RESIDENTIAL PHOTOVOLTAIC SYSTEM SPECIFICATION

Lawrence Shaw
Lawrence@HigherPoweredSolar.com

Rev 2021.09.01

Contents

Rev 2021.09.01

Photovoltaic Solar

Disclaimer

This is the photovoltaic (PV) solar system specification we at Higher Powered, LLC. adhere to. We've shared this online to assist with transparency and to provide some clarity to potential purchasers of solar regarding decision making. It may be used as you see fit with the following caveats: First, that subject matter contained herein is taken "as-is" and not regarded as prescriptive in nature. Second, that no claim of ownership or authorship is made by the user. Lastly, that the user indemnifies Higher Powered, LLC. against all liabilities resulting from the use of the material or subject matter contained herein unless related to a PV system purchased from Higher Powered, LLC.

We recommend using licensed professionals to install your PV system and doing your own diligence to confirm the material, comments, and subject matter contained herein.

Why This Matters

We like the gallon of milk analogy. If you (the reader), or I (the writer) were to purchase a gallon of milk, we know certain things about what we should be getting. We would expect it to be cold and not smell sour. We would also expect not to see any curdling. Although we may not know every step that goes into homogenization, or getting the milk from the cow into a bottle in the store, we do know, because we purchase it often enough, what we should be getting and that it shouldn't cost $20 per gallon.

The cost of solar can be a little tricky. It's roughly the same magnitude as what a person might spend when they purchase a vehicle. Similar to purchasing a car, the buyer can go grand, petite, or something more in tune with their budget. Dissimilarly however, there's no Kelly Bluebook to consult and unlike the purchase of a vehicle, going solar is typically a one-time transaction.

There's a lot to consider when going solar and unfortunately, the details can be a bit overwhelming. Presumably the system owner will want the system to operate as advertised and not be a safety concern. In our experience, this can only be accomplished with a proper design specification provided as a scope to the installer, and periodic maintenance. This specification has been written with the objectives of delivering safe systems that will perform admirably from year to year.

The details contained in our specification are based upon decades of experience and hard lessons learned in the field. If it looks lengthy and complicated, that is because providing a home with electricity from solar is complicated. Handling those complications is the job of the installer and doesn't need to be a headache for a homeowner. This is why we've shared this material in a checklist format. A good installer should have no problem adhering to a checklist scope given to them if they're truly committed to their customer's safety and product quality.

System Design

SAM Performance Model

- ☐ The performance of the PV system shall be modeled using the National Renewable Energy Laboratory's System Advisor Model (SAM).
  - ✓ This is an open-source software.

- ✓ This is considered a bankable model (some lending entities view it to be accurate enough to help justify financing).
- ✓ It is free and can be downloaded by the customer.
- ✓ It is created by an internationally recognized laboratory.

☐ A report indicating anticipated system production shall be included with the PV system project documents.

- ✓ Provides a quick summary of key information, including financial, for the project.

☐ In addition to a SAM report, the project documentation shall include a copy of the simulation file (extension: .sam).

- ✓ Provides transparency. The customer could always doublecheck the inputs used by the installer.

☐ Payback calculations shall be completed by using SAM and the off-taker's applicable utility rate plan. It's noteworthy to mention some utility companies require switching to a new rate plan with the installation of solar and this is the plan that needs to be used when calculating the payback period. The good news is SAM has an online interface that can often automatically download all of the rate details.

- ✓ A transparent, traceable way to ensure the seller isn't overpromising.
- ✓ The entire 20- or 25-year cash flow analysis can be easily exported as a spreadsheet.

Maintenance

☐ For grid connected systems, the installer will specifically discuss the maintenance requirement included in the interconnection agreement (IA) by the utility.

- ✓ We have yet to read an IA where maintenance wasn't required.

☐ The installer shall provide an annual maintenance plan that includes infrared (IR) imaging of the PV modules (solar panels), and electrical terminations.

- ✓ You have to do maintenance for your car or your AC unit. You wouldn't put your laptop in the sun and expect it to work 20 years later without any attention. A solar system is no different. There are now solar panels (PV modules) that have been working for 40 years, but in our experience, this is only achievable with upkeep.
- ✓ Fires in the U.S. caused by solar systems are increasing from year-to-year but can be prevented with proper system specification and maintenance.
- ✓ Many safety issues will eventually become hotspots which can be detected by an IR camera.

  ▫ The infrared camera shall be able to detect (and display) high and average temperature.
    - One key PV module (solar panel) safety defect to check for is 20 deg C relative to average cell temperature.

  ▫ The yearly cost of the maintenance plan shall be included in the SAM model file.
    - Helps ensure a better estimate on the customer's return on investment (ROI).

☐ Maintenance shall be documented in a report that includes photographs of IR images with temperatures displayed.

- ✓ If it wasn't documented, it didn't happen.

Rev 2021.09.01

PV Modules

Equipment Selection

Modules

In general, the photovoltaic (PV) modules (aka solar panels) selected, shall at a minimum, meet these criteria:

- ☐ Shall be Tier 1 (currently included on Bloomberg's list).
  - ✓ This may be an indicator of the manufacturer's potential ability to honor a warranty claim but should not be used as an indicator for PV module quality.
- ☐ Shall be manufactured by Jinko, REC Solar, or Hanwha.
  - ✓ These manufacturers are listed as top performers following lab testing, in terms of quality and reliability, by PV Evolution Labs year after year.

SUSTAINABILITY NOTE: We don't think shipping products manufactured across seas is the best option for our planet and people domestically. Since Hanwha has an assembly plant in Georgia, our firm will always source Hanwha solar panels (modules), giving preference to their made in America models, if they're available.

- ☐ Shall have tempered glass as the top surface material.
  - ✓ Tempered glass may hold up better than annealed to damage from hail.
- ☐ Shall have IEC 61215 certification.
  - ✓ This will help minimize material, process, or design flaws that could lead to premature failure in the field.
- ☐ Shall have UL 1703 certification.
  - ✓ This helps ensure fire safety.
- ☐ If possible, the bill of materials (BOM) shall be the same BOM as was used for modules (solar panels) during the IEC 61215 and UL 1703 testing certifications.
  - ✓ Sometimes solar panels are made with different materials than were used during their testing. This creates problems with safety, durability, and reliability.
  - ✓ An installer may push back on this claiming the 10-30 solar panels needed for a residential project doesn't provide the needed purchasing power with the manufacturer to guarantee this. While there may be a modicum of truth in that, most installers obtain their panels from a "go-to" supplier who does in fact have the purchasing power to request this.
- ☐ Shall not have anti-reflection coating.
  - ✓ This type of coating makes the output of solar panels artificially high for the first few years of operation. It's hard to get manufacturers to tell you how much power will be reduced after sunlight degrades this coating.
  - ✓ If product without anti-reflection coating cannot be found, this will be accounted for by increasing the degradation rate to a minimum of 0.6% starting year five of system operation in the SAM model.
- ☐ Connectors (typically MC4) shall not have dissimilar metals.
  - ✓ The metal in the connector shall be the same as is used in the DC conductors (PV Source Circuits as defined by NFPA 70). Different metals will have different expansion and

contraction rates. This could lead to weakened connections and/or failed connectors that could become a fire hazard.

Racking

- ☐ Shall be UL 2703 certified if attached to the house.
  - ✓ Ensures proper grounding to prevent shock hazards, fire safety, and construction standards.
- ☐ Shall be based on the specified location type and mobility type as described below.
  - ✓ A practical matter.

Layout Plan

In general, these guidelines shall be followed:

- ☐ The planned layout, or mechanical arrangement, of the PV modules (solar panels) shall be in a fashion to ensure that no PV module will receive row-to-row shade while the angle of incidence (the direct beam component of solar radiation) is equal to or less than fifty-five degrees for any day of the year. A copy of this calculation shall be included in the drawing submittal.
  - ✓ Greater than 55-degree angle of incidence for the direct beam component of solar radiation results in a significant portion of light being reflected. However, while the PV module is absorbing direct beam solar radiation, if cells are shaded, current can be dissipated as heat through a bypass diode. Heat degrades solar cells and shortens the useful life of PV modules (solar panels).
- ☐ The planned layout, or mechanical arrangement, of the PV modules (solar panels) shall be in a fashion to ensure that no PV module (solar panel) will receive shade, from any source (i.e. trees, adjacent buildings, power lines, etc.) from 0700 – 1800 Local Solar Time for any day of the year. This shall be accomplished via a 3D environment modeled shade simulation for the Winter Solstice, Solmetric SunEye, or Solar Pathfinder, and the file shall be included with the construction drawing package.
  - ✓ Why plan to install panels in the shade when there will be less electricity, shorter equipment life, and potentially a voided warranty?
- ☐ Only PV Source Circuits supplied current from various array circuits with PV modules (solar panels) with the same tilt angle, and same azimuth angle shall feed, or be combined together to feed, the same inverter maximum power point tracker (MPPT) channel.
  - ✓ Mismatches in circuits can result in power losses.
- ☐ For flush mounted configuration, a minimum of six inches shall be provided for airflow between the rooftop or other such surface, and the PV modules (solar panels).
  - ✓ Hotspots may be less hazardous than if there was less room for airflow.
  - ✓ Better heat dissipation can help reduce degradation and maximize equipment life.
- ☐ Shall be in landscape orientation unless using a single panel (as defined by NFPA 70) (only one row of PV modules) if installed on a horizontal surface (flat rooftop without a slope, ground, etc.).
  - ✓ This may help prevent all of a system from turning off if the designer and/or installer didn't provide adequate spacing between rows.
- ☐ Shall face the equator and be tilted at an angle within five degrees (usually less than) of latitude.

- ✓ Orientation towards the sun will maximize system production and the return on the investment.
- ✓ Occasionally a residential rooftop will necessitate not facing panels due south (northern hemisphere), or site conditions may not be suitable for a tilt angle near latitude. In these instances, the impact on production and return on investment should be modeled for the customer using a comprehensive tool such as the National Renewable Energy Laboratory's software: System Advisor Model. The model file (not just the report) shall be provided to the customer for their documentation.

Module Level Electronics *(micro-inverters, optimizers, monitors, rapid shutdown devices, etc.)*

Layout Plan

- ☐ The planned layout, or mechanical arrangement, of the electronic equipment shall be in a fashion to ensure that no device will receive direct beam sunlight, at a minimum, from 0700-1800 solar time for any day of the year.
  - ✓ Heat kills electronics. Shade help mitigate this. Would you leave your laptop in your vehicle in the Phoenix Valley during summer months?
- ☐ The physical gap, allowing for airflow, between any PV module and any electronic device shall be a minimum of six inches.
  - ✓ Again, heat kills. In this case, heat from the MLE could go directly into the solar panel potentially shortening its useful life. Heat degradation of solar panels is well documented in industry.
- ☐ The securing of the device shall be planned/designed/engineered in such a way as to minimize the surface area of the device that comes into contact with any material that has high thermal conductive capacity (e.g. aluminum) while allowing for the maximum amount of airflow possible.
  - ✓ Another strategy to reduce heat and maximize equipment life.

Inverter(s)

Equipment Selection

In general, inverter(s) selected, shall at a minimum, meet these criteria:

- ☐ Verified PV Source Circuit minimum voltage will not be lower than the low voltage setpoint of the MPPT operating voltage range by taking into account module cell temperature via the following methodology:

  - ▫ Determine highest expected cell temperature from an 8760-output dataset from NREL's System Advisor Model (SAM) based on the nearest (geographically) TMY file available from NREL as input to the project model. When given a choice between TMY2, and TMY3 datasets, TMY2 shall be used.
  - ▫ Using the highest expected cell temperature (not ambient) and the voltage temperature coefficient published by the module manufacturer, calculate the lowest expected string voltage.

- Lowest expected string voltage as well as the MPPT operating voltage range shall be included on the drawings.

  ✓ This will ensure the inverter is producing power even during hot summer months. Not all inverters will do this.

- ☐ Highest DC voltage calculated in accordance with Article 690.7 of NFPA 70, Calculation results shall be included on the drawings.
  ✓ This calculation is intended to prevent exceeding voltage limits for the inverter during the colder winter months (i.e. fire safety).
- ☐ Shall not be 1500V_{dc} system topology. 600V_{dc} (or lower) system topology preferred (utility interactive applications).
  ✓ High voltages can reduce the maximum power output of solar panels over time thereby reducing the return on investment. This is sometimes called potential induced degradation (PID). Although there are numerous manufactures that claim to have PID resistant panels, since the physical causes are not fully understood by researchers, it is hard for us to believe the marketing material. For this reason, we design systems with lower voltages.
- ☐ GFDI, and Arc Fault detection and interrupt included.
  ✓ Will turn the inverter off during certain hazardous conditions.
- ☐ UL 1741, and UL 1741 SA certified if grid connected.
  ✓ Intended to ensure the safety of electrical workers during a grid power outage.
- ☐ Complies with IEEE 1547, and CA Rule 21 grid connection standards if grid connected.
  ✓ These are the standards industry is moving to.

SUSTAINABILITY NOTE: We don't think shipping products manufactured across seas is the best option for our planet and people domestically. We're told Sol-Ark inverters are designed, engineered, and assembled domestically.

Layout Plan

- ☐ The planned layout, or mechanical arrangement, of the inverters shall be in a fashion to ensure that no inverter will receive direct exposure to the sun from 0700-1800 solar time for any day of the year.
  ✓ Again, heat kills electronics. Shade helps.
- ☐ Original equipment manufacturer wire termination torque requirements shall be included on the drawings.
  ✓ Creates a record of how tight to ensure electrical connections are for the home-owner and maintenance providers. Tight connections help ensure electrical safety.

Electrical Panels *(combiner boxes, dc panels, ac panels, etc.)*

Equipment Selection

- ☐ Shall be rated to at least NEMA 3 or better (NEMA 4X).
  ✓ Helps prevent water from getting in during weather including precipitation.
- ☐ Shall have lockable switches.

- ✓ Provides electricians with a means to keep themselves safe when they service equipment.

☐ Shall have dead front boundaries (DC combiners may be excluded only if necessary).

- ✓ Provides electricians with a means to keep themselves safe when they service equipment.

Layout

☐ Shall be located, wherever possible, in places that the enclosure will not receive sunlight from 0700-1800 solar time.

- ✓ Heat kills electronics. Shade helps prevent this.

☐ Original equipment manufacturer wire termination torque requirements shall be included on the drawings.

- ✓ Creates a record of how tight to ensure electrical connections are for the home-owner and maintenance providers. Tight connections help ensure electrical safety.

Energy Storage (Batteries)

☐ Shall have a cabinet rated for the environment (e.g. outdoors) that the batteries are installed.

- ✓ Offers protection from the sun and weather.

☐ The battery cabinet shall have a path for airflow.

- ✓ Lithium ion and lead acid battery technology can sometimes off-gas. Having a path for airflow can help prevent the accumulation of gases which can be explosive.

☐ Thermal barriers shall be used for each battery cell.

- ✓ May help keep a thermal event in one battery cell from spreading to adjacent battery cells.

☐ There shall be a minimum of 0.75 inch, unobstructed, gap for airflow between each of the battery cells (and thermal barriers).

- ✓ Airflow will allow for dissipation of heat from the individual battery cells.

SUSTAINABILITY NOTE: We don't think shipping products manufactured across seas is the best option for our planet and people domestically. Also, right now lithium ion has a limited supply which generally comes from mining activities abroad and cannot be easily recycled whereas nearly 100% of lead can. MK Deka is based in America, supplies lead acid batteries, and were told recycles lead from old batteries for reuse.

Weather Station

Components

☐ Should the budget permit, at the customer's option, and sole discretion, shall include a silicon irradiance sensor that is configurable with the data acquisition system.

- ✓ It's best to have the same material for the irradiance sensor as the solar panels because they will have similar spectral response.

☐ The irradiance sensor should measure global irradiance (GHI) as this is the value that was used to model anticipated performance in a typical meteorological year.

- ✓ If you want to know how your system is doing, the measurements for sunlight need to be the same type as the measurements that were taken for the performance model.

Layout Plan

- ☐ The irradiance sensor shall be installed in in an area where it will not receive shade nor cast shade onto the arrays.
  - ✓ Why would you put your fuel gauge in the shade (this happens more often than one might initially suspect) if it is supposed to be measuring sunlight?

Data Acquisition System (DAS)

- ☐ Unless otherwise specified, the default DAS is the monitoring platform offered by the inverter manufacturer.
  - ✓ Many inverter manufacturers have a way to monitor their equipment. Sometimes this is built in and will work with a wireless internet signal. Why pay extra for redundant monitoring systems?
- ☐ A line-diagram of the DAS, including any mod-bus mapping, shall be included in the drawings.
  - ✓ This saves headaches (time and money) later when equipment needs to be troubleshot or serviced.
- ☐ Where a dedicated enclosure is required for the DAS, the enclosure shall be rated to a minimum of NEMA 3 weather tolerance.
  - ✓ Intended to keep water out of the electrical box. Always a good idea.

Layout Plan

- ☐ Where a dedicated enclosure is required for the DAS, the enclosure shall be installed at a location that will ensure it will not receive direct exposure to the sun from 0900-1600 solar time for any day of the year.
  - ✓ Heat kills electronics. Shade helps.

Conductors

- ☐ Shall be sized in accordance with NFPA 70 (most current year published).
  - ✓ NFPA 70 is National Electric Code which is written with the intent of preventing fires.
- ☐ Shall not have dissimilar metals in connections.
  - ✓ Dissimilar metals have different expansion and contraction rates. This can be hazardous.
- ☐ When connecting a conductor to a connector (MC4, and others), the conductor shall have the same gauge of wire as was used during UL certification for the connector.
  - ✓ Sometimes suppliers, manufacturers, and even installers can try to pull a fast one. If it isn't the same as it was during certification, this can also be hazardous.
- ☐ Shall not be routed or laid out on the ground surface, or areas that could collect accumulation (pooling) of water.
  - ✓ Electrical and fire safety.
- ☐ DC wiring between PV modules (solar panels) where sunlight can travel shall be protected another material (UV and fire resistant) from direct sunlight:

DC wiring between modules (solar panels) protected by loom (underneath modules)

- ✓ The gap between panels can let solar radiation through and break down the insulation of the direct current conductors.

☐ All wiring and conductors shall be routed and secured in such a way as to minimize the amount of sunlight exposure to the lowest amount reasonably achievable:

DC wiring on edge of array protected from sun prior to entering conduit

- ✓ Sunlight can break down the wire insulation.

☐ All raceways, cable-trays, transitions, fasteners, shall have no sharp metal edges or other rough and or sharp surfaces.

- ✓ This will help ensure there are no sharp edges which will cut through wire insulation.

☐ All conductors shall be secured at reasonable intervals to ensure there is no movement from wind or other such external force that could wear out insulation due to friction.

- ✓ Friction could wear our wire insulation over time.

Zip Ties

☐ Shall be stainless steel coated in rubber, or polyester, or some other insulation that is UV resistant, flame retardant, and rounds off any metal edges (to prevent cutting into the wire being secured). Additionally, if the rounded edge might be a point of friction for the wire insulation, a second material shall be used to protect the wiring from any potential friction:

Example of ideal securing of DC wire

- ✓ Will hold up to the sun and prevent wire movement (friction) which could wear out the wire insulation.

Electrical Conduit

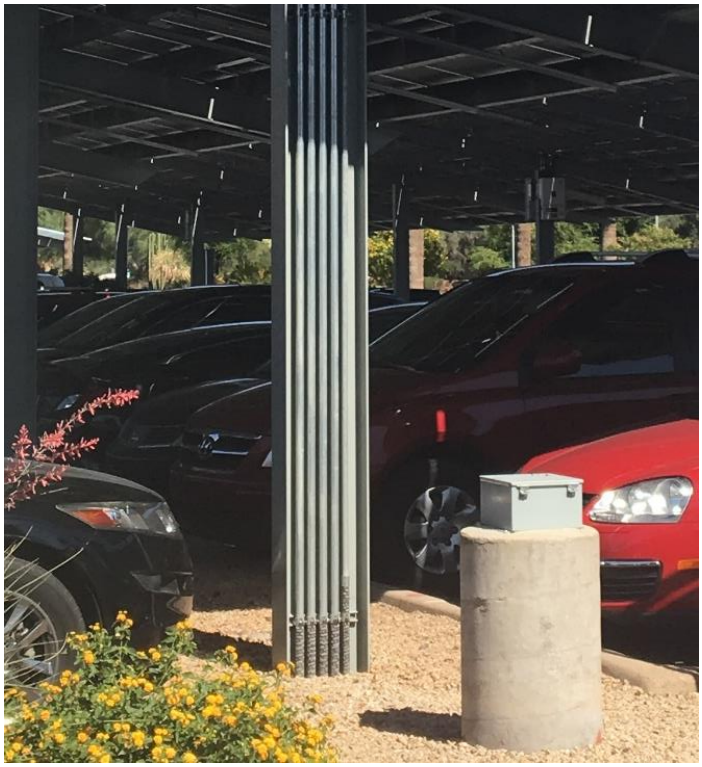
Material Selection

☐ Shall be metal.

- ✓ Should hold up against the sun year after year.

Layout Plan

☐ Wherever possible, shall be routed to avoid as much sun exposure as possible. For example, the conduit in this I-beam could have been routed on the east side (other side) of the I-beam in order to reduce the amount of sunlight received by the conduit since afternoon sun is a problem:



Conduit in I-beam, and j-box directly exposed to afternoon sun.

- ✓ Commercial project, but the concept applies to residential systems as well.
- ✓ Heat will cause thermal expansion and contraction of the wire in the conduit. Sometimes this will create a need for extra wire (i.e. added cost) to allow for this.
- ✓ Atoms will vibrate more when their temperature increases and oppose the flow of electrons.

- ☐ Shall have no less than 3.5 inches distance from the rooftop and any parapet wall(s).
  - ✓ Provides room for airflow and heat dissipation.
- ☐ Shall have no less than the minimum distance from the rooftop and walls as required by National Electric Code (most current year published), prudent industry practice, and local rules and regulations.
  - ✓ Provides room for airflow and heat dissipation.
- ☐ Shall be routed in such a way to comply will National Electric Code (NEC) (most current year published), prudent industry practice, and local rules and regulations.
  - ✓ Provides room for airflow and heat dissipation.
  - ✓ Helps keeps walking paths free from obstacles.

Labeling

- ☐ Shall be labeled in accordance with National Electric Code, prudent industry practice, and local rules and regulations. Labeling requirements shall be included in the drawings.

- ✓ Helps contractors and other people who may access the area know where hazardous circuits are.
- ✓ Helps emergency responders know where to isolate energized circuits if needed.

System

Safety

- ☐ All electrical enclosures shall have appropriate arc flash boundary and PPE requirements posted (label) which shall be included in the drawings.
  - ✓ Helps any electrician who may service the equipment know what protective equipment / clothing they'll need to wear.
- ☐ The system design, equipment selected, equipment layout, and equipment labeling shall be in accordance with NFPA 1, NFPA 70 (most recent year), and any other applicable laws, codes, industry standards and/or best practices. All labeling, and labeling adhesive, shall be rated for UV exposure.
  - ✓ Fire safety.
- ☐ When metal riveting won't interfere with the UL listing, codes, or NEMA rating of the encloser, riveted metal labels shall be used.
  - ✓ Stickers are notorious for only surviving a few years of direct sunlight.
- ☐ Each inverter AC output circuit shall have the capacity to be isolated via a lockable circuit breaker or switch external to the inverter enclosure. If using micro-inverter technology, the point in the AC circuit where inverter outputs combine shall have the capacity to be isolated via a lockable circuit breaker or switch.
  - ✓ This is important for the safety of service personnel.
- ☐ Each inverter (unless using micro-inverters) DC input circuit shall have the capacity to be isolated via a lockable dual bladed switch (opens positive and negative). This circuit interrupt device may be integrated with the inverter enclosure or external to the inverter enclosure provided that, if integrated with the inverter enclosure, the circuit interrupt device is in a separate housing (or enclosed area if you prefer) than the primary inverter enclosure.
  - ✓ This is important for the safety of service personnel.
- ☐ System shall incorporate listed dc surge protection (SiO varistor type) into the system design at a location close to the common system ground point.
  - ✓ May help protect the system from lightning.
- ☐ There shall be a lightning rod integrated with the design, connected to ground, with as much distance from the system's electronic components as is reasonable and achievable.
  - ✓ May help protect the system from lightning.

Output

- ☐ Conductors shall be sized to ensure that current loss is less than 2%, and in accordance with NFPA 70 (most recent year).
  - ✓ Less power loss (i.e. more money saved).
- ☐ Conductors shall be copper.
  - ✓ Copper typically doesn't thermally expand and contract as much as aluminum. This means less material can be used since you don't have to provide extra slack, and a better chance conductors won't become loose (i.e. hazardous) where they're terminated.

Mobility Type

Depending on the mobility type, at a minimum, the following framework applies:

Fixed Tilt

- ☐ Preferred system configuration.
  - ✓ No moving parts. This usually means fewer maintenance issues.

Single Axis Tracking

- ☐ Hydraulic actuators will not be utilized.
  - ✓ Can leak oil which could be considered an environmental contaminant.
- ☐ Tilted (towards the equator) single axis tracking (atypical of single axis trackers) would be the preferred configuration (if using single axis tracking).
  - ✓ Most bang (power generation) for your buck.

Dual Axis Tracking

- ☐ Not a good idea.
  - ✓ Lots of moving parts which usually equates to lots of maintenance headaches.

Location Type

At a minimum, the following framework applies:

Canopy (consider an area to park vehicles)

- ☐ Preferred choice.
  - ✓ No rooftop penetrations mean no chance of a roof leak.
  - ✓ Off the ground means little chance of dry grass catching fire.
  - ✓ Cooler ground around a house may mean less energy will be needed to cool the house during the summer.
  - ✓ For car canopy parking, a cooler vehicle from being in the shade may mean less gas or energy spent cooling the vehicle off and less stress on the body.
  - ✓ This setup could work very well in concert with electric vehicle charging stations.
  - ▫ Shall be engineered to meet or exceed all mechanical stresses and loads, in accordance with the local AHJ's rules, laws, building codes, and prudent industry practices.
    - Structural safety.

Rooftop

- ☐ Our second choice regarding preference for the location type.
  - ✓ If the roof isn't new, may require reroofing.
  - ✓ Rooftop penetrations create potential leaks.
  - ✓ May create issues with the roof warranty.
  - ✓ Might interrupt the appearance of a roof (e.g. beautiful Spanish tile surface abruptly changes into solar panels).
  - ▫ Shall provide a minimum 48-inch-wide pathways around the perimeter in accordance with NFPA 1 to allow rooftop access to firefighters.

- Firefighters will need a path around the panels if, for whatever reason, they need to fight a fire.

- Shall be engineered in such a way that minimizes the number of rooftop penetrations.
  - More penetrations mean more potential places for the roof to leak.
- Shall be engineered in such a way that will not cause rips or other damage to rooftop membranes or supporting structural members.
  - Intended to reduce the risk of a roof leak.
- Shall be designed in accordance with the local AHJ's rules, laws, building codes, and prudent industry practices. (Exceed where appropriate. Most AHJs appreciate it while sometimes it is best to discuss it with them.)
  - Everyone's safety.

Ground-mount

☐ Our last choice
  - ✓ potential safety hazard due to accessibility, and proximity of equipment to vegetation like dry grass.
- Shall be engineered in accordance with the local AHJ's rules, laws, building codes, and prudent industry practices.
  - Everyone's safety.
- Gravel shall be used on the ground in the vicinity of, under, and around the solar arrays.
  - ✓ This helps prevent vegetation growth which could be a fire hazard during drought conditions.

Documents

Drawings

In addition to all requirements already set forth, the PV solar drawings shall include, at a minimum, the following:

Cover Page

☐ Shall include the project's address.
  - ✓ Seems obvious but it's sometime omitted.

☐ Shall include the project's coordinates (with decimal places instead of minutes and seconds).
  - ✓ Coordinates are way more accurate than an address.

☐ Shall in include a layout photo with a legend indicating the direction of True South (Northern Hemisphere), and the location of the PV system.
  - ✓ A sanity check to ensure the installer knew what direction (hopefully towards the sun) they were orienting the solar panels.

☐ Shall include a system description including: mobility type, location type, DC nameplate capacity, AC nameplate capacity, DC to AC ratio, number make and model of inverters, number make and models of PV modules (solar panels), module tilt in degrees, and module azimuth in degrees if fixed tilt.
  - ✓ This helps ensure the installer is providing what was promised to the customer.

☐ Shall include any other requirements of the local Authority Having Jurisdiction (AHJ).
  - ✓ May help streamline permitting for the project.

Electrical

- ☐ Shall include a single-line diagram.
  - ✓ Pretty standard really. Most permitting offices will require this.
  - ✓ This will also help service providers should any maintenance issues arise.
- ☐ Shall include a three-line diagram for all unique circuits (after a circuit is drawn, it may be referenced in lieu of drawn again for replication).
  - ✓ Again, most permitting offices will require this.
  - ✓ This will also help service providers should any maintenance issues arise.
- ☐ Shall include a schedule of electrical equipment.
  - ✓ Most permitting offices will require this.
  - ✓ This will also help service providers should any maintenance issues arise.
- ☐ Shall include any other requirements of the local Authority Having Jurisdiction (AHJ).
  - ✓ Most permitting offices will require this.
  - ✓ This will also help service providers should any maintenance issues arise.

Mechanical

- ☐ Shall include a layout map of equipment.
  - ✓ Most permitting offices will require this.
  - ✓ This will also help service providers should any maintenance issues arise.
- ☐ Shall include dimensional (including units to scale) drawings of all unique equipment (after a particular piece of equipment is drawn, it may be referenced in lieu of drawn again).
  - ✓ Most permitting offices will require this.
  - ✓ This will also help service providers should any maintenance issues arise.
- ☐ Shall include a schedule of mechanical equipment.
  - ✓ Most permitting offices will require this.
  - ✓ This will also help service providers should any maintenance issues arise.
- ☐ Shall include any other requirements of the local Authority Having Jurisdiction (AHJ).
  - ✓ Most permitting offices will require this.
  - ✓ This will also help service providers should any maintenance issues arise.

Additional

- ☐ The initial project drawings should also include anything required by the local AHJ to obtain a construction permit.
  - ✓ Streamlines permitting the project.
- ☐ An As-Built drawing set shall be provided which shall include all these drawing requirements as well as any irregularities identified (changes from the permit set) during construction.
  - ✓ Most permitting offices will require this.
  - ✓ This will also help service providers should any maintenance issues arise.

Warranty

- ☐ A copy of manufacturer warranty cards shall be included for all system components incorporated in the system design including (if installed) but not limited to:

- ✓ May help ensure the customer has needed documentation should a warranty claim become necessary.

- ▫ Photovoltaic modules (solar panels)
- ▫ Module level electronics
- ▫ Mounting hardware components
- ▫ Single axis-trackers
- ▫ Tilt sensors
- ▫ DC combiner boxes
- ▫ Inverter(s)
- ▫ AC combiner boxes
- ▫ Data acquisition system (DAS) equipment
- ▫ Transformers
- ▫ Batteries
- ▫ Charge controllers
- ▫ Other?

Inverter(s)

- ☐ An achievable field test procedure to identify performance issues relating to the equipment's warranty shall be provided, in writing, by the original equipment manufacturer.
  - ✓ Helps ensure the customer will be able to follow through with a warranty claim.

PV Modules (solar panels)

- ☐ An achievable field test procedure to identify performance issues relating to the equipment's warranty shall be provided, in writing, by the original equipment manufacturer.
  - ✓ Many times, proving a solar panel is underperforming would require correcting sunlight and temperature for laboratory conditions.
  - ✓ An installer may not be savvy enough to test equipment in the field or reference the right literature.
  - ✓ The hourly rate on an engineer who can reference the right literature may be too high to justify a warranty claim compared to simply replacing the panels with newer ones.
  - ✓ Having a field procedure approved by the manufacturer in advance may help avoid the expense of hiring an engineer or sending the panels to a laboratory for evaluation.

Exceptions

- ☐ It's possible that a particular photovoltaic solar system design / installation may include exceptions to this list resulting from requirements by the local authority having jurisdiction, unique site conditions, equipment availability or other similar reason. Any time this occurs, it should be documented and shared with the customer.
  - ✓ Provides transparency.