklist

**TABLE 2. MAINTENANCE CHECKLIST. (Source: http://www.contractorsinstitute.com/)**

**PV system – Maintenance Check List**

<table>
<thead>
<tr>
<th>Installation address</th>
<th>Inspection by:</th>
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<tbody>
<tr>
<td></td>
<td>Date:</td>
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<tr>
<td></td>
<td>Reference:</td>
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</tbody>
</table>

#### Array Installation and Wiring
- Condition
- Proper insulation on module wiring
- Proper connectors on array wiring extensions
- Proper grounding of array & array mount
- Grounded conductors installed
- Array mount properly secured and sealed
- Suitable transition from open wiring to enclosed wiring
- Metallic conduit through attics to array disc
- Damages of modules observed
- Dirt accumulation observed
- Shading observed on modules

#### DC Connections
- Source Circuit Combiner Boxes
- DC-rated circuit breakers or fuses with adequate voltage rating
- Listed equipment

#### DC Component Enclosures
- Proper conductor sizes and insulation types
- Proper conductor terminations
- DC ratings on DC components
- Listed equipment
- SINGLE POINT GROUNDING!
- Optional grounding electrode conductor

#### AC Component Enclosure
- Isolated Neutral busbar
- Listed components
- Labelled disconnects and C/B

#### Utility Disconnect
- Labelled
- Visible, lockable, accessible, load break, external handle

#### Appropriate Signs installed
- Check for sign identifying PV power source system attributes at D.C. disconnect
- Check for sign identifying A.C. point of connection
- Check for sign identifying switch for alternative power system.
<table>
<thead>
<tr>
<th>Building Main Disconnect</th>
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<tbody>
<tr>
<td>□ Labelled</td>
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<table>
<thead>
<tr>
<th>Inverters</th>
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<tbody>
<tr>
<td>□ Listed inverters (type, serial number, configuration)</td>
</tr>
<tr>
<td>□ Status/Condition</td>
</tr>
<tr>
<td>□ Defects founded</td>
</tr>
<tr>
<td>□ Noise levels</td>
</tr>
<tr>
<td>□ Open circuit voltage (V)</td>
</tr>
<tr>
<td>□ Impp (A)</td>
</tr>
<tr>
<td>□ Input and output disconnects labelled</td>
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<tr>
<td>□ Proper wire sizes</td>
</tr>
<tr>
<td>□ Grounded</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Batteries (Battery backup systems only)</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ Terminals protected from shorting</td>
</tr>
<tr>
<td>□ Cables properly terminated (no set screw lugs on fine stranded wire)</td>
</tr>
<tr>
<td>□ Maintenance-free vented for cooling</td>
</tr>
<tr>
<td>□ Flooded vented to outside</td>
</tr>
<tr>
<td>□ Labelled with proper safety procedures</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Charge Controllers (Battery backup systems only)</th>
</tr>
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<tbody>
<tr>
<td>□ Status/Condition</td>
</tr>
<tr>
<td>□ Input and output disconnects labelled</td>
</tr>
<tr>
<td>□ Listed charge controllers</td>
</tr>
<tr>
<td>□ Proper wire sizes</td>
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<tr>
<td>□ Grounded</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Standby Circuits (Battery backup only)</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ Watch for multiwire if 120V</td>
</tr>
<tr>
<td>□ Labelled</td>
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<table>
<thead>
<tr>
<th>Point of Utility Connection</th>
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<tbody>
<tr>
<td>□ Labelled</td>
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<tr>
<td>□ Compliance</td>
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<table>
<thead>
<tr>
<th>Handover of PV system</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ Mentioned faults</td>
</tr>
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</table>
2. PRACTICAL TIPS

2.1. On site visit

PV installer should

- have all the necessary equipment for the site survey (Tape measures, compasses, solar shading calculators, Graph paper, calculator, audio recorders, cameras etc) in order to ensure that extra on site visits will be avoided
- estimate whether fall protection methods are required and if extra personal protective equipment will be necessary when installing the system
- obtain detailed information during the survey so as to plan and execute PV installations in a timely and cost-effective manner
- check whether the array can operate without being shaded during critical times
- take into account potential shadings that will be a barrier for the PV system in the future
- have in mind that unless site shading or local weather patterns dictate otherwise, the optimal azimuth angle for facing tilted PV arrays is due south in the N. Hemisphere, and due north in the S. Hemisphere
- have in mind that for unshaded locations, the maximum annual solar energy is received on a surface that faces due south, with a tilt angle slightly less than the local latitude
- locate potential location of BoS and wiring to gain time
- check if the structure is strong enough to support the array and himself
- check if there is enough area for easy installation and future maintenance
- determine the distance between the array and the other system equipment
- record in detail the load in case of a stand-alone system taking into account potential future needs
- have in mind that for systems with winter-dominant loads, arrays should be tilted at an angle of latitude +15° (for summer-dominant load, the array should to be tilted at an angle of latitude −15°)
- have in mind potential urban planning barriers, current building codes etc
- consider zoning and land use restrictions, Terrain, elevations and grading requirements, Security requirements and fencing in case of ground mounted PV arrays
- observe if the building is fitted with a lightning protection system, a lightning protection installer should be consulted as to whether, in this particular case, the array frame should be connected to the existing lightning system
be direct with the potential investor whether or not the site is proper for the installation of the PV systems

be ready to answer in general questions of the PV investor

inform the potential investor for available FiTs

be able to make some draft initial estimations (have in mind that \(10\text{m}^2 = 1\ kWp\); cost of a grid connected PV system is 2,800-3,600 €/kWp)

slightly underestimate the annual production yield in order to avoid creating unrealistic expectations to the client

2.2. Sizing / Design

PV installer should have in mind that

- modules should be checked in order to comply with the international standards: IEC 61215 in the case of crystalline types, or IEC 61646 in the case of thin film types.
- modules must also carry a CE mark
- the filling factor for a good module is around 0.75.
- at low temperatures, the module voltage increases. The highest voltages are recorded for open-circuit voltages at low temperatures
- the voltage and current generated by the PV modules must fit within the inverter range
- the nominal AC power of the inverter is the power that the inverter can supply continually at an ambient temperature of 25° ± 2°C.
- the DC power rating of the inverter (\(P_{\text{INV DC}}\)) is approximately 5% higher than the inverter's nominal AC power
- a typical value of inverter sizing factor \(C_{\text{INV}}\) would be in the range 0.83 < \(C_{\text{INV}}\) < 1.25, but it seems to be cost effective for \(C_{\text{INV}} < 1\).
- the maximum temperature reached on a PV panel is used to determine the minimum number of modules in a string
- on a sunny day in summer, the PV will have a lower voltage than 25°C (STC) because of the increased temperatures
- The maximum PV array current must not exceed the maximum inverter input current.
- Class II insulation on the DC part of the PV system, even if less than 120 V_{DC}, is strongly recommended.
- cables routed behind a PV array must be rated for a minimum temperature of 80°C.
- cables must be selected so as to minimise the risk of earth faults and short-circuits
external cables should be UV stable, water resistant, and it is recommended that they be flexible (multi-stranded) to allow for thermal/wind movement of arrays/modules.

- cables should be sized such that overall voltage drop at STC between the array and the inverter is <3%
- the AC cable connecting the inverter(s) to the consumer unit should be oversized to minimise voltage drop. A 1% drop or less is recommended
- connectors must have the same or greater voltage and current ratings as the string/DC main cable to which they are fitted.
- to minimise the risk of faults, cable runs should be kept as short as practicable
- to size the cable cross-section according to the maximum current
- that the voltage drop in the DC circuit should be < 1% of the nominal voltage of the PV system at STC in order to limit the power loss through all DC cables to 1% at STC
- PV systems with excessive voltage drop are inefficient and can perform poorly
- string fuses must be provided for all arrays formed of ≥ 4 strings. Fuses must be fitted in both positive and negative string cables for all strings
- accessible disconnection device shall be provided to isolate individual strings
- in order to avoid false trips the nominal current of the fuse should be at least 1.25 times greater than the nominal string current
- the DC switch must be double pole – to effectively electrically isolate both PV array positive and PV array negative.
- the bonding to earth of any of the current carrying DC conductors is not recommended.
- the inverter must be treated as standard electrical apparatus and earthed
- the battery should be sized so that the output of the PV array falls between the manufacturer’s maximum and minimum recommended charge rates
- battery banks must be housed in such a way that access can be restricted to authorised personnel, adequate containment is assured appropriate temperature control can be maintained
- In an enclosed location, ventilation must be provided to battery
- when using a simulation tool a hand calculation of some sort should always be used to cross check computer based calculations
- standard formats and symbology should be implemented when elaborating technical drawings to avoid any possible margin of error in their interpretation
- a complete permit package is critical to an expeditious permitting and approval process
2.3. Installation

PV installer should

✓ avoid to work under extreme weather conditions
✓ take appropriate precautions like using sunscreen, keeping well-hydrated and wearing light-colored clothing when working on rooftop
✓ always follow the site safety plan
✓ use the necessary personal protective equipment
✓ keep the workplace clean in order to avoid tripping over something.
✓ never leave tools lying out on a roof, as the chance of the tools falling off the roof and injuring someone below is increased
✓ use an existing safe place of work to access work at height
✓ use a mobile elevating work platform when necessary
✓ ensure easy access to the tools and machinery necessary for the transfer, lifting and installation of the equipment
✓ use properly grounded or double-insulated power tools maintained in good condition
✓ use the technical drawings or outlines developed in the design phase
✓ “go by the book”; follow the manufacturer’s instructions regarding the installation of the PV modules and the rest BoS
✓ always de-energize circuits before beginning work on them
✓ use a meter or circuit test device such as a current clamp to ensure the circuit is dead prior to working on it.
✓ lock out the power on systems that are capable of being locked out.
✓ remember that turning off the main breaker does not stop a solar electric system from having the capacity to produce power
✓ have in mind the even low light conditions can create a voltage potential that can lead to a shock or arc-flash.
✓ be aware that a surprise shock delivered at the wrong time could cause a fall from a roof or ladder
✓ remember that electric arc-flash hazard exists while adding or removing a series of solar PV panels
✓ cover PV panels during installation if necessary with an opaque covering
✓ do not install or use PV modules near hazardous locations with flammable gases
✓ sort the panels to match their Vmp/Imp specifications
✓ Ensure that the module edges are not chipped or cracked, when handling and mounting the modules
✓ take care when handling PV modules as the edges, particularly where glass edges are exposed, may be sharp
✓ put the panels together in formation in such a way as to prevent any deterioration
✓ provide sufficient ventilation must behind the array for cooling (roof mounted systems should have at least 50mm free space beneath)
✓ 25mm vented air gap to the rear).
✓ have in mind that the risk of shock is greatly increased if a PV module or installation is damaged.
✓ take into account that a poor connection can become more influential with time and lead to poor performance long-term.
✓ avoid excess cable wherever possible
✓ do not coil excess cable as this will reduce the cable’s ability to dissipate heat
✓ pay careful attention to the location of module junction boxes so the lengths of electrical wiring can be minimized and organized into source circuits as needed, once modules are mounted
✓ support properly the cables, especially the ones exposed to the wind
✓ protect cables from sharp edges
✓ use only the modular holes of the panel that is specifically designed by the manufacturer
✓ be aware of the dimensions and weight of the inverter in order to carefully plan out its positioning and needs for transport
✓ position the inverter in an enclosed space, sheltered from the outside weather
✓ never modify or alter the installation of the inverter; the inverter usually comes with the appropriate holes and anchors
✓ ensure that the inverter will be ventilated adequately
✓ simplify the earthing requirement, an inverter with an isolating transformer
✓ provide a manual AC switch-disconnector in an accessible position
✓ wear eye protection when working with batteries
✓ take care to prevent arcing at or near battery terminals
✓ be aware of the dimensions and weight of the batteries in order to carefully plan out its positioning and needs for transport
✓ place battery terminals in such a way as to isolate contact and avoid potential corrosion
✓ first transport the empty batteries in the appropriate location and then fill them up with the electrolyte
always locate batteries in an enclosed area free of any potential elements that might cause flames or sparks
not connect batteries of different manufacturer or model
ensure that the availability of storage batteries is equal to the specifications included in the original design
be sure that all labeling of the equipment is done properly; labels must be clear, easily visible, constructed to last and remain legible for the lifetime of the system
perform several test to ensure that the system functions well

2.4. Maintenance/Inspection

PV installer should

have in mind that PV systems are not “maintenance free”; PV systems require a periodical inspection to confirm that the system is working properly and has no faults or failures.
perform any other periodic maintenance or testing recommended by the manufacturer
check for any unexpected values in the recorded data
prepare a checklist of things to be maintained and inspected before visiting the system
record all the necessary tools and equipment to be taken along to avoid further visits
calibrate instruments to be used, if necessary
use the necessary personal protective equipment (look tips for installation)
de-energize circuits before beginning work on them
cover PV panels during installation if necessary with an opaque covering; work at night (using proper light if necessary)
remember that turning off the main breaker does not stop a solar electric system from having the capacity to produce power
have in that PV inverters may have significant capacitors that could hold a charge after the power source is removed
use a current clamp to check for hazardous energy prior to working on the PV array
remove Layers of dust and dirt from the modules with water; do not use any chemical detergents or rough brushes or sharp tools
check for any obvious defects (e.g. crack) during cleaning
check for corrosion on the mounting frame
try to spot new shading sources that were not taken into account during installation
trim surrounding trees if necessary
✓ check for loose connections, corrosion etc
✓ compare ac power output of an interactive PV system at any moment with expected values using the basic translation formulas for solar irradiance and temperature
✓ check and replenish electrolyte in batteries (in autonomous systems)
✓ replace as soon as possible damaged or failed system components

2.5. Operation & maintenance manual /customer needs

PV installer should explain
✓ the benefits of an LCD monitor to the customer (easy to monitor the system)
✓ how to interpret signs (LED signs of the inverter etc) of malfunctions of the system
✓ the necessity of keeping monthly and yearly records of the energy production
✓ how to trim trees in order not to shadow the array
✓ how to spot new shadow sources that can influence the energy production of the array
✓ the checking procedure for any obvious defects (e.g. panel cracks, loosen cables, corrosion on the mounting frame)
✓ proper methods of cleaning the glass of the PV panels

The PV installer should not forget to provide all the necessary documentation to the customer (user manual with the maintenance requirements of the system)
INDICATIVE REFERENCES

- Contractors Institute: http://www.contractorsinstitute.com
- John Wiles SWTDI/NMSU 2005/2008/2011, Photovoltaic electrical power systems inspector/installer checklist,
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A great deal of additional information on the PVTRIN project is available on the web at: www.pvtrin.eu.

We would welcome feedback on this publication, if you have comments or questions please contact the project coordinator.

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## PVTRIN PARTNERS

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<tr>
<th>Partner</th>
<th>Country</th>
<th>Website</th>
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<tbody>
<tr>
<td>Technical University of Crete</td>
<td>Greece</td>
<td><a href="http://www.resel.tuc.gr">www.resel.tuc.gr</a></td>
</tr>
<tr>
<td><em>Environmental Engineering Dpt.</em></td>
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<tr>
<td><em>Renewable and Sustainable Energy Systems Lab</em></td>
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<tr>
<td><em>PROJECT COORDINATOR</em></td>
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<tr>
<td>Agency of Brasov for the Management of Energy and Environment</td>
<td>Romania</td>
<td><a href="http://www.abmee.ro">www.abmee.ro</a></td>
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<tr>
<td>Building Research Establishment Ltd</td>
<td>UK</td>
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<td>Energy Institute Hrvoje Požar</td>
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<td><a href="http://www.eihp.hr">www.eihp.hr</a></td>
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<td>European Photovoltaic Industry Association</td>
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