
# Solar Photo-Voltaic (PV) Power Plant Earthing Design Services

In 2015 1.7GW of renewable energy capacity was added in Australia (46% of this was solar), while 1.3GW of coal based capacity was decommissioned. Large scale PV power plants proposed in Australia may exceed a gigawatt in the next few years. Together with rooftop PV generated power, total installed Solar capacity exceeded 5GW in 2016, and has become an integral part of the electricity supply network (Australia's current electricity generation capacity is 56GW). Recently commissioned plants at Royalla (24MW), Broken Hill (53MW), Moree (56MW) and Nyngan (102MW) have highlighted electrical earthing design issues which need to be addressed up front to save costs later in the project. Future large scale plants in the pipeline (Bulli Creek 2GW, Kidston 150MW, Clare 100MW) emphasise the need for designers to be aware of the likely fault scenarios and how to design earthing systems accordingly. Liberty Consulting Services (LCS) uses CDEGS software to adequately model very large, extended earthing systems, and is uniquely placed to provide a range of earthing design and testing services to assist with these projects.

**Earthing systems in a large scale Solar PV Farm**

Large solar plants consist of many PV panels mounted on support frames with structural steel piles or footings. These form large arrays, connected together through DC systems to inverters, feeding AC power to step-up transformers at a specified export voltage.

Sections of PV arrays, inverter groups and step-up transformers are often combined into larger blocks that connect to the main HV substation.

This means there are several distinct earthing systems that are interconnected and cover large areas, often many times larger than typical power plant earth grids. This extended earthing system requires design optimisation for an economical solution.

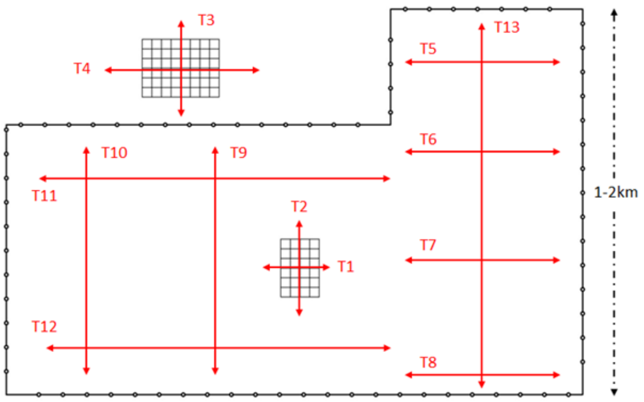
**Relevant Earthing Related Standards & Codes**

- AS/NZS 5033 Installation and safety requirements for photovoltaic (PV) arrays
- ENA EG-0 Power System Earthing Guide, Part 1: Management Principles (including Argon)
- ENA EG-1 Substation Earthing Guide
- AS/NZS 2067 Substations and high voltage installations exceeding 1 kV a.c. (Section 8)
- AS/NZS 1768 Lightning protection
- AS/NZS 3000 Electrical installations (Australian & New Zealand Wiring Rules: Section 5)

While AS5033 applies to small systems up to 240kW, it may be applied to larger installations. However the utility scale PV plants require knowledge from the library of other Australian earthing standards, and also need to follow State based utility requirements.

**Soil resistivity testing for large earthing systems**
Soil resistivity testing in the proposed solar farm area is essential for accurate earthing analysis. This is to be done at the start of the project, by experienced and qualified testers. Guidance is not readily available on how many traverses are required, or the maximum spacings that are required in Wenner tests, so experience is necessary to determine this.

Many test traverses are necessary in large solar farms, with suitably powered test equipment for the longer spacings. Portable, off the shelf testers are often unsuitable for testing these large solar farms.




Different resistivity values are often apparent across the site, and seasonal weather variation means the designer must allow for scenario analysis when interpreting the soil resistivity test data.

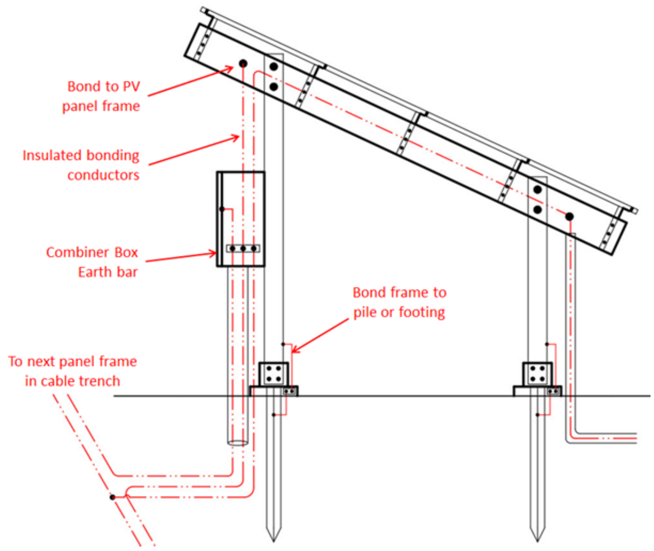
**Earthing design approach for large Solar PV Farms**
Software modelling is necessary for main substation grid areas, step-up transformer earthing, enclosures for DC/AC inverters and switches, and PV frames with their structural footings and piles.

Many software programs assume all earth conductors are at the same potential under earth fault conditions. However CDEGS MALZ accounts for voltage drop along earth conductors which significantly alters the performance of a large, extended earthing system.

Due to the large number of steel footings and buried piles that support the solar PV panel frames, these equivalent earth electrodes are readily available, negating the need for additional ground rods. Buried earth conductors may be used to interconnect the PV panel frames, or this may be achieved by short, PVC insulated conductors in DC cable trays. Therefore extensive, buried earthing systems may not necessarily be recommended.

**Earthing and bonding methods for PV modules**
The PV panel frame is typically part of the earth-fault current path (-ve polarity of DC circuit), and is required to be electrically bonded to the installation earth system. Earthing bonds for PV module frames are susceptible to corrosion and weathering failures, hence need to be selected carefully for longevity (e.g. Aluminium versus Copper dissimilar metal contact).

Secure connections from the module frames to the piles or reinforced concrete footings are required to last the life of the solar farm, 20 years or more.




**Perimeter fence – to bond or not to earth system**
A metallic perimeter fence may exist, and if it is connected, it will contribute to the solar farm earth system. If the fence is isolated it needs to be assessed for touch potential hazards based on the fault scenario and EPR.

**Earth fault current scenarios for EPR design analysis**
Fault scenarios include direct and indirect effects from lightning, DC earth faults (live DC circuit connection to frames), leakage current, and AC earth faults. Usually a load flow and fault protection study is performed for the site. This often shows fault current levels will vary considerably across the solar farm.

The highest fault levels typically occur either at the HV side of the step up transformers (if they are not current limited), or at the main collector substation, which has a utility source contribution.

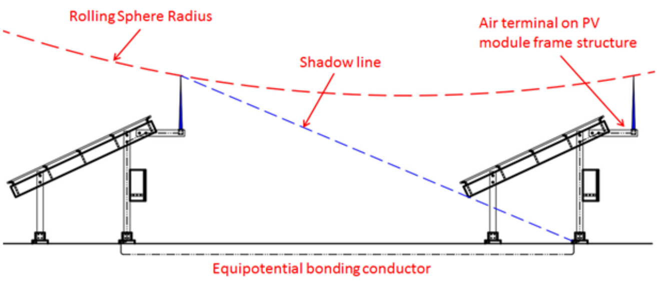
However as with typical substation earthing analysis, the worst case touch voltages will often be found at the edges or corners of the earth system, where there is minimal installed earthing to control voltage gradients. These areas should be examined closely, especially if soil resistivity is higher here.

Small leakage currents occur from the PV cells to the module frames, via the module glass. This flows from the frame to the earth system and returns via earthed (-ve polarity) conductors to the modules. Typically these are not dangerous, but for large systems, with aging defective PV modules with damaged glass or delamination, in wet conditions, leakage current can be hazardous.

**Lightning and surge protection considerations**

There is definitely a correlation between solar radiation, humidity and lightning frequency. Solar farm sites are selected for their high solar radiation, and the associated high humidity means they may be more susceptible to lightning.

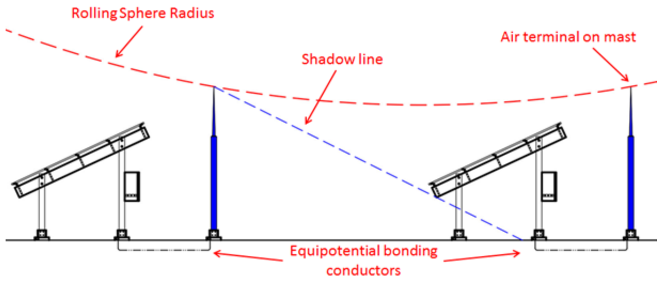
Experience in Europe and the US has shown the devastating impacts of not installing adequate lightning and surge protection during the construction phase of large solar farms. The cost of LPS is negligible compared to overall cost of plant. Just one electrical storm could prove catastrophic with enormous financial implications, and some recent installations in Australia appear to have neglected the need for LPS.




A standard LPS approach will either have air terminals spaced from the module frames, or mounted directly on them. The air terminals pre-installed on module frames may be a more economical solution.

The earth termination system of the installed LPS is also critically important. Equipotential bonding is required to the main electrical earth system so that lightning induced EPR does not create significant potential differences.

Long runs of earthing conductors and services will mean some voltage drop is expected, hence the importance of surge protection devices (SPDs).

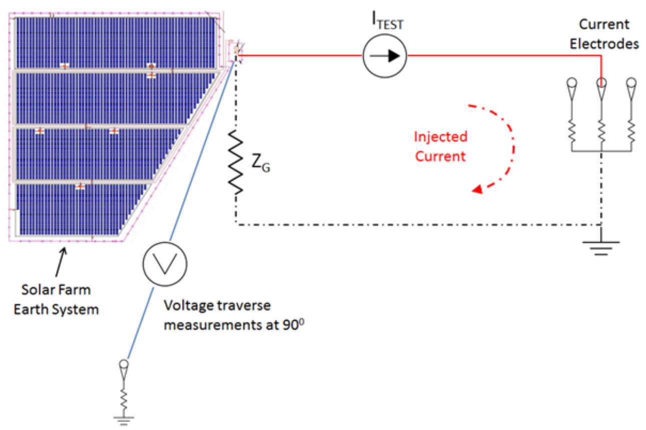



The damage associated with nearby strikes needs to be averted with the correct selection of SPDs. Both DC and AC SPDs are needed to protect sensitive electronics in collector units and substation areas.

**Testing of completed PV array earthing system**

Testing a large solar farm's earthing system is often impractical due to the sheer size of the earth system footprint. The result will be a fraction of an Ohm, but how useful is this number in practical terms?

Off frequency current injection techniques using the fall of potential method, may still be employed to investigate localised EPR and touch and transfer voltage hazards at specific areas around the solar farm, to confirm agreement with the design model. This should be considered on a case by case basis.




Testing should also concentrate on the collector substations, and the main solar farm substation, prior to connection with the rest of the PV arrays.

Earth grid continuity, integrity testing of earthing connections, bonds to equipment and module frames, and periodic integrity checks over the life of the installation form an essential part of any test regime.