SunLink™
PV MODULE MOUNTING SYSTEM

INSTALLING PV MODULES USING THE SUNLINK™ MODULE MOUNTING SYSTEM

This **Installation Information** is supplemented by an *Installation Plan* when Eastwood Energy (EE) receives a Purchase Order to design, furnish and deliver a Sunlink Module Mounting System. The *Installation Plan* adds additional essential information this is applicable to location, lay-out and module type. In order to develop an *Installation Plan*, EE relies on its customer to provide the information gathered through the process described in LAYOUT AND PLANNING below.

IMPORTANT SAFETY INFORMATION
PLEASE READ CAREFULLY

Safety is of paramount concern during the installation and startup of a PV System. Plan for safe practice during installation and startup in respect to trip and fall hazards, lifting hazards, overhead hazards and electrical hazards. This document is not prescriptive in respect to safety and does not purport to address all the safety concerns that may arise with its use. Contractors should become familiar with all applicable safety, health and regulatory requirements before beginning work.

LAYOUT AND PLANNING

1. In this document, various terms are used in a context-sensitive manner. Here are some definitions. At the end of this document, additional sources of information are listed.
    a. MODULE – the primary field-deliverable component in a photovoltaic array and a source of direct current electrical energy when illuminated by the sun.
    b. PANEL – the primary field-installable unit, consist of a four-module assembly. In panel form, all the modules are in a "landscape" or horizontal orientation.
        1. For other module-panel combinations and orientations, contact EE.
    c. SUNLINK – an inherently flexible, high-strength engineered system the enables rapid, accurate installation of modules in four-by-one (4X1) panel assemblies.
2. Good installations require good planning and layouts. Don't consume cost and time doing detailed drawings before completing assessment of rooftop conditions and dimensions.
3. PV systems are electrical, structural and mechanical and include interfaces to existing building systems and features. Electrical work includes placement of conduit and combiners in addition to location of power electrical equipment. PV arrays do not allow for field cut-and-fit. They occupy and redefine large rooftop areas. Good installations take account of the location of all equipment: roof, wall and ground-mounted.
4. Go onto the roof to make a layout equipped with a rough plan, including a plan for marking out datum locations. Layout tools include clipboard and pencils, a digital camera, fluorescent tape or paint, 25- and 100-foot tape measures, a Leica Disto on a short tripod, Disto targets and a Solar Pathfinder. A roof is often a windier place than the ground; take account of this fact. Allow the time required to obtain accurate results.
5. Establish a rough 0,0 point, mark it out and then take photos down the coordinate axes. Mark out intermediate locations along the axes at 25- or 50-foot intervals. As the rough perimeter of the array takes shape, identify rooftop features such as vents, roof-mounted equipment and rough, out-of-plane repairs that require layout workaround. Pencil in key dimensions, note features and recheck before leaving the roof. Take lots of pictures.
6. When possible, orient the array to true south. A sun compass is preferable to a magnetic compass. For low tilt angles, moderate rotation away from true south will not have a significant impact on array output. A Solar Pathfinder is a useful tool for assessing the

shading effects of rooftop features such as penthouses and roof-mounted equipment. High-season hard shadows that occur after 8 AM or before 4 PM should be avoided.

7. The capacity of a rooftop to accept a PV array requires assessment of many factors. Refer to the International Building Code, 2003 edition or to the building code adopted by the local authority having jurisdiction. Developers and installer / contractors should review roofing system issues carefully when planning an installation. Early determination of roof type and condition and of the capability of the roof to accept a PV array is a key planning milestone that should occur early in project feasibility analysis.

8. After the roof survey, prepare the roof layout drawing and then consider going back on the roof to verify assumptions and accuracy. Although the ability to make high-grade improvisations is the hallmark of an experienced contractor, since PV arrays occupy very large areas with repeating patterns, accurate location and layout for the array is essential.

INSTALLATION

1. Coordinate with equipment suppliers regarding the timing of equipment receipt. Establish pre-staging areas and lay-down areas. Avoid double handling whenever possible. Obtain all required permits and bonds before mobilizing for installation.

2. Observe applicable safety codes regarding equipment handling, including weight limits. SunLink installation crew sizes are established by work practice pertaining to lifting.

1. A 4X1 SunLink panel consists of four modules and upper and lower spar assemblies and weighs 205 pounds. Two workers will handle a SunLink panel for about one minute in order to rough locate it in and on the tilt brackets.
2. A two-person crew can handle this task. A three-person crew is ineffective. A four-person crew will complete this handling task faster and easier than a two person crew assuming good team coordination.

3. Tools required for SunLink installation are as follows.

1. Utility sawhorses, 32-inch working height, four (4) per work area.
    a. Depending on the size of the array, local working conditions and time allowed for installation, one or more four-person crews are required.
2. 3/16-inch hex bits, straight or ball-point, with manual drive and with torque-limiting power drive, air or electric for module installation with nut plates.
    a. Establish tool quantities according to number of four-person crews.
3. 1/4-inch extra-clearance power nut-driver bit with torque-limiting power drive, air or electric for installing self-drilling SSTL grounding screws.
    a. Establish tool quantities according to number of four-person crews.
4. 9/16-inch socket drivers, six-point, with manual drive and with torque-limiting power drive, air or electric for 4X1 SunLink panel installation at the tilt brackets and for installing links between the tilt brackets.
    a. Establish tool quantities according to number of four-person crews.

4. Assembly aids provided by EE for SunLink Module mounting Systems are as follows.

1. An *Installation Plan* that EE prepares after receipt of your rooftop layouts. The plan includes a PARTS KEY coordinated to shipments of Sunlink components and marking of SunLink components that require specific location in the array.
    a. The *Installation Plan* includes specific details that pertain to the methods selected to secure the array on the rooftop.

b. As described in the *Installation Plan*, most SunLink components are interchangeable. Certain components on the perimeter and/or used to secure the array on the rooftop are identified in the PARTS KEY for specific rooftop location(s).

2. TILT BRACKET SPACER TOOL – a one-piece lightweight aluminum assembly aid that helps control lateral spacing between the tilt brackets.

5. SunLink installation consists of three primary activities. These activities are easily coordinated with other array installation requirements e.g., string interconnection.

1. Locate, install and fasten together link-tilt bracket assemblies parallel to the array solar orientation axis and at controlled lateral spacing.
2. Locate and rough-in details e.g., extended base tilt brackets that are used to secure the array on the roof. Finish the detail set used to secure the array to the roof after completion of SunLink panel placement.

a. Completion of this work should be coordinated with 4X1 SunLink panel placement for ease of crew access.

3. Assemble, locate and fasten in place 4X1 SunLink panels.

6. Tilt brackets are delivered marked as follows.

1. INTERCHANGEABLE – These pre-assembled tilt brackets may be installed anywhere in the array. The great majority of tilt brackets are interchangeable.
2. LOCATION SPECIFIC – These pre-assembled tilt brackets are installed on the array perimeter in locations called out in the *Installation Plan* PARTS KEY.

a. Details associated location-specific tilt brackets are called out in the *Installation Plan* and pertain to the means (e.g., ballast) selected to secure the array on the rooftop.

b. Tilt brackets may have a roofing system compatible layer. Detailing of this site-specific feature is achieved through coordination with the roof system installer and is a key element of LAYOUT AND PLANNING.

7. INTERCHANGEABLE tilt brackets are located in continuous straight lines. On the rooftop, they are interconnected with links in an orientation parallel to the solar axis of the array system as shown on the roof layout and in the SunLink *Installation Plan*.

1. The tall end of each tilt bracket always points south.
2. Remove the 3/8-16 UN x 2.0 hex head capscrew, washer and hex nut sets pre-installed in the tilt brackets at the link connection points, then fit the links in place and reinstall the fastener sets.

a. The nuts and washers always install to the outside face of the tilt bracket, as shown in the *Installation Plan* drawing details.

b. Links line up south to north on the two pairs of bolt holes at the bottom of each tilt bracket. The oval holes in the pair of holes at each end of the link allow the array to accommodate local variation in roof flatness.

3. Lateral spacing between links is controlled to enable installation of the 4X1 sub-array panel, which attaches by bolting at the pivot and anchor block locations.
4. Use the TILT BRACKET SPACER TOOL to establish and control the required separation between tilt brackets. The tool incorporates integral blocks that fit into the openings at the top of each tilt bracket. The blocks are located on the

tool at a separation distance that matches up to anchor and pivot block spacing on the spars. Expect the blocks to engage the tilt brackets with a running slip fit.

5. It is the responsibility of the installation contractor to assure installation of the tilt bracket assemblies along straight lines and to assure that lateral locations are along lines-of-sight that are perpendicular to the N/S tilt bracket centerlines.

    a. RECOMMENDED PRACTICE – Always coordinate installation to established datum locations on the rooftop. Tilt bracket assemblies install rapidly and easily. Work teams need only to pre-install a few rows of tilt brackets to keep ahead of 4X1 SunLink panel installation.

8. LOCATION SPECIFIC (LS) tilt brackets integrate with INTERCHANGEABLE tilt brackets through the assembly links, which are always interchangeable. There is no change in installation practice when interconnecting these two types of tilt brackets.

9. LS tilt brackets are located per the SunLink *Installation Plan*. This tilt bracket type may have an extended base (greater width, length or both). These tilt brackets are shop pre-assembled and are stenciled for location on the rooftop.

10. According to the SunLink *Installation Plan* and in order to meet local rooftop conditions, LS tilt brackets may incorporate a fastener connection to ballast trays, which are detailed for installation and to accommodate ballast in the form and quantity specified.

1. LS tilt brackets may be detailed for other, alternative or optional means of securing the array on the roof, including adhesives or bolting. These connections may be used for wind uplift resistance or separately for seismic resistance.

11. RECOMMENDED PRACTICE – SunLink panels are assembled on the rooftop directly adjacent to final location. In this way, module and panel handling is minimized.

1. Alternatively, SunLink sub-array panels are assembled in a lay-down area and lifted up onto the rooftop. (This alternative takes more time and coordination.)

12. Begin SunLink panel assembly by establishing movable-reconfigurable work areas at the rooftop starting points of the array build. The work areas consist of four 32-inch high 36-inch long sawhorses on centers that vary with the work sequence. Establish a four-foot wide work zone around the saw horses and provide light-duty deck wagons for staging modules, components and fasteners and workforce tools and equipment.

13. PV MODULES arrive from the manufacturer in banded cardboard boxes. Removing and managing the cardboard is a significant task. When PV modules are exposed to sunlight, they are producing energy and represent electrical hazards, including shock hazard.

14. Invert two (2) PV MODULES and place them in landscape orientation on the sawhorses. Locate an UPPER SPAR and a LOWER SPAR assembly. Center the spars relative to the two modules. Space the modules parallel and with ~ 1.25-inches of separation.

1. Install the two (2) center JULIO BLOCKS on the upper and lower spars with 5/16-18 UN x .50-inch button head capscrews (BHCS). Engage the modules under the clamping edges and locate the modules in full face contact with the SPARS along the side and bottom of the module frames.

    a. Prior to fastener installation, sparingly apply Sur-Lok 1243. Fasten the BHCS to “finger tightness” only.

15. Locate NUT PLATES for installation along each long edge of each module. Nut plates orient “notch in” on the inside face of the module frame and match up with the mounting holes on the modules and the mounting holes on the spars.

1. Nut plates are 5/16-inch x 1-inch aluminum flat bars with threaded holes. Install with 5/16-18 UN x .50-inch BHCS – quantity per *Installation Plan*.

a. Prior to fastener installation, sparingly apply Sur-Lok 1243. Fasten the BHCS to "finger tightness" only.

16. As shown in the *Installation Plan*, locate and install four (4) JULIO BLOCKS, two each on each spar, directly adjacent to the already "panelized" modules. Secure the julios with 5/16-18 UN x .50-inch BHCS. Prior to fastener installation, apply Sur-Lok 1243. Fasten loose to allow for immediate installation of the two (2) outer PV MODULES.

17. Invert the two (2) outer PV MODULES and place them in landscape orientation on the sawhorses for clamping fit to the julios and for installation with four (4) NUT PLATES. The modules should be in full face contact along the long side and bottom faces of their frames with the UPPER SPAR and the LOWER SPAR.

1. Fit and install the nut plates to make the frame-spar with 5/16-18 UN x .50-inch BHCS – quantity per *Installation Plan*.

a. Prior to fastener installation, sparingly apply Sur-Lok 1243. Fasten the BHCS to "finger tightness" only.

18. A 4X1 SunLink panel now rests on the sawhorses, with all components in correct position, secured in engineered joints completed to finger tightness and incorporating thread locker. Using a torque-limiting power drive, air or electric, tighten the fastened connections to the torque values specified in the *Installation Plan*.

19. Install four (4) self-drilling stainless steel screws to electrically bond the upper spar with each of the four modules. The screws are installed at the locations on the spar marked with the ground symbol. Pilot holes for this purpose are pre-drilled by EE. The self-drilling screws are installed using 1/4-inch extra-clearance power nut-driver bit with torque-limiting power drive. Take care to avoid "over-torquing" these connections.

1. RECOMMENDED PRACTICE – Among various requirements pertaining to grounding, the National Electrical Code and UL 1703 require a durable, low-resistance connection to the module frame and require PV system grounding continuity in the event of removal of a module from the array.

a. Consult the local authority having jurisdiction with respect to intended grounding plan since preference and practice may vary with locality.

b. Provide EE with information on approved local grounding practice so that SunLink can be furnished consistent with approved practice.

20. Depending on the EE scope of work, the *Installation Plan* may include power electrical schematics and a module-string-combiner wiring plan. Consult applicable project sources and interconnect the four modules according to drawing requirements. EE provides a pre-drilled hole at the appropriate end of the UPPER SPAR for grounding interconnection.

1. Grounding lugs such as manufactured by Thomas & Betts or by Ilsco are suggested for use in making panel-to-panel grounding connections.

21. Remove and set aside the 3/8-16 UN x 2.0 hex head capscrew, washer and hex nut sets pre-installed in the tilt brackets at the anchor and pivot block connection points on the forward and aft tilt brackets. Visually verify that the tilt bracket sets line up to accept the 4X1 SunLink sub-array panel, now ready for final installation.

22. Secure all module wiring to avoid making a trip hazard, then rotate the 4X1 SunLink panel up 90° – well-balanced and resting on the sawhorses with pivot blocks down.

1. Lift up and walk the SunLink panel to the nearby tilt bracket set. Lower the SunLink panel in place, so that the pivot blocks clear the tilt bracket caps and the pivot blocks are forward and well into the tilt bracket.

2. Rotate and lower the panel so that the anchor blocks clear the caps of the opposing tilt brackets. The SunLink panel is now safe and secure, resting on the links as connected to the forward and aft tilt brackets.

23. Align the holes common to the pivot blocks and tilt brackets and install the 3/8-16 UN x 2.0 hex head capscrew, washer and hex nut sets at four places, two per side, nuts out. Repeat this process for the anchor blocks: align the common holes and install the 3/8-16 UN x 2.0 hex head capscrew, washer and hex nut sets at four places.

1. Tighten all the fastener sets on the tilt brackets to the torques values specified in the *Installation Plan*. Adhesive thread lock is not required for these connections.

The process described above as INSTALLATION, No. 1 through No. 23, is repeated in order to build out the array. A suggested build sequence is provided with the EE *Installation Plan*.

SECURING THE ARRAY ON THE ROOFTOP

The PV array perimeter experiences the highest wind load and is secured with ballast or by other means to assure stable performance under rooftop wind loading conditions defined using ASCE 7-02. Ballast trays are fastened to extended tilt bracket bases. Ballast tray designs include provision for assured drainage and provision to preclude water ponding or flow impediment as a result of ballast placements. The form of the ballast ranges from architectural pavers to reinforced concrete "stock" sections. Ballast form is determined by wind loading, owner preference, and by roof capacity. Ballast trays are fabricated to fit the ballast form using corrosion resistant materials.

Detailed installation instructions that pertain to "application specific" perimeter tilt brackets and related components are developed and provided after EE receives information on roof capacity and local conditions. In addition to the *Installation Plan*, EE will provide procurement information on ballast, which should be supplied by the installation contractor using local supply sources.

BASIC INSTALLATION RATE ESTIMATING GUIDELINES

To install small to moderate size arrays (30-120 kW) built with a SunLink system, a four-person crew size is effective. Two close-by movable-reconfigurable work areas are recommended, both with identical equipment. The crew will typically function as two paired work teams to assure a good mix of work in parallel and serial. One team can place and assemble tilt brackets and links while the other team assembles 4X1 SunLink panels. After 20-24 tilt bracket sets are positioned and assembled, both two-person teams work on 4X1 SunLink panel assembly. When two 4X1 panels are completed, the two-person teams reconfigure as a four-person crew in order to "walk" the panels into final location. This pattern is easily repeated and team work "swap" is easy too.

With the right equipment and good rooftop logistics, a four-person crew builds, installs and interconnects four SunLink sub-array panels per hour, including tilt bracket and link placement. Assuming BP 3160 modules, without difficulty or undue haste, a four person crew installs 2.5 kW per hour or 20 kW per day. This rate should be considered a "fair conditions" estimate.

For large systems (> 120 kW) increase the number of crews proportionately to achieve equivalent daily production. Best practice is to equip workers with good ergonomic tools and assure strong logistical support. By use of four-person crews to position and final locate SunLink panels, strain and fatigue is not a factor and installation rates are predictable and sustainable.

SUNLINK DELIVERABLES

With each order, EE furnishes a SunLink™ Module Mounting System, FOB Livermore California loaded on common carrier trucks for delivery to Purchaser facilities or to final jobsites in support of agreed-to schedules and terms of sale. SunLink components are packaged to preclude in-transit

damage and are marked in order to facilitate site unloading, storage and final installation. EE uses low-bulk packaging materials suitable for recycling whenever possible.

1. Equipment furnished by EE is intended to securely support the specified type and quantity of MODULES and to enable the Purchaser to secure the array on the rooftop, in a manner that is consistent with good engineering practice and local requirements.
2. Roof interface materials such as slip sheets should be furnished by the Purchaser. EE will assist the purchaser in evaluating installation options for any roof type.
3. Ballast materials made from masonry or concrete should be furnished by the Purchaser. EE will assist the purchaser by specifying ballast options and by providing ballast trays.

With each order, EE furnishes an *Installation Plan* as described in this document. The *Installation Plan* guides the Purchaser toward an attractive and economic SunLink installation. Working from customer-furnished information describing site location, array size and rooftop conditions, EE develops an illustrated SunLink installation sequence, provides a list of suggested installation equipment, and prepares a PARTS KEY that coordinates to component marking, to component packaging, to the Bill of Materials and to the suggested installation sequence.

SunLink is the result of extensive engineering development and engineering validation testing. With each order, EE furnishes the Purchaser with information describing the stress analysis of the design, the results of wind tunnel testing and the results of static load testing. This information package includes certification by third-party registered professional engineers. EE authorizes limited disclosure of this information to third parties such as authorities having jurisdiction in support of obtaining construction or installation permits for PV systems.

1. On request and for a lump sum or hourly rate price, EE provides full-scope electrical engineering support for PV system development, specification and installation.
2. EE will coordinate with professional engineers who are local to PV system installations. EE does not offer registered professional engineer review outside of California.

REFERENCES

1. International Building Code, 2003 edition

2. California Building Code, 2001 edition, Part 2, Volume 2

3. SEI/ASCE 7-02 Minimum Design Loads for Buildings and Other Structures

4. National Electrical Code, 2002 edition Articles 250 and 690

5. IEEE Standard 928: Recommended Criteria for Terrestrial Photovoltaic Power Systems

(The above-referenced IEEE Standard is available for purchase at www.ieee.org. This document provides an excellent reference for PV array terminology and may be used as a foundation for specification writers supporting the development of larger scale PV systems.)