Utility Connections, Safety & Code Issues
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How to plan for and design PV systems including Structural design considerations of basic PV systems, such as span or rafters, Wind forces, Gravity loads, Seismic forces And information regarding relevant International Building Code (IBC) and ASCE7 structural engineering design manual, and the relationship to the utility grid and interconnection.
Grid Interconnection and Relationship to the Utility
A grid-connected solar PV system feeds *excess energy* directly into the grid, typically the public electricity grid. Grid-connected systems vary in size from residential of 2–10 kW, to solar power stations up to 10s of MW.

It is important to involve the utility early (in planning stages). Be aware of correct metering coordination and scheduling of hookup and utility rate schedules (such as net metering), activation with your contractors, as well as coordination between your Electrical Monitoring System (EMS), BAS, and other monitoring or dashboards on your on-site generation, and review what to expect in terms of billing with your utility rep for solar connections and the present owner.
Here is how the energy flows from the solar PV system through a string inverter.

The DC electricity produced from a PV system will first flow through a DC disconnect, then through the string inverter where it is converted to AC electricity. Then the AC electricity will flow through an AC disconnect, and then to the building’s service panel. The electricity will flow into the building if there is a demand at that moment, if not, the electricity will flow through the utility meter and to grid.

If the project is net metered, the electricity can be pulled back from the grid through the utility meter to the service panel, like normal.
Advantages to grid connection

Net metering and value-of-solar tariffs can offset a customer’s electricity usage costs

Systems such as Net Metering and Feed-in Tariff which are offered by some system operators, can offset a customers electricity usage costs. In some locations though, grid technologies cannot cope with distributed generation feeding into the grid, so the export of surplus electricity is not possible.
Grid-connected PV systems are comparatively easier to install as they do not require a battery system.
Electricity collected by solar panels starts out as “Direct Current” (DC) and must be converted to “Alternating Current” (AC) if it will be used in a building connected to the grid. An “INVERTER” converts the electricity from DC to AC.

The typical AC operating frequency is 60 Hertz (60 Hz) in the U.S. CURRENT is measured in Amps, with the unit Amp symbolized by a capital “A”. The voltage is measured in “Volts” (V). The product of current (amps) and voltage gives you power (in the units of “Watts” (W)).

Any connection of an electrical generation system such as a PV system required permitting and approval from the power company.

The Department of Energy has supported many projects intended to decrease costs and waiting time associated with grid-interconnection of PV systems.

On average, 1kw PV array would require approximately 100 square feet of roof space. Smart inverters improve grid resilience and improves grid power.
The inverter must monitor grid voltage, waveform, and frequency. For normal operation the inverter must synchronize with the grid waveform, and produce a voltage slightly higher than the grid itself, in order for energy to smoothly flow outward from the solar array.

Here in the photo we see from left to right, the DC disconnect, two string inverters, the AC disconnect, and the service panel with the meter combined. As previously mentioned, the DC electricity produced from a PV system will first flow through a DC disconnect, then through the string inverter where it is converted to AC electricity. Then the AC electricity will flow through an AC disconnect, and then to the building’s service panel. The electricity will flow into the building if there is a demand at that moment, if not, the electricity will flow through the utility meter and to grid.

Two different ways to connect: (1) Load-side connection and utility-side connection. (2) It’s a financial contribution to the grid, and lowers your energy bill.

- A “feed in tariff” you sell ALL the power you make to the utility, and then you get a credit for what you put into the grid, so you don’t pay the utility for that.
“Islanding” is the condition in which a solar photovoltaic generator continues to power a location even though power from the electric utility grid is no longer present. Islanding can be dangerous to utility workers, who may not realize that a circuit is still powered, even though there is no power from the electrical grid. For that reason, solar PV inverters must detect islanding and immediately stop producing power; this is referred to as anti-islanding.

It’s so that the electricity has a place to go, and doesn’t end up in the inverter. So that if you lose energy connection, and since the panels are still making energy and sending it to the inverter. Inverters that are grid-interactive must have a feature to prevent islanding.

When the grid is down, the anti-islanding function within the inverter shuts down the inverter; you will not have the use of the solar electricity in the event of a grid failure.
With the anti-islanding mechanism, the inverter will stop converting DC to AC when the utility service is disconnected. This means the building will not be receiving power from the solar PV system when the utility grid does down.
To continue to receive power, the system will need to be paired with a battery back-up. The battery can either charge from the grid, or from the solar PV system.

In this diagram we can see the backup AC circuits will still receive power when the inverter stops converting the power. Note, the AC circuits are typically limited to emergency power only and not power for the entire building.
Design professionals should be advised that every location and jurisdiction will have its own variation for regulation of PV installations and possibly ‘solar-ready’.
What makes SOLAR permitting unique?

- Impacts multiple disciplines/areas of the building
- Most frequently retrofits
- Inexperience of code officials
- Rooftop access needed for inspection
- Wide variation in local permitting requirements
- Local laws and ordinances addressing solar
- Scale and pace of solar installs
- Unique financing and marketing of systems
- Multiple inspections
- Applicability nationwide, on most types of structures, new and existing construction

In a recent survey by ICC, over 80% of code officials surveyed report that they would benefit from training on conducting solar inspections.
Clean Power Finance conducted a survey of installers and AHJs in 2012 to better understand the current state of solar permitting. It surveyed 273 residential installers, gathering data on 500+ installations spanning 12 states comprising over 90% of the residential solar market. Most notably, it found that:

- Permitting processes vary widely among locales and usually involve 2 distinct agencies (and up to 5 agencies), each with different processes.
- More than 1 in 3 installers avoid selling in an average of 3.5 jurisdictions because of associated permitting difficulties.
- AHJs require, on average, nearly 8 work weeks to complete their tasks. The staff time of the installer, however, averages just 14.25 hours.
- There are likely significant opportunities for installers to reduce costs by improving processes around customer acquisitions and operations.

While the situation has clearly improved somewhat in places like CA (as we’ll see later in this presentation), the problems remain.
The Problem from Both Perspectives

**Installer’s Perspective**
- Varying requirements across AHJs create confusion, rework, and frictional costs.
- Requirements within the same AHJ suffer from inconsistent application. Requirements are not readily accessible and can be updated without notice.
- Inconsistent processing and cycle times disrupt sales and operations flows (e.g. scheduling staff time, routing crews, and site visits to customers).

**AHJ’s Perspective**
- Installer errors and incomplete/inconsistent paperwork (e.g. design doesn’t match documents) creates extra work and delays.
- AHJs often operate in sub-optimal conditions - strained budgets, under-resourced, staff turnover.
- No channel to communicate updates or simplification of processes to installers.
- Solar installations are uncommon; AHJs are unaware of existing best practices or that a problem even exists.

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<th>Installer’s Perspective</th>
<th>“I find myself having to educate the city staff on their own requirements”</th>
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<td>“AHJs can change their interpretations of existing codes and you only find out after you are about to submit your paperwork…”</td>
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**AHJ’s Perspective**
- Perhaps a fifth of submittal packages are poorly organized and may require hours of red-lining.
- “This is a matter of safety, not red tape.”

The survey of Installers and AHJs conducted by the DOE and Clean Power Financing revealed some very clear differences between the two groups.

Along these lines, this presentation seeks to highlight the challenges experienced by both groups and steps code officials can take to improve solar permitting.
PV’s Overlapping Permitting Approval Processes

**Code Approvals**
- Submit permit application
- Permit application, plan review & approval
- Construction of solar PV system
- Site inspection & final approval

**Grid-Tie Approval**
- Submit “request to interconnect” to the local electrical grid
- Utility site inspection
- Interconnection approval

**Incentive Approval**
- Submit incentive application
- Incentive program inspection
- Incentive program approval and payout.
What is “expedited permitting”?  

- Definition: An organized permitting process by which a majority of small PV systems can be permitted quickly and easily (Brooks).
- Simple eligibility checklist to determine eligibility.  
  - 10-15 kW maximum power output  
  - Simplified structural and electrical review  
  - Minimize the need for detailed engineering studies  
  - Not intended to apply to all PV systems  
  - Widespread use of expedited permitting and growing.

Expedited permitting is a term that has become common in the solar industry. Bill Brooks, in the Solar ABCs Expedited Permit Process for PV Systems document defined it as follows:

“An organized permitting process by which a majority of small PV systems can be permitted quickly and easily”

For solar PV systems, this is often accomplished by establishing a simplified system of permitting for systems that meet key eligibility requirements that allow assurance of safety to be streamlined. Examples of these eligibility requirements include:
- Limited maximum power output or inverter rating.
- Simplified structural review through the use of engineered and listed racking systems and modules and limited, low-risk geometries. Simplified electrical review by limiting expedited permitting to certain system types, requiring listed electrical components and by adopting standardized submittal requirements.
- Limits or eliminates the need for detailed engineering studies in permitted structures that meet minimum codes and for specific, low-risk system designs.

Key point – expedited permitting is not intended to apply to all systems! For more complex systems or those to be implemented on structures that were not permitted and constructed to modern building codes, a more detailed, tradition permitting approach will be necessary. For example, the criteria established in the Solar ABCs process are assumed to apply to approximately 90% of PV installations – primarily simple, residential installations.
Solar Training for Code Officials is Happening

- Strong growth of the solar industry is expected to continue
- Many code officials recognize the need to improve knowledge of solar
- Focus is now on reducing non-hardware costs

In a recent survey by ICC, over 80% of code officials surveyed report that they would benefit from training on conducting solar inspections.
Ask AHJ if they have a solar checklist

BENEFITS TO DESIGNERS
• Helps you prepare plans for application / inspections
• Helps you establish client/subcontractor expectations

BENEFITS TO AHJs
• Increase consistency of inspections
• Consolidate material from different depts/trades

BENEFITS TO CONTRACTORS
• Advance preparation for inspection
• Set expectations for subcontractors

See IREC’s Model Inspection Checklist for Rooftop PV Systems:
file:///C:/Users/mellingson/Downloads/Model-Inspection-Checklist.pdf

A checklist can get all involved on the same page; helping to assure nothing falls through the cracks.
Some AHJ Offer Expedited Permitting

**Eligibility requirements may include:**

- A limit on system capacity and complexity
- Limit applicability to certain building types
- Installation by licensed solar contractors
- Utilize listed/certified components
- Exclude sites with special zoning, historical and architectural requirements

Since expedited permitting does not apply to all systems, criteria are needed to discriminate between those that are included and those that are not. This is often done by means of an eligibility checklist or series of questions. There are differences between the specific requirements to be eligible in different locations, but they follow several clear themes. And overall, the intent is to find those systems where the risk and complexity is low.
Codes and Standards Related to PV Systems

Design professionals should be advised that every location and jurisdiction will have its own variation for regulation of PV installations and possibly ‘solar-ready’.
The ICC Codes are the basis for the code ordinances adopted by most jurisdictions. The International Code Council (ICC) is an organization that develops a single set of comprehensive international model construction codes focused on building safety and fire prevention. The Code publications include many provisions relevant to solar thermal and solar PV installations (IBC, IRC, IFC, IECC, IGCC – and the 2015 ISEP (Int’l Solar Energy Provisions) incorporates all of the solar thermal provisions in one document http://www.solar-rating.org/press/ISEP_02-12-2015.pdf).

The 2015 IECC includes an Appendix for residential solar-ready provisions. The 2018 IECC will include an Appendix for commercial solar-ready provisions. The 2015 IECC includes an Appendix for residential solar-ready provisions. The 2018 IECC will include an Appendix for commercial solar-ready provisions. This PDF describes how all states adopt codes: https://www.iccsafe.org/gr/Documents/AdoptionToolkit/HowStatesAdopt_I-Codes.pdf

The current model building code adopted:

The International Solar Energy Provisions incorporates all code provisions for both solar PV and solar thermal in one book. This is not really a separate code (does not contain any original information), it is a compendium of all provisions related to solar from the building, mechanical, plumbing, fire, energy AND electrical codes.

This is a tremendous resource to have on your shelf....and it’s less than $50.

Knowing that there is a one-stop resource for you to get all this information, we are quickly going to review what the code requirements for PV include and where they are located.
The code requirements pertaining to PV are found throughout many of the I-codes. For example, in the IBC and IRC you will find basic information on structural requirements, material standards including rating of roof coverings, and standards for roof construction.

The International Building Code (IBC) scope covers all buildings except detached one and two family dwellings and townhouses not more than 3 stories in height. The IBC contains safety concepts, structural, and fire and life safety provisions covering means of egress, comprehensive roof provisions, and innovative construction technology. The IBC includes requirements for the fire class rating of PV systems and wind load calculations. See Chapter 15 for roof penetrations and fire classification, and Chapter 16 for structural, wind and seismic concerns.

The International Residential Code (IRC) establishes minimum regulations for one- and two-family dwellings and townhouses up to three stories. It brings together all building, plumbing, mechanical, fuel gas, and energy and electrical provisions, which include PV systems for one- and two-family residences. See Chapter 9 for roof penetrations and fire classification, and Chapter 3 for structural, wind and seismic concerns.
Basically, Fire classification for the rooftop PV is for the system as an assembly.

The fire classification is based on the type of construction and required fire rating, and is not based on the type of roof installed. Just because someone puts a class A composition roof on a dwelling does not mean you need a class A PV system, you only need a class A PV system if the Class A is required based on the type of building or the building is located in a high fire area.
IBC section 1505.8 Building Integrated photovoltaic (BIPV) requires that where BIPV products are installed as the roof covering they shall be tested, listed and labeled for fire classification conformance with Section 1505.1 which is the for roof coverings for class A, B and C roof assemblies.
IBC Section 1505.9 requires that Rooftop mounted photovoltaic panel systems and shingles shall be test, listed and identified with a fire classification in accordance with UL 1703. The fire classification shall comply with table 1505.1 based on the type of construction of the building.
The dead load of rooftop PV systems, which includes the racking support systems, must be identified on the construction documents.

Both the International Building Code (chapter 16) and the International residential Code (chapter 3) require that the dead load of rooftop PV systems, which includes the racking support systems, must be identified on the construction documents. (photo source AIA Arizona)
The IBC and IRC require that the structure of roofs which support solar PV modules or panel systems must be designed to accommodate the entire load of PV modules, panels and ballast dead load, including concentrated loads from supporting structure and other applicable loads, and if applicable, snow drift loads created by the PV array.

The photo shows the difference live loads in blue and dead loads in red. The dead load will be the weight of the solar PV system and the live loads will be wind and snow.
International Building Code section 1608 requires that design snow loads shall be determined in accordance with Chapter 7 of ASCE, but the design of the roof shall not be less than that determined by section 1607 of the IBC.

Is this dead load or live load?
Determination of wind loads: The Building Code requires that wind loads on every building or structure shall be determined in accordance with Chapters 26 to 30 of ASCE 7 or provisions of the alternate all-heights method in IBC Section 1609.6

**SEAOC – Struc Eng Assc of CA. Look it up.**

Is this dead load or live load?
The International Plumbing and International Mechanical Codes have some requirements for solar thermal systems, which includes; Solar Heating & Cooling (SHC) aka “Solar thermal”, Solar Thermal panels, Storage tanks, Heat exchangers and Roof anchors for fall protection.
The International Energy Conservation Code (IECC) is a building code created by the International Code Council in 2000. It is a model code adopted by many states and municipal governments in the United States for the establishment of minimum design and construction requirements for energy efficiency. The IECC is a model energy code, but it is written in mandatory, enforceable language, so that state and local jurisdictions can easily adopt the model as their energy code. The IECC references several ASHRAE Standards, in particular the ASHRAE 90.1 for commercial building construction, which is included as an alternative compliance path for commercial construction projects.

Section C406 of the IECC is called Additional Efficiency Package Options. It requires the inclusion of at least one item from the list of additional energy efficiency measures – one of these is on-site renewable energy. Specifically, the requirement is that the on-site renewable energy must meet one of the two following conditions:
- Provide at least 0.50 watts per square foot of conditioned floor area, OR
- Provide at least 3% of the energy used in the building for HVAC, service water heating, and lighting.

2015 IECC includes Solar Ready Appendix for Residential; 2018 IECC will also include Solar Ready Appendix for Commercial
The International Green Construction Code (IgCC) and ASHRAE Standard 189.1 provide total building sustainability guidance for designing, building, and operating high-performance green buildings (commercial only). The green codes cover areas familiar to users of LEED, such as site location, material selection and recycling, energy use, water use and commissioning.

Going forward starting with the 2018 IgCC, these documents will be merged into a single standard.
NEC & Solar PV:

- Art. 690 Solar Photovoltaic (PV) Systems
- Art. 705 Interconnection of Electric Power Production Sources
- Art. 250 Grounding and Bonding

The National Electrical Code (NEC) provides the electrical code provisions which apply to solar photovoltaic electrical energy systems. This lesson will focus on the electrical code and concerns which are most likely to benefit the design professional, including; Definitions, point of connection of the PV system, main electrical service sizing, and how to approximate size of array. The primary PV specific codes are contained in article 690 and 705.

Most of the provisions in the NEC which are solar PV specific are contained in NEC articles 690 for solar Photovoltaic (PV) systems, and 705 for Interconnection of electric power production sources. Also, article 250 for grounding and bonding should be considered to facilitate PV system grounding and bonding to building steel etc.
The International Fire Code (IFC) includes regulations governing the safeguarding of life and property from all types of fire and explosions hazards, which include and pertain to PV systems. Topics include general precautions against fire, provisions for requirements for achieving roof access, pathways and spacing of modules and equipment for fire fighter access and smoke ventilation.
The primary concern for the design professional in regards to fire fighter safety is the location of roof mounted equipment and arrays to ensure first responder safe access and egress to facilitate smoke ventilation.
For fire fighter safety the National Electrical Code requires Rapid Shutdown of PV system to be installed outside the building, typically at the electrical service or the front of the building. NEC requires signage notifying presence of solar system - location up to AHJ.
With the rapid shutdown requirement the power from the system needs to be shut off within 10 feet of the panels.

The rapid shutdown requirement is different than anti-islanding, as they serve different purposes. Rapid shutdown is a safety measure for firefighters when the building is on fire. The anti-islanding is a safety feature for utility linemen when the grid goes down.
Access and Ventilation

IFC: Access

• 6 ft. wide clear perimeter at edges of roof
• Pathways provided in both axes

Regarding perimeter clear space, if either roof axis is less than 250 ft, clear perimeter can be reduced to 4 ft.

Pathways located in areas that can support the fire fighters; must be 4 feet clear around standpipes, ventilation hatches, roof access hatches.
IFC: Smoke Ventilation

- Max. 150' x 150' array
- Min. 4' pathway with venting cutouts

IFC requires provisions for smoke ventilation and gives example of solar arrays on small and large commercial buildings.
Access and Ventilation

IFC:
Smoke Ventilation

IFC 605.11.1.2.5 Requires allowance for smoke ventilation in pathways between the array sections.
Prior to being put into service, to ensure a safe installation a PV system should be properly tested and commissioned. Commissioning verifies that the system has been properly installed per minimum testing procedures. Commissioning can include visual inspections, tests, user training, start up and output performance testing.

Currently, commissioning of a solar system is not required by code, but it is best practice.
Quiz & Discussion
Rapid shutdown of the PV system is required by the:

a) Building code  
b) Residential code  
c) Fire code  
d) Electrical code  
e) All of the above
Rapid shutdown of the PV system is required by the:

a) Building code  
b) Residential code  
c) Fire code  
**d) Electrical code**  
e) All of the above
Question 2

Approximately how many pounds per square foot will the panels and racking of a solar PV system add to the roof of a building?

a) 1
b) 3
c) 8
d) 10
Approximately how many pounds per square foot will the panels and racking of a solar PV system add to the roof of a building?

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Question 3

A roof mounted PV array is which type of load?

a) An equipment load
b) An accessory load
c) A live load
d) A dead load
e) All of the above
Question 3

A roof mounted PV array is which type of load?

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