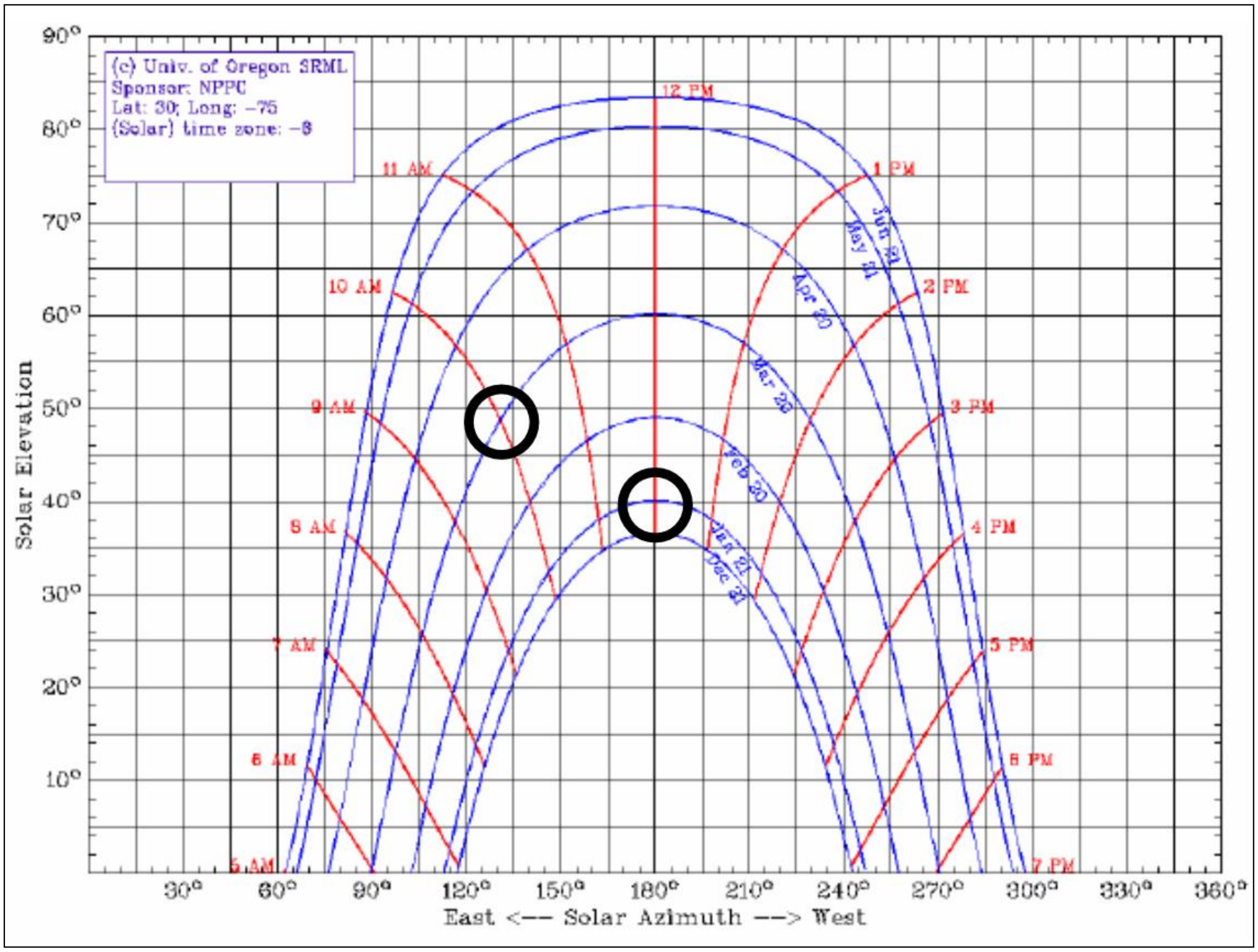
Technical Concepts & Glossary



At 12:00 noon in January in the US, the sun position will be due south (azimuth 180°) and at an altitude of approximately 40° above the horizon.

At 10:00 a.m. in March in the US, the sun azimuth will be 130°, in the east, and the altitude angle will be approximately 48° above the horizon.

AC System Output Factors	Derating Multiplier	
	Low	High
Manufacturer nameplate variance	0.8	1.05
Module current mismatch	0.97	0.995
DC wiring	0.97	0.99
AC wiring	0.98	0.993
Dirt and dust on module	0.3	0.995
Inverter efficiency	0.88	0.96
Diodes and connections	0.99	1.0
System availability	0	0.995
Shading	0.75	1.0
Aging	0.7	1.0

These factors are used by many of the performance estimation tools. Each of the factors has an effect on system performance, however, depending on the tool in use, all of these factors may not be available for the estimator to alter. Consult the user guide for the particular tool you are using if you have any questions about the applicability of these particular factors.

It is important to note that, except for shading and aging, all of these derate factors can be applied to nearly all sites. Shading is a site-specific derate factor, and should be applied after a detailed site analysis is performed. Aging is also a site-specific factor, and generally does not apply when estimating the performance of a new system. Another important site-specific derate factor is system orientation (azimuth and tilt angle).

The following table provides a definition for each of the factors:

Factor	Definition
Manufacturer nameplate variance	The variation that can occur with respect to the "nominal" or nameplate power value of the module. While typical manufacturer allowance is ± 5%, most SunPower modules average approximately + 1–2%.
Module current mismatch	All modules do not produce the same current, even if their output power rating is the same. Modules connected in series are limited to the current output of the lowest-producing module. A variation of 1% is common for most modules.
DC wiring	Although power loss due to voltage drop and connections may be 1–3%, SunPower recommends keeping this to no more than −1% in your designs.
AC wiring	Power losses similar to those in DC wiring occur in the AC wiring as well. For residential systems this value tends to be very low (< 1%), but for commercial systems it can vary greatly and should therefore be evaluated on a case-by-case basis.
Dirt and dust	Soiling on the module glass decreases the amount of sunlight getting through to the solar cells. Seasonal rains will clean the modules to some extent, but residue and dust can still build up, potentially causing a significant reduction in output. The value of this reduction is heavily influenced by the local climate as well as by system maintenance schedules.
Inverter efficiency	This refers to the actual conversion efficiency from input DC power to output AC power. (For reference, SunPower's grid-connected inverters operate at approximately 94–96% efficiency at most voltage and power levels.)
Diodes and connections	This is a relatively small factor that can arise when, for example, blocking diodes are used to prevent backflow from parallel strings. There is a small voltage drop across the blocking diodes in such cases (but we ignore it for our purposes here).
System availability	This factor estimates the potential loss of energy due to the entire system being offline, perhaps due to utility outages or to equipment failures during a given year. A factor of 0.98 means that 98% of the time the system was available, and 2% of the time the system was offline. • 0.98 × 365 days = 358 days available • 0.02 × 365 days = 7 days offline
Shading	This is the estimate of energy loss due to horizon shading by nearby obstructions or other objects, or the distant horizon.
Aging	Loss of output power due to weathering of the modules. This is approximately 0.5–1% per year. (For a new system, there would be no adjustment for this.)

Key Design Equations

Estimating Array Size and System Output

Use the following equations to determine the appropriate array size (PTC kilowatts) and calculate system annual energy output based on an array size (PTC kilowatts).

Estimating Array Size (PTC) to Meet Energy Requirement w/ Peak Sun Hours

$$\text{Array PTC rating (kW)} = \frac{\text{daily energy requirement target (kWh)}}{0.835^{*} \times \text{azimuth/tilt factor} \times \text{shading} \times \text{peak sun Hours}}$$

Estimating System Annual Energy Output with Peak Sun Hours

Average daily energy output (kWh) =

Array PTC power × 0.835* × azimuth/tilt factor × shading × peak sun hours

*0.835 is a recommended general system derate factor.

Matching the Array and Inverter

Use the following equations to determine the appropriate inverter size for an array and to determine the minimum and maximum number of modules in series.

Minimum Inverter Output Power Based on Total Number of Modules

$$\text{Minimum inverter output power} = \frac{\text{module STC power} \times \text{total number of modules}}{1.15}$$

OR

Maximum Number of Modules in Total Based on Inverter Output Power

Maximum total modules =

$$\frac{\text{Inverter rated maximum continuous AC output power}}{\text{CEC weighted efficiency} \times \text{module PTC power}}$$

Calculating Maximum System Voltage

Maximum system voltage =

$$[\text{Module } V_{OC@STC} + ((\text{cold design temperature} - 25°\text{ C}) \times T_{coef\ V})] \times \#\text{ of modules in series}$$

Note: Temperature Coefficient for Voltage ($T_{coef\ V}$) factors in −V/° C.
Always consult the specific module datasheet for the specific values.

Maximum Number of Modules in Series

Manufacturer's $T_{coef\ V}$ method

$$\text{Maximum series modules} = \frac{\text{Inverter maximum DC input voltage}}{\text{Module } V_{OC\ @STC} + [(\text{Cold Design Temperature} - 25°\text{ C}) \times T_{coef\ V}]}$$

OR

NEC 690.7 Table Method (Pre-2008)

$$\text{Maximum series modules} = \frac{\text{Inverter maximum DC input voltage}}{\text{Module } V_{OC\ @STC} \times \text{NEC Correction Factor}}$$

Minimum Number of Modules in Series

Minimum series modules =

$$\frac{\text{Inverter minimum MPPT DC input voltage}}{\text{Module } V_{MP\ @STC} + [(\text{high avg. temp} + 35\ °\text{C} - 25\ °\text{C}) \times T_{coef}\ V]}$$

Determining Ampacity

Use the following equations to calculate both **Minimum Ampacity** and **Ampacity for Conditions of Use** for DC and AC circuits. To meet NEC requirements for safety, always select the **greater** of the two minimum ampacity values when selecting the conductor size [*Table 310.16]*.

DC Circuits (all PV circuits)

Minimum Ampacity

$$\text{Minimum ampacity} \geq I_{SC@STC} \times 1.25 \times 1.25$$

OR

Adjusted Ampacity for Conditions of Use

$$\text{Adjusted ampacity (PV circuits)} \geq \frac{I_{SC} \times 1.25}{\text{conduit-fill derate} \times \text{temp. derate}}$$

Table 310.15(B)(2)(a) *Table 310.16*

Greater of Minimum or Adjusted Ampacity Values

Use the greater of the two ampacity values to select the conductor size

AC Circuits (inverter output circuits)

Minimum Ampacity

Minimum ampacity ≥ rated maximum inverter output current × 1.25

OR

Adjusted Ampacity for Conditions of Use

$$\text{Adjusted ampacity} \geq \frac{\text{rated maximum inverter output current}}{\text{conduit-fill derate} \times \text{temp derate}}$$

Table 310.15(B)(2)(a) *Table 310.16*

Greater of Minimum or Adjusted Ampacity Values

Use the greater of the two adjusted ampacity values to select the conductor size

Sizing Conductors Based on Voltage Drop

Use the following equations to calculate conductor percent voltage drop; maximum conductor size given a specific percent voltage drop; or maximum distance given a specific percent voltage drop.

D = one-way distance (ft)

I = current (nominal actual value, no 125% factors, use I_{MP} for solar circuits)

R = resistance of conductor (ohms/1000 ft) [Chapter 9, Table 8]

V = voltage (typical, nominal, use V_{MP} for solar circuits)

$$\% \text{ drop} = \frac{0.2 \times D \times I \times R}{V}$$

$$R = \frac{\% \text{ drop} \times V}{D \times I \times 0.2}$$

$$D = \frac{\% \text{ drop} \times V}{R \times I \times 0.2}$$

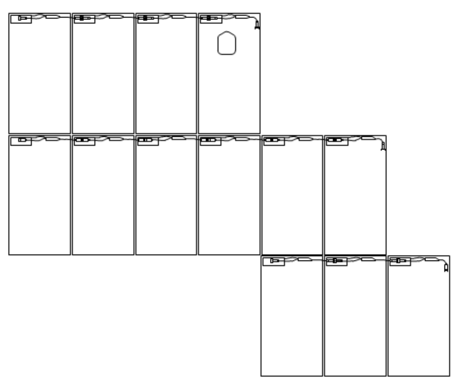
AC Module Overview

What is an AC Module?

- AC module is not a conventional “micro inverter”
    - Listed to both UL1703 (Modules) and UL1741 (Inverters)
    - Is defined separately from DC modules in the NEC [690.2]
    - Is exempt from all unique requirements for PV DC circuits [690.6(A)]
    - Inherently compliant with rapid shutdown (RSD) requirements in [690.12]
- Additional Value
    - Factory-attached MI and “AC module” listing enable much faster installation
    - Module level MPPT and monitoring
    - No string sizing and simplified inventory

Wiring and Overcurrent Protection

- AC output cables connect modules in parallel at 240 VAC
- Not strings of modules but ***branch circuits***
- Maximum 12 modules on one branch circuit connected to a 20A two pole breaker (for 240 VAC)
- Max of 85 modules per PV Supervisor 6



Service Voltage	Max Modules/Circuit	DC Watts/circuit (with 327-AC)
240	12	3,924 Watts

Design Basics

- Single Phase only
- L1-L2-G
  - **No neutral** in the AC module circuit
  - No raceway requirement: Non-Metallic Sheathed (NMSC) cable may be used.
  - If 10-2 NMSC is used: mark the white wire with red phase tape
- Use best discretion based on the AHJ
- PV Supervisor 6 must be wired 120/240 Vac
  - **G-L1-N-L2**

Key Design Messages for AC Modules

- AC module circuits are exempt from the requirements that apply to DC circuits.
- AC modules are Rapid Shut Down compliant.
- When used with InvisiMount, equipment grounding is achieved with a lay-in ground lug assembly and row-to-row grounding clips.
- **The location of the J-box MUST be determined in the initial system layout to ensure proper cable selection.**
- New mandatory trunk cable is suitable for both portrait or landscape designs.

Design Process Checklist

Customer Inquiry

- □ Assess potential customer's needs and interest
- □ Assess potential customer's site remotely with a satellite program

Site Assessment

Gather all relevant information. (There is no such thing as too much information!)

- □ Current electrical demand
- □ Exact roof dimensions (including parapet heights)
- □ Roofing material and condition
- □ Structure
- □ Tilt and azimuth
- □ Shading potentials
- □ Existing electrical infrastructure for point of connection
- □ Complete comprehensive site assessment checklist

System Sizing

- □ Analyze current electrical usage through utility bills
- □ Compare usage to usable roof area
- □ Choose modules
- □ Size system using PV sizing program (PVWatts™ or equivalent)
- □ Choose inverters to match array DC size
- □ Determine the string configuration that will match array and inverters
- □ Access the SunPower Dealer Portal and use the string calculator tool
- □ Input average daily high and record low temperatures
- □ Adjust system size or inverter size to accommodate possible string configurations if needed
- □ Confirm that arrays composed of the final string configurations will fit on the structure while still avoiding potential shading

Mechanical Design

- □ Choose a module racking system
- □ Determine basic wind speed and exposure for the area
- □ Design racking system to comply with local restrictions as well as manufacturer's restrictions
- □ Determine spacing of standoffs and lag length
- □ Determine how racking will interface with roofing material: flashings, custom flashings, possible roofer assistance
- □ Create structural layout drawings

Electrical Design

- ▫ Evaluate and design point of connection
- ▫ Determine equipment layout
- ▫ Determine conduit routing and sizing (ampacity and voltage drop)
- ▫ Develop detailed single-line and three-line electrical drawings
- ▫ Generate values for all required labels

Bill of Materials Aggregation

- ▫ Compile bill of materials which reflects all of the design decisions

Permitting

- ▫ Create permit package, contents determined by jurisdiction, typically to include:
    - Layout drawings
    - Equipment datasheets
    - Single-line electrical drawing

Post-construction Feedback

- ▫ Verify the record drawing report from the field (and record it as well)
- ▫ Assess whether the design process resulted in the desired product
- ▫ Assess whether the construction crew had everything they needed for an optimal completed project
- ▫ Create revisions to the process where needed

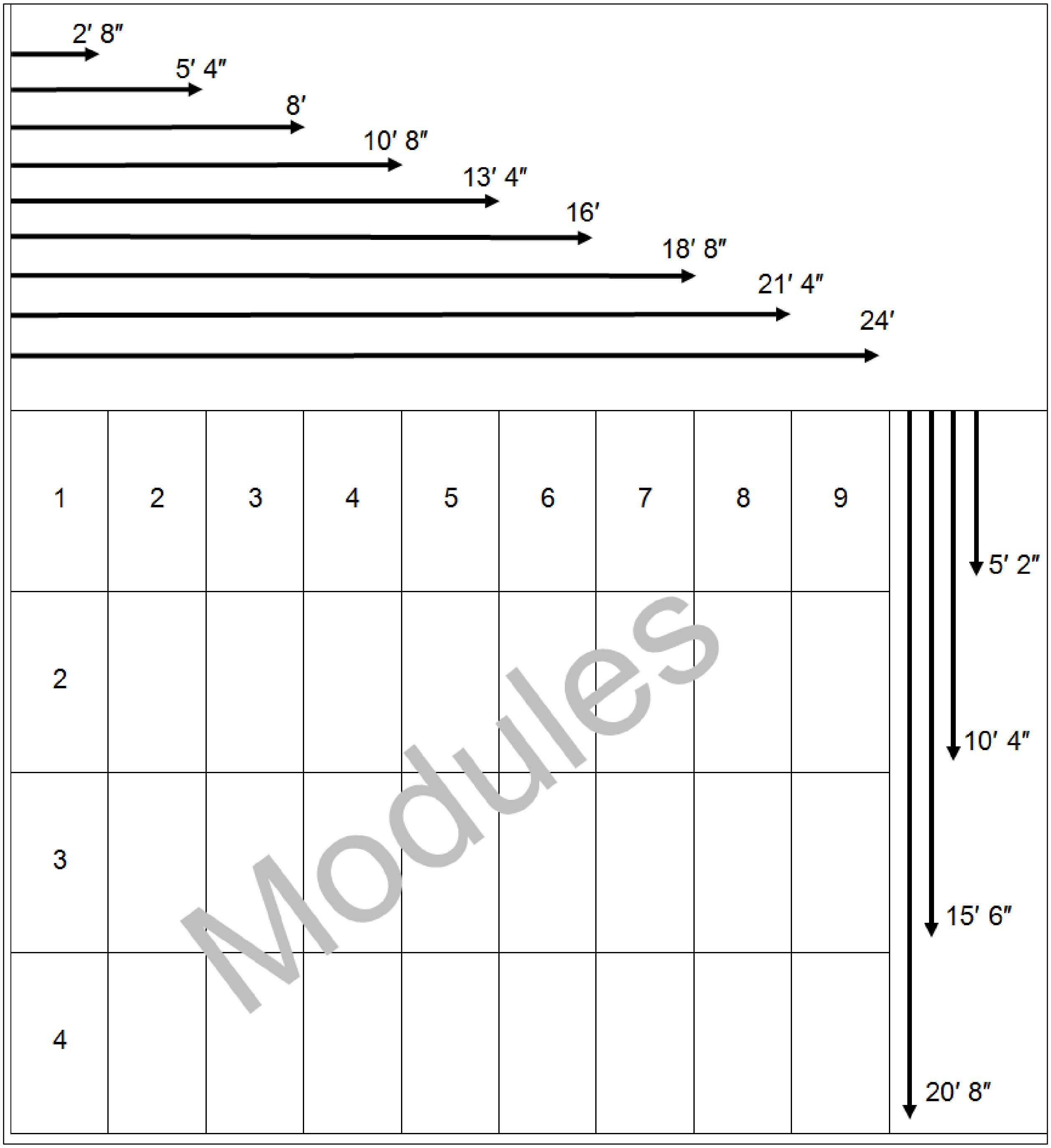
Create a rough site map which includes the proposed placement of all modules, conduit, BOS, switch gear, obstacles, and important references. Include accurate measurements so that the sketch can serve as the basis for a scaled computer drawing. Always include the south direction.

Roof Pitch Conversion Table

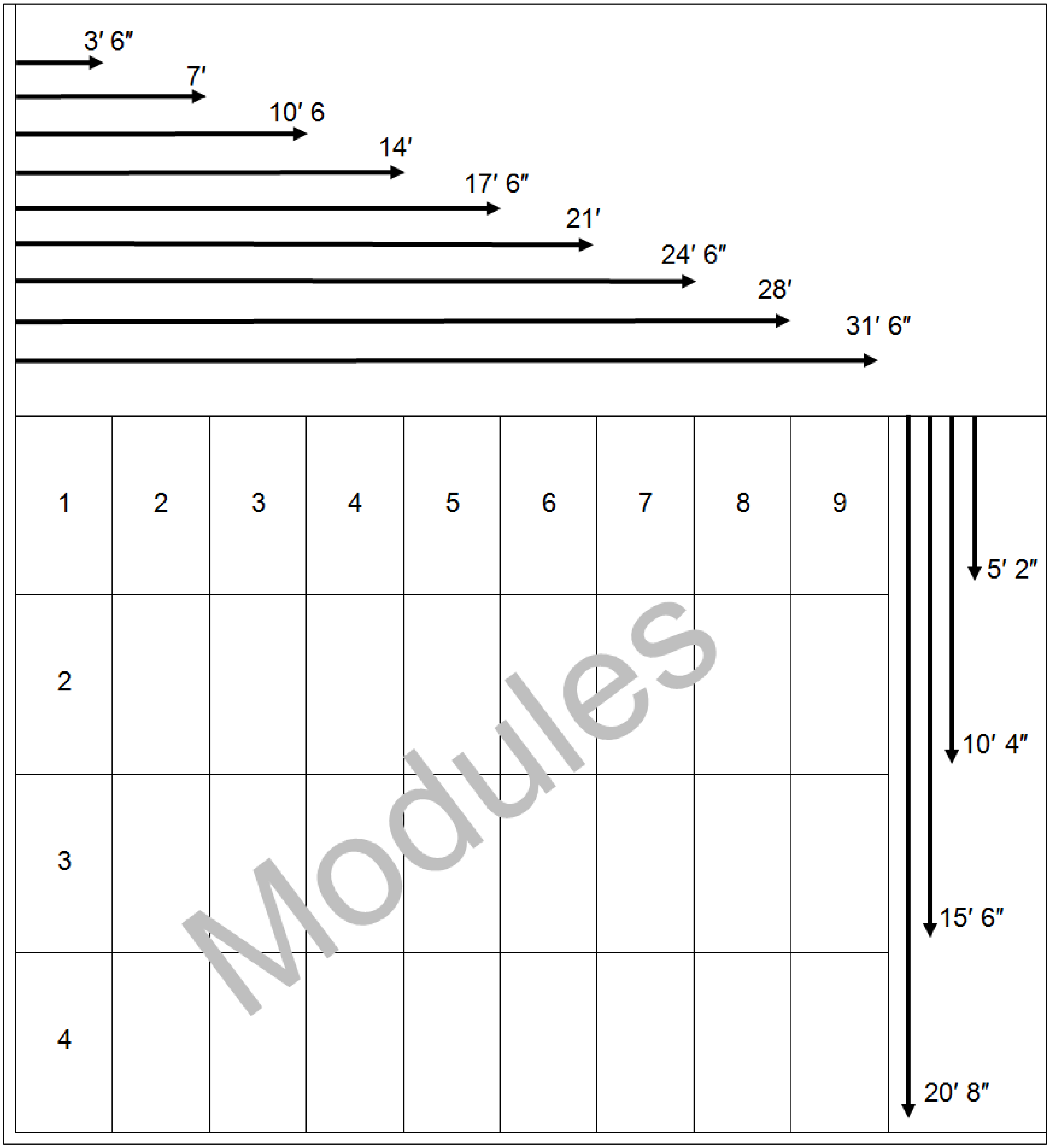
Roof Pitch	Equivalent Tilt Angle
Flat	0°
1:12	5°
2:12	10°
3:12	14°
4:12	19°
5:12	23°
6:12	27°
7:12	30°
8:12	34°
9:12	37°
10:12	40°
11:12	43°
12:12	45°

Rooftop Layout Module Dimensions

72-Cell SunPower Modules



96-Cell SunPower Modules



System Performance Benchmarking

ONLY PERFORM THIS TEST ON PV SYSTEMS THAT HAVE ALREADY BEEN INSPECTED FOR SAFETY AND PROPERLY COMMISSIONED.

Tools and Materials: *Irradiance meter, IR temperature meter, inverter display, digital multimeter (600 Vdc), digital clamp-on DC current meter, PPE.*

STEP 1. Calculate array characteristics at STC (based on actual system):

Module type: ______________ Voltage temp coef (T_{coef}): _________ –V/° C

___________	x	___________	=	___________
Module V_{MP}		# of series strings		Array V_{MP}
___________	x	___________	=	___________
Module I_{MP}		# of parallel strings		Array I_{MP}
___________	x	___________	=	___________
Array V_{MP}		Array I_{MP}		Array power

(STC Conditions: Irradiance = 1000 W/m^2; Cell Temperature (Tc) = 25˚ C, Air Mass 1.5)

STEP 2. Measurements taken on operating system (collected at one point in time):

Actual site conditions:		
Irradiance =		W/m^2
Cell Temperature (Tc) =		˚C
Actual system measurements:		
Array Operating Voltage (V_{MP}) =		V
Array Operating Current (I_{MP}) =		A
AC Power =		W

STEP 3. Calculations (based on data collected above):

A. Calculate array voltage (at max power point):

1) Actual value: (from inverter LCD or multimeter) = ________________ _ **V**
Actual array V_{MP}

2) Theoretical value: _____ × ____________________ = ____________ V
series × [module V_{MP} − (V_{Tcoef} × (Tc − 25)] = theory array V_{MP}

B. Calculate array current (at max power point):

1) Actual value: (from inverter LCD or multimeter) = ____________ A
Actual array I_{MP}

2) Theoretical value: _____ × ______ × ______ = ________ A
module I_{MP} × # of parallel strings × irradiance/1000 = theory array I_{MP}

C. Calculate array DC power (at max power point):

1) Actual value: ________ × __________ = _____________ W
actual V_{MP} (A:1) × actual I_{MP} (B:1) = actual array DC power

2) Theoretical value: _________ × __________ = __________ W
theory V_{MP} (A:2) × theory I_{MP} (B:2) = theory array DC power

3) Actual vs. theoretical performance: _______ ÷ ______________ = ________
actual WDC (C:1) ÷ theory WDC (C:2) = performance ratio

Record actual inverter CEC weighted efficiency: _________ % (from manufacturer's inverter datasheet).

D. *Calculate inverter dc-to-AC conversion efficiency:*

1) Actual AC power: (from actual readings above) = _____________ W
actual system AC power

inverter power level %:___________________ ÷ ______________= ________%
actual AC power (D:1) ÷ inverter max AC power output = actual %

2) Theoretical AC power: _____________ × ____________ = ____________ W
actual DC power (C:1) × CEC efficiency = theory AC power

3) Actual efficiency: _____________÷ ______________= ___________%
actual AC power (D:1) ÷ actual DC power (C:1) = actual inverter efficiency

STEP 4. Conclusions (based on calculations above):

1. Under Array Voltage (at maximum power point):
    a. How similar are these two values? Divide the actual value by the theory value to obtain a ratio.
    b. Which measured value significantly affects this calculation?
    c. How confident are you in your measurement techniques, tool accuracy, and math?
2. Under Array Current (at maximum power point):
    a. How similar are these two values? Divide the actual value by the theory value to obtain a ratio.
    b. Which measured value significantly affects this calculation?
    c. Are you confident in your measurement techniques, tool accuracy, and math?
3. Under Array DC Power (at maximum power point):
    a. How similar are these two values?
    Consider other derate factors that might affect performance, such as shading; dirt and dust; resistance in wiring, breakers, and switches; the module nameplate DC rating variable; module mismatch, and module age.
4. Under Inverter dc-to-AC Conversion Efficiency:
    a. How similar was the Actual Efficiency to the CEC value? Divide the actual value by the CEC value to obtain a ratio.
    b. Which factors might affect actual inverter efficiencies?
    Evaluate inverter power vs. efficiency curves, for example.
    c. Are you confident in your measurement techniques, tool accuracy, and math?

Minimum solar breaker is sized to inverter output:

Inverter Maximum Output Current multiplied by *Continuous Duty Factor*
equals minimum breaker size (rounded up to next available trade size)

Example: 6 SunPower AC Modules
Maximum Current = 1.33 A x 12 = 15.96 A
15.96 A x 1.25 = 19.95 A Minimum Solar Breaker
20 A Selected Breaker → 12 AWG

20 A Breaker = 12 AWG minimum
25 A Breaker = 10 AWG minimum
30 A Breaker = 10 AWG minimum
35 A Breaker = 8 AWG minimum
40 A Breaker = 8 AWG minimum

Glossary

Term	Definition
Air mass (AM)	A measurement of atmospheric thickness that describes the length of the path that solar radiation travels to reach the surface of the earth. At Standard Test Conditions (STC) air mass is set to 1.5 g, corresponding to an average thickness of atmosphere for a day. The *g* stands for global irradiance.
accessible, readily	See *Readily accessible*
Albedo radiation	Radiation that is reflected—bounced from the ground or nearby objects.
Alternating current (ac)	Electric current that changes direction periodically. Utilities typically supply AC electricity to a home or business.
Ambient temperature	The air temperature surrounding a person, place, or thing. Distinct from *cell temperature* which is the actual temperature inside a solar module's cells.
Ampacity	From NEC Article 100: *The current, in amperes, that a conductor can carry continuously under the conditions of use without exceeding its temperature rating.*
Ampere (A)	Unit of measure for electric current; it is the rate of flow of electrons in a conductor.
Angle of incidence	The angle that light striking the surface of a PV module makes with a line that is perpendicular to the surface of that module.
ANSI	American National Standards Institute. This governing body oversees the creation and use of thousands of standards and guidelines for products and procedures in the US.
Antireflective coating (AR coating)	A thin coating of a material, usually a mixture of metal oxides, which reduces light reflection and increases light transmission, applied to a photovoltaic cell or module surface.

Array	A group of electrically connected PV modules.
Array current	The electrical current produced by a PV array when it is exposed to sunlight and connected to a load. Measured in amperes (amps), it is typically the sum of the current of parallel series strings of PV modules that comprise an array.
Array operating voltage	The voltage produced by a PV array when it is exposed to sunlight and connected to a load. Measured in volts, it is typically the voltage of a single series string of PV modules. Arrays are typically operated by inverters at their V_{MP}.
Authority having jurisdiction (AHJ)	From NEC Article 100: *The organization, office, or individual responsible for enforcing the requirements of a code or standard; or for approving equipment, materials, an installation, or a procedure*.
Azimuth	The azimuth angle of an array or roof surface is the direction reading on a compass, corrected for magnetic declination, when that compass is held in the direction in which the array or roof surface is facing. Zero is north, 90° is east, 180° is south, 270° is west.
Bypass diode	A diode connected in parallel with a group of cells within a PV module for the purpose of providing an alternative path for current in case of module shading or failure.
Cell efficiency	The ratio of the electrical power actually produced by a photovoltaic cell to the solar power striking the cell.
Circuit breaker	From NEC Article 100: *A device designed to open and close a circuit by non-automatic means and to open the circuit automatically on a predetermined overcurrent without damage to itself when properly applied within its rating.*
Conductor (electrical)	Something that allows electricity to flow through it easily. Water and most metals are good conductors. Conductors allow electricity to flow through them because the electrons in their atoms move very easily between atoms.
Continuous duty	Operation of an electrical circuit servicing a substantially constant load at maximum current for a minimum of three hours.

Converter	A device that converts an electrical circuit's voltage to another voltage, usually to maximize power production.
Crystalline silicon (c-Si)	A type of PV cell made from a single crystal or polycrystalline slice of silicon. SunPower PV cells are made from crystalline silicon. (Not to be confused with amorphous silicon [a-Si]).
Current	The rate of flow of electrons in a circuit. Measured in amps; represented by *A* or *I*.
Derate factor	A factor that allows for rating differences that result from final conduit heights as well as variations in conduit routing and thus is used to more accurately predict the output of a PV system.
Diffuse radiation	Radiation from the sun after that radiation has scattered in the atmosphere.
Direct beam radiation	Radiation received directly from the sun with little or no diffusion.
Direct current (dc)	Electric current that flows in one direction only. SunPower PV modules produce direct current.
Disconnect	A device which can disconnect the flow of current in a circuit from its source of power supply. A PV system has both an AC and a DC disconnect.
Efficiency	The ratio of output power (or energy) to input power (or energy); expressed as a percentage. PV cells, modules, and inverters all operate with varying levels of efficiency.
Energy (Wh or KWh)	Measured in watt-hours or kilowatt-hours, energy is an amount that is determined by a rate of power (W) multiplied the duration of time (T) that power is flowing, or E = P × T.
Equipment grounding conductor (EGC)	From NEC Article 100: *The conductive path installed to connect normally non-current-carrying metal parts of equipment together and to the system grounded conductor or to the grounding electrode conductor, or both.*

Exclusion area	An area adjacent to objects that are in proximity to a solar array, in which none of the array's modules are to be placed (in order to prevent shading that occurs in the exclusion area).
Fixed-tilt array	An array installed such that its modules are positioned at a fixed angle; as opposed to a tracking array that moves with the sun during the day.
Frequency	The number of repetitions of a complete waveform of alternating current; expressed in Hertz (Hz).
Fuse	From NEC Article 100: *An overcurrent protection device with a circuit-opening fusible part that is heated and severed by the passage of overcurrent through it.*
Grid	A term often used to describe an electrical utility's infrastructure and distribution network.
Ground	From NEC Article 100: *The Earth.*
Ground-fault circuit interrupter (GFCI)	From NEC Article 100: *A device intended for the protection of personnel that functions to de-energize a circuit or portion thereof when a current to ground exceeds safe values.*
Ground-fault protection device (GFPD)	From NEC Article 100: *A device intended to provide protection of equipment from damaging line-to-ground currents by operating to cause a disconnecting means to open all ungrounded conductors of the faulted circuit. This protection is provided at current levels less than those required to protect conductors from damage.*
Grounded	From NEC Article 100: Connected (connecting) to ground or to a conductive body that extends the ground connection.
Grounded conductor	An electrical conductor, AC or dc, which is bonded to ground, typically at the inverter or point of interconnection.
Grounding electrode	A conducting object through which a direct connection to earth is established. Common examples include driven rods, concrete encased rods, and metallic water pipes.
Grounding electrode conductor (GEC)	An electrical conductor that connects the grounding electrode to the grounded conductor.

Insolation	Now more commonly referred to as *irradiation*, this is the amount of solar radiation incident on an area over time; equivalent to energy and usually expressed in kilowatt-hours per square meter (kWh/m^2). Insolation now more commonly referred to as irradiation.
Inverter	In a PV system, the inverter converts DC power from the PV array to AC power compatible with the utility and AC loads; also performs maximum power point tracking (MPPT) by adjusting array voltage levels to achieve maximum power output; and provides data for the end user.
Inverter efficiency	The ratio of AC output power to DC input power of the inverter.
Irradiance	The rate of solar power incident on a surface; usually expressed in kilowatts per square meter. Irradiance multiplied by time equals irradiation (formerly *insolation*).
Irradiation	The amount of solar energy that falls on a surface over time; formerly insolation. This is the energy density of solar radiation and is measured in units of kilowatt-hours per square meter per day ($kWh/m^2/day$).
IV curve	The plot of the current versus voltage characteristics of a photovoltaic cell, module, or array. Three important points on the IV curve are the open-circuit voltage V_{OC}, short-circuit current I_{SC}, and maximum power operating point (V_{MP} and I_{MP}).
Kilowatt (kW)	A unit of power; one thousand watts; often used to describe the size of a PV array.
Kilowatt-hour (kWh)	A unit of energy; one thousand watt-hours. Used to describe the energy output of a PV system as well as the energy demand of a household or business. Power multiplied by time equals energy.

Listed	From NEC Article 100: *Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with the evaluation of products or services, and whose listing states that the equipment, material, or services meets appropriate standards or has been tested and found suitable for a specified purpose. Examples include Underwriters Laboratory (UL), Intertek-Edison Testing Laboratory (ETL) and the Canadian Standards Association (CSA).*
Load	The amount of electric power used by a building, motor, appliance, or other electrical device at any given time.
Load current	The current required by a given electrical device; measured in amps (A).
Maximum power current (I_{MP})	The current at the point on an IV curve at which a PV cell, module, series string, or array produces maximum power.
Maximum power point (peak power point)	The point on an I-V curve that represents the largest area rectangle that can be drawn under the curve; the location of the V_{MP} and I_{MP}. Operating a PV array at that voltage will produce maximum power.
Maximum power point tracking	Performed by the inverter, this is the operation of the array at the peak power point of the array's IV curve where maximum power is obtained.
Maximum power voltage (V_{MP})	The voltage at the point an IV curve at which at PV cell, module, series string, or array produces maximum power.
Module	An assembly of solar cells connected in series to give useful voltage and encapsulated to protect the cells from the environment.
Module derate factor	A factor that lowers a given module type’s power output to account for field operating conditions such as dirt accumulation or aging.
Module efficiency	The ratio of the electrical energy produced by a photovoltaic module to the solar energy striking the module surface area.

NEC	The National Electrical Code; contains guidelines for all types of electrical installations. The 1984 and later editions of the NEC contain Article 690, "Solar Photovoltaic Systems" which should be followed, along with all other articles, when installing a PV system.
Negative conductor	The conductor in a DC circuit that carries a negative polarity.
NEMA	National Electrical Manufacturers Association; sets standards for some non-electronic products like equipment enclosures and J-boxes. For example, NEMA ratings dictate the environment in which an enclosure or box may be located.
Neutral conductor	The conductor in an AC circuit connected to the neutral point of a system that is intended to carry current under normal conditions.
Nominal voltage	A value assigned to a circuit or system to designate its voltage class. Typical values are 120, 208, 240, 277, and 480.
Normal operating cell temperature (NOCT)	The measured temperature of solar cells inside a PV module when operating under typical real-world operating conditions. Defined as the cell temperature inside a module when exposed to these defining conditions: 800 W/m^2 irradiance, 20° C ambient temperature, average wind speed of 1 m/s, and module in open-circuit state.
N-Type silicon	Silicon material that has been doped with a material that has more outer electrons in its atomic structure than does silicon, such as phosphorous. The free-charge carriers in this type of silicon (electrons) carry a negative charge, thus the *N*.
Ohm (Ω)	The unit of electrical resistance. Electrical resistance is a measure of the opposition to the flow of electricity through a conductor.
Ohm's Law	V = I × R; Fundamental law of electricity that states voltage equals current times resistance.
Open-circuit voltage (V_{OC})	The maximum voltage produced by an illuminated photovoltaic cell, module, or array with no load connected. This value will increase as the temperature of the PV material decreases.

OSHA	Occupational Safety and Health Administration; provides protection to workers by enforcing safety standards; exists at both the federal and state level.
Overcurrent	Any current in excess of the rated current of equipment or the ampacity of a conductor. A state of overcurrent may result from overload, short circuit, or ground fault.
Overcurrent protection device (OCPD)	From NEC Article 100: A device that provides overcurrent protection for conductors and equipment by opening the circuit if the current reaches a value that will cause an excessive or dangerous temperature in conductors or conductor insulation. Examples include fuses and circuit breakers.
Parallel connection	The opposite of series connection, this wiring configuration is used to increase current (amperage). Parallel wiring is positive to positive (+ to +) and negative to negative (− to −).
Peak load	The maximum load demand of a system or building.
Peak sun hours	The equivalent number of hours per day when solar irradiance averages 1,000 W/m². For example, six peak sun hours means that the energy received during total daylight hours equals the energy that would have been received had the irradiance been 1,000 W/m² for six continuous hours.
Photon	The particle unit of light. A PV cells captures the energy inherent in photons from the sun and converts it to electricity.
Photovoltaic cell	A device composed of specially prepared semiconductor material and having the capacity to convert incident solar energy directly into electrical energy.
Photovoltaic Effect	The phenomenon that occurs when photons knock electrons loose from the atoms they strike. When this property of light is combined with the properties of semiconductors, electrons flow in one direction across a junction, setting up a voltage. With the addition of circuitry, current will flow and electric power will be available.
Positive conductor	The conductor in a DC circuit that carries positive polarity.

Power (W or kW)	Power is the rate of using energy to do work. Measured by watts or kilowatts, power is a rate determined by the amount of current (I) times the voltage (V) level at a given point in time, or $P = I \times V$.
Power factor (PF)	The ratio of real power (watts) to apparent power (volt-amps) in an AC circuit. Power factors of less than 1.0 occur when AC current and voltage waveforms are out of sync with each other.
P-type silicon	Silicon material that has been doped with a material, such as boron, that has fewer outer electrons in its atomic structure than does silicon. The free charge carriers in this type of silicon have a positive charge, thus the *P*.
Readily accessible	From NEC Article 100: *Capable of being reached quickly without requiring a person to climb over or remove obstacles or to resort to portable (temporary) ladders, or other tools to gain access.*
Resistance	Electrical resistance is a measure of the opposition to the flow of electricity through a conductor. Measured in ohms (Ω).
RMS	Root mean squared; a method for calculating the effective average value of AC current or voltage; square root of the mean (average) of the squares of values over time.
Semiconductor	An element, such as silicon, which has a crystalline structure that will allow current to flow under certain conditions. Semiconductors are usually less conductive than metals, but more conductive than an insulator.
Series connection	A wiring configuration used to increase voltage. Series wiring is positive to negative (+ to −) or negative to positive (− to +). See Also *parallel connection.*
Series string	A collection of PV modules that are electrically connected together in series to increase the voltage to a useable amount. An array is made up of one or more strings of modules.
Short circuit current (I_{SC})	The maximum current produced by a PV cell, module, string, or array under specific conditions. The positive and negative terminals are connected directly together with no resistance.

Short circuit	An unintended connection between two conductors or between a conductor and ground or some other unintended surface, at low resistance, such that excessive and often damaging current flows through it.
Silicon	A non-metallic semiconductor element, that when specially treated, is sensitive to light and capable of transforming light into electricity. Silicon is the basic material of most beach sand or silica (along with oxygen), and is the raw material used to manufacture most photovoltaic cells.
Sine wave	A waveform corresponding to the periodic swing between positive and negative polarity in an alternating current (ac) electrical circuit.
Tilt angle	A fixed angle measured up from the horizontal at which a roof or solar array is tilted.
Tracking array	An array that is mounted on a movable structure that follows the path of the sun.
Ufer grounding electrode	A concrete-encased grounding electrode.
Ungrounded conductor	A conductor not connected to ground.
Voltage (V)	A measure of the force or "push" given to the electrons in an electrical circuit; a measure of electrical potential. One volt produces one amp of current when acting against a resistance of one ohm, or V = I x R. See Also *Ohm's Law*.
Watt	A unit of power. Power is the rate of using energy to do work.