Residential/Commercial Solar PV installations

Basic information and installation guides for roof mounted systems (Ed Larsen, Building Official)

May-June 2008

City of Flagstaff/Project Review Section

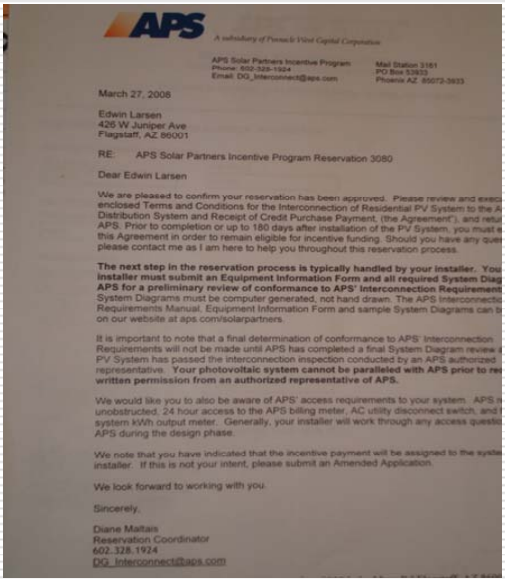
Design and Permits

- A building permit is required for a Solar PV or thermal solar system. Staff has prepared a Memorandum (Memo #106; which is periodically updated) on the submittal requirements. These permits are not issued over-the-counter.
- If the system is to be connected to the grid (APS utility system), then a copy of the approved interconnect agreement and a licensed contractor is required for the final installation and "green tag". For off-grid or battery systems, a licensed contractor is not necessarily required.
- If the system is not roof mounted, then the arrays must be protected from the general public. This can be done by establishing racks at eight (8) feet or greater above the ground level or by providing fencing or a skirting system around the underside of the panels to prevent contact with wiring.
- Permits are not issued over the counter, but require plan review. Simplified drawings are allowed. A one line or block schematic is required and a three-line wiring diagram (indicating wiring sizes and all leads) is also required.

Design and Permits - continued

- There are some minor conflicts between Article 690 of the 2005 NEC and the wiring sizes for various breakers. The inverter specifications should be carefully compared to the general requirements [i.e., a PV system may only require #10s or #12 AWG wiring on the AC side and the max current (amps) may be 30 or less; however, the designer goes for the maximum size for the panel of a double pole 40 amp breaker….this requires #8 AWG wiring, ooops!
- Grounding is important and the use of Weib grounding clips to the channels makes it easier. One key factor is that the Weib clips can only be torque'd once, so make sure panel alignment is correct the first time.
- All of the components of the solar PV system need to be UL listed and manufactured specifically for solar installations.
- When combining the metal conduit with plastic or non-metallic boxes (which are superior on roof tops or any location exposed to weather), then grounding lugs with interconnections between the ends of the conduit needs to be used – bonding requirements.

Permit application



APS

A subsidiary of Pinnacle West Capital Corporation

APS Solar Partners Incentive Program
Phone: 602-328-1924
Email: DG_Interconnect@aps.com

Mail Station 3161
PO Box 53933
Phoenix AZ 85072-3933

March 27, 2008

Edwin Larsen
426 W Juniper Ave
Flagstaff, AZ 86001

RE: APS Solar Partners Incentive Program Reservation 3080

Dear Edwin Larsen

We are pleased to confirm your reservation has been approved. Please review and execute enclosed Terms and Conditions for the Interconnection of Residential PV System to the APS Distribution System and Receipt of Credit Purchase Payment, (the Agreement"), and return to APS. Prior to completion or up to 180 days after installation of the PV System, you must submit this Agreement in order to remain eligible for incentive funding. Should you have any questions please contact me as I am here to help you throughout this reservation process.

The next step in the reservation process is typically handled by your installer. Your installer must submit an Equipment Information Form and all required System Diagrams to APS for a preliminary review of conformance to APS' Interconnection Requirements. System Diagrams must be computer generated, not hand drawn. The APS Interconnection Requirements Manual, Equipment Information Form and sample System Diagrams can be found on our website at aps.com/solarpartners.

It is important to note that a final determination of conformance to APS' Interconnection Requirements will not be made until APS has completed a final System Diagram review and PV System has passed the interconnection inspection conducted by an APS authorized representative. **Your photovoltaic system cannot be paralleled with APS prior to receiving written permission from an authorized representative of APS.**

We would like you to also be aware of APS' access requirements to your system. APS requires unobstructed, 24 hour access to the APS billing meter, AC utility disconnect switch, and the system kWh output meter. Generally, your installer will work through any access questions with APS during the design phase.

We note that you have indicated that the incentive payment will be assigned to the system installer. If this is not your intent, please submit an Amended Application.

We look forward to working with you.

Sincerely,

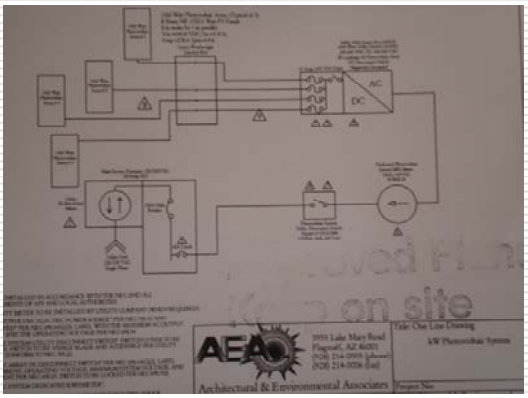
Diane Maltais
Reservation Coordinator
602.328.1924
DG_Interconnect@aps.com

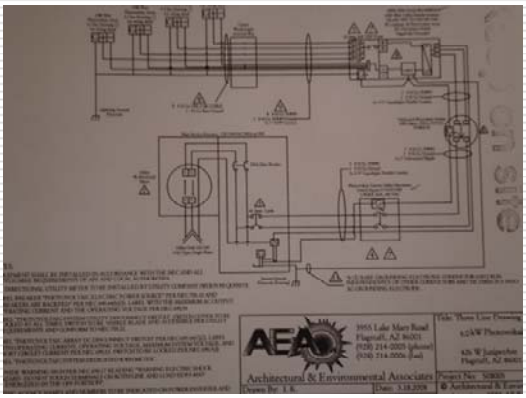
The applicant must include a copy of the APS inter-connection agreement for grid tied systems.

A regular residential or commercial building permit application is also required. The residential permit will only include fees for the electrical items. The City of Flagstaff does not do a technical review for "good design", so the applicant must make sure that the efficiency for the system has been reviewed and discussed with the designer.

A licensed contractor is required for the grid connection systems.

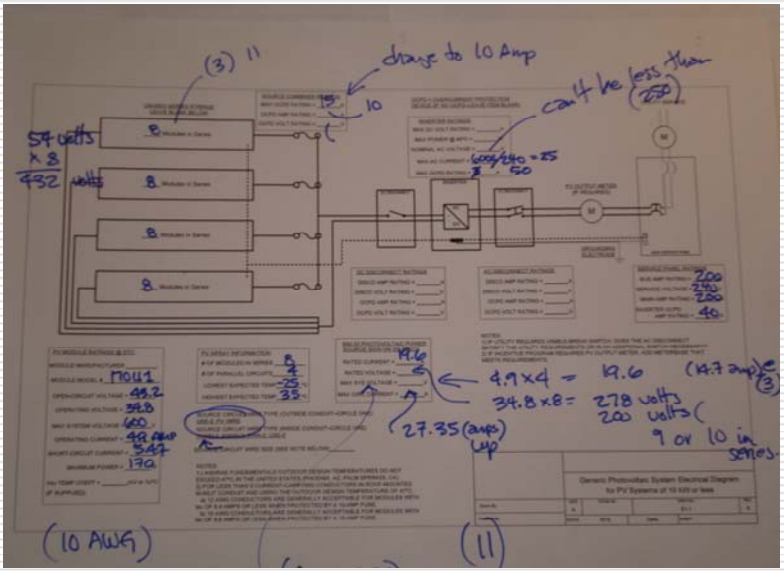
Other drawings required





Both a one-line block diagram is required showing the critical components of the solar PV system (right) and a three-line drawing which indicates the sizes of conductors, fuses, disconnects, breakers, etc. These are the same requirements for APS or the Utility company.

Calculation worksheet



The calculation worksheet (which can be obtained from Brooks Engineering (or other solar PV websites) allows the designer to quickly match the inverter information, the PV panel specifications, temperature & wiring sizes for the entire system. It will help even the plan reviewer note discrepancies or potential problems (recommended, but not required for submittal).

Solar definition basics

*Definitions from Brooks Engineering

- **PV Cell** – The basic photovoltaic (PV) device that is the building block of PV modules. The cell is a thin wafer of silicon which changes light into electric current
- **PV Modules** - one solar cell produces 0.5 volts and 36 cells are connected together to charge 12 volt batteries, pumps and motors. The new standard is 72 cells per module for 24 volts and operating at about 30 volts. The module is the basic building block of systems. The PV cells are connected in series and/or parallel and encapsulated in an environmentally protective laminate
- **Integrated PV Modules** are often constructed to look like materials normally found in construction – i.e., shingles
- **PV Array** – A group of panels that comprises the complete direct current PV generating unit. (Sometimes referred to as a "string").

Residential Install

Typical roof top installation uses a rack mounting system, panels set in arrays or “strings” (multiple panels) and conduit for interconnection of panels. Shown here are Sharp 170s. A cell or module is a single silicon unit and generators 0.5 volts.

Day one of installation

The layout crew will measure the surface area of the roof and must check the exact location of the roof framing members beneath. Since the panels add a tributary load of between 3-5 psf, this extra dead load is minimal and should not require a structural engineer. However, the rack system requires that the anchors are embedded into the roof framing, not just the sheathing.

Track system and mounts

This “standoffs” or spacers of this Pro-Solar system is attached using 5/8” diameter, 3” long lag bolts through the metal roofing, ½” OSB and penetrating the 2-1/8” wide TJI top chord webs. The holes are pre-marked and drilled. Henry’s 9000 gutter and flashing sealant is used to prevent roof leakage.

Racks and vertical supports

The front “rails” will have small restraining clips to hold the front of each panel. The vertical uprights [shown behind the rail] will elevate the panel to the desired angle for the specific latitude of the project. The clips are adjustable from side-to-side. For the vertical support legs (once cut to the correct length) also allow the installer to adjust the tilt of the legs. This system will be set @ 35 degrees (optimal for Flagstaff)

Racks and vertical supports

Although installation could be done by one individual, a multi-crew installation makes holding the rails to the vertical supports much easier. These rails are aluminum and easy to cut and hold in place.

Racks and connections

The spacing between the solar PV arrays is critical. As the sun moves to the maximum height (azimuth) during the summer months to a lower height during the winter months, the panels must not shade each other. Partial vertical shading will only “short circuit” part of a panel; but horizontal shading will stop electrical production for the entire panel and thus the array. The spacing needs to be done during the design phase and prior to any installation. The legs get minor adjustments using flat washers to keep the bars level.

Racks and connections

The alum. “C” channel shaped rails are connected together and must have a grounding bond between the rails. Charlie is securing a pre-drilled connector that will snuggly clamp two twenty foot sections together. A bonding scrap, using a lock washer straddles the two channels and is tightened down. The Weeb splicers are used as the grounding is not sufficient with just the ProSolar splice kit.

Rack installation - continued

The installer works to keep the legs and rails plumb. Care is given during the “setup” stage to prevent having to disassemble or make major adjustments once the panels are installed. This system has a total of 33 Sharp 170 watt panels or a maximum production of 5.61 Kwh. The layout and rack installation took 2-1/2 days to complete (prior to installing any panels).

First Panels going up

The first panel goes in and the installers check the racks for plumb and alignment. There will be a total of eleven (11) panels per array. The Sharp 170 watt panel being used here is guaranteed for 25 years. The open current voltage is 43.2 volts, the Max power is 34.8 volts, the Max current is 4.9 amps and the model efficiency is 13.1% The panels weigh 37.8 pounds each and are 62”x32-1/2”x1-3/4” in size. (array configuration depends upon the maximum size of 600 Volts, DC)

(Price of panels for this installation was approximately $725 each)

Panel install continues

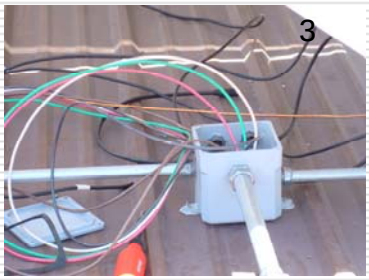
Panel arrays must be kept at the same angle (when the roof plane changes) to keep the voltage production the same. Some adjustments may be required; Kelly, Drew and Chuck are keeping the first panel square prior to tightening the lags.

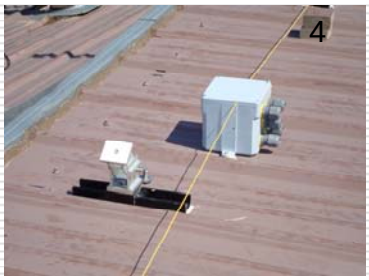
Conduit & Conductors

Conduit sizing is covered by Article 690 & 230 of the NEC (City of Flagstaff is using 2005 NEC). The boxes must be grounded; so there are several key considerations in using plastic boxes (weather proofing for snow and water) with metal conduit. The metal conduit here uses grounding lug end connectors and "jumper" wires (sized per Code) to keep the grounding and bonds of the conduit, rails, panels and boxes consistent. This is all connected to a grounding terminal in the box adjacent to the inverter. Sizing of the wire should be based upon the panel voltage requirements.

The proposed system would allow standard 12 gauge wiring; however, going to the next larger size (10 gauge) is more efficient and doesn't cause voltage loss to heat because the gauge is marginal or undersized. Because this is a metal roof installation, THWN 90 high heat wiring and insulation were used.

Wiring & Connections

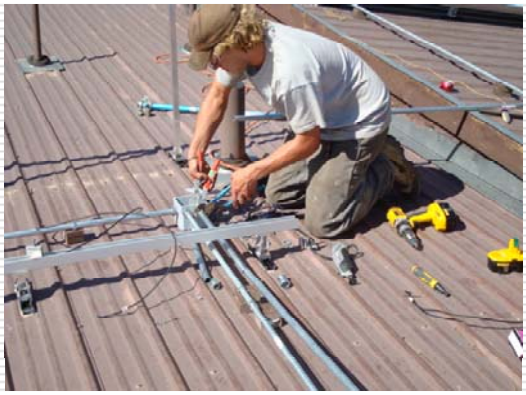




Photos: #1, wire spool racks with 10 gauge wiring and color coded make the pulling of wires easier. #2, the DC switch with grounding and lug terminals are used to connect the arrays to the inverter (this is a Sun Boy 6000). #3, junction boxes and conductors are elevated above the roof deck to prevent damming of leaves and debris during rain and snow storms. #4 The conduit is held up from the decking with artificial decking blocks (pre-drilled) and caulking; string line keeps system aligned.

More electrical

Electrician checks grounding between conduit in plastic boxes.



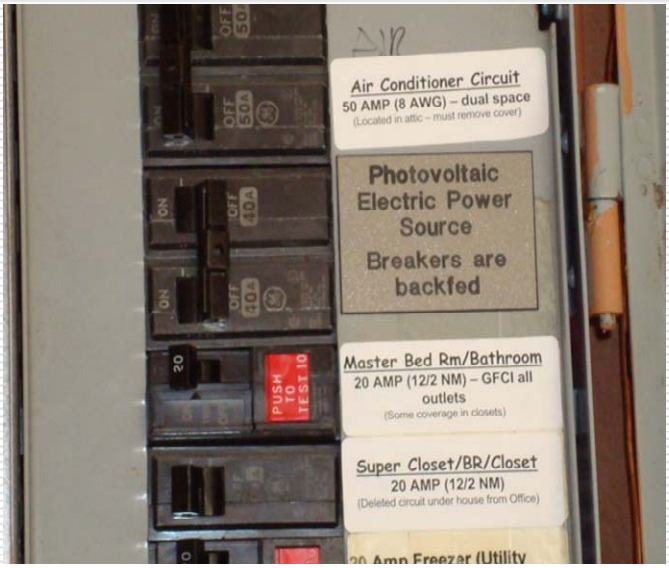
The inverter needs to be shaded and out of the weather. For this roof top installation, the Sunny Boy 6000 is mounted under an overhang. The inverter weighs 145 pounds and comes with a special mounting bracket. The owner here wanted the entire system secured and used a ¾" plywood backer that was supported by three vertical studs and secured with 12, evenly spaced 3" deck screws to hold the weight. The entire mounting board was painted prior to installation.

Misc. connections

The solar panels come pre-wired with a male and female plug system. The panels are "active" or capable of producing DC voltage the minute the sun light hits the panel.

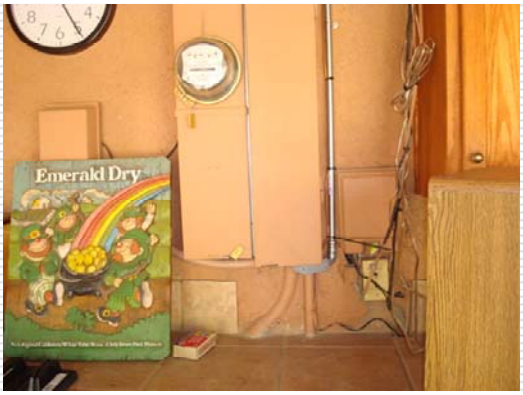
Photos: **#1**, solar cell junction box at back of panels; **#2** cabling for panels is carefully tucked into the rack channels [care to prevent crimping of connectors under panel edges]; **#3** lightening arresting system installed in junction box ahead of inverter; **#4**, conduit down to photo voltaic meter at ground level.

Connection to Service panel



Feed breaker may not exceed 20% of the panel service size. This case, the house service was 200 amps, this limits the breaker to 40 amps; max. output for this system is 25 amps. During final inspection, it was determined that the wiring size (10 gauge) needed to be a double pole 30 amp fuse or increase the wire size to #8s for the 40 amp breaker. Breaker was changed.

Conduit from roof to panel



Since this panel is exterior to the house (open to the environment), the panel needs to be connected through the bottom of the existing service panel. The bare copper wire is connected to the service panel grounding lug and uses the existing UFER to complete the ground.

Metering

A digital AC “power” production meter is installed after the lock out junction box for the system. The Utility Company (APS) wants this lock out accessible without going into a fenced backyard. The meter must be read once a year and the information sent to the Utility Company within 15 days.

The safety requirement for the metering is to prevent the customer from “back feeding” the grid system. If this disconnect wasn’t there and APS had to work on the lines, then the lines could be “hot” even though air-breakers had been tripped

Panel labels

Note: More warning labels are required adjacent to the inverter and DC disconnect at the roof location. Once APS or the utility company authorizes the connection to the grid, a secondary digital meter with remote reading capability will be added to the service panel. During a light usage day and with full sunlight, the service panel meter will run “backwards”.

APS (servering the Flagstaff Area) will require the owner of the system to read this meter once a year and report the total PV generating quantities. Now that the applicant is in a generator capacity, a log or notebook is probably going to be needed!

More details

Key reminders

- If a solar panel is partially shaded vertically, then it only reduces the panel production by the percentage of cells shaded; however, shading the top or bottom of a panel horizontally will "short out" the entire panel and reduce the electricity produced.
- One of the leaders in authoring the Article 690, National Electric Code – Bill Brooks of Brooks Engineering, LLC [Bill@brooksolar.com; 707-332-0761] provides an excellent seminar through AZBO. Excellent source of information. [http://www.solarenergy.org/workshops/solarindustry.html]
- **Factoid:** "silicon" or sand is the 2nd most abundant material on the plant!
- When sunlight hits the ground, each square meter (approximately 10 square feet) of earth is capable of producing 1000 watts. The basic formula is P=V*I (v=voltage and I = intensity or current).
- **Factoid:** Temperature affect voltage, so voltage increases as temperature drops and is reduced when it gets hotter. Light affect current (intensity) or the amperes.
- Photo voltaic systems are somewhere between 10-15% efficient (without intensifiers). Solar water heaters (thermal systems) are 40% or greater in efficiency.
- One silicon solar cell produces 0.5 volts. Electricity is produced when light knocks loose electrons from silicon atoms. The freed electrons have extra energy or "voltage". Cells never "run out" of electrons.

Common Problem Areas

- Insufficient conductor ampacity and insulation – wiring is undersized for the load or the insulation type is not designed for hot locations. Roof tops often exceed 90 (F) degrees.
- Excessive voltage drop – DC (direct current) loss because of long distances to inverter.
- Unsafe wiring methods – inexperience by the installer
- Lack of or improper placement of over current protection and disconnect devices
- Use of unlisted or improper application of listed equipment (i.e., AC in DC use)
- Lack of or improve equipment or system grounding
- Unsafe installation and use of batteries
- Improper mounting and connection of equipment and racks

Completed panel array

From the street side, this roof top solar panel generating system (5.61 Kwh) awaits the City inspection and “green tag”. Once that it completed, APS is scheduled to replace the service panel meter with a bi-direction digital meter and approve the installation for operation. Then during the peak months, the owner hopes to run the meter backwards as it generates more than used.

Now what everyone wants!!!

Click the picture on the left to see the meter in normal operation. Click the picture on the right to see what happens when the inverter kicks in and you are on “solar” power!!!

Commercial Applications

- Key considerations for Commercial jobs is a factor of sizing. Per the NEC, systems over 600 amps require a design professional (Arizona State Registrant) to be involved.

- The following example was for a new commercial grocery store; “New Frontiers” and the system is rather large at 35 Kwh production

New Frontiers – 35 Kwh system (May 2008)

This system uses multiple converters and several large arrays of solar modules (panels) to produce the desired electricity

New Frontiers – array over shed roof (May 2008)

New Frontiers – roof mounted portion

The racking system for this installation is laid flat on the built up roofing system. Care must be taken to interconnect the panels before they are lowered and connected. Obviously, maintenance to an interior panel is more complex.

New Frontiers – another view

The electrical boxes (at ends of panel arrays) and conduit with conductors for the connections to the inverter bank(s) are snaked through a roof mounted and protected conduit (shown in the foreground).

Photo voltaic meter and APS dis-connect switching box