THE UNIVERSITY OF ARIZONA
COLLEGE OF AGRICULTURE & LIFE SCIENCES
Cooperative Extension

az1703 August 2017

Mounting Your Solar Photovoltaic (PV) System

Dr. Ed Franklin

Introduction

Using the sun to provide electrical power for residential, commercial, or agricultural use is effective when a solar photovoltaic (PV) system is set up to access an unobstructed view of the sun. This includes mounting the single solar module or a solar array at the appropriate tilt angle (in Arizona, this will vary with the latitude of your nearest city: Flagstaff: 35°; Prescott: 34°; Phoenix: 33°; or Tucson: 32°), and orienting the module or array toward the south (180°). Unfortunately, not every location has the desirable characteristics for installing a solar module or array with a clear, unobstructed view of the sun. For example, the owner of a house with east and west-facing roof orientation needs to determine which direction will gain the most output from the sun, without having to design and install a costly tilt-mount racking system. Are there nearby structures (buildings, trees, utility poles or towers) which cast shade on the desired location? If so, what times of the day, and months of the year is the shade problematic? Can the module or array be mounted on the ground, or on a pole? These issues may be dealt with by considering different module or array mounting options.

Figure 1. A roof mount array on a pitched roof. There is open roof space on all sides of the array for access. The empty space is next to the roof vent. Courtesy Nunatak Alternative Energy Solutions

Roof - Mount

For users with limited space consideration, a solar system mounted on the roof is a common option. These systems take advantage of the available space and require no excavation or concrete work, as with needed with other systems (Sanchez, 2013). Commercial mounting systems are available for flat or low-slope roofs, pitched shingle roofs, and pitched tile roofs. Mounting systems can be installed by a professional or a do it yourselfer if you are handy with tools. Care must be taken when working on roofs to avoid falling.

The rails and mounts for supporting solar modules are made of aluminum. Attaching the system involves penetrating the roofing material and securing the system feet to the roof using lag bolts and sinking into the rafters. Care must be taken to seal the penetration to prevent moisture from invading the roof and resulting in possible long-term damage. Appropriate flashing materials are recommended for roof-mount systems. In locations with steep roofs

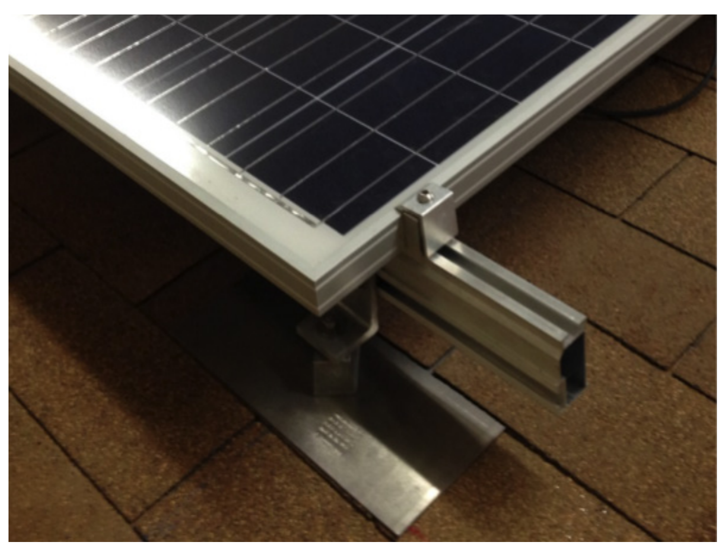

Figure 2. A roof-mount system for an asphalt shingle roof includes aluminum flashing and mounting materials such as L-feet, rails, and clamps to secure the modules in place.

Figure 3. In a higher elevation, the array needs to be mounted so snow is not piling up on the edges of the modules. Courtesy Nunatak Alternative Energy Solutions

Figure 4. Tilt-up mounting systems on low slope or flat roofs are a method to set the tilt of the array to the latitude of the location to maximize the energy output of the array. Although this system is facing south, shading cast on modules from nearby trees can limit the amount of energy an array is capable of producing.

and snow, system design must take into consideration snow load and removal. Consulting with a roofing company to determine how a roofing material warranty might be affected is advisable.

The roof mount system includes a set of feet which are affixed to the roof surface. A set of rails are bolted to the feet. Solar modules are mounted directly to the rails with bolt-on clamp connectors. One-inch spacers (called mid-clamps) are installed between the side edges of modules to hold them in place. End clamps secure the modules to the rails.

The array itself is mounted approximately 4 to 6 inches off the surface of the roof to allow access to pull and connect the PV cables, and permits air circulation around the array to minimize overheating of the solar modules. Lower material costs compared to other mounting systems is an advantage of roof mount systems, and minimized access by unqualified individuals. Disadvantages include extra weight placed on the roof, possible leaks from penetration, access to the roof, and higher solar cell temperatures.

System installation design of the roof-mount system must adhere to local fire codes. This includes a recommended set back of the array from all edges of the roof to allow access by emergency personnel, and to conduct system maintenance. Keeping the

Figure 5. Modules or array affixed to a rack and mounted on the top of or to the side of a pole. The pole-mount can be oriented in a specific direction. The amount of excavation depends on the size of the array.

edges of the array from the corners of the roof can reduce the impact of the forces of any wind. The location of the array on the roof is impacted by the location of vents, stacks, chimneys, valleys of changing roof profiles, heating and air conditioning units, and shade cast from nearby structures.

Pole Mount

A single module or a small array can be mounted on a frame and attached to a pole. A single module can be mounted on a side-mount frame attached to the side of a pole whereas an array can mounted on the top of the pole. The pole size will vary with the size of the array. Pipe diameter may be from 4 to 8 inches depending on the number of modules in the array (Mayfield, 2008). The frame can be mounted at a height where it is out of reach of individuals standing at ground level. The mounting frame can be attached at the desired angle and oriented in a direction to maximize exposure to direct sunlight. The pole is usually installed in a concrete foundation to support the weight. Controls can be mounted to the pole. A pole-mount system takes up less room, and can allow for tilt adjustment to increase output efficiency during different times of the calendar year when the sun is higher or lower in the sky. However, the post and concrete requirements per module (array) area are greater than a ground-mount with a single-row with multiple poles (ground-mount) (McPheeters & Vaughn 2011). A ladder may be needed to access the cables and frame, depending on the height. Pole mount systems require excavation to install the pole and to run electrical connections to the house. Due to the space requirements, this type of system may not be suitable for small yards in a residential setting.

Ground-Mount

A ground-mount system works well in areas where there is room for the system to be installed away from buildings and shade-producing structures. Ground mounts can be more expensive than roof mounts (McPheeters & Vaughn, 2011). The modules are mounted on rails which are fixed to a steel structure installed in the ground or attached to concrete pylons or blocks. The advantages of ground-mount systems include cooler solar cell temperatures as air circulates around the array resulting in lower cell temperatures and higher performance (Hren, 2010). Ground-mount systems are safer to install because the work is done on the ground. There is no need for climbing or safety roping. This method provides easy access to the array

Figure 6. A ground-mount system requires space for installation. The size of the modules and array will impact the size and type of mounting system materials. Accessibility for maintenance, and air circulation for cooling modules are and advantage of this type of mounting system

Figure 7. Solar modules arranged in two rows on a large fixed-plate ground mount system. The larger size modules require larger mounting materials to support the weight and to keep the system stable during high wind winds and at a tilt angle to allow snow loads to be easily removed.

for maintenance. The disadvantages to this method include: the amount of time needed for installation; the space required for the system; dealing with uneven ground or unstable soil-type, and keeping the surface area below and around the array free from growing brush. Accessibility to the system by humans and animals may need to be controlled to prevent damage to cables and access to system controls. Increased theft, or vandalism may be an issue and require a security fence or enclosure. In high elevations where snow is an issue, the system needs to be designed to allow for easy snow removal. A system consisting of multiple rows of modules needs to be spaced so shadowing from one row does not interfere with the next row behind it. A decision on the maintenance of the ground area below and around the ground-mount array needs to take into account the time and expense for weed and brush control. A ground cover such as gravel can be used for drainage, minimize erosion, and can eliminate (or reduce) the need for vegetation control, but is an added expense.

Ballast-Mount

Roofs with low slopes or no slope can use a ballast-mount system. This is a common type of method used in commercial locations. The module array is mounted on an aluminum frame or rack mounted to a sled. The sled is held fast using weighted

Figure 8. Ballast mounting systems rest on the surface of the roof and are held in place with cinder blocks. Modules are clamped to the aluminum frame at an angle of 10 degrees.

Figure 9. An array mounted on a flat roof of a commercial facility. Shade from a nearby wall is cast upon a portion of the array.

ballast, such as cinder block and the weight of the modules (Mayfield, 2008). The advantage of this system is there is no penetration of the roofing material and minimal tilt angle requiring additional racking materials. Some ballast systems are designed with a fixed low slope for modules. Other systems will permit the installer to adjust the angle of slope for the modules. The roof must be engineered to support the weight of the ballast-mount and weights. The loads can be as much as 30 pounds per square foot (Mayfield, 2008). This type of system may be useful where the array must be hid from view.

Tracking System

Most mounting systems are fixed-plate in design. The array is mounted in a fixed position at particular tilt angle and orientation. The ability to track the movement of the sun over the course of the day from east to west is called a single-tracking system. The advantage of this type of system is a 30 to 48% increase in energy output with the ability of the array to move

Figure 10. A ground-mount system with a north-south tracking capability to keep the array perpendicular to the sun. Array tilt can be set to latitude during spring and fall, and adjusted 15 degrees during the summer (latitude – 15 degrees) and the winter (latitude + 15 degrees).

Figure 11. An east-west tracking commercial-sized array. A hydraulic ram pulls and pushes a rod connecting multiple rows of arrays. The array position begins facing the east in the early morning. The array moves a slight bit every 15 minutes to follow the sun as it crosses the sky. At sun down, the array is repositioned to face the east.

and maintain a perpendicular orientation to the sun over the course of the day. A limitation of the system is there are moving parts, and moving parts need to be maintained. Additionally, the added cost for the system. Fortunately, todays' affordable cost of solar modules makes more sense to increase the number of modules to a fixed-plate system to make up the difference in energy output than to go to the expense of installing a tracking system. Dual-tracking systems allow the array to change the tilt angle (north to south) as well as east to west. This is done to take advantage of the changing location of the sun in the sky at its highest point in the sky during the summer solstice and the lowest point in the sky during the winter solstice. A small array on an adjustable mounting system can be tilt from a latitude position up or down 15 degrees. For example, an array set to latitude in Tucson, AZ at 32° during spring can be lowered 15 degrees to a 17° tilt on June 21 when the sun is highest in the sky, and moved up to latitude, plus 15 degrees (47°) on December 21 to account for sun in the lowest point of the sky in winter to keep the module perpendicular to the sun.

Conclusions

The solar user has multiple options when it comes to mounting solar modules. Available space, size of the system, array tilt, orientation, shading, durability, and cost are factors to consider when deciding the appropriate mounting method. Each mounting system has advantages and disadvantages. Many PV mounting system vendors have engineered diagrams available. If your project is a Do-It-Yourself (DIY), shop around for modules and mounting materials. Check your electrical connections before energizing your system and have a qualified electrician check your system. An inspector may be required to sign off on the system before it is connected. Always check with the local building codes and home owner associations to determine what is permitted.

Mounting System Resources

AEE Solar ▪ www.aeesolar.com

Conergy ▪ www.conergy.us

Direct Power Solar ▪ www.power-fab.com

EcoFasten Solar ▪ www.ecofastensolar.com

HatiCon Solar ▪ www.haticonsolar.com

IronRidge ▪ www.ironridge.com

Jac Rack ▪ www.jac-rack.com

Next Generation Energy ▪ www.zillarac.com

Professional Solar Products ▪ www.prosolar.com

Quick Mount PV ▪ www.quickmountpv.com

S-5! ▪ www.s-5.com

Schletter Inc. ▪ www.schletter-inc.us

Schüco ▪ www.schuco-usa.com

Sharp ▪ www.sharponenergy.com

Solar Racks ▪ www.solar-racks.com

SunEarth Inc. ▪ www.sunearthinc.com

Thompson Technology Industries ▪ www.ttisolar.com

Unirac ▪ www.unirac.com

Zep Solar ▪ www.zepsolar.com

References

Hren, R. (October/November 2010). Ground mounts for PV arrays. Home Power 139, Available at: http://www.homepower.com/articles/solar-electricity/design-installation/ground-mounts-pv-arrays?v=print&print=true

Mayfield, R. (April/May, 2008). Rack & stack – PV array mounting options. Home Power 124, Available at: http://www.homepower.com/articles/solar-electricity/equipment-products/rack-stack-pv-array-mounting-options

Mayfield, R. (Feb/March 2009). Flat roof mounting systems. SolarPro Magazine 2.2, Available at: http://solarprofessional.com/articles/products-equipment/racking/flat-roof-mounting-systems

McPheeters, G. & Vaughn, T. (August/September 2011). PV ground-mounting. Home Power 144, Available at: http://www.homepower.com/articles/solar-electricity/design-installation/pv-ground-mounting?v=print&print=true

Sanchez, J. (June/July, 2013) PV array siting & mounting considerations. Home Power 155, Available at: http://www.homepower.com/articles/solar-electricity/design-installation/pv-array-siting-mounting-considerations

Wilensky, L. (September/October, 2015). When you can't go west…or east. Home Power 169, Available at: http://www.homepower.com/articles/solar-electricity/design-installation/when-you-can%E2%80%99t-go-south-go-west-or-east

The University of Arizona
College of Agriculture and Life Sciences
Tucson, Arizona 85721

Dr. Edward A. Franklin
Associate Professor, Agriculture Education
Associate Professor, Agricultural-Biosystems Engineering

Contact:
Dr. Edward A. Franklin
eafrank@ag.arizona.edu

This information has been reviewed by University faculty.
extension.arizona.edu/pubs/az1703-2017.pdf

Other titles from Arizona Cooperative Extension can be found at:
extension.arizona.edu/pubs