



DESIGN, INSTALLATION PROCEDURES, AND OPERATIONAL CONSIDERATIONS FOR DOMESTIC SOLAR PHOTOVOLTAIC SYSTEMS: COMPONENTS, WIRING, SAFETY AND PERFORMANCE REQUIREMENTS

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ABSTRACT

Solar photovoltaic (PV) systems have become increasingly important as global demand for clean, reliable and affordable electricity rises. This growth is driven by concerns over fossil-fuel depletion, environmental degradation, geopolitical conflicts, and fluctuations in global energy prices. Solar energy offers a renewable, emission-free alternative that reduces greenhouse gas emissions and mitigates climate change. This paper provides a comprehensive overview of the principles, components, installation processes, and safety practices required in domestic solar PV systems. It examines key system elements including solar panels, batteries, inverters, wiring, mounting structures, and appliances, while explaining the technical principles behind series and parallel connections, battery management, grounding, and grid-tie operations. The study further outlines step-by-step installation procedures, electrical integration, inspection requirements, and maintenance needs to ensure system longevity and efficiency. A structured literature review highlights international best practices in panel orientation, battery technologies, inverter functions, and safety systems. Findings show that proper installation planning, component selection, and adherence to safety protocols significantly enhance performance, operational reliability, and user safety. The paper concludes that solar PV systems play a vital role in promoting energy

1. INTRODUCTION

In this article, we will explain how to install solar panels and detail their advantages. Due to rising energy costs, foreign conflict and damage to nature, solar energy has become a more popular way to generate energy. The largest benefit of solar energy is that it doesn't add any greenhouse gas emissions to the environment. Rather than adding to global warming like fossil fuels, solar energy is a clean and green source of power. Solar panels allow us to produce energy in a way that greatly decreases our impact on the environment and helps address the problems of climate change.

Solar energy can help us use less of our standard energy sources. Alternative energy sources such as coal and oil are limited in what is available and may soon cost more. Because it is renewable, solar energy can always be accessed and does not have the same large changes. This action could reduce our energy prices and give us a reliable way to meet our needs well into the future.

In addition, solar energy contributes to less political tension than are seen with traditional forms of energy. Since many fossil fuels are found in unstable nations, this often results in disputes over power sources and disputes over energy. Switching to solar helps us tackle these challenges and achieve secure energy supplies.

Anyone with the right knowledge, training and skills can find solar design and installation fairly easy. We will now cover the components needed for solar installation and what they do. A solar panel includes other components that are needed for its proper operation. These include

- a. Solar System
- b. Solar Panels
- c. Mounting System
- d. Battery
- e. Inverter
- f. Connecting Wires
- g. Appliances

The solar system is made up of the Sun and everything that orbits around it, including satellites. However, in this paper, we will only refer to the Sun and Earth as the solar system. Solar energy is the energy that originates from the Sun, reaching us in the form of light and heat. Nigeria has a land area of 923,786 square kilometres and receives approximately 1500×10^9 Mega Watthour (MWh) of solar radiation annually. The average daily impact is around 19 Mega Joules (MJ) per square meter per day. The duration of this radiation is typically around 6 hours per day, although it varies from about 4 hours in coastal areas and up to approximately 9 hours in the far North (<https://eyowhite.com/solar-energy-in-nigeriauntapped-potential-and-recent-progress/>).

A solid cell or photovoltaic cell is a device that converts light energy into electrical energy through the photovoltaic effect. This effect generates voltage across the P-N junction in a semiconductor through the absorption of light radiation. Devices that use this effect are called photovoltaic devices. Solar panels convert solar energy into electrical energy for the purpose

of charging batteries. To effectively use solar panels, they are connected in series, known as a string, and in parallel connections, known as an array, to collect a good amount of sunlight. This collected sunlight is capable of supplying the amount of electricity needed to run an entire household.

Solar panels are rated in different watts, depending on their use. In Nigeria, In Nigeria, the most common types of solar panels are polycrystalline and monocrystalline, with polycrystalline often preferred for its affordability and suitability for large installations, while monocrystalline is favored for its higher efficiency in smaller spaces. Sizes vary widely depending on energy needs, but common residential wattages range from **100W to 550W**. To install a 5-kilowatt solar system in a house, 10 plates of 545 watts would be required. Two types of connections are done while connecting the solar panels.

In a series connection, each plate is connected to its neighbouring plate, meaning that the positive terminal of one plate is connected to the negative terminal of the adjacent plate. This arrangement forms a string, allowing the voltage of each panel to add up to the total number of plates. [3] However, the current remains the same as that of an individual plate. This type of configuration is used when high voltage is required in the system. Side-by-side connections of plates link the positive terminals of each plate and the two negative terminals together. This means that the total voltage doesn't vary, but the total current has the sum of the separate plate currents. This method is important for providing high operating current.

Making these types of connections means ensuring that the solar panel's input voltage is lower than the inverter's PV voltage maximum. To make sure the voltage and current are evenly balanced, we assembled two arrays of five solar panels, joined them in parallel and attached them to the system.

A solar panel stand is made to support solar panels as shown in Figure 1. Their structure is often aluminum which enables them to resist problems caused by the weather. Solar stands keep the panels lifted so they can be angled right for maximum benefit. Solar panel wiring in series is shown in Figure 2.



Figure 1: Mounting the solar panels (ground and Roof-mounted)

Source: <https://solarssk.com/solar-ground-mounting-systems/>; <https://greentumble.com/types-of-solar-panelmounting-systems-and-their-installation>).

Solar panels wired in series

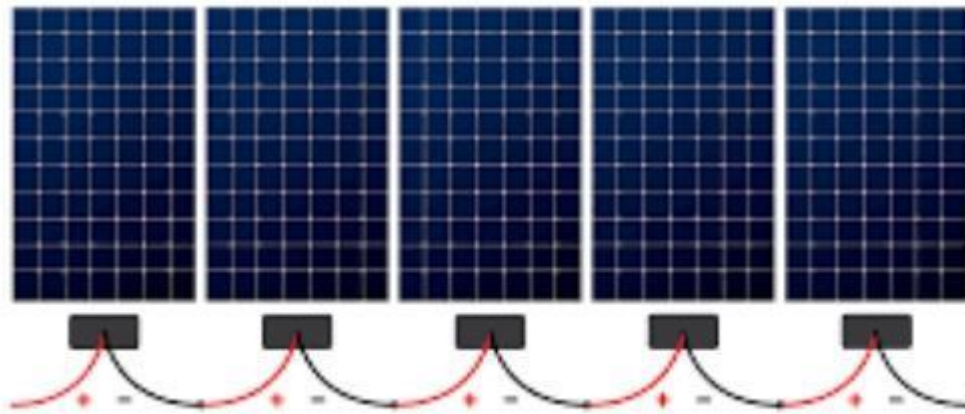


Figure 2. Solar panel wiring in series. (Source: <https://www.solarreviews.com/blog/you-wire-solar-panels-series-or-parallel>)

Solar panels wired in parallel

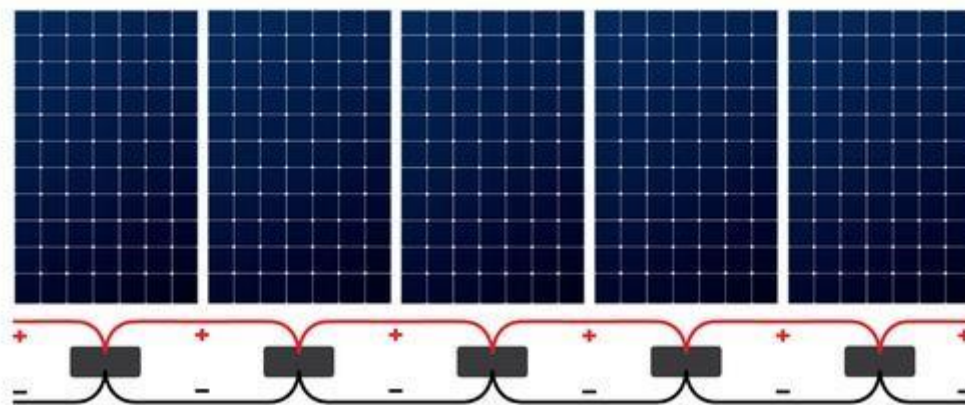


Figure 3. Solar panel wiring in parallel. (Source: <https://www.solarreviews.com/blog/you-wire-solar-panels-series-or-parallel>)

2. LITERATURE SURVEY

Solar photovoltaic (PV) technologies have rapidly expanded due to increasing energy demand, environmental concerns, and the need for decentralized power solutions. Studies show that solar energy reduces greenhouse gas emissions, improves energy security, and supports global climate change mitigation (IEA, 2020). The cost of PV modules has declined significantly over the past decade due to technological advancements and increased manufacturing scale (REN21, 2023). These trends have made solar installations more accessible for households, rural communities, and industries.

Proper installation remains essential for ensuring the performance and durability of PV systems. According to Kalogirou (2014), installation quality directly affects energy yield, system lifespan, and user safety. Therefore, understanding system components—panels, batteries, inverters, wiring, and mounting structures—is necessary to guarantee optimal function and compliance with electrical standards.

Solar electricity generation largely depends on the angle and direction of solar panels. Research shows that tilt angles between 20° and 35° provide optimal yearly energy production in regions

with high solar irradiance (Muhsen et al., 2017). Similar findings apply to Pakistan and other tropical regions, where 20°–30° tilt is considered ideal (Shukla et al., 2016).

Mounting systems—including rack, roof, and ground mounts—anchor panels securely while ensuring proper ventilation and alignment (Razak et al., 2016). Aluminum and galvanized steel are commonly used due to their durability and resistance to corrosion. Proper mounting prevents wind uplift, water penetration and structural failure, especially on rooftops (Kalogirou, 2014).

PV cells operate based on the photovoltaic effect, producing direct current (DC) electricity when exposed to sunlight (Sharma & Kumar, 2020). To increase voltage or current, solar panels are wired in series or parallel configurations. Series connections increase voltage while maintaining current, whereas parallel connections increase current while keeping voltage constant (Walker & Brown, 2019). The literature emphasizes the importance of maintaining voltage levels below the inverter's maximum input rating to avoid damage.

Combiner boxes, junction boxes, and appropriate cabling are critical for merging solar outputs safely (Ramabhotla & Natarajan, 2018). International standards such as the National Electric Code (NEC) mandate proper conductor sizing, insulation, surge protection, and grounding to ensure safe operation (NEC, 2020).

Battery storage is essential in off-grid and hybrid solar systems. Two broad categories dominate literature: lead-acid and lithium-ion batteries. Lead-acid batteries—including flooded and sealed types—are economical but require ventilation and regular maintenance (Bahramipناه et al., 2018). Deep-cycle batteries can discharge up to 80% of their capacity without damage, making them suitable for PV applications.

Lithium-ion batteries offer higher efficiency, longer lifespan, deeper discharge, and better energy density, though at higher cost (Mao et al., 2018). Temperature variations significantly impact battery health, and studies recommend maintaining storage temperatures around 25°C to prolong battery life (Riffat & Cuce, 2018). Proper wiring, ventilation, and safety precautions reduce risks such as thermal runaway, gas emissions, and electrical fires.

Inverters convert DC power from solar panels into alternating current (AC) suitable for homes and the grid. Modern inverters integrate monitoring systems, safety features, and automatic shutdown in hazardous conditions (Zhang et al., 2019). Three main inverter types dominate installations:

- *String inverters*: cost-effective and widely used
- *Micro-inverters*: improve performance where shading occurs
- *Hybrid inverters*: used in storage-based systems

Grid-tied inverters synchronize with grid electricity to ensure safe operation and enable net metering (IEA PVPS, 2021). Overvoltage, ground-fault and arc-fault protection mechanisms reduce hazards and system failures.

Solar installations involve electrical work, heavy lifting, and roof activities; hence safety is a core requirement. International standards emphasize the use of gloves, insulated tools, harnesses, grounding conductors, and fall protection systems during installation (NEC, 2020;

NJRER - Vol. 1, No.4 - 2025: Design, Installation Procedures and Operational Considerations for Domestic Solar Photovoltaic Systems: Components, Wiring, Safety and Performance Requirements; by Mumah et al. OSHA, 2019). Research on PV system failures confirms that improper grounding, loose connections, and poor wiring are leading causes of fires and electrical accidents (Brooks & Dunlop, 2018). Planning requirements include system design evaluation, load assessment, shading analysis, wiring diagrams, and component compatibility checks (Razak et al., 2016). Safety assessments ensure electric shock prevention, surge protection, battery gas ventilation and structural integrity of mounting frames.

Maintenance improves long-term performance. Dust, debris, and shading can reduce output by up to 25% if not regularly addressed (Kazem et al., 2016). Studies recommend cleaning panels several times per year depending on climate conditions. Inverters and electrical components require periodic inspections to ensure no loose connections, corrosion or overheating (Kalogirou, 2014).

Monitoring systems track production levels, voltage, current, and faults in real-time, allowing early intervention and improving system reliability (Zhang et al., 2019). Vegetation trimming and professional maintenance also extend system lifespan.

Daylight creates power with solar panels which is then stored in batteries ready for use. The stored energy is sent to the panel to keep up the output when it doesn't produce enough power. Any solar system relies most on its batteries, but they are the easiest to damage. For this reason, the battery should have enough Ampere-hour (Ah) capacity to meet the system's power requirements which are usually greater when the skies are overcast.

There are two types of batteries: deep cycle discharge (used in photovoltaic (PV) systems) and shallow cycle discharge (used in cars). The daily discharge rate of shallow-cycle batteries should not exceed 10% to 20% of their Ah capacity. Discharging them beyond this point without recharging them may shorten their lifespan. In contrast, deep-cycle batteries can discharge between 60% and 80% of their Ah capacity. It's important to remember that a battery with a 1-amp discharge rate will have a larger Ah capacity than one with a 4-amp discharge rate. For instance, a 100 Ah capacity battery can provide 1 amp of power for 100 hours. To generate enough electricity to power the entire residence, two 24-volt 200 Ah batteries wired in series are used in the 5KWatt system.

An inverter is a key component of a solar electric system because it transforms the direct current (DC) electricity produced by solar panels into alternating current, or AC, electricity, which may be utilized to power lights, appliances, and other electrical equipment in residences or commercial buildings. The function of an inverter in the solar power setup is broken down as follows:

DC to AC Conversion: The solar panels in your home generate direct current (DC). Most homes and the grid itself depend on alternating current (AC). An inverter is used to change the DC electricity made by solar panels into AC, so it can be used by the household appliances and sent to the electrical grid.

Voltage Regulation: They also modify the voltage so that the power generated by solar is suitable for both the grid and the devices working in your home. As a result, equipment in the electrical system continues to operate safely and no unnecessary damage happens. Grid-tied solar panels regularly use inverters to match the electricity generated from the cells with that

on the electrical grid. With this synchronization, the solar system operation is secure and it can put extra power back onto the grid. (Kalogirou, 2023) Monitoring and Control: There are many inverters today that give people access to real-time monitoring of their photovoltaic system. It means following the solar panel system's total energy output, the energy being consumed and the way the system works. Some inverters also come with online systems or apps so you can control and watch your solar system from anywhere.

Safety Measures: A range of safety features is built into inverters to protect solar power systems and avoid electrical issues. Proper operations and safety of the system can be protected with ground fault, overvoltage and overcurrent protections. For power to pass safely between all the parts of a solar system, connecting cables are very important. Here, I explain the different kinds of wires and what role they play in a standard solar installation.

Solar Panel Wiring: To obtain suitable voltage and current, solar panels are often arranged either in series or parallel. Copper wires cover each solar panel and are often coated to make them safe against shock. Solar panel electricity is carried by the cables to be put together at the junction or combiner box.

Combiner Box Wiring: In big solar systems, combiner boxes gather each panel's wiring, then send it to the inverter. The correct electrical cords connect each solar panel string to the contacts in the combiner box. Following this, the mixtures of DC from the combiner box go to the inverter (Kabir et al., 2018).

Inverter Wiring: DC input terminals are used to link the inverter to the solar panels. Using the proper connections, wires transporting the DC current from the photovoltaic cells are linked to these terminals. The building's electrical panel receives the alternating current (AC) that the inverter has transformed from direct current (DC).

Electrical Panel Wiring: The building's electrical panel, sometimes referred to as the distribution board or breaker box, receives the AC energy generated by the inverter. Usually, insulation and electrical wires with the proper gauge are used for this. The circuit breakers or fuses in the panel, that distribute power to different circuits throughout the building, are connected to the wires.

Grid-Tied System Wiring for Grid Connections: Adding solar systems to the utility grid requires wires in grid-tied configurations. Once on the grid, the solar-powered AC electricity takes over powering the building when it is synchronized with the grid.

Grounding Wiring: The safety of a solar power system is achieved mainly through correct grounding. To prevent electric shock or fire due to any stray electricity, grounding wires are hooked into the solar panels, inverter systems and a variety of metal parts.

Your safety and the efficiency of the solar system will be best served if you adhere to both manufacturer and local electrical rules when wiring everything together. Moreover, the safety of the solar system over the long term and the reduced chance of electrical risks are both possible with the use of top-quality parts and suitable installation approaches (Hernández-Callejo et al., 2019)

In a solar system installation, the kind of appliances chosen can make a big difference in how much energy is used and how efficient the system is. Before installing appliances, keep the following suggestions in your mind:

Energy Efficiency: Use equipment that uses the smallest amount of electricity. Buy only appliances that have been certified for energy efficiency by ENERGY STAR. Solar-powered appliances help you get the most out of your system and decrease your energy bill.

Grid-Tied and Off-Grid Systems: Off-grid systems differ from grid-tied systems, so your solar choices will affect the appliances you buy. Because these homes are off the grid, solar power runs them and the appliances used in such homes are usually made to be power efficient and suit off-the-grid living. You can connect regular home appliances to grid-tied panels, but it is smart to pick energy-saving ones to use less electricity.

Size of Appliances: Be certain that the appliances you intend to use are sized according to your solar energy system. To find out how much power an appliance uses, count its wattage or kilowattage and the length of time it is running. You can simplify your analysis by looking at how much your solar system and battery storage can supply shown in Figure 4.

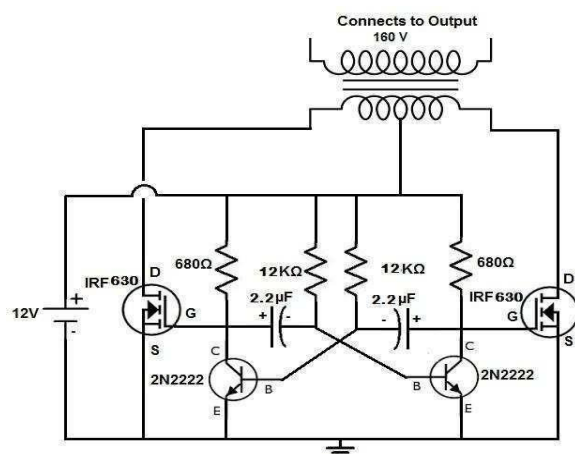


Figure 4. Schematic of appliances connection.

Load Control: One way to make better use of your solar system's power is to install and use load control methods. A lower total demand for power might be achieved by carrying out energy-intensive activities at the brightest hours or by turning on lower energy-use appliances. **Battery Compatibility (Off-Grid Systems):** Choose appliances matched to your battery voltage and charger if you are not linked to the main grid. It is possible that a few pieces of equipment may work better with conventional electrical sources than they do with battery-powered solar and these can be altered or added for better operation.

Backup Power Requirements: Get appliances that work with backup power, so you can keep using them if the electricity is often not available. Even when the grid fails or sunshine is limited such systems will ensure critical services continue.

Appliances That Work with Solar Power: A limited number of appliances are specially built to be powered by solar electricity systems. Examples of solar energy devices are solar-powered lights, solar freezers and solar water heaters. Getting these tools can make your solar installation run more smoothly and help the environment. Make sure the choices in monitoring

and control on your appliances match your solar panel setup. As a result, you can check your energy use, improve your efficiency and turn on or off equipment from another location to save energy (Bird et al., 2016)

3. STEP-BY-STEP INSTALLATION OF SOLAR PANEL

There is a sequence to installing a solar system, starting with designing, planning and then mounting the panels and joining the system to your home's electrical grid. This section will walk you through the whole process:

In the planning stage, your energy needs are studied closely and solar panels are evaluated for suitable installation on your property. Remember to think about the area you have, the shade in your yard and where the roof is facing. Define the system's size, what kind it is (options include ground-mounted and rooftop) and how it will be connected to the electric grid (offgrid or grid-tied). Get the necessary consent from utility firms, organizations for homeowners or city agencies before starting. A properly designed solar system yields more energy, complies with rules and fits what you require.

Select your solar panels by considering how efficient they are, their expected lifespan, the kind of guarantee they offer and how they look. Make sure to check how efficient the units are, what the manufacturer is known for and if the solar panels are monocrystalline or polycrystalline. Work out the number of panels needed to accomplish your energy goals. Talk to solar professionals or engineers to help you pick the best solar panels for yourself and your budget. Make sure the solar system you get is compatible with your chosen system mounting method and the inverter you want.

a. Inverter Installation

Depending on your panel design and energy needs, choose the right inverter type (string inverter, micro-inverter, etc.) and capacity. Place the inverter next to the electrical panel in a well-ventilated location. By utilizing DC wire and according to electrical rules and manufacturer requirements, plug the inverter into the solar panels. To transform DC power from the panels into useful alternating current power for your house or the grid, efficient inverter installation is essential.

b. Mounting the Panels

Getting the most sunlight means placing and positioning your solar panels smartly. Properly mounting the equipment will ensure your roof or ground system stays intact against weather elements. Install the solar panels so they are guided by the designer's plans for the angle and spacing. For a solar energy system to work well and last over time, panels must be installed correctly.

To make sure energy does not get lost and harm doesn't occur, route DC wire from the solar panel array to the inverter securely. Connect the inverter to the electrical panel by using conduit that meets the strictures of local electrical rules. Before attaching the inverter outlet to your home's electrical system, always take all the needed precautions and ground it.

c. Electrical Connections and Wiring

Solar panels should be connected to the inverter by using DC wire. In addition, attach and arrange the cables so that they do not lose energy or put you at risk. Be sure to install the conduit according to local electricity rules when you connect the inverter to the electrical panel. It is

important to ensure you have grounding and have taken the right steps before you link the inverter outlet to your house's electrical system. For safe and building code-approved wiring, knowing electrical workings is often necessary.

d. Grid Connectivity

Work with your utility company to meet their rules and procedures for setting up solar energy systems on your grid. A bi-directional meter is needed to see how electricity moves from the solar panels to the grid. Team up with the utility company to get all the permission needed and make sure you adhere to interconnection requirements. Being linked to the grid lets you earn credits from net metering, as your extra solar energy goes to the grid (Al Garni, et al., 2016).

e. Examining and Verifying

Check and follow the rules by carefully testing your solar energy system after installation. Check each part such as panels, inverters and electrical links, to see how it works. Work with the suppliers and local authorities to check that codes, rules and connection demands are met during the inspection.

f. Maintenance and Regulation of Solar System

For photovoltaic or PV, panels to operate reliably and efficiently over the long term, maintenance is essential. The following is a thorough overview of solar PV system maintenance procedures:

g. Regular Cleaning

In time, the panels can become covered by dirt, bird and other waste, lowering their effectiveness as they block sunlight. Based on guaranteeing full sunlight usage, cleaning the panel regularly is necessary to keep your solar energy bottom line at its peak. Brush the panels clean by hand using a little bit of water, sparkling water and a water-based detergent solution. The number of cleanings will depend on what surrounds your panels and the weather, but experts suggest washing them several times each year. You should plan regular cleanup after there is a lot of rain or strong winds stirring up dust. Cleaning your solar PV system on a regular basis will ensure its reliable efficiency and avoid energy loss (Abdmouleh et al., 2015)

h. Inspection of Panels

You should inspect your solar panels from time to time to catch and fix any worries before they shorten the system's lifetime or its performance. During your check, watch for chips, cracks and any color changes that might suggest something is wrong. Look at parts of the roof that are next to large neighboring objects, plants or obstacles to see if any shade is preventing the panels from working their best. To ensure everything is secure, the frame and its mount are part of every inspection. Rapidly handling problems found is necessary to prevent added damage and keep the installation running well. Key checkups can keep your solar energy system in top shape for a long time by helping you address Issues early.

i. System Performance Monitoring

If you track your solar PV system's operation, you can follow its energy production, identify trends and notice if anything is working differently than it should. Place devices that measure energy output, monitor how available the system is and check for factors that can reduce the system's performance, for example, soiling or shading. Updates and watches performance reports day by day, to watch for any problems and learn about the health of the system. As

action is needed fast in some cases, monitoring systems can also warn when they see abnormal situations. Supervising how your system functions can improve its outputs, show areas where it may struggle and ensure it keeps running efficiently for many years.

j. Testing Electrical and Inverter Components

The solar panels make DC power and the inverters and electrical equipment are needed to convert this into AC electricity for your house or the grid. Proper performance and working can only be ensured for inverters, wiring and electrical connections through routine testing. Regularly inspecting your sound system will help you spot loose parts, signs of rust and overheating. If you want your test equipment to perform well, reference both the user guidelines and industry standards when checking inverters and assemblies. Adapt the inverters when needed for maximum results and safety compliance. Testing inverters and electrical pieces often allows you to identify faults early and solve them before they become serious (Denholm et al., 2015)

k. Trimming Vegetation

Solar panels work less effectively when shade is cast on them by trees, bushes and shrubs. The plants near the solar panels should be carefully cut back on a regular schedule to avoid them blocking too much sun. Cut back branches that block the light from your solar panels in the hours when they get the most sunlight. Ensure that nothing is next to the panels so they get all the sunshine they can. If you want to get more sunlight on your solar panels, consider planting plants that won't grow tall enough to block the light. Keeping vegetation from your solar panels will allow your system to generate a regular amount of energy and ensure your initial cash outlay is well spent.

l. Professional Maintenance

Though homeowners may manage a lot of the upkeep themselves, it's important to arrange frequent checks by certified techs or experts to keep a solar PV system operating well. Because of their training and the unique equipment, they have, experts can inspect large structures clearly, detect possible problems and perform the necessary corrections or additions. Maintenance crews may check every part of the system, examine the electrical connections and test how everything is working during a visit. They are often able to provide useful advice for improving the system's performance and handling any problems. Reduce costly maintenance by having documents to keep track of all your maintenance work and following the instructions given to you by the manufacturer. If you use skilled maintenance, you can expect a lasting system, less downtime and guaranteed reliability in your solar energy system.

4. SOLAR PANEL INSTALLATION PLANNING & SAFETY

The key to any successful solar panel installation project is having a clearly constructed plan with measures in place to ensure the safety of everyone involved.

In fact, there are a few things an Installer can do before an Installer even unpack the system to make sure the solar installation process goes smoothly from beginning to end. These include:

- Purchasing materials that are not included in the shipment (wiring, tools, etc.)
- Staying organized while unboxing the system
- Inspecting the shipment to ensure nothing is missing or damaged
- Reviewing safety guidelines for installing the system

4.1 Materials needed

Wiring

The electrical wiring diagram will outline the size and length of wire needed for the project. Ask for a copy of the wiring diagram to source materials from the local hardware store.

Junction Boxes & Splices

- Use insulated lugs or other approved splicing devices (no wire nuts for DC splices).
- All junction and splice boxes must meet the voltage and amperage requirements for the circuit they are part of.
- Outdoor boxes must be rated for outdoor use.
- Ground splices typically require an irreversible splice.

AC Breakers & Sub-Panels

AC breakers are required to import/export AC power from the equipment.

- Circuit breakers have several different mounting options. Check the AC breaker panel for a list of compatible options.
- Dedicated sub-panels are often used to combine AC solar circuits. Sub-panels do not allow for load breakers to be placed inside of them.
- AC sub-panels must be sized with enough headroom to cover the output coming in from the solar circuits.

AC Disconnects & Fuses

- Most systems require a lockable safety disconnect.
- A conventional connection that backfeeds the grid will require a non-fused manual AC Disconnect. This may be included with the system—check the parts list on the quote/order form.
- A line-side tap connection will require a fused manual AC disconnect. The fusing provides the necessary overcurrent protection for the circuit.
- AC disconnects must be mounted outside, generally within 10 feet or in direct line of sight of the main billing meter. Check with the AHJ (Authority Having Jurisdiction) for specific details on placement requirements.

PV Meters

- If a grid-tied system is being installed, the utility may require a dedicated PV meter to measure production coming from the solar array.
- In many cases, an Installer just need to install the meter socket or base. The utility company will install the meter face once an Installer are approved to activate the system.
- Contact the utility company for a list of approved meter sockets

Conduits & Meters

- The NEC (National Electric Code) requires solar wiring to be transitioned to conduit before leaving the array. EMT (electrical metallic tubing) is required unless otherwise specified.
- You can use larger conduit than specified if necessary, to ease the conductors in. **Never** use smaller conduit than what is spec'd in the plans.

EMT vs. ENT Conduit

EMT is a thin-walled, rigid raceway that must be grounded. It is almost always made out of steel. EMT must be used unless the local authority approves ENT conduit for the project.

ENT is a non-metallic, pliable raceway that does not need to be grounded and can be bent by hand. ENT is more cost-effective and easier to work with, but is not allowed under most building codes.

Mounting Materials

Ground Mounting — Ground mounts require concrete, form bracing and 2- or 3-inch mechanical tubing. Since these materials are costly to ship, it's cheaper to source them locally. the racking report will specify the total linear feet of pipe and cubic yards of concrete required for the project.

•
The Installer will also need lumber to build a frame to hold the pipes in place while the concrete cures. The ground mount section of this solar panel installation guide also contains more information on building a substructure.

Roof Mounting — Buy several tubes of roof sealant to prevent leaks and wind damage. Make sure an Installer get a sealant that is appropriate for use with the roof material.

Also, consider buying a good drill if an Installer don't own one. an Installer will be using a long 1/8 inch drill bit and a 7/16 inch deep socket for lag bolts.

Unboxing

After the system arrives, there is a 24-hour window from delivery to submit shipping claims to Unbound Solar. Unpack the system immediately when it arrives to check for damage or missing parts.

- Find a clean, open space where an Installer can unbox and inspect the equipment.
- Place loose parts into resealable plastic bags and label them so they don't get lost.
- Check the contents of the shipment against the packing list to verify everything is there.
- If there are any missing or damaged items, take photos for reference and contact Unbound Solar immediately to fix the issue.
- If an Installer don't plan to install right away, place batteries on a charger ASAP. Batteries can fail if they sit for an extended period of time without charging.
- If an Installer bought micro-inverters or power optimizers, keep any documentation with stickers or QR codes. These will be used to create an array map later on so an Installer know which unit controls which panel.
- *Staying organized while unboxing can make installation easier.*

4.2 Safety Considerations

Since solar installation involves heavy lifting, electrical work, and potentially climbing on the roof, ***safety should be prioritized at all times***. After all, what good is a shiny new solar system if the installer is not around to enjoy its benefits?

Use our solar panel installation guide for ensuring the safety of yourself and others throughout the installation process.

Protective Equipment

Solar equipment can cause cuts, scrapes, lacerations, gouges, and puncture wounds. Use the proper equipment and remember to take breaks to avoid getting fatigued.

- Wear eye protection, gloves, and closed-toe boots at all times.
- Remove all metallic jewelry, including watches.
- Wear long sleeves when mixing concrete to avoid burning the skin. Use a roof anchor and safety harness for roof work.

Fall Protection (Roof Mounts)

If an Installer are installing a roof-mount system, fall protection is required any time an Installer or the helpers are on the roof.

- Install roof anchors.
- Use a safety harness attached to the anchor any time an Installer are on the roof.

- Roof-ready boots with flat soles can help get a grip on roof shingles, tiles, or metal.
- Consider renting scaffolding and/or a boom-lift to make it easier for people and equipment to get to high places.
- Be aware of weather conditions which may make rooftop work temporarily unsafe.

Dig Safety (Ground Mounts)

Even if the feet are firmly planted on the ground, there can still be danger afoot. If you're ground mounting the panels, be sure to always observe the following safety precautions.

Call the local authority before starting any digging projects to avoid hitting buried gas or electrical lines.

- If an Installer use a concrete truck, don't drive over septic or drainage lines, and avoid low-hanging power or phone lines.
- Avoid contact with wet concrete, which can cause caustic burns on bare skin. Wear gloves, eye protection, and long sleeves.
- Use an N-95 respirator mask if an Installer are mixing the own concrete to avoid inhaling harmful chemicals.
- If an Installer use heavy equipment, get training on how to operate the equipment, or have an experienced operator on site.

The Installer should wear an N-95 respirator mask to avoid breathing unsafe chemicals when mixing concrete.

Electrical Safety

- Remove all metallic jewelry, including watches.
- Keep a multimeter on hand. Check conductors and terminators to confirm there are zero volts present before proceeding.
- Ensure that all wires are stripped and/or terminated properly using a torque wrench/driver when necessary.
- Route wires away from sharp edges and pinch points that could damage the wire.
- *Keep a multimeter handy to ensure no voltage is present before an Installer work on the system.*

Heavy Lift Safety

- Plan the lift; know what an Installer are moving and where before lifting.
- Have two or more people carry panels in heavy winds to avoid accidents.
- Be sure the footing is stable.
- Lift with the legs by squatting so an Installer don't put added stress on the back.
- Avoid twisting while lifting and keep the weight close to the body.
- Ask for help when an Installer need it and wait for help when an Installer have to. If an Installer aren't sure whether an Installer can lift something alone, err on the side of caution.
- Use a hoist or crane to lift heavy equipment if necessary.

4.3 Wiring & Electrical

Wiring the electrical run is a critical part of any solar installation, and the specifics differ based on the kind of system you're installing. This section of the solar panel installation guide will outline how to plan the wiring run, ground the system, and install a backfeed breaker to connect to the utility grid if needed.

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Wiring Management

Wiring management is an important (though often overlooked) consideration that will make the solar panel installation easier in the long run. Here are a few tips to keep in mind:

- Plan the wiring run in advance so the wires don't interfere with access to the array.

- Use wire clips to secure the factory wire leads in place so they don't move in the wind or touch the roof (required under the National Electric Code). Wire clips allow an Installer to run the wires along the rails or the frame of the solar panel.
- Many solar components use spring clamps, which require an Installer to push down on a metal bar (or another mechanism) to open the terminal so an Installer can seat the wire. Once the wire is firmly seated, release the spring, which clamps the wire in place.

Electrical Connection

The actual path of the wiring system will differ based on the type of system you're installing. Below are some summaries showing how wiring is connected for each system type:

Grid-Tie Wiring Path (Centralized SolarEdge / SMA Inverter)

- PV strings to junction box
- Junction box to inverter(s)
- AC Out to main/sub-panel

Grid-Tie Wiring Path (Enphase Micro-Inverters)

- PV panel to micro-inverter
- Micro-inverter to trunk cable
- Trunk cables to junction box
- Junction box to main panel

Off-Grid Wiring Path

- PV strings to combiner box
- Combiner box to charge controller(s)
- Charge controller(s) to battery bank
- Battery bank to inverter(s)
- Inverter(s) to load panel
- The generator also wires into the inverter (separate from the solar circuit)

Array Maps for Micro-Inverters/Optimizers

If the system uses micro-inverters or power optimizers, it's a good idea to make an array map that identifies where each device is located in the array. These products come with stickers, QR codes or other unique identifying markers. Attach these stickers to a piece of paper to make a map of the array.

During commissioning, plug this array map into the monitoring software to tell it the location of each panel in the array. This allows the software to properly monitor production and report defective equipment. Figure 5 shows an array map for micro-inverters/optimizers.

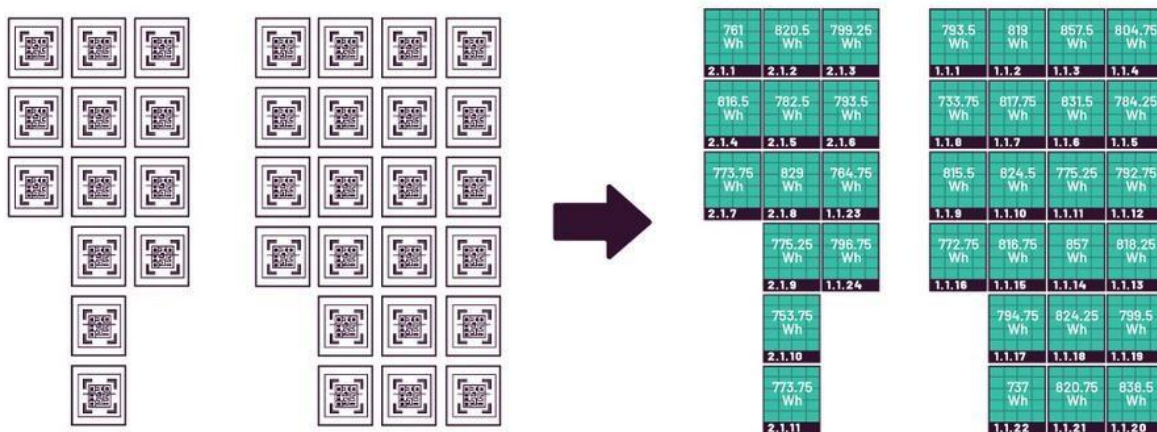


Figure 5. Array Maps for Micro-Inverters/Optimizers

Off-Grid DC Wiring

Off-grid systems tend to have more wire terminations and work with higher amperages. Check all AC, DC, and communication connections to be sure everything is properly connected and torqued.

- Mark connections with a paint pen after an Installer tightens them so an Installer knows which connections have been torqued.
- If an Installer brings combined DC power from a solar panel array to a power center, take care to terminate the solar positive wire at the SOLAR INPUT (+) busbar, not the DC BATT (+) busbar.
- *Be careful not to confuse the solar input with the DC battery input.*
- After wiring, check terminals or busbars with a meter and determine they are operating at a safe voltage before proceeding with the rest of the build.

Planning Electrical Route

The Installer would want to plan the electrical run beforehand, taking into consideration which type of system you're installing. Again, safety is of the utmost importance: make sure an Installer wears the recommended protective equipment (gloves, eye protection, and closed-toe boots) and install the wiring according to the wiring diagram.

PV Sub-Panels

- Systems with multiple inverters can use an AC sub-panel to combine the AC circuits into a single set of conductors.
- Dedicated solar sub-panels must not contain any load breakers.

Roof Mount Electrical Route

- You can run the wiring through the attic to hide it from view, but make sure it is accessible to connect to the array, breaker box, panel, meter, and other parts of the system.
- Use cable clips to secure wiring from solar panels and micro-inverters/power optimizers. The clips should hold the wires in place during strong winds.
- Do not allow exposed wiring to make contact with the roof surface.
- Run the wiring from the solar source to a junction box, then transition to the conduit run. The wiring must remain in the conduit run until it reaches the inverter (for grid-tie systems) or charge controller (for battery-based systems).

-
- Use conduit mount flashings to secure rooftop conduit runs in place.
- If possible, use conduit penetration flashings to transition conduit into the attic to hide it from view.
- *A conduit run held in place by a Quick Mount conduit penetration flashing.*

Ground Mount Electrical Route

- Use cable clips to organize exposed wiring under the array. They should be secured against strong winds and kept out of the way so they don't interfere with maintenance.
- Call the local authority before starting any digging projects to avoid hitting buried gas or electrical lines.
- If an Installer use a concrete truck or other heavy machinery, don't drive over any buried gas lines, plumbing, or septic systems that could be damaged.
- The wiring diagram will tell an Installer how deep to dig the trench, the size/type of wiring and conduit required, and the total distance of the run. It will also take voltage drop/voltage rise into account. Refer to it often as an Installer plan the run.

Mounting the Inverter

Inverter installation can look different depending on the solar system type. Inverters for gridtie systems can be wall-mounted indoors, outdoors, or rigged on the back of a ground mount substructure. Off-grid inverters must be wall-mounted indoors.

Wall-Mounted Inverters (Grid-Tie & Off-Grid)

- Follow manufacturer guidelines for installation clearances to ensure that the equipment can cool effectively.
- Inverters with integrated disconnect switches must be mounted less than 2 meters (6.5 feet) off the ground. The exception to this is if the system design contains another switch that meets the AC disconnect requirements of the NEC (National Electric Code).
- If installed in a garage, any ignition source (inverters and disconnects) must be at least 18 inches off the ground.
- If installed outside, keep the inverter out of direct sunlight and clear of any sprinkler systems.

Inverters Mounted on Ground Mount Substructure (Grid-Tie Only)

- Mount the inverter higher than 36 inches off the ground to avoid mud splatter during heavy rains.
- Keep the inverter out of direct sunlight.
- Use threadlocker on the hardware that secures the inverter bracket to the support structure.

Grounding the System

Properly grounding the electrical components of the solar system is an essential step. For one, grounded electrical connections reduce the risk of shock, power surges, and build-up of static electricity. Moreover, if the circuit fails, grounding allows a safe pathway for fault current. Metal parts of an electrical system must be connected (bonded) to the ground, and conductive materials (EMT, metal boxes, etc.) must be grounded together. The latter ensures that each piece of equipment in the system shares the same resistance to the ground, or "ground reference."

The following sections of our solar panel installation guide outline grounding methods and some extra tips to help an Installer ground the system properly.

EGC and GEC Grounding

- *EGC (Equipment Grounding Conductor)* is the green or bare copper wire that connects the racking hardware, metal enclosures, and EMT conduit together.
- *GEC (Grounding Electrode Conductor)* is the wire connecting the ground rod to the electrical distribution service. In most AC power systems, the neutral conductor has a single bonding point where it is connected to the ground.
- Neutral to ground bonds can be found in generators, breaker distribution panels, power centers, and other equipment. the system should only have a single neutral-to-ground bond.
 - A DC negative to ground bond is necessary for any system. It is included with any system that features “ground fault protection.”

Integrated Grounding

- IronRidge’s UFO (Universal Fastening Object) and bonded fasteners make it so that an entire solar array can be grounded with a single grounding lug.
- Other mounts, like pole mounts, will not have integrated grounding solutions. Each panel and racking component needs to be grounded using UL listed grounding clips or lugs.

Backfeed Breaker Installation (Grid-Tie Only)

Grid-tie solar systems require a backfeed breaker, which is a device added to the main breaker panel. This enables the system to feed the power it generates into the utility grid.

A solar backfeed breaker is installed at the opposite end of the breaker panel from the grid input breaker. An Installer may need to re-arrange circuits in the breaker panel to put the solar breaker in the last position.

If an Installer need to make room for an extra breaker, Tandem Breakers make a single slot on the breaker panel that serves two circuits on the same phase (these are different from 120/240volt multi-phase breakers).

How to Install a Backfeed Breaker

If you're not comfortable working on the breaker panel, don't be afraid to call a professional electrician. Many of our customers DIY their solar array and bring in a professional for the electrical work.

That said, if you're comfortable (and safe!) with this kind of work, here's a step-by-step outline of how to get a backfeed breaker hooked up:

1. Determine the proper breaker size and source a breaker that will work with the existing panel. It's ideal to use the same make and model as other breakers in the panel.
2. As an Installer work, stand on plywood or a rubber mat to insulate yourself from the ground. An Installer will want to gather insulated tools and a voltmeter with fresh batteries before an Installer begin.
3. Shut off the branch circuit breakers one at a time.
4. Shut off the main circuit breaker.
5. Remove the panel cover.
6. Test all the wires with a multimeter to make sure there's no current before proceeding.
7. Disconnect the wire of the breaker you're removing from the load terminal.
8. Carefully pull out the old breaker, paying close attention to how it's positioned.
9. Insert the new breaker and push it into position.
10. Attach the properly stripped solar circuit wires to the breaker terminals and torque into place.
11. Inspect the panel for any other problems. Tighten any loose terminals.
12. Replace the panel cover.
13. Turn on the main breaker.
14. Turn on the branch breakers one by one, leaving solar for last. Do not turn on the solar backfeed breaker until after inspection and interconnection agreement are completed.
15. Test the breakers with a multimeter to make sure everything works.

4.4 Mounting the Solar Panels

With a solid wiring & electrical plan in place, the next step is mounting the solar panels. Whether an Installer decide to roof mount or ground mount the array, the following sections will outline everything an Installer need to build a solid mounting foundation.

Roof Mounting

If an Installer decide to roof mount the solar panels, there are 5 main steps to take:

1. Locate and mark roof rafters
2. Install roof attachments to secure the rails in place
3. Install racking rails
4. Lift panels on to the roof

5. Mount panels on the rails

Step 1: Marking Roof Rafters

For a sturdy foundation, roof-mount flashings should be bolted to the roof rafters. There are a couple of methods for locating where exactly the rafters are:

Visual Location

Look for rafters under the eaves of the roof. If an Installer can't spot them, look for the nails that hold the fascia board and/or gutter to the ends of the rafters.

Echo Location

If it's safe, an Installer can get a feel for where the rafters are by walking around on the roof. The rafters will feel firm, while the space between them will feel a little spongy. an Installer can also use a rubber mallet to tap around on the roof and listen/feel for the rafters. This method is less effective on roofs with skip sheathing (a layer of boards that sit perpendicular to the rafters). The boards cover the rafters, which makes it difficult to know whether you've found a rafter or a skip sheathing board.

Exploratory Drilling

If none of the previous methods work, an Installer can drill exploratory holes in the roof to search for rafters.

- Start where an Installer plan to place the first flashing and drill a small hole in the roof.
- If the drill does not hit a rafter, bend a metal wire into an L shape and insert it into the hole.
- Rotate the wire to see if it hits a rafter.
- Once a rafter is found, measure 0.75 inches from the edge to the center of the rafter. Mark this location so an Installer can drill the lag bolt directly through the center of the rafter.
- If an Installer have attic access, an Installer can follow this process from the inside of the attic. Drill a hole on one side of the rafter, leaving the drill bit sticking through the roof so an Installer can locate it from the outside. Once an Installer climb on the roof, measure 0.75 inches from the drill bit to the center of the rafter to mark the location of the lag bolt.

Mark Rafters with Chalk Lines

Once an Installer mark both endpoints of each rafter, an Installer can connect them with a chalk line on top of the roof. This will give an Installer a visual indication of where to line up the flashings. The chalk will wash away the next time it rains, so don't worry about the lines being permanent.

- Attach the chalk line at the starting point of the line.
- Pull the string loaded with chalk out of the chalk reel.
- Secure the chalk line at the endpoint of the line.
- Use the finger to press the middle of the chalk line against the roof.
- Pull up on the line, then let go so it "snaps" against the roof. The impact will leave a temporary line of chalk for an Installer to work from. Do this on both sides of the point where an Installer are holding the line in place.
- Repeat until an Installer have marked the location of each rafter in chalk.

Step 2: Install Roof Attachments

With the location of the roof rafters marked, it's time to start installing the attachments that will secure the mounting rails in place.

Depending on the type of roof an Installer have, the process will differ, but we've included steps for the most common types below, along with some tips on spacing and layout for flashings.

Spacing and Layout Tips

The flashings should be spaced to align with the mounting holes on the solar panel. The distance between mounting holes will be listed on the panel spec sheet. Stagger the flashing layout so that they alternate between the top and bottom rail. Distribute the flashings evenly across all the roof rafters to spread the weight of the array across the entire mounting surface.

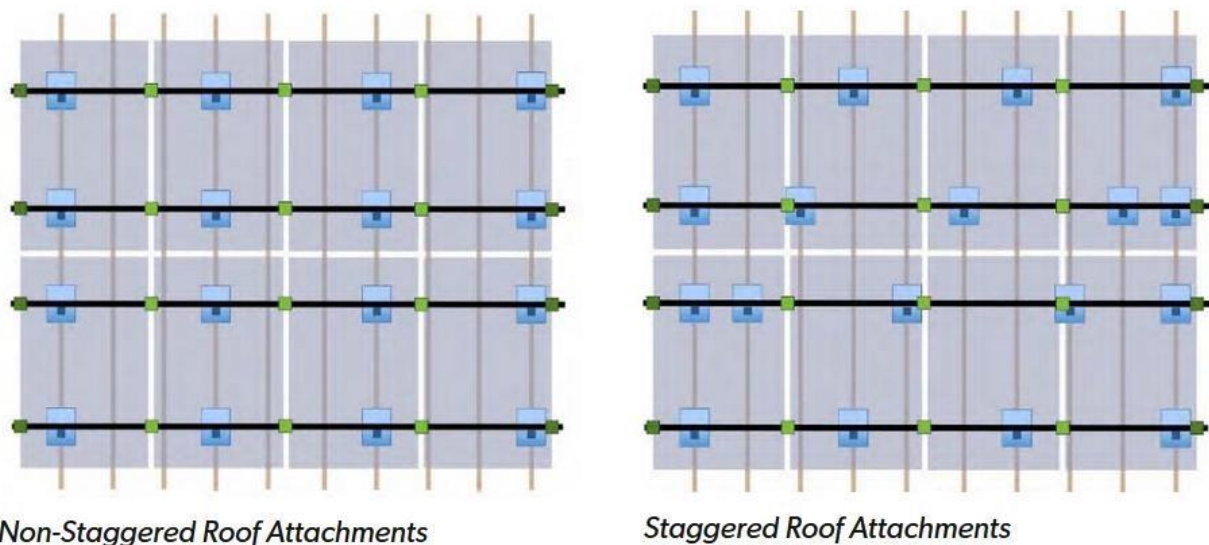


Figure 5. Layout for roof attachment

The layout on the left is more visually appealing, but all of the wind/snow load is concentrated on a few rafters. The staggered layout on the right makes for a more structurally sound array.

Composite / Asphalt Shingle Roof

Our systems commonly use the Ironridge Flashfoot 2 flashing system for composite/asphalt shingle roofs, so we've included installation instructions for that product here. If the system uses different flashings, consult the manufacturer's manuals for installation instructions.

1. Gently break the seal between the shingles with a flat bar.
2. Remove any nails that would prevent an Installer from sliding the flashing under the shingle.
3. Slide the flashing under the shingle, lining up the hole with the marked rafter.
4. Tuck the flashing into place. The bottom edge of the flashing should sit above the drip line (the bottom edge of the shingle). The top edge of the flashing should reach into the third course of shingles (see reference image).
5. Mark the drilling location through the hole in the flashing.
6. Remove the flashing and drill a pilot hole using a 7/32 inch drill bit. Double-check to make sure the hole is in a rafter.
7. Fill the hole with roof sealant and place the flashing.
8. Use an impact drill with a 1/2 inch deep socket to tighten to the flashing manufacturer's specifications.

Metal Roof

Metal rooftops use roof clamps that either attach onto a seam or bolt into the structure. There are dozens of clamp configurations and each one is a little bit different, depending on the rooftop. Check with the clamp manufacturer for specific installation instructions.

Tile Hooks

Tile hooks slide under the shingles and fasten to the rafters. A vertical hook provides clearance from the roof tiles. The racking rails bolt into slots in the tile hooks. Tile hook installation may require some cutting or grinding of tiles, but they are generally universal and work on most tile rooftops.

Tile Replacements

If an Installer bought a tile replacement system, an Installer will remove tiles on the roof and swap them out for the tile replacement flashing. A lag bolt is bolted to the rafter through the tile replacement, which serves as a foundation to attach the rails.

Ballasted Mounts for Low-Slope/Flat Roofs

Ballasted mounts do not require an Installer to make penetrations in the roof—the weight of the racking base and the array itself holds the system in place. Ballasted mounts only work on flat or low-slope roofs. Higher tilt angles mean less downward force holding the array in place, which makes them ineffective on steeper rooftops.

Step 3: Install Racking Rails

With the flashings in place, you're ready to attach the racking rails. Be sure to keep the Racking Report handy during this step—it specifies rail size and spacing for the system.

- Measure and cut the rails on the ground so an Installer don't get metal shavings on the roof.
- Rails should be spaced to match the distance between the mounting holes on the back of the solar panel frame. The flashings need to match this spacing as well.
- Use the supplied hardware to attach the rail to the flashing. (Pro tip: install the lower rail flashings on the upslope side of the rail so that the array hides the flashings from view.)
- Use a level to ensure the rails are even. The slots in the L-feet allow for vertical adjustment if needed.
- Tighten rails with a quality torque wrench according to the manufacturer's torque specs.
- Attach plastic end caps to keep spiders, bees, and other critters out of the rails.
- Attach wire management clips and any hardware for micro-inverters/optimizers to the rails.
- Install grounding equipment as an Installer install the rails. IronRidge systems contain one grounding lug per array.
- When starting a new row, leave space to account for the panel overhang on both sides, as well as a ½- to 1-inch clearance gap between the panels.

Step 4: Getting Panels on the Roof

Remember: **safety first!** As an Installer prepare to move the panels onto the roof, keep in mind the safety procedures outlined in the Planning & Safety section of this guide. Be sure to wear protective equipment, use fall protection, and never stand on panels or lift them by the electrical wires.

If an Installer want, an Installer can wrap the panels in a blanket to protect them from hard surfaces as an Installer move them.

Lifting Methods

Chances are, you'll want to rent some equipment to help lift the panels on the roof. There are a few options to choose from:

Ladder Lift: A ladder with a conveyor belt mechanism on it to help move heavy objects up and down the ladder.

Scissor Lift: A lift which extends up and down, as well as side-to-side. The horizontal movement means an Installer can take fewer trips from the ground to the roof and then back again.

Boom Lift: A lift with a full range of movement, giving an Installer access to tight spaces. Useful to get over and around obstacles that prevent an Installer from parking a lift directly under the spot where an Installer plan to install the panels.

Scaffolding: Scaffolding works great if there are no obstacles and an Installer don't need lift assistance. There's no mechanism to make lifting easier, but it does offer a sturdy platform to work on and some extra fall protection. Scaffolding provides a platform to stage materials and walk freely around the roof.

Step 5: Mounting Panels

Now that you've got the installed racking and panels in the same place, an Installer can finally put the two together and mount the panels!

The instructions outlined below use the IronRidge racking system (XR10, XR100, and XR1000), which comes standard with all of our packages, as an example. If an Installer purchased a specialty mount (like a pole mount), consult the product manual for instructions on how to mount the panels.

1. Place the panel so the mounting holes line up with the rails.
2. Use the IronRidge UFO (Universal Fastening Object) clamps to secure the panel in place. Start with the end on the outside edge of the array and drop the T-bolt in the slot in the rail.
3. Torque the UFO clamps with stopper sleeves (one in each rail) so they are snug against the outside of the first panel, locking it into place.
4. Slot the next pair of UFO clamps on the inside edge of the first panel.
5. Place the next panel on the rails, so that the clamps are wedged snugly between both panels.
6. Tighten the clamps between the panels.
7. Repeat this process for each panel in the array. Use the UFO with stopper sleeves attachment to secure the final panel in the row.

Ground Mounting

If an Installer decide instead to ground mount the solar panels, there are 3 key steps:

1. Build a foundation
2. Install racking railing
3. Mount panels on the rails

Step 1: Building a Foundation

Though ground mounting is quite a bit different from roof mounting, some of the same principles apply. First, you'll want to construct a solid foundation upon which you'll mount the racking rails.

Our ground mount racks use the IronRidge Ground Mount system. We provide an engineering report that specifies how deep and wide to dig anchor holes, pier spacing, and placement, as well as how much concrete and pipe to buy.

Follow the specs outlined in the Engineering Report (provided by Unbound Solar[®]) to ensure the structural integrity of the ground mount.

Pouring Concrete & Setting Piers

Always use proper protective gear (outlined previously in Planning & Safety) when working with concrete. Wet concrete will cause serious burns if exposed to the skin for prolonged periods. In addition, a respirator with a minimum rating of N95 is required when working near concrete dust.

Bearing safety precautions in mind, here are some guidelines for pouring concrete & setting up piers.

- Check if the site is level. Considering leveling the grade if necessary.
- Use chalk or a string line to mark the outer dimensions of the array and the locations of the piers on the ground.
- Call the local authority to locate buried power lines and septic systems before an Installer dig. Do not drive heavy machinery (like a cement mixer) over the buried lines.
- Carefully follow the pier placement and hole depth/width outlined in the engineering report.
- Create a temporary lumber substructure to keep piping in place while the concrete hardens. If pipes move before the concrete is fully cured, that can compromise the structural integrity of the mount.
- Underground pipe should be fully suspended in concrete. If the pipe touches the dirt, it can cause galvanic corrosion that will detract from the strength of the structure.
- Get everything else in place before an Installer mix the concrete. Once the concrete is wet, an Installer won't have time to adjust forms and make changes.
- Wait at least a week between setting piers and building the rest of the array. Concrete will take up to 21 days to fully cure. Leave the wooden brace in place until the concrete is fully cured.

Step 2: Installing Racking Rails

Your Racking Report will specify rail size and spacing for the system. Keep it handy during this step.

- Space the rails to match the distance between the mounting holes on the back of the solar panel. the racking report has the exact measurements.
- The Ironridge Ground Mount system uses a rail connector bracket which attaches the rails to the horizontal support pipes using U-bolts.
- When starting a new row, leave space to account for the panel overhang on both sides, as well as a 1/2- to 1-inch clearance gap between the panels
- *IronRidge rail connectors secure the rails to the support beam anchored in the ground.*

Step 3: Mounting Panels

With the racking rails installed and housed in a solid concrete foundation, the panels are ready to be mounted.

The instructions provided below use the IronRidge ground mount racking system as an example. If an Installer purchased a different racking solution (such as a ground mount system from Unirac), consult the product manual for instructions on how to mount the panels.

1. Place the panel so the mounting holes line up with the rails.
2. Use the IronRidge UFO (Universal Fastening Object) clamps to secure the panel in place. Start with the end on the outside edge of the array and drop the T-bolt in the slot in the rail.
3. Torque the UFO clamps with stopper sleeves (one in each rail) so they are snug against the outside of the first panel, locking it into place.
4. Slot the next pair of clamps on the inside edge of the first panel.
5. Place the next panel on the rails, so that the clamps are wedged snugly between both panels.
6. Tighten the clamps between the panels.
7. Repeat this process for each panel in the array. Use the UFO clamps with stopper sleeves to secure the final panel in the row.

4.5 Solar Battery Installation

If you're installing an off-grid system (or a grid-tie system with a battery backup) the last step of installation for the system will be to install a battery bank.

There are **three** types of batteries used in solar storage systems:

- Flooded Lead-Acid Battery
- Sealed Lead-Acid Battery
- Lithium-Ion Battery

Each of them has unique requirements in terms of installation and battery room design, detailed in the sections below.

Lastly, the Installer should consult the manufacturer's installation instructions and datasheets for important installation instructions. We have provided some general guidelines in this solar panel installation guide, but each manufacturer does things a bit differently, so it's best to refer to their specific guides when in doubt.

Safety Tips

As with every step of the solar panel installation process, proper safety precautions should always be taken. Before working with batteries, review the following safety guidelines:

Safety Guidelines for All Batteries

- Be careful to never short-circuit a battery! A short circuit occurs when the positive and negative terminals of a battery are connected together, either from improper wiring or when a metal object falls onto the battery terminals. Use insulated tools and be cautious to avoid short circuits.
- Remove all metallic jewelry, including watches and rings. Secure any long hair and avoid loose-fitting clothing that could get caught on wires or terminals.
- Always wear protective gloves and safety goggles when working with the batteries.
- Keep a multimeter with fresh batteries on hand. Use it to check conductors to verify voltage and polarity.

- Ensure that all wires are stripped and/or terminated properly using a torque wrench/driver when necessary.
- Route all wires away from sharp edges and pinch points that could penetrate and damage the wire.

Additional Safety for Flooded Lead-Acid Batteries

- Keep baking soda and an eye-wash kit on-hand. Baking soda is used to neutralize acid spills.
- Always wear nitrile gloves and safety goggles when working with flooded lead-acid batteries.

Battery Room Designs

Your battery bank should be installed in an enclosure to limit accidental contact with the batteries. The enclosure should allow for ventilation and leave enough space for batteries to cool effectively. While an Installer will need to consult the wiring diagram and manufacturer's manuals for specific installation instructions, this section contains broad advice about designing and installing a safe enclosure for each kind of battery bank.

Sealed Lead-Acid & Flooded Lead-Acid Battery Room Design

Heat has a major impact on battery lifespan. While batteries can safely operate in a broad temperature range, the ideal ambient temperature for the battery bank is 77°F.

Prolonged exposure to higher temperatures will shorten battery lifespan, while lower temperatures reduce battery capacity. Install the battery bank in a temperature-controlled environment to keep them as close to the target temperature as possible. Natural fluctuations in room temperature based on time of day and seasonal factors are perfectly acceptable. The main concern is prolonged exposure to extreme temperatures. Batteries lose half their lifespan for every 15°F of continuous exposure over the ideal temp of 77°F. The battery bank should be built in a well-ventilated, temperature-controlled environment. At least, 1" of clearance should be left between each battery.

Considerations for Sealed Lead-Acid Battery Rooms:

- Keep a whiteboard or notepad in the room to record battery data during maintenance checks. an Installer can also use the Battery Maintenance Log provided at the end of this solar panel installation guide.
- Sealed lead-acid batteries do not off-gas as a normal part of operation, but they still have valves that will open if they are overcharged or overheated.
- Make sure the floor is structurally sound and can hold the weight of the batteries.

Considerations for Flooded Lead-Acid Battery Rooms:

- Flooded lead-acid batteries should be installed over a spill containment tray.
- Keep a whiteboard or notepad in the room to record battery data during maintenance checks.
- Flooded batteries off-gas hydrogen when they are charging and must be installed in a properly vented battery enclosure that is built according to fire and electrical codes. Consider buying a hydrogen gas monitor and don't keep anything in the room that could ignite the gas.
- Make sure the floor is structurally sound and can hold the weight of the batteries.

Lithium-Ion Battery Room Design

Temperature can have a major impact on battery performance. Li-ion batteries can be sensitive to extremely cold temperatures and typically cannot handle being charged below freezing (32°F/0°C).

Check the battery manufacturer's guidelines on the acceptable temperature range for charging and discharging the batteries. Install batteries in a temperature-controlled environment to keep them within the recommended operating range.

Considerations for Lithium-Ion Battery Rooms:

- Keep a whiteboard or notepad in the room to record battery data during maintenance checks.
- Make sure the floor is structurally sound and can hold the weight of the batteries. If mounting on the wall, make sure the wall is structurally sound to support the load.

Battery Bank Installation

Unsurprisingly, battery bank installation methods will be different depending on type and manufacturer. Included below are some general guidelines to follow while installing the batteries, arranged by battery chemistry.

Sealed Lead-Acid Battery Installation

- Though the batteries are sealed, they may release a small amount of flammable gas if overcharged/overheated. Do not install it close to electrical equipment or appliances that could discharge sparks.
- Batteries should be well-ventilated to keep them in a safe temperature range. Ventilation and other installation requirements for battery systems are covered under NEC article 480.10.
- The battery case should not come in contact with organic solvents or adhesive materials.
- Use UL-listed terminal lugs on battery interconnects, crimped according to the manufacturer's guidelines.
- Leave at least 1 inch of space between each battery to provide adequate ventilation and cooling.
- If the batteries will be subject to vibration (for example, in an RV system), fasten the battery bank securely and consider using shock-absorbent material inside the enclosure.
- Do not attempt to dismantle or touch the inside of the battery! Sealed lead-acid batteries will not leak under normal conditions, but they could spill if they are damaged. If accidental contact is made with the electrolyte, wash the affected area with liberal amounts of water, and seek IMMEDIATE medical attention.
- Baking soda can be used to neutralize small acid spills.

Ventilating Sealed Lead-Acid Batteries

Sealed Lead-Acid Batteries do not off-gas as a normal part of operation. However, they still have vents to relieve internal pressure in case of overcharging. If the battery is exposed to overheating, excessive voltage or current, it will release gas.

Though off-gassing is rare for sealed batteries, it could still happen in a worst-case scenario. Because off-gassing is possible, the battery enclosure needs to be ventilated properly. In many cases, building codes will apply the same requirements as they do for flooded lead-acid batteries.

Your vent should be at the top of the battery enclosure at the highest point so the hydrogen can escape. Seal any conduit to prevent hydrogen gas from going through the conduit and into the

inverter and other equipment. Also, be sure there is nothing blocking the vents so that air can circulate freely.

Flooded Lead-Acid Battery Installation

- Wear nitrile gloves while installing or maintaining the batteries to prevent exposure to the battery electrolyte.
- Batteries should be well-ventilated to keep them in a safe temperature range and prevent the buildup of hydrogen gas. Ventilation and other installation requirements for battery systems are covered under NEC article 480.10.
- The battery case should not come in contact with organic solvents or adhesive materials.
- Use UL-listed terminal lugs on battery interconnects, crimped according to the manufacturer's guidelines.
- Leave at least 1 inch of space between each battery to provide adequate ventilation and cooling.
- If the batteries will be subject to vibration (for example, in an RV system), fasten the battery bank securely and consider using shock-absorbent material inside the enclosure.
- Do not attempt to dismantle or touch the inside of the battery! Battery acid will burn the skin. If accidental contact is made with the electrolyte, wash the affected area with liberal amounts of water, and seek IMMEDIATE medical attention.
- Baking soda can be used to neutralize small acid spills.

Ventilating Flooded Lead-Acid Batteries

Flooded lead-acid batteries off-gas a small amount of hydrogen gas as a normal part of their operation. The battery room must be well-ventilated to keep the Hydrogen gas levels below a safe threshold (less than 1% concentration by volume).

Battery rooms should be ventilated at a minimum rate of 1.5 cubic feet per minute. Make sure there is nothing blocking the vents so that air can circulate freely. Larger systems will typically use a battery vent fan to actively expel gases.

Since hydrogen gas is lighter than air, it will rise up in the enclosure. the vent should be at the top of the battery enclosure at the highest point so the hydrogen can escape. Be sure to seal any conduit to prevent hydrogen gas from going through the conduit and into the inverter and other equipment. Hydrogen gas is very corrosive and flammable in high concentrations, which makes proper ventilation extremely important.

Lithium-Ion Battery Installation

- The battery case should not come in contact with organic solvents or adhesive materials.
- Use UL-listed terminal lugs on battery interconnects, crimped according to the manufacturer's guidelines.
- Leave at least 1 inch of space between each battery to provide adequate ventilation and cooling.
- If the batteries will be subject to vibration (for example, in an RV system), fasten the battery bank securely and consider using shock-absorbent material inside the enclosure.
- Do not attempt to dismantle or touch the inside of the battery! Follow the manufacturer's guidelines for any troubleshooting procedures.

Battery Wiring

With the batteries safely installed in a suitable room, all that's left to do is wire them together. As with installation, The Installer should be sure to follow the wiring instructions provided by

the manufacturer of the batteries. However, there are some general rule-of-thumb guidelines that is recommended:

For wires connecting the battery bank:

- All interconnection cables should be the same wire size and length.
- Do not place anything between the battery terminal and the ring terminal of the interconnect cable.
- Make sure all connections are torqued properly. Re-check them when an Installer perform battery maintenance to make sure they are secure. Connections that are loose or excessively tight can cause melted battery terminals and other failures.

For wires running from the battery bank to the inverter(s):

- Keep the battery bank and inverter as close together as possible.
- Positive and negative cables must be of the same length.
- Positive and negative cables should be zip tied together every 18 inches and installed in the same conduit to maintain maximum surge capability and reduce electromagnetic interference.
- Route the cables so that they do not interfere with the ventilation of the battery enclosure.

5. CONCLUSION

Solar photovoltaic systems have emerged as a clean, reliable and cost-effective alternative to fossil-fuel-based energy sources. This paper has provided a detailed examination of solar energy benefits, system components, wiring methods, safety procedures and installation techniques. Literature findings confirm that solar power reduces greenhouse gas emissions, enhances energy independence and offers long-term economic advantages. The successful installation of a solar PV system depends on careful planning, appropriate component selection, correct mounting, and strict adherence to electrical and safety standards. Regular maintenance—including cleaning, monitoring, battery inspection, and professional servicing—ensures that the system operates efficiently for many years. As renewable energy technologies continue to advance, solar PV systems will play an increasingly vital role in promoting environmental sustainability, improving household energy supply, and reducing dependence on non-renewable resources.

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Conflicts of Interest

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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