Asia-Pacific Economic Cooperation

Rooftop Solar PV System Designers and Installers

Training Curriculum

APEC Secretariat

March 2015


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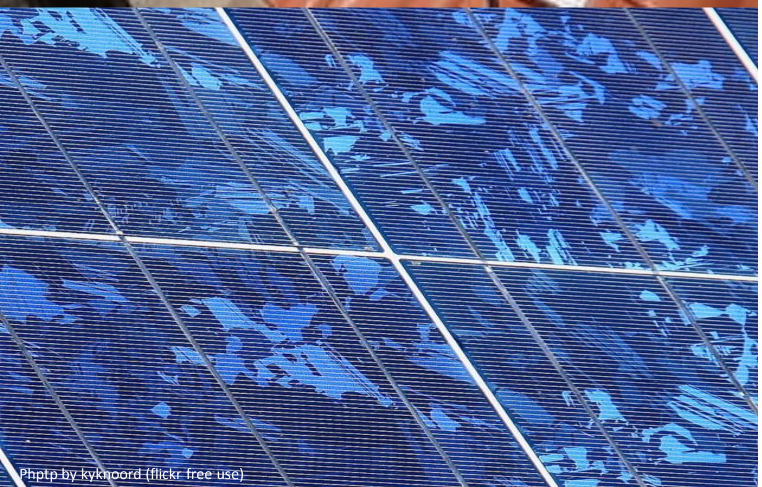
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COMMISSIONING AND PERFORMANCE VERIFICATION

Training of PV Designer and Installer

APEC
Asia-Pacific Economic Cooperation

Cu International Copper Association
Copper Alliance

castlerock consulting

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A. Basic commissioning procedures

Commissioning is a critical part of a well-installed system. Understanding and paying attention to PV commissioning is important to the industry.

Commissioning is a way to formalize quality control of installed PV systems. The process ensures that systems are safe and high performing.

http://www.solarworld-usa.com/

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A. Basic commissioning procedures

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Safety first

Please note to take the safety precautions when commissioning the system.

Fall protection, ladder safety, electrical safety, personal protective equipment and common sense are all required.

A. Basic commissioning procedures

Safety first

Proper testing and planned sequencing will ensure that neither equipment nor people are subject to destructive voltage or current.

Be alert, if something seems wrong or if unexpected phenomena result when energizing equipment—such as pops, bangs, smoke or sudden darkness—do not rush to try to "fix" the problem.

Photo 6. Workman verifying that equipment is de-energized; note protective clothing.

http://iaeimagazine.org/magazine/2003/05/16/electrical-inspector-workplace-safety/

A. Basic commissioning procedures

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Safety first

Slow down; determine the cause; make sure no hazard is present; and then determine the best course of action.

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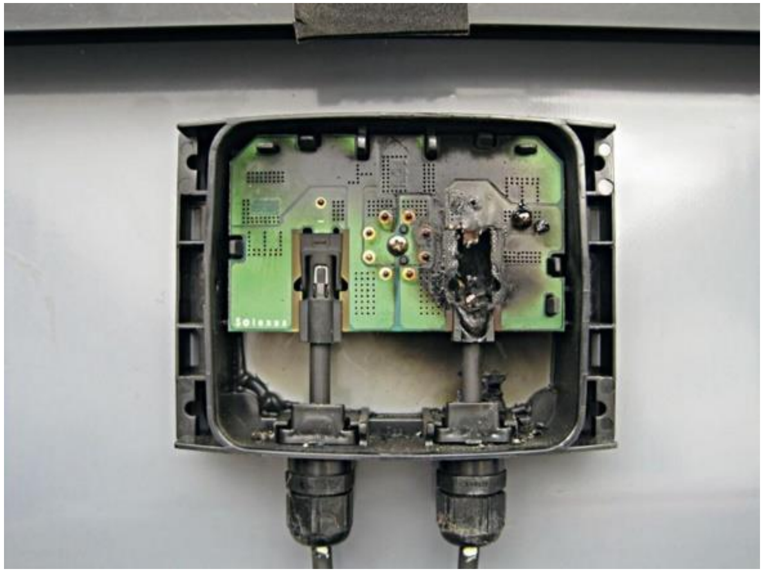

A. Basic commissioning procedures

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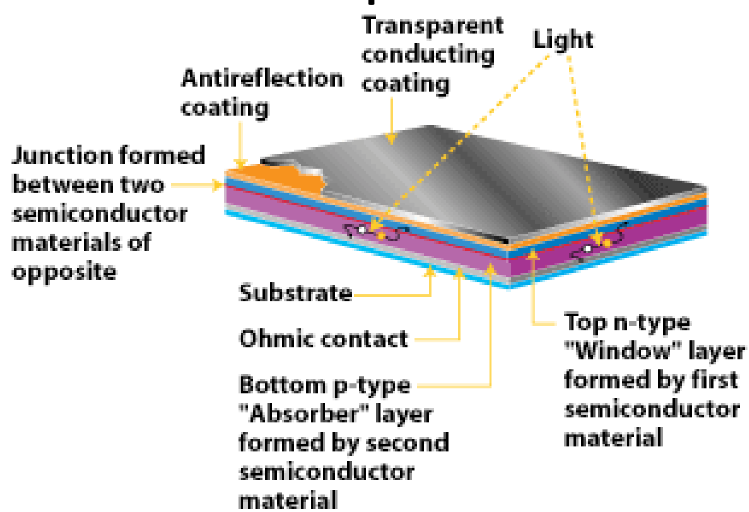
A. Basic commissioning procedures

One exception for systems that have a “burn in” period, such as thin film amorphous silicon systems. These systems will experience a significant, but expected, drop in production over the first few weeks and months of operation.

Therefore, performance measurements made at initial system startup will be artificially high.

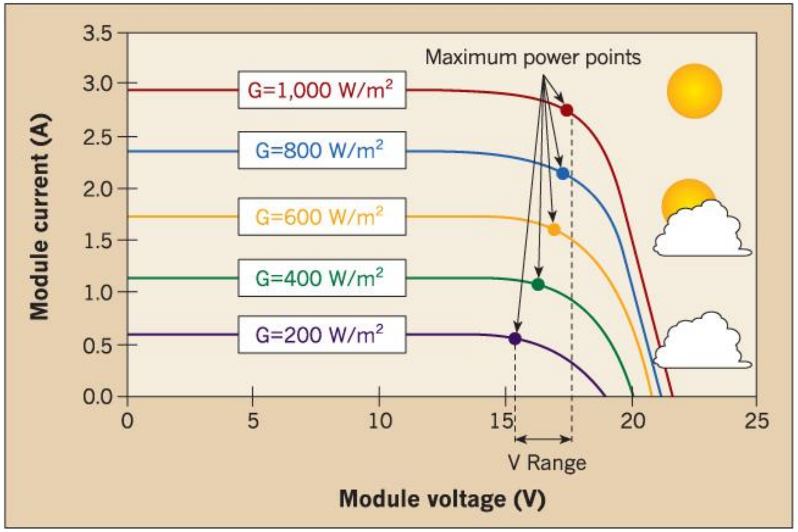


http://en.wikipedia.org/wiki/Thin_film_solar_cell

A. Basic commissioning procedures

The commissioning schedule should be as soon as possible after PV system construction is complete, but within a suitable window of weather.

For example, to commission when there is irradiance of less than 400 W/m2 in the array plane. Not only must the weather be good, but the time of day must also be appropriate (usually in the middle of the day).



A. Basic commissioning procedures

Commissioning tasks:

- **Verify that the installation is complete.**
  - → Are all components permanently installed? Is everything wired completely? Permanent utility power should be connected at the site. In addition Web based monitoring is being used, the Internet connection should be operational. Examine the most recent installation punch list to make sure all items are complete.

A. Basic commissioning procedures

- **Verify that the installation is safe.**

  → Are the mechanical and structural systems adequate and built according to plan? Has any required waterproofing been completed satisfactorily? Has the electrical design been adapted properly?

  A few common problem areas are worth checking:

  ➢ Make sure working clearances are maintained.

A. Basic commissioning procedures

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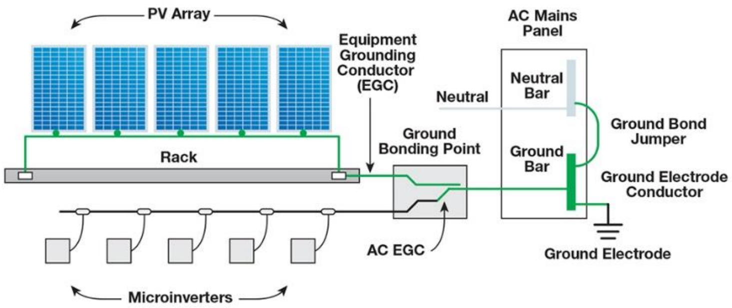
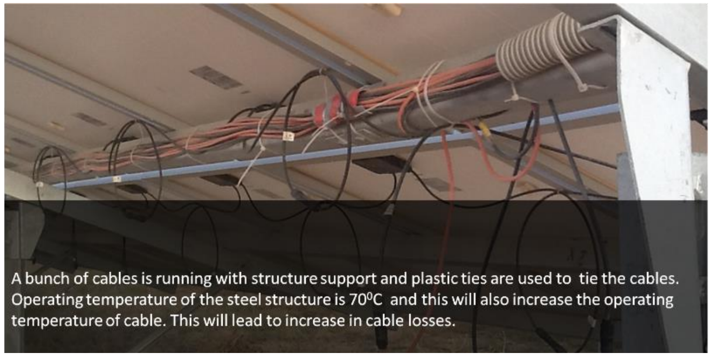
- Verify that all metallic surfaces that might become energized are grounded.

Microinverter-Integrated Ground with EGC-Connecting PV Frames & Rack



- Ensure that wire and conduit sizes installed in the field are as shown on the plans.

http://www.pv-magazine.com/archive/articles/beitrag/cable-care-_100011160/572/#axzz3Mcgih1rg



https://firstgreenconsulting.wordpress.com/2013/05/18/dc-cable-layout-planning-in-solar-power-projects/

A. Basic commissioning procedures

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- **Verify that the installation is aesthetically acceptable**

  → Check to see that the PV array is only as visible as it was designed to be. Verify that module lines are straight. Check that all other equipment installed plumb, level and with good workmanship.

VS

A. Basic commissioning procedures

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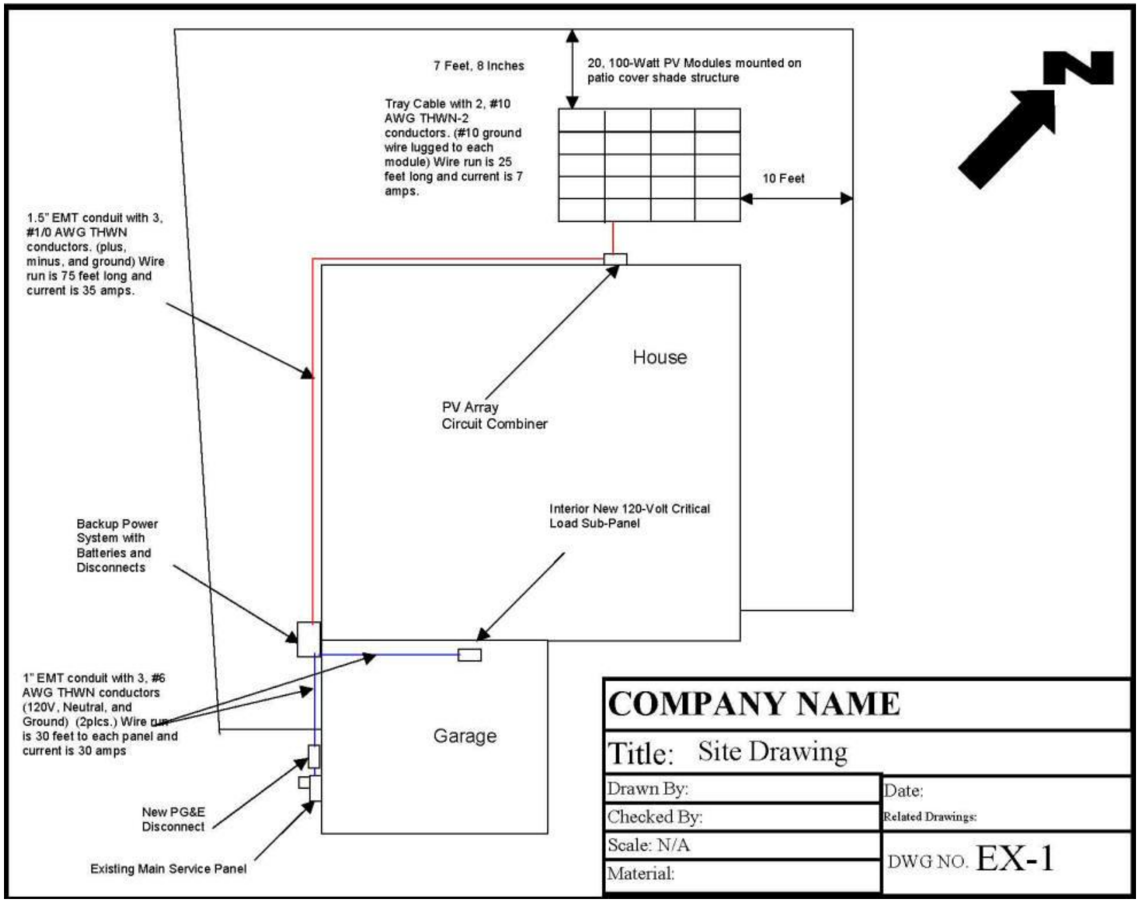
- **Verify that the installation is robust and permanent**

  → Ensure that all outdoor equipment is designed to withstand the elements and the environment it will be subjected to for the design life of the system. Fasteners should be stainless steel, and steel rack elements should be hot-dipped galvanized or better. Dissimilar metals must be isolated to avoid galvanic corrosion. Wiring and raceways must be suitable for their location. Sunlight resistant wire is required under arrays, for example, and electrical metallic tubing (EMT), intermediate metal conduit (IMC) or rigid metal conduit (RMC) is required on the roof.

- **Document as-built**
  - → Note anything out of the as-built document, written down and photographed, with the photo location marked on a roof plan or other appropriate drawing. Take pictures of all arrays, ideally from at least two angles. Also take pictures of conduit runs, combiner boxes, disconnects, inverters and the interconnection.



B. Basic performance verification

At initial system commissioning, very little historical production data is available. Therefore, the single best metric to verify system performance in the short term is the instantaneous power output of the system. The following process is one way to estimate the expected value of the system power output at any moment.

1. Determine the peak dc power rating of the system (PSTC)

This value will be the sum of the power outputs of ideal individual modules at STC.

Example: System consist of 26 pcs of 200 Wp modules = 26 x 200 = 5200 Wp

B. Basic performance verification

2. Calculate the irradiance factor (KI)

Use a pyranometer to measure the actual irradiance in watts per square meter. This measurement should be taken in the same plane as the modules, with the same azimuth and tilt angle. Divide the measured irradiance by the STC irradiance (1000 W/m2) to obtain the irradiance factor.

3. Calculate the module cell temperature factor (KT)

Measure the cell temperature TC of the modules in Celsius using a thermocouple, thermistor or infrared (IR) thermometer. Or we can find the module temperature coefficient of power, CT, from the module data sheet or module manufacturer. This coefficient is typically in the range of −0.003/°C to −0.005/°C for crystalline silicon modules.

$$\mathbf{KT = 1 + (CT \times (TC - TSTC))}$$

The cell temperature factor usually represents a reduction in power from the STC rating of a module due to cell operating temperature well above STC temperature (25°C).

B. Basic performance verification

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4. Determine the system derating factor (KS)

This factor is a product of all of the system efficiencies and miscellaneous subfactors, including: module mismatch, inverter efficiency, module soiling, module nameplate tolerance, wiring losses, shading, system availability, tracking efficiency and age. Typically, the resulting *system derating factor*, the product of all system derating subfactors, is approximately KS = 0.90.

5. Calculate expected system performance (PE)

Irradiance, cell temperature and system efficiency adjusts the expected output of the system relative to the controlled STC power rating. The overall expected power output from the combination of these calculated and measured factors is determined as follows:

$$PE = PSTC \times KI \times KT \times KS$$

B. Basic performance verification

From now on, we can compare the expected power output to the measured power output. After we have verified that all of the specified equipment was installed, you can measure and document the performance of that equipment and compare it to the expected values.

We can now measuring system performance by doing some tests:

a. Voc (Voltage Open Circuit)

   Open-circuit voltage can be measured only while the strings are independent of each other and before they are combined. Verifying individual string Voc measurements is the quickest way to ensure that all strings have the same number of modules and the correct polarity.

B. Basic performance verification

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b. Imp (Maximum Power Current)

Use a dc clamp meter to measure the current in the ungrounded source circuit conductor of each string. If weather conditions are consistent during the testing and all strings are oriented with the same azimuth and tilt angle, the measured current values should be identical, or at least within about 0.1 A of each other.

c. Inverter startup

After we have completed all the visual inspections and confirmed the dc open-circuit string voltages, the system can be started up. Always follow the inverter manufacturer’s directions for initial startup. Typically, the steps will include the following:

- Verify all connections.
- Verify correct ac voltage at the AC disconnect.
- Verify correct dc voltage and polarity at the DC disconnect(s).
- Close the AC disconnect.

B. Basic performance verification

- Verify correct AC voltage at the inverter ac terminals.
- Close the DC disconnect(s).
- Verify DC voltage and polarity at the inverter dc terminals.
- If applicable, switch the inverter “ON.”
- Wait for the inverter to step through its internal startup sequence.
- Once the inverter is running, wait about 15 minutes for internal temperatures and power point tracking to stabilize

d. AC power output

Using a clamp meter for current and a multi-meter for voltage, verify that the voltage, current and power displayed on the inverter match the measured values.

C. COMMISSIONING CHECKLIST

A commissioning checklist need to be made for each country and local region based on the regulations and laws. Many of the basic construction and installation workmanship practices and industry standards can be used. However they need to be compared against the local regulations for compliance.

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