NY-Sun PV Trainers Network

Fire and Safety Considerations for Solar PV

Presented by the

NY-Sun PV Trainers Network

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About the PV Trainers Network

The NY-Sun PV Trainers Network aims to lower the installation cost and expand adoption of solar PV systems throughout the state.

training.ny-sun.ny.gov

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About the PV Trainers Network

Lead Organizations

MEISTER CONSULTANTS GROUP

ENTECH Engineering INCORPORATED

CUNY

Supporting Organizations

LAND USE LAW CENTER, PACE LAW SCHOOL

BRONX COMMUNITY COLLEGE

Delhi STATE UNIVERSITY of NEW YORK

SUNY CANTON

ULSTER BOCES

SUNY ECC Workforce DEVELOPMENT

3

PV Trainers Network Services Offered

Trainings

Trainings targeting specific audiences to help them quickly get up to speed on key solar issues

Free Technical Assistance

Targeted assistance through the "Ask the Expert" portal:

- Municipal procurement processes
- Solar ordinance adoption
- Technical questions through the FAQ link

Resources

- Webinars, Podcasts
- Toolkits
- Model documents, Case studies

Visit: https://training.ny-sun.ny.gov/trainings

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Solar Photovoltaic PV Systems For First Responders




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Acknowledgments and Disclaimer

Acknowledgments

The material contained within this presentation includes pictures, schematics and graphics taken from a multitude of sources as well as developed specifically by the authors for this presentation.

We would like to acknowledge the use of International Association of Electrical Inspectors (IAEI), the National Electrical Code (NEC), Solar ABCs, and the Department of Energy materials.

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Acknowledgments and Disclaimer

Disclaimer

This presentation should be considered an introductory course in the recognition and disabling, to the extent practicable, of solar electric systems. Solar electric systems can be installed in a very large number of configurations and it is not possible for this course to cover all possibilities. As with all electrical technology, safe practices must be followed at all times to minimize exposure to dangerous and even lethal voltage and current.

Photographs or specifications of manufacturers' equipment does not constitute an endorsement.

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Acknowledgments and Disclaimer

Important Information Regarding the National Electrical Code in New York State

Currently New York State is in the NEC 2008 code cycle. New York will adopt NEC 2014 on October 3, 2106, bypassing NEC 2011. In order to create presentation material that will not be outdated in the near future, we have focused primarily on presenting information applicable to NEC 2014. This presents a problem for Building Officials especially in that code compliant installations may be installed NOT using NEC 2014 until it is adopted.

Many changes to the most current and future editions of the NEC have changed as a result of concerns expressed by firefighters with respect to solar electric systems.

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2016 NYS Uniform Code and Energy Code Update

Important Information Regarding the Building and Fire Codes in New York State

- On March 9, 2016, the NY State Fire Prevention and Building Code Council completed major updates to the Uniform Fire Prevention and Building Code (Uniform Code) and State Energy Conservation Construction Code (Energy Code). The Uniform Code update incorporates the following documents by reference:
  - *2015 International Building Code*
  - *2015 International Residential Code*
  - *2015 International Existing Building Code*
  - *2015 International Fire Code*
  - *2015 International Plumbing Code*
  - *2015 International Mechanical Code*
  - *2015 International Fuel Gas Code*
  - *2015 International Property Maintenance Code*

- ***The 2016 Uniform Code Supplement details NY State amendments to the international codes (download from DOS site):***
  - See: http://www.dos.ny.gov/dcea/noticadopt.html

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NY State Uniform Code and Energy Code Implementation Schedule

- **Effective Date:** April 6, 2016
- ***Uniform Code Transition Period*** *– beginning on April 6th, regulated parties submitting a complete building permit application may comply with either the current Uniform Code or newly adopted Uniform Code. The transition period will last from April 6, 2016 until October 3, 2016. On October 3rd, the newly adopted Uniform Code will become fully effective.*
- ***Energy Code Effective Date*** *– On October 3, 2016, the newly adopted Energy Code as described above will become formally effective. There is no transition period for the Energy Code.*

- **Free public access to the ICC Codes:**
  - http://codes.iccsafe.org/New%20York%20State.html#2015

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Agenda

1. **Basic Facts and Safety Overview**
2. Fire Safety Code Discussion
3. Information Systems and How They are Used
4. How Do Solar Electric Systems Work?
5. System Types and Schematic Representation
6. Site Plans and Identification of Components
7. How to Identify and Disable Different Solar Electric Systems
8. Worksheets for System Type Identification

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Safety Hazards of Solar PV

Number One Consideration: Electric Shock

- PVmodules should be treated as electrically charged ***at all times.***
- PV modules generate direct current (DC) electricity. This means that an alternating current (AC) sensor will not detect a current ***even though there is one.***
- PV modules present a shock hazard when damaged and/or appear to be disconnected from the site's electrical system.

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Safety Hazards of Solar PV

Additional Safety Considerations

- **Chemical burns:** if there is on-site battery storage, or if there are thin-film solar cells.
- **Rooftop load:** the structural integrity of the roof may be damaged by the fire.
- **Stinging/biting insects:** may nest underneath the modules.
- **Note:** solar hot water systems are not the same as solar electronic systems and do not produce electricity

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Safety Hazards of Solar PV

Which is PV and Which is Solar Hot Water?

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Safety Procedures of Solar PV

1. Never break, cut into or walk across PV-modules

- Solar PV is *always generating electricity during daylight.*
- Even at night, the lights from the fire engine or from the fire itself may be enough for the modules to generate electricity.
- All precautions should be taken to not damage the modules.

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Safety Procedures of Solar PV

2. Survey the site

- Impact of the fire
- Is there a Site Plan of the area?
  - Where are the different solar PV system components?
- Information retrieval
  - From labels, the utility or the local building official/inspector

  A code compliant system should provide the location of the dc and ac disconnect switches

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Safety Procedures of Solar PV

3. Protective clothing

- Self-Contained Breathing Apparatus (SCBA)
- No jewelry
- Keep boots/gloves dry
  - They provide little to no protection against electric shock when wet (even when dry may not offer complete protection).

4. Tools

- All tools should have insulated handles

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Safety Procedures of Solar PV

When possible:

5. Lock out/tag out main electrical panel

- This will isolate the solar PV system.

6. Lock out/tag out system disconnect

- At the module, controller, batteries and/or inverter (start at the meter and work back to the array).

7. Roof ventilation

- Ventilate at the highest possible point over the fire *without damaging the PV modules.*

8. Nozzle type

- Use fog nozzles and maintain at least 10' distance
- Spray nozzles require at least 20' (see following UL slides)
- Foam will slide off pv modules, and is not effective

9. Extinguishing battery area fires

- Use CO_2, foam or chemical extinguishers.
- Hydrogen gas may be present and is highly flammable

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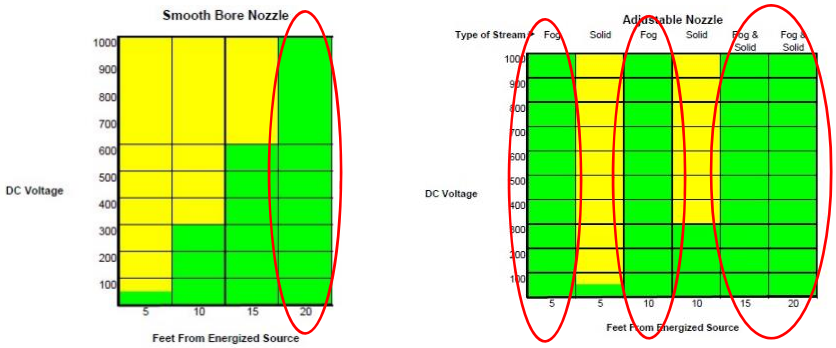
Safety Procedures of Solar PV

Firefighter Safety and Photovoltaic Systems



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Fire Code and Structural Code Issues in Siting Residential and Commercial Systems

Safety concerns expressed by the fire fighting community, regarding exposure to high dc voltage roof top, or concealed conductors has fostered many changes in the 2014 NEC.

Access to, and ventilation of roofs with solar arrays on them are also of concern. This has resulted in restrictions in the area that can be covered by modules.

NY State has updating its building codes with respect to the location of solar modules for roof and ground mounted arrays during the development of this course.

The following is not an all –inclusive summary of these updates

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Fire Codes Issues in Siting PV Systems

- The 2015 International Fire Code (IFC), Section 605.11 addresses requirements for solar photovoltaic power systems.
  - Requires minimum setbacks for roof-mounted PV arrays to allow firefighters safe access, pathways and areas for smoke ventilation.
- The 2016 New York State Uniform Fire Prevention and Building Code (the “Uniform Code”) has adopted by reference the 2015 edition of the International Fire Code (2015 IFC) with amendments.
  - Portions of the 2015 IFC have been adopted in the 2015 edition of the International Residential Code (2015 IRC) with amendments in SECTION R324: SOLAR ENERGY SYSTEMS.

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2015 International Fire Code Residential vs. Commercial

- The 2015 International Building Code (2015 IBC) Section 101.4.5 on fire prevention requires compliance with the 2015 International Fire Code (2015 IFC) for commercial buildings and other structures permitted under the 2015 IBC.
- The NY State Uniform Code Supplement has amended Section 605.11 of the 2015 IFC by the replacement of sections 605.11.1 through 605.11.1.2.5 in their entirety, and the addition of a new section 605.11.1.2.6.
  - *These NY amendments change the 2015 IFC setback requirements for rooftop mounted PV arrays based on new definitions for ACCESS ROOF, GROUND ACCESS AREA, and ROOF ACCESS POINT.*
- NY State has amended the 2015 International Residential Code (2015 IRC) in the 2016 Uniform Code Supplement to include certain fire code requirements for residential construction in Section R324.

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2015 IRC Section R324.7.4 Access and Pathways: Single Ridge Roofs

- **R324.7.4 Single ridge roofs.** Panels, modules, or arrays installed on roofs with a single ridge shall be located in a manner that provides two, 36 inches wide (914 mm) access pathways extending from the roof access point to the ridge. Access pathways on opposing roof slopes shall not be located along the same plane as the truss, rafter, or other such framing system that supports the pathway.
- **Exceptions:**
  - 1. Roofs with slopes of 2 units vertical in 12 units horizontal (16.6 percent) and less.
  - 2. Structures where an access roof fronts a street, driveway, or other area readily accessible to emergency responders.
  - 3. One access pathway shall be required when a roof slope containing panels, modules or arrays is located not more than 24 inches (610 mm) vertically from an adjoining roof which contains an access roof.

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NYSERDA's Assessment of These Changes

- The residential building code as amended for New York State allows the designers of photovoltaic systems several options and alternatives. These illustrations are offered as possible examples. It is not possible to show every possible scenario. It is however up to the judgement of the local code official to determine final compliance with the code.
- Contractors, design professionals, and AHJ's must consider many ventilation scenarios and consider that:
  - 1. A fire can break out anywhere in a building.
  - 2. Emergency responders do not have x-ray vision. Alternate ventilation methods should consider fires occurring in less than ideal locations.
  - 3. Contractors and AHJ must remember that the direction and magnitude of a prevailing wind can affect the location of the ventilation opening

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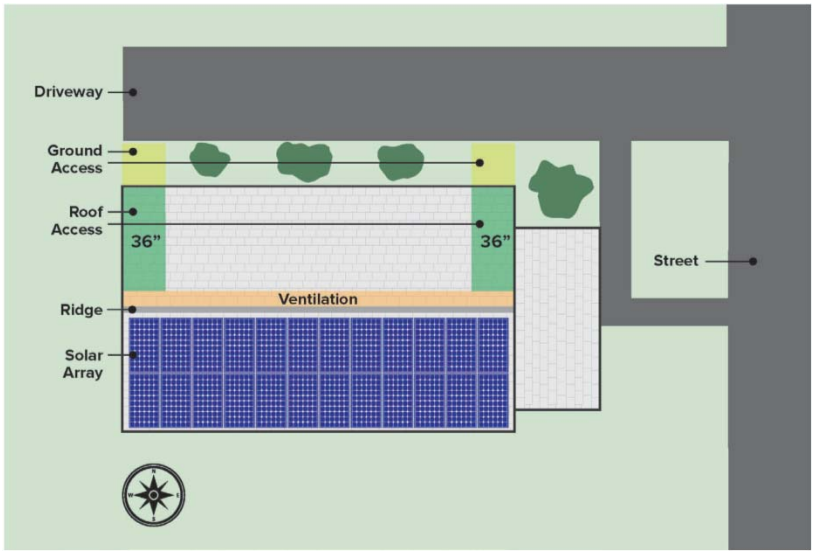
Single ridge roof indicating ground access



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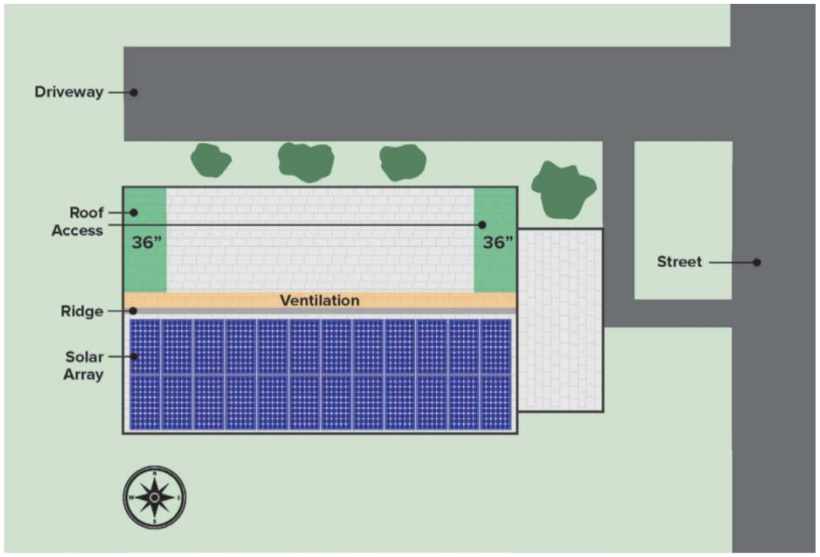
Source: NYSERDA

Single ridge roof with alternate ventilation and two access points



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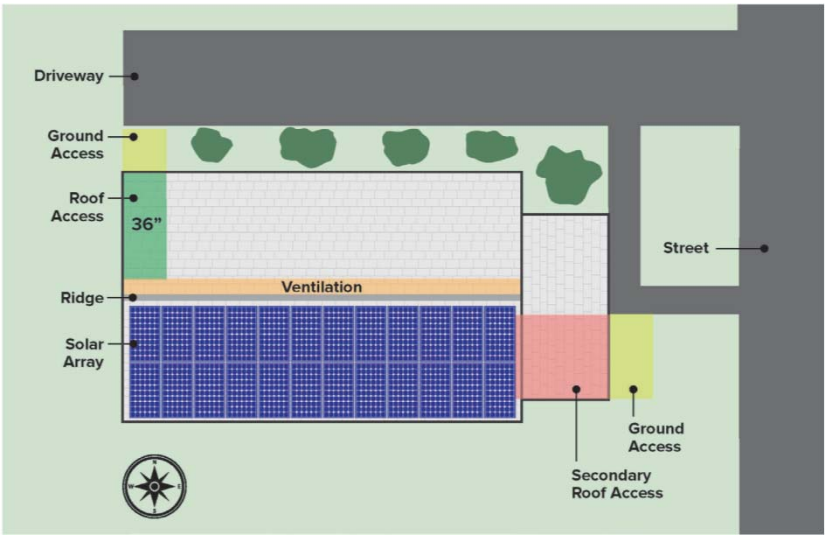
Source: NYSERDA

Single ridge roof — single pathway with exception #3 adjoining roof within 24 Inches



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Source: NYSERDA

2015 IRC Section R324.7.5: Access and Pathways: Hip Roofs

- **R324.7.5 Hip roofs.** Panels, modules, and arrays installed on dwellings with hip roofs shall be located in a manner that provides a clear access pathway not less than 36 inches wide (914 mm), extending from the roof access point to the ridge or peak, on each roof slope where panels, modules, or arrays are located.
- **Exceptions:**
  - 1. Roofs with slopes of 2 units vertical in 12 units horizontal (16.6 percent) and less.
  - 2. Structures where an access roof fronts a street, driveway, or other area readily accessible to emergency responders.

- **R324.7.6 Roofs with valleys.** Panels and modules shall not be located less than 18 inches (457 mm) from a valley.
  - **Exception:** Roofs with slopes of 2 units vertical in 12 units horizontal (16.6 percent) and less.

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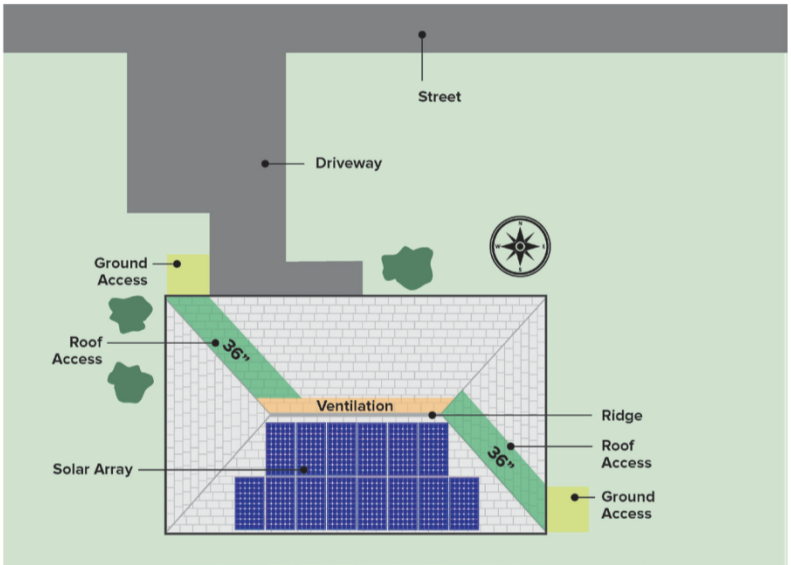
Hip roof showing alternate venting with two roof pathways and ground access



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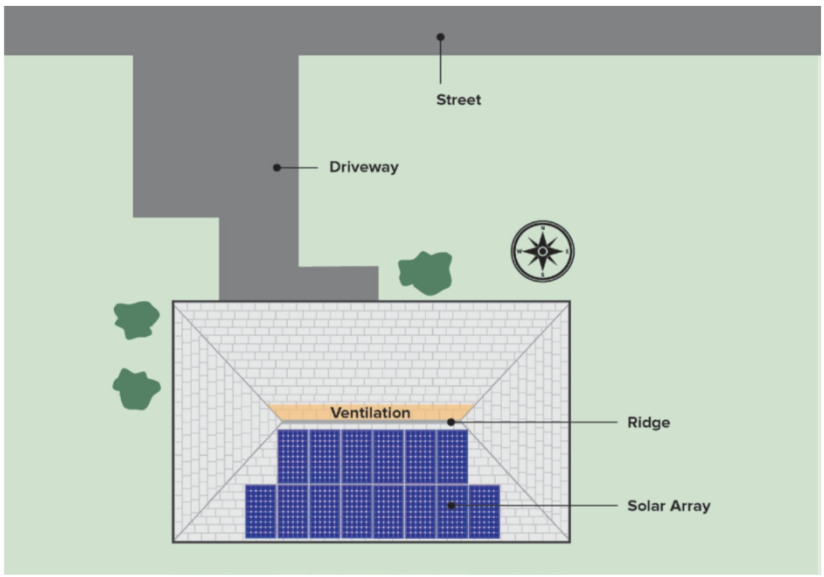
Source: NYSERDA

Hip roof with exception #2 where access roof fronts a street or driveway



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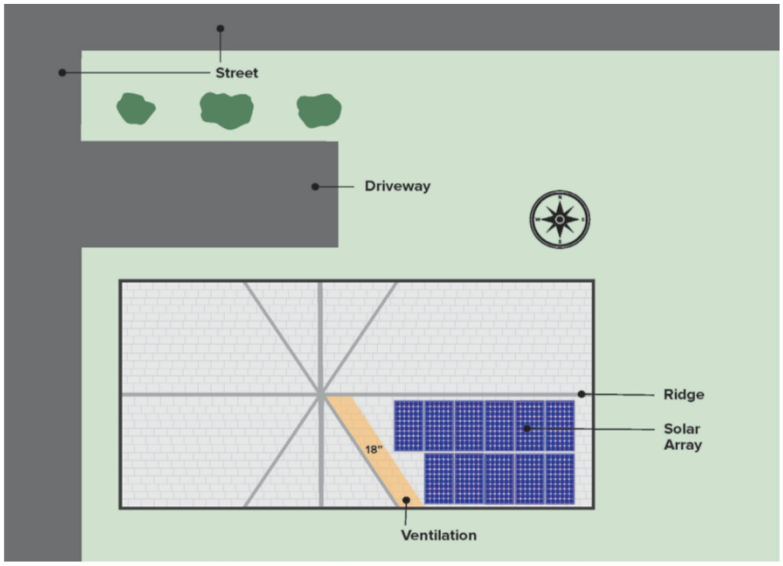
Source: NYSERDA

Valley Roof showing 18” clearance in yellow to the array



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Source: NYSERDA

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2015 IRC Section R324.7.7 Allowance for Smoke Ventilation

- **R324.7.7 Allowance for smoke ventilation operations.** Panels and modules shall not be located less than 18 inches (457 mm) from a ridge or peak.

- **Exceptions:**
  - 1. Where an alternative ventilation method has been provided or where vertical ventilation methods will not be employed between the upper most portion of the solar photovoltaic system and the roof ridge or peak.
  - 2. Detached garages and accessory structures.

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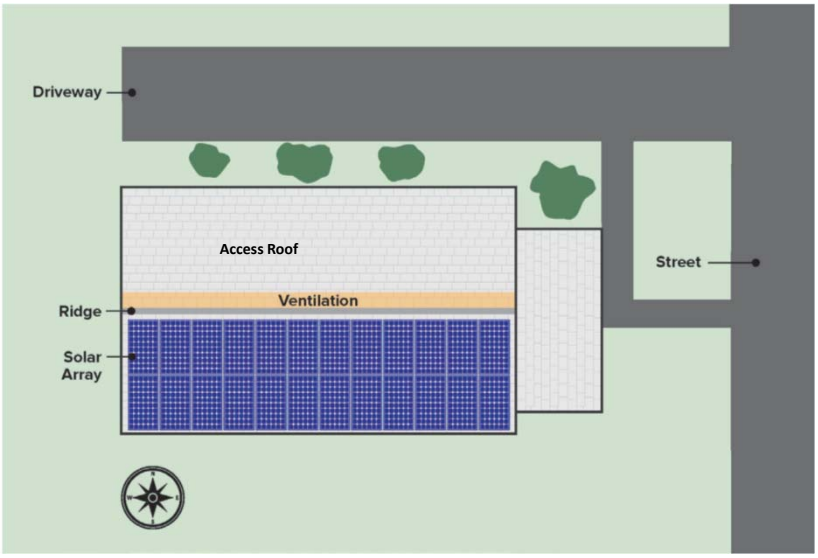
Alternate Ventilation Location



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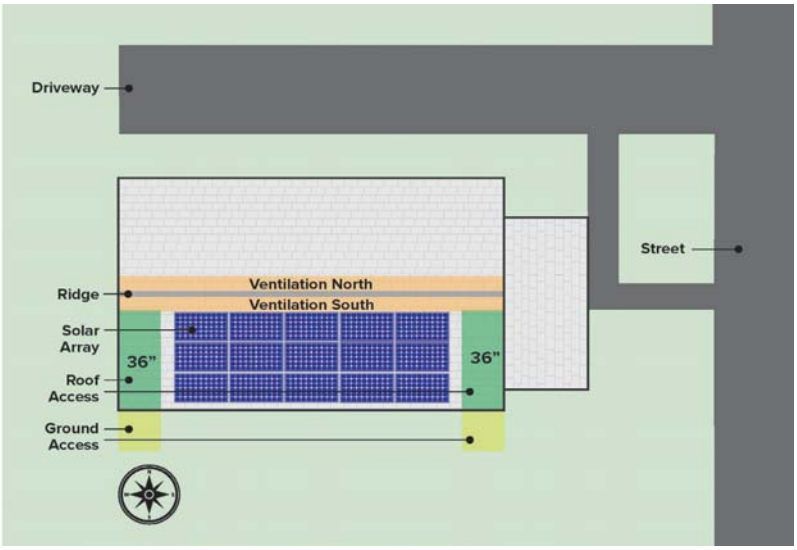
Source: NYSERDA

Single ridge roof showing a smaller array without any exceptions



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Source: NYSERDA

2015 IFC Section 605.11.1.3 Requirements for Other Than Group R-3 Buildings

- The following slides provide NY amendments to the 2015 IFC that apply to COMMERCIAL buildings constructed per the 2015 IBC. Many of the requirements are the same as amended to the 2015 IRC Section 324.7 regarding new requirements for access, pathways and ventilation.

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2015 IFC Section 605.11.1.3 Requirements for Other Than Group R-3 Buildings

- **605.11.1.3 Other than Group R-3 buildings.** Access to systems for buildings, other than those containing Group R-3 occupancies, shall be provided in accordance with Sections 605.11.1.3.1 through 605.11.1.3.3.
  - **Exception:** Where it is determined by the fire code official that the roof configuration is similar to that of a Group R-3 occupancy, the residential access and ventilation requirements in Sections 605.11.1.2.1 through 605.11.1.2.5 shall be permitted to be used.

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Requirements for Other Than Group R-3 Buildings 2015 IFC Section 605.11.1.3.1: Access

- **605.11.1.3.1 Access.** There shall be a minimum 6-foot-wide clear perimeter around the edges of the roof.
  - **Exception:** Where either axis of the building is 250 feet or less, the clear perimeter around the edges of the roof shall be permitted to be reduced to a minimum 4 foot wide.

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Requirements for Other Than Group R-3 Buildings 2015 IFC Section 605.11.1.3.2: Pathways

- **605.11.1.3.2 Pathways.** The solar installation shall be designed to provide designated pathways. The pathways shall meet the following requirements:
  - 1. The pathway shall be over areas capable of supporting fire fighters accessing the roof.
  - 2. The centerline axis pathways shall be provided in both axes of the roof. Centerline axis pathways shall run where the roof structure is capable of supporting fire fighters accessing the roof.
  - 3. Pathways shall be a straight line not less than 4 feet clear to roof standpipes or ventilation hatches.
  - 4. Pathways shall provide not less than 4 feet clear around roof access hatch with not less than one singular pathway not less than 4 feet clear to a parapet or roof edge.

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Requirements for Other Than Group R-3 Buildings 2015 IFC Section 605.11.1.3.3: Smoke Ventilation

- **605.11.1.3.3 Smoke ventilation.** The solar installation shall be designed to meet the following requirements:
  - 1. Arrays shall be not greater than 150 feet by 150 feet in distance in either axis in order to create opportunities for fire department smoke ventilation operations.
  - 2. Smoke ventilation options between array sections shall be one of the following:
  - 2.1. A pathway 8 feet or greater in width.
  - 2.2. A 4-foot or greater in width pathway and bordering roof skylights or gravity-operated dropout smoke and heat vents on not less than one side.
  - 2.3. A 4-foot or greater in width pathway and bordering all sides of nongravity-operated dropout smoke and heat vents.
  - 2.4. A 4-foot or greater in width pathway and bordering 4-foot by 8-foot venting cutouts every 20 feet on alternating sides of the pathway.

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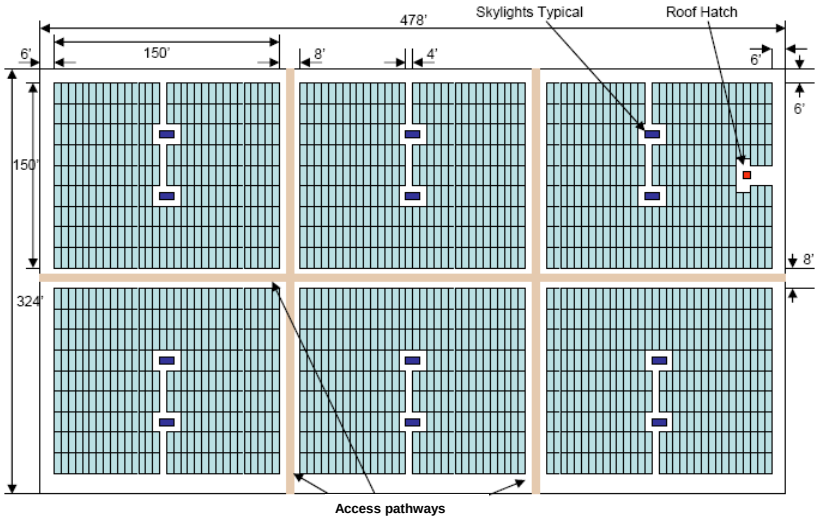
Access, Pathways and Ventilation: Examples

Access pathways are provided around the perimeter and throughout building-mounted PV arrays to provide for firefighter access and ventilation.

Access, Pathways and Ventilation
Large Commercial Example

Building Requirements: Large Commercial Example

Code Compliant for Large Commercial



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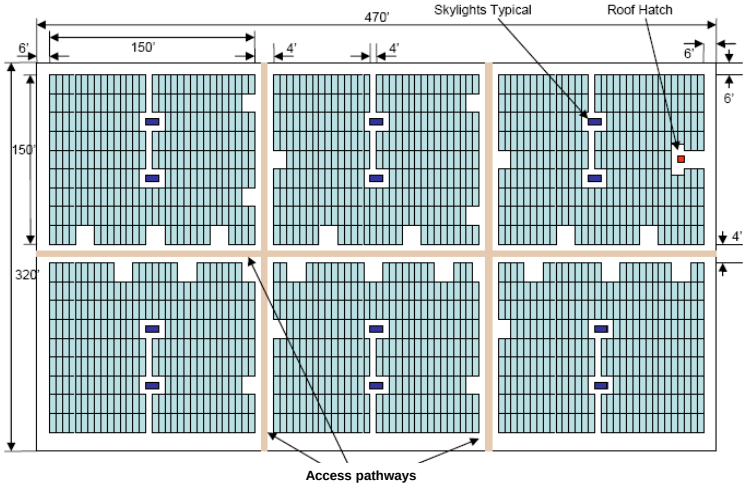
Fire Code Issues in Siting Systems

Building Requirements: Large Commercial Example

Access and Ventilation Requirements are a function of Building Size

Code Compliant for Large Commercial



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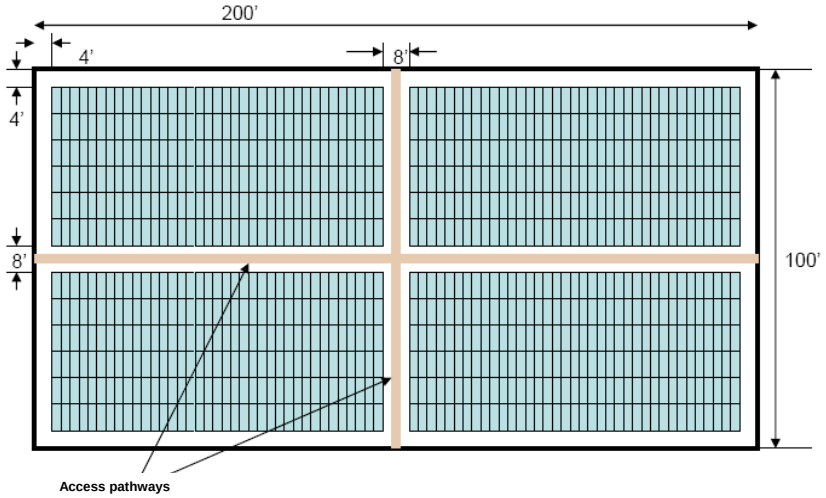
Fire Code Issues in Siting Systems

Building Requirements: Small Commercial Example

Access and Ventilation Requirements are a function of Building Size

Code Compliant for Small Commercial



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Fire Code Issues in Siting Systems

Building Requirements: Small Commercial Example

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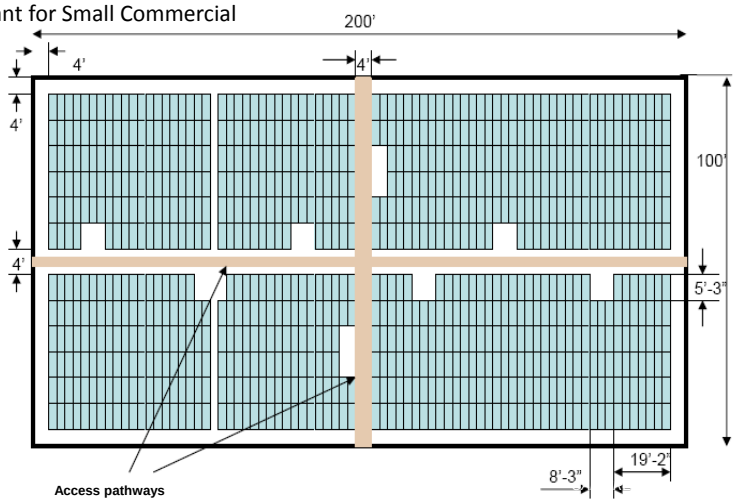
Code Compliant for Small Commercial



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Fire Code Issues in Siting Systems

Ground Mounted Systems

Photos courtesy of DOE/NREL

- **R324.6 Ground-mounted photovoltaic systems.** Ground-mounted photovoltaic systems shall be designed and installed in accordance with Section R301 (Design Criteria).
  - **R324.6.1 Fire separation distances.** Ground-mounted photovoltaic systems shall be subject to the *fire separation distance* requirements determined by the *local jurisdiction.*

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Personal Protective Equipment: Gloves

- Firefighter's gloves are not presently tested or rated for electrical insulation in the NFPA standards.
- However, UL tests show that dry leather gloves can provide adequate insulation up to 1000 V. Little or no protection is provided by wet gloves even with moisture barriers.
- Voltage-rated insulating gloves should always be used unless the electrical component is known to be de-energized.

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Personal Protective Equipment: Boots

- Firefighter's boots certified to the NFPA 1971 Standard provide insulation resistance up to 14,000 volts only in dry conditions.
- UL experiments found that boots provide poor electrical insulation resistance when wet, or when the outer boot material is damaged or worn.
- Firefighter boots incorporate conductive metal toe plates, reinforcing shanks, and sole plates for crush and puncture resistance.

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Personal Protective Equipment: Helmets

- Protect head, eyes, face ears and neck areas against impacts, falling debris, heat and burns.
- Must include shell, energy absorbing system, reflective markings, face shield, ear covers and retention system.
- Tested to NFPA standards for electrical insulation.

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How to Coordinate Building Official Info with Additional Government Needs

Questions to Consider

- Is solar electric system information being shared?
- How is solar electric system information shared?
- How is solar electric system information verified?
- How is solar electric system information maintained?
- Examples of systems in use?

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What Is PV? How Does It Work?

Definition: Solar Photovoltaic System

- The total components and subsystems that, in combination, convert solar energy into electrical energy suitable for connection to a utilization load.

NEC 690.4(A) Photovoltaic systems

- Photovoltaic systems shall be permitted to supply a building or other structure in addition to any other electricity supply system(s).

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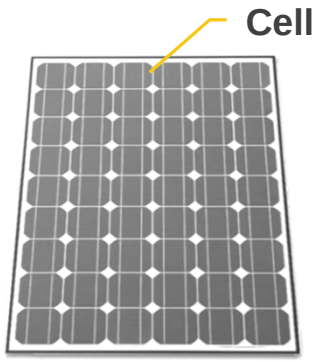
How Do Solar PV Systems Work?

- Solar photovoltaics convert sunlight into electricity by using the energy of speeding photons to create an electrical current within a solar panel.
- A number of solar cells electrically connected to each other and mounted in a support structure or frame is called a photovoltaic module. Modules are designed to supply electricity at a certain dc voltage. The dc current produced is directly dependent on how much light strikes the module.



Panel / Module

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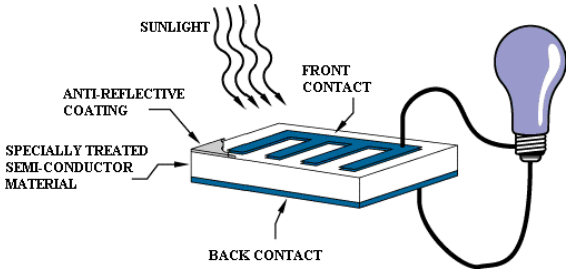
How Do Solar PV Systems Work?



The direct current and voltage (dc) is converter to ac current and voltage by the Inverter. AC electricity from the inverter then is used to power the electrical needs at the site, or is exported to the utility. Electricity is imported from the utility if the PV system is producing insufficient energy to meet the needs of the site.

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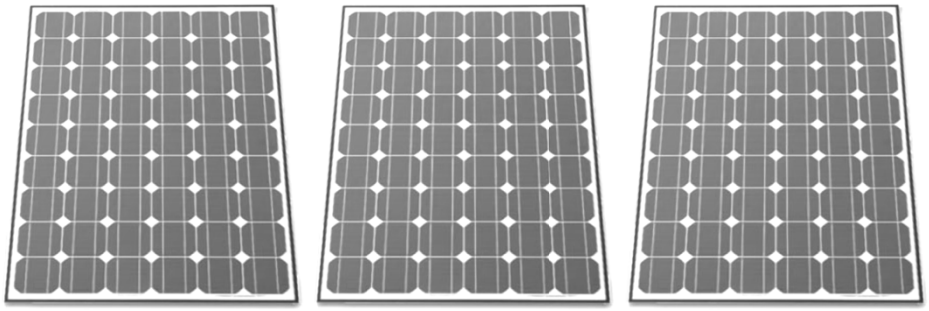
How Do Solar PV Systems Work?



Array

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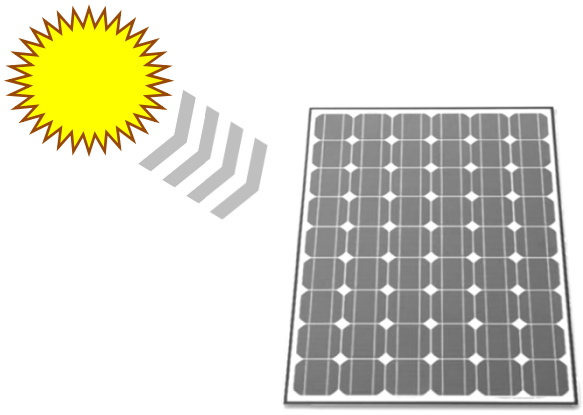
How Do Solar PV Systems Work?



Capacity / Power
kilowatt (kW)

Production
Kilowatt-hour (kWh)

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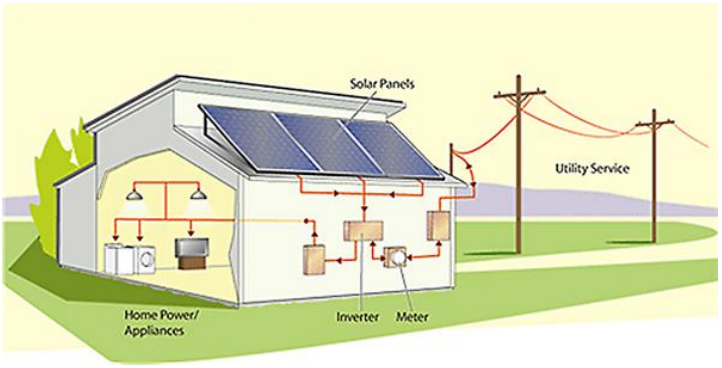
How Do Solar PV Systems Work?

- DC electricity is created whenever there is sunlight on the solar modules.
- Non-battery backed-up inverters stop producing electricity when the ac source (usually the utility) is disconnected from it.
- Battery backed up Inverters will still supply electricity to a separate subpanel unless the battery bank that supplies energy to the Inverter is turned off.



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Residential Rooftops

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Commercial Rooftops

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Shade Structures

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Ground Mounted

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Windows

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Skylights

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Awnings

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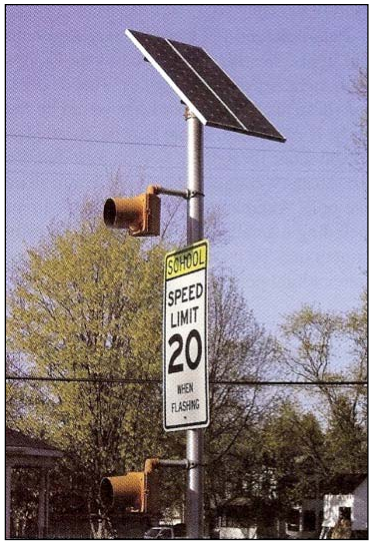
Pole Top Mount



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Agenda

1. Basic Facts and Safety Overview
2. Fire Safety Code Discussion
3. Information Systems and How They are Used
4. How Do Solar Electric Systems Work?
5. **System Types and Schematic Representation**
6. Site Plans and Identification of Components
7. How to Identify and Disable Different Solar Electric Systems
8. Worksheets for System Type Identification

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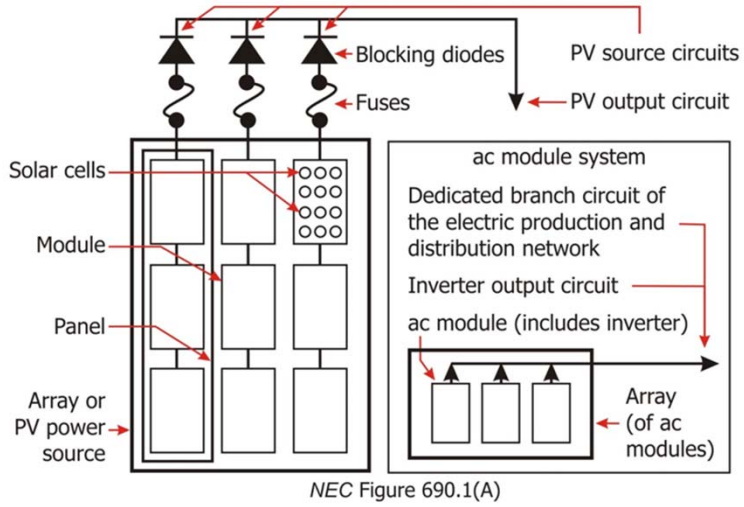
Energy Producing Components of a Solar Photovoltaic System

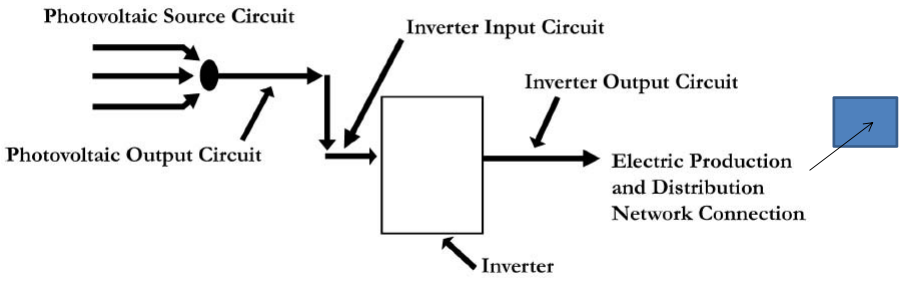


NEC Figure 690.1(A)

69

Different Configurations of PV Installations

String or Central Inverter Grid Interactive System, w/o batteries.
(The most common system)

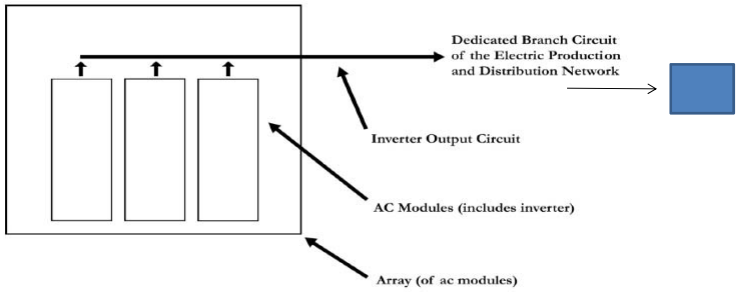


70

Different Configurations of PV Installations

AC Module or Micro Inverter System

These are very similar systems though not identical systems. They are grouped together here for today's discussion because they are an increasingly popular type of system.

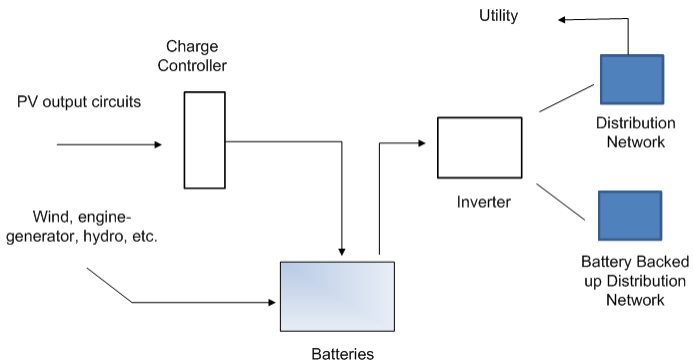


71

Different Configurations of PV Installations

**Solar, and/or Wind, and/or Hydro,
or any combination (Hybrid) System with Batteries**

Great care must be taken with these systems as it is much more difficult to completely shut down the AC power

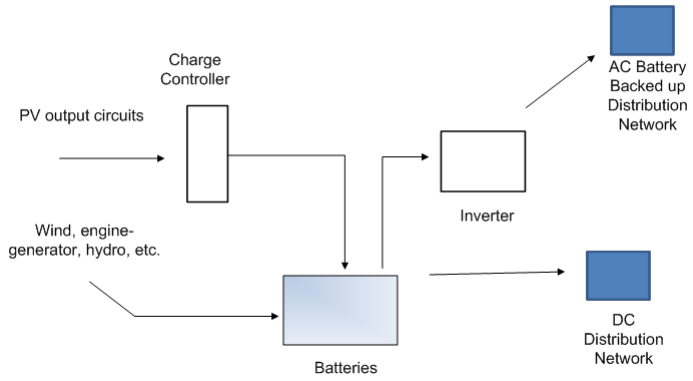


72

Different Configurations of PV Installations

Stand-Alone or Grid-Isolated System

These are usually cabin, camp, or boat systems. There is no utility interconnection.



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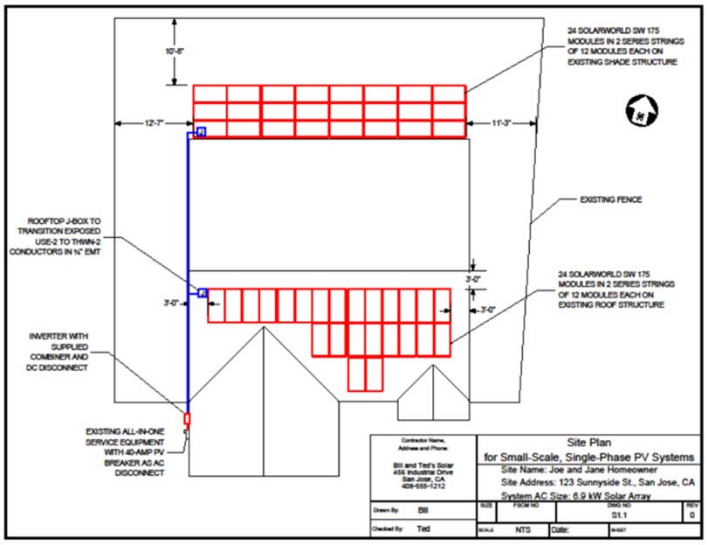
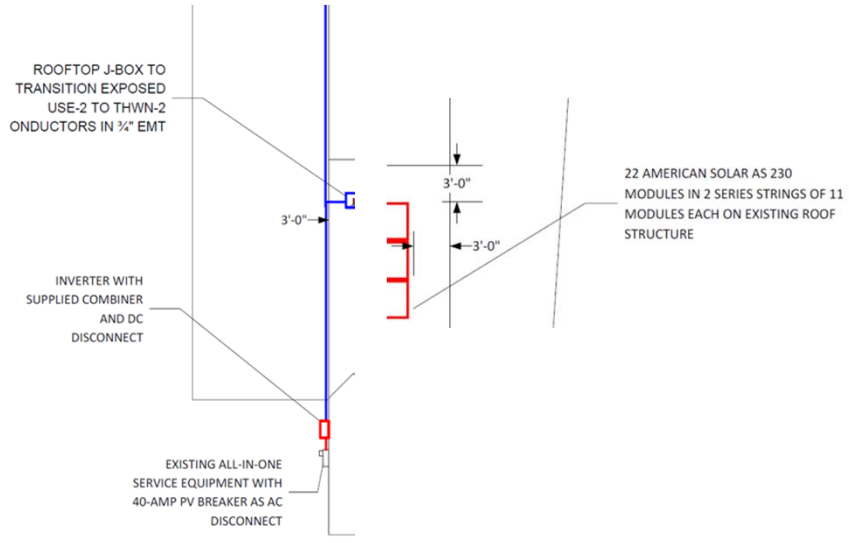
Site Plan- Indicates Location of Major Solar Electric System Components



75

Site Plan- Indicates Location of Major Solar Electric System Components



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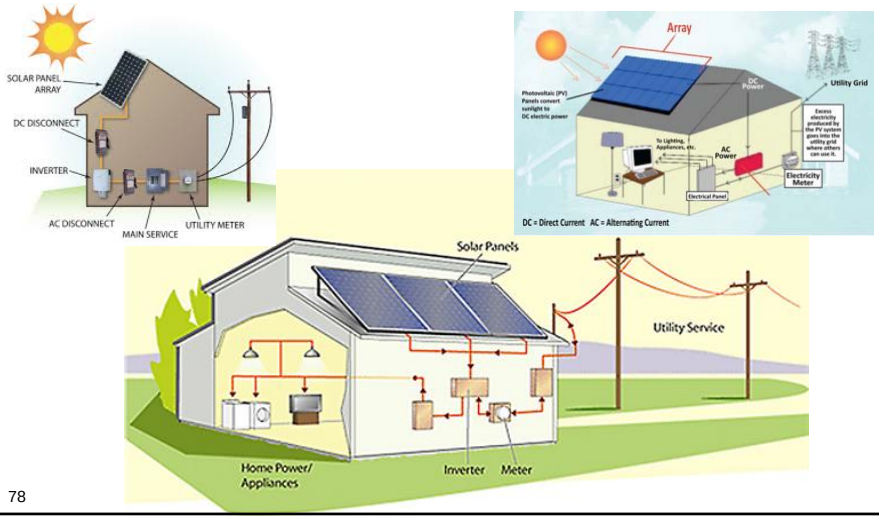
Site Plan- List of Major Solar Electric System Components (not all components in all systems)

1. Modules
   -------- DC conductors
2. Combiner Boxes/Overcurrent Protection
   -------- DC conductors
3. DC Disconnect Switch/Overcurrent Protection
   -------- DC conductors
4. Inverter
   ~ AC conductors
5. AC Disconnect Switch/Overcurrent Protection
   ~ AC conductors
6. Utility Interconnection/Overcurrent Protection

7. Batteries

77

Solar Electric System Components



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1. Modules

Typical Specification Sheet

THE NEW VALUE FRONTIER

KYOCERA

KD205GX-LP

HIGH EFFICIENCY MULTICRYSTAL
PHOTOVOLTAIC MODULE

HIGHLIGHTS OF KYOCERA PHOTOVOLTAIC MODULES

Kyocera's advanced cell processing technology and automated production facilities produce a highly efficient multicrystal photovoltaic module.
The conversion efficiency of the Kyocera solar cell is over 16%.
These cells are encapsulated between a tempered glass cover and a pottant with back sheet to provide efficient protection from the severest environmental conditions.
The entire laminate is installed in an anodized aluminum frame to provide structural strength and ease of installation.
Equipped with plug-in connectors.

APPLICATIONS

KD205GX-LP is ideal for grid tie system applications.

- Residential roof top systems
- Large commercial grid tie systems
- Water Pumping systems
- High Voltage stand alone systems
- etc.

QUALIFICATIONS

- **MODULE** : UL1703 listed
- **FACTORY** : ISO9001 and ISO 14001

QUALITY ASSURANCE

Kyocera multicrystal photovoltaic modules have passed the following tests.

- Thermal cycling test
- Thermal shock test
- Thermal / Freezing and high humidity cycling test
- Electrical isolation test
- Hail impact test
- Mechanical, wind and twist loading test
- Salt mist test
- Light and water-exposure test
- Field exposure test

LIMITED WARRANTY

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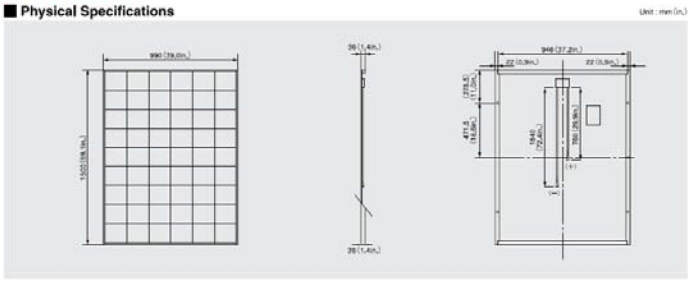
1. Modules

SPECIFICATIONS **KD205GX-LP**

■ **Physical Specifications**

Unit : mm (in.)



■ **Specifications**

■ Electrical Performance under Standard Test Conditions (*STC)	
Maximum Power (Pmax)	205W (+5%/−5%)
Maximum Power Voltage (Vmpp)	26.6V
Maximum Power Current (Impp)	7.71A
Open Circuit Voltage (Voc)	33.2V
Short Circuit Current (Isc)	8.36A
Max System Voltage	600V
Temperature Coefficient of Voc	-1.20×10^{-1} V/℃
Temperature Coefficient of Isc	5.02×10^{-3} A/℃

*STC: Irradiance 1000W/m², AM1.5 spectrum, cell temperature 25℃

■ Electrical Performance at 800W/m², *NOCT, AM1.5	
Maximum Power (Pmax)	145W
Maximum Power Voltage (Vmpp)	23.5V
Maximum Power Current (Impp)	6.17A
Open Circuit Voltage (Voc)	29.9V
Short Circuit Current (Isc)	6.82A

*NOCT: Nominal Operating Cell Temperature: 45℃

■ Cells	
Number per Module	54

■ Module Characteristics	
Length × Width × Depth	1520mm(59.8in)×990mm(39.0in)×36mm(1.4in)
Weight	18.5kg(40.8lbs.)
Cable	(+)1780mm(29.9in)/(−)1640mm(72.4in)

■ Junction Box Characteristics	
Length × Width × Depth	110mm(3.9in)×108mm(4.3in)×15mm(0.6in)
IP Code	IP65

■ Others	
*Operating Temperature	−40℃~90℃
Maximum Fuse	15A

*This temperature is based on cell temperature.

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1. Modules

Specifications

Electrical Performance under Standard Test Conditions (*STC)	
Maximum Power (Pmax)	205W (+5%/
Maximum Power Voltage (Vmpp)	26.6V
Maximum Power Current (Impp)	7.71A
Open Circuit Voltage (Voc)	33.2V
Short Circuit Current (Isc)	8.36A
Max System Voltage	600V

DC

Module Characteristics	
Length × Width × Depth	1500mm(59.1in)×990mm(39.0in)×36mm(1.4in)
Weight	18.5kg(40.8lbs.)
Cable	(+)760mm(29.9in),(-)1840mm(72.4in)

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1. Modules

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1. Modules

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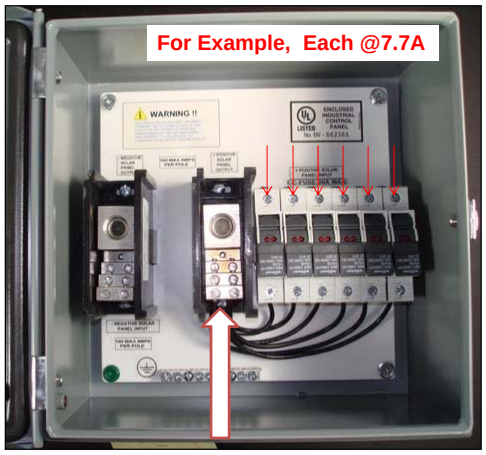
2. Combiner Boxes

Likely one of several System Combiner Boxes



Current = 6 x 7.7 A = 46.2 A

Photos courtesy of DOE/NREL and Jeff Fecteau

84

2. Combiner Boxes

Required External Disconnect Switch

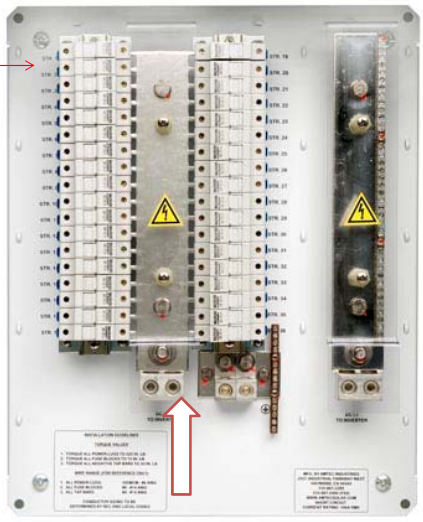
Large System Combiner

85

2. Combiner Boxes

Each @7.7A

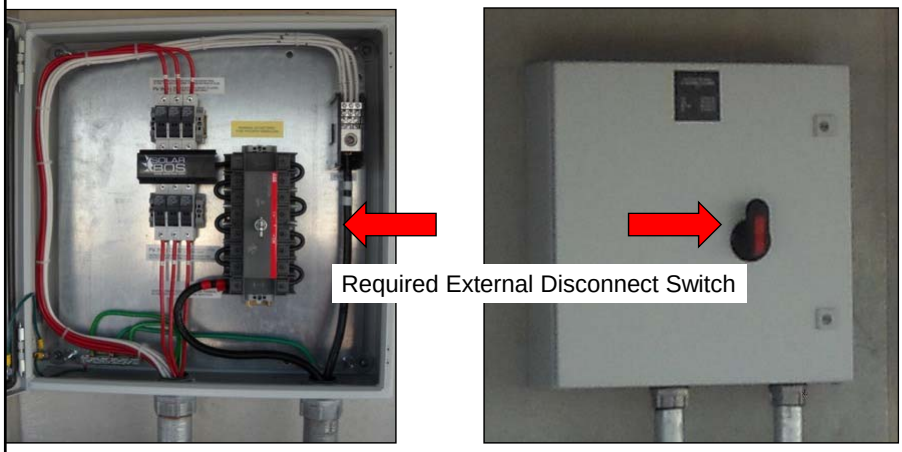
Large System Combiner



Current = 36 x 7.7 A = 277 A

86

2. Combiner Boxes



Large System Combiner

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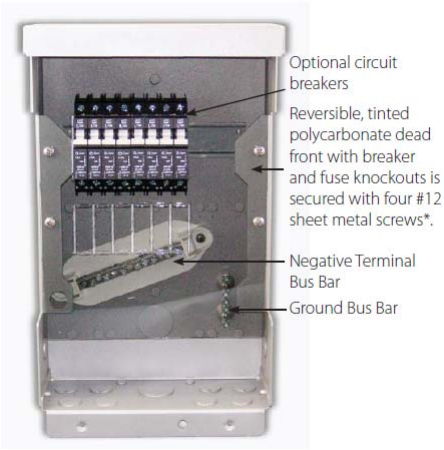
2. Combiner Boxes

88

2. Combiner Boxes

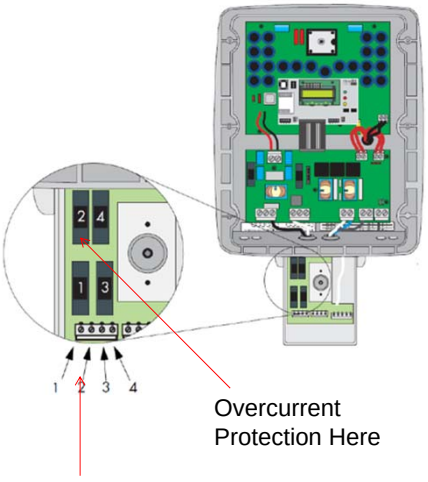
Small System Combiner



Usually located on roof, near ground mounted array or inverter.

89

2. Combiner Boxes



Many inverters have the combiner box integral to the inverter.

90

3. DC Disconnect Switches

DC Disconnect Switches are usually located on roof tops for larger commercial/ industrial systems or may be on the side of a building near ground level.

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3. DC Disconnect Switches

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3. DC Disconnect Switches

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3. DC Disconnect Switches

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3. DC Disconnect Switches

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3. DC Disconnect Switches –Rapid Shutdown

Conductors 10 feet from an array or 5 feet inside a building are required within 10 seconds to measure::
-30 volts (max. limit)
-240 volt-amps (max. limit)
-Labeled with:

PHOTOVOLTAIC SYSTEM EQUIPMENT WITH RAPID SHUTDOWN

The location of the Rapid Shutdown switch is not specified in the NEC. Good practice is to locate the switch at the System Directory.

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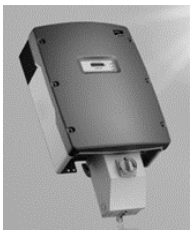
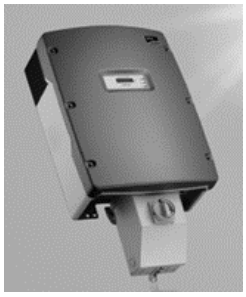
4. Inverters





97

4. Non Battery String or Central Inverters



Non Battery Inverters convert dc power into ac power matching the utility voltage and frequency to generate utility quality power. Disconnecting the ac utility power source turns off the inverter, but DOES NOT disable the dc solar module circuit.

98

4. Non Battery String or Central Inverters

4. Battery Inverters

Battery Inverters convert module and battery power into ac power matching the utility voltage and frequency. The have two outputs, 1) AC Main Panel, and 2) AC Emergency Panel.

The AC Emergency Panel is energized by the battery system. Disconnecting the utility ac connection DOES NOT de-energize the AC Emergency Panel or the connected loads, and DOES NOT de-energize the dc solar module circuit.

100

4. Micro Inverters

Micro Inverters convert dc power into ac power matching the utility voltage and frequency to generate utility quality power. They are attached to the back of a solar module. The dc circuit is the distance from the output of the solar module to the inverter, usually less than 12 inches. Disconnecting the ac utility source de-energizes most of the circuitry in a system. AC modules are in essence a National Testing Lab certified assembly of a solar module and an inverter.

101

4. Micro Inverters

Solar modules are installed over the micro inverter

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4. Micro Inverters

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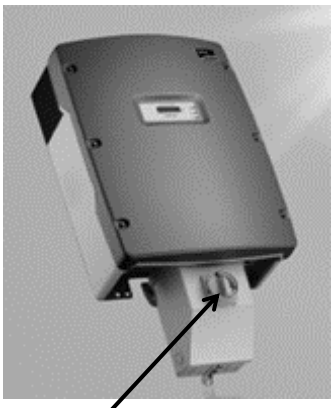
5. AC Disconnect Switches



Integrated AC and DC Disconnect Switch

DC Disconnect Switch

AC Disconnect Switch

Most inverters now come with an integrated disconnect switch though some only disconnect the dc circuit.

104

5. AC Disconnect Switches

240 Vac, 60A Fusible Disconnect Switch

This would be the minimum rating for connecting to conductors that are not in a Load Center (Supply Side Connection)

240 Vac, 30A Non-Fusible Disconnect Switch

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5. AC Disconnect Switches

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5. AC Disconnect Switches

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6. Utility Interconnection

There are three (3) fundamental ways to interconnect a solar electric system to the utility grid:

1. **Load-Side Connection**
   a. Main Panel or Sub Panel Overcurrent Protection.
   b. Feeder with AC Disconnect Switch w/ Fuses or Breaker.

2. **Supply-Side Connection** (Between Utility Meter and Main Service Panel/Disconnect) with AC Disconnect Switch with Fuses or Breaker.

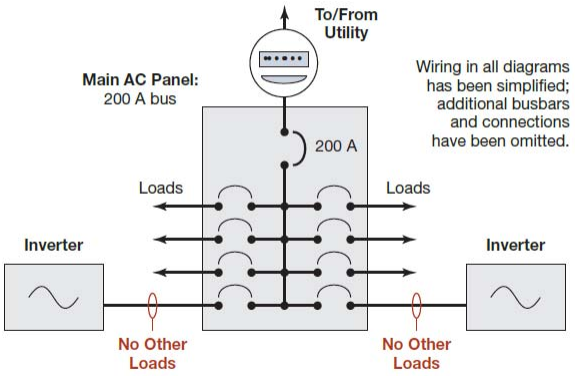
3. **Utility-Side Connection** (Between Utility Feeder and Site's Meter, or Directly Connected to Utility Feeder) – ***usually large systems without an occupied building.***

108

6. Utility Interconnection

1. Load-Side Connection

At Main Panel or Subpanel Breaker



Drawing taken from Brain Mehalic article in Code Corner, Home Power, # 162 A/S 2014

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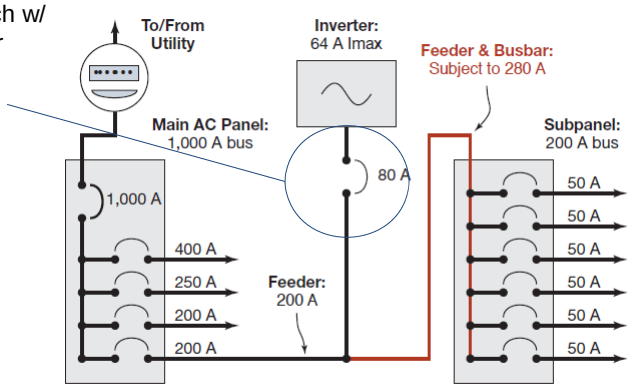
6. Utility Interconnection

1. Load-Side Connection

Feeder with AC Disconnect Switch w/ Fuses or Breaker



Drawing taken from Brain Mehalic article in Code Corner, Home Power, # 162 A/S 2014

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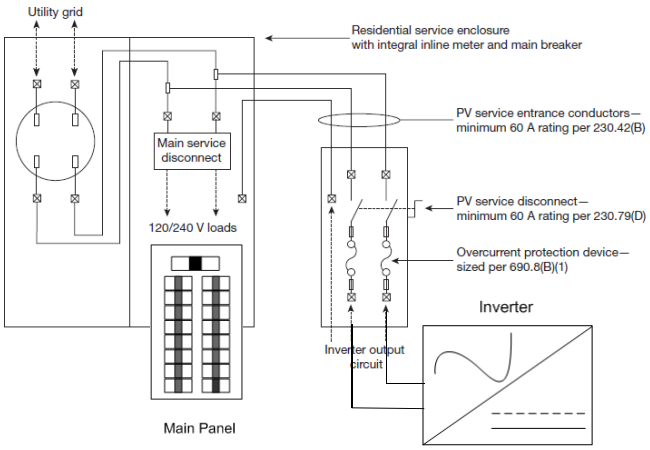
6. Utility Interconnection

2. Supply-Side Connection
Between Utility Meter and Main Service Panel/Disconnect

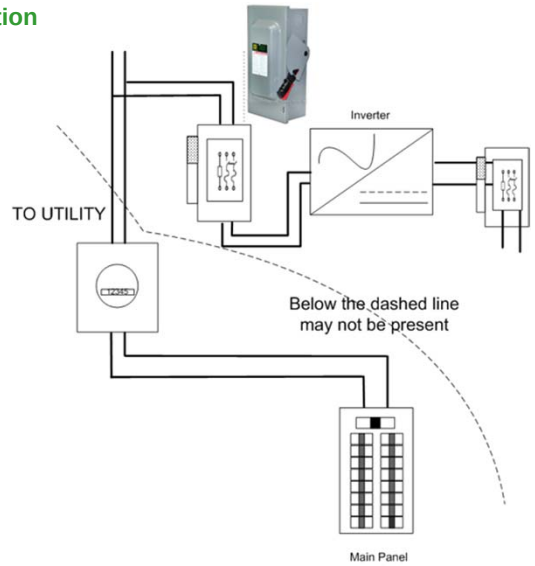


Drawing taken from Ryan LeBlanc and Tarn Yates article in Solar Pro, J/J 2009

111

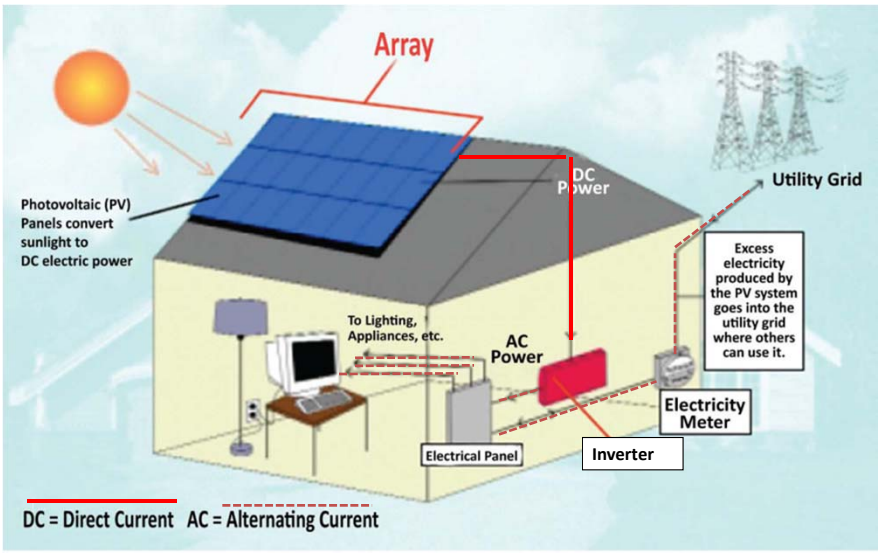
6. Utility Interconnection

3. Utility-Side Connection



112

7. DC and AC Conductors



113

Requirements for PV(DC) Circuit Routing

- New requirements were added for visibility and roof marking of certain PV (DC)circuits.

2014

- Firefighting community has expressed concern about the safety of ventilating roofs where PV (DC) circuits are present.
- Routing PV (DC) circuits along the building structural members will lower probability that the structural members will be compromised by the firefighting process during a fire.

2014

- When PV (DC) module system circuits are integrated into the roof, PV (DC) associated circuits are to be clearly marked on the surface of the roof as a visual aid for firefighters and other maintenance personnel.

2014

11
4

Requirements for Circuit Routing

Direct-Current DC Source and Output Circuits Inside a Building

1. Where DC source or output circuits from a building-integrated or other PV system are run inside a building or structure, they shall be contained in the following wiring methods:
   - Metal raceways
   - Type MC metal-clad cable that complies with 250.118(10)
   - Metal enclosures
2. Shall comply from the point of penetration of the surface of the building or structure to the first readily accessible disconnecting means.

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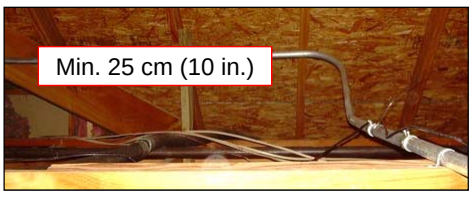
Requirements for Circuit Routing

Photos courtesy of Bill McGovern

Direct-Current DC Source and Output Circuits Inside a Building

- Wiring methods shall not be installed within 25 cm (10 in.) of the roof decking or sheathing except where directly below the roof surface covered by PV modules and associated equipment.
- Circuits shall be run perpendicular to the roof penetration point to supports a minimum of 25 cm (10 in.) below the roof decking.



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Circuit Routing

Flexible Wiring Methods

2014

- Where FMC smaller than MD 21 (trade size ¾) or Type MC cable smaller than 25 mm (1 in.) in diameter containing PV power circuit conductors is installed across ceilings or floor joists, the raceway or cable shall be protected by substantial guard strips that are at least as high as the raceway or cable
- Where run exposed, other than within 1.8 m (6 ft) of their connection to equipment, these wiring methods shall closely follow the building surface or be protected from physical damage by an approved means.

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Photo courtesy of Jeff Simpson

Circuit Routing

Marking or Labeling Required

2014

- The following wiring methods and enclosures that contain PV power source conductors shall be marked with the wording "Photovoltaic Power Source" by means of permanently affixed labels or other approved permanent marking:
  - (1) Exposed raceways, cable trays, and other wiring methods.
  - (2) Covers or enclosures of pull boxes and junction boxes.
  - (3) Conduit bodies in which any of the available conduit openings are unused.

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Circuit Routing

Marking or Labeling Required 2014

- Labels or markings shall be visible after installation.
- PV power circuit labels shall appear on every section of the wiring system that is separated by enclosures, walls, partitions, ceilings, or floors.
- Spacing between labels and markings shall not be more than 3 m (10 ft).
- Labels shall be suitable for the environment where they are installed.

119

7. DC and AC Conductors

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7. DC and AC Conductors

121

Installation Requirements of DC Disconnecting Equipment

- Means shall be provided to disconnect equipment, such as inverters, batteries, charge controllers, and the like, from all ungrounded conductors of all sources.
- If the equipment is energized from more than one source, the disconnecting means shall be grouped and identified.

122

Photo courtesy of Bill McGovern

Installation Requirements of DC Disconnecting Equipment

- PV (i.e. dc) disconnecting means shall be grouped with other disconnecting means for the system.
- Shall not be required at the PV module or array location.

123

Installation Requirements of DC Disconnecting Equipment

- Means shall be provided to disconnect all conductors in a building or other structure from the PV system conductors.

1. Shall be installed in a readily accessible location such as the outside of a building or structure, or inside nearest the point of entrance.
2. Not to be installed in bathrooms.

*** Review 690.31 (E) 690.14(C)(1) Exception: Installations that comply with 690.31(E) shall be permitted to have the disconnecting means located remote from the point of entry of the system conductors. 690.31(E) requires dc conductors to be run in metal raceway. This exception is very commonly used.

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Identification and Installation Requirements for DC and AC Disconnecting Equipment of Inverters

In Non-Readily Accessible Areas

Utility-interactive inverters shall be permitted to be mounted on roofs or other exterior areas that are not readily accessible.
These installations shall comply with (1) through (4):

1. A direct-current PV disconnecting means shall be mounted within sight of or in the inverter.
2. An alternating-current disconnecting means shall be mounted within sight of or in the inverter.

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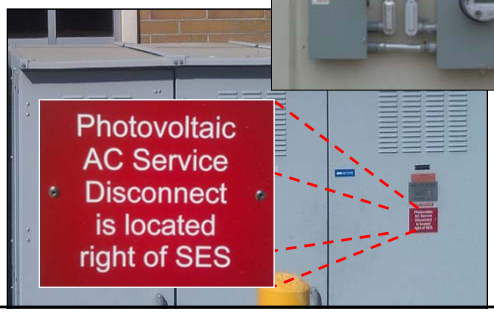
Identification and Installation Requirements for DC and AC Disconnecting Equipment of Inverters

In Non-Readily Accessible Areas

3. The ac output conductors from the inverter and an additional ac disconnect for the inverter shall be readily accessible.
4. A plaque/directory shall be installed denoting all power sources.



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Identification or Labeling Requirements for Disconnecting Equipment

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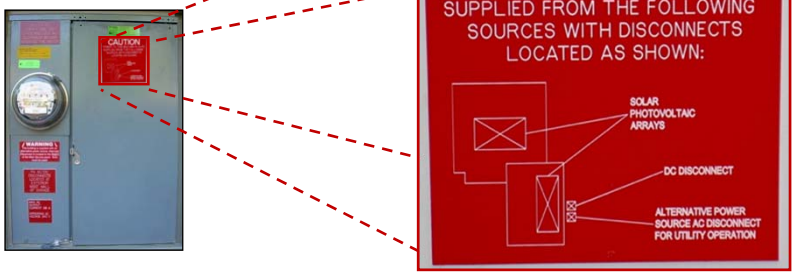
Identification or Labeling Requirements for Disconnecting Equipment- THE DIRECTORY

Facilities with Utility Services and PV Systems

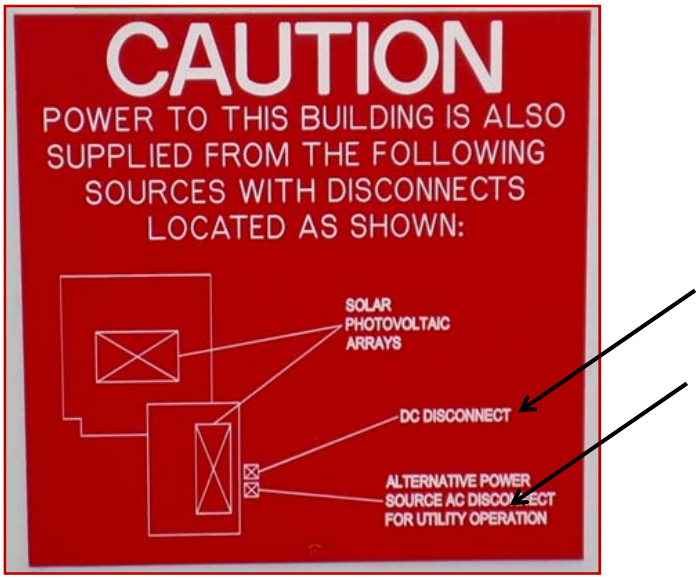
Buildings or structures with both utility service and a PV system shall have a permanent plaque or directory providing the location of the service disconnecting means and the PV system disconnecting means if not in the same location.



128

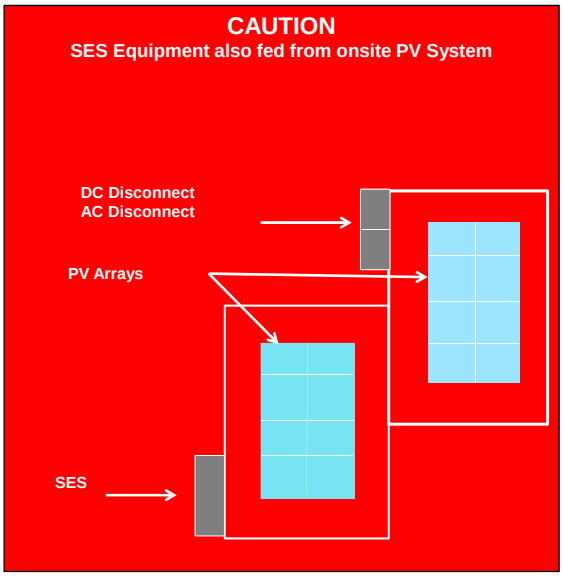
Photos courtesy of Rhonda Parkhurst

Identification or Labeling Requirements for Disconnecting Equipment- THE DIRECTORY



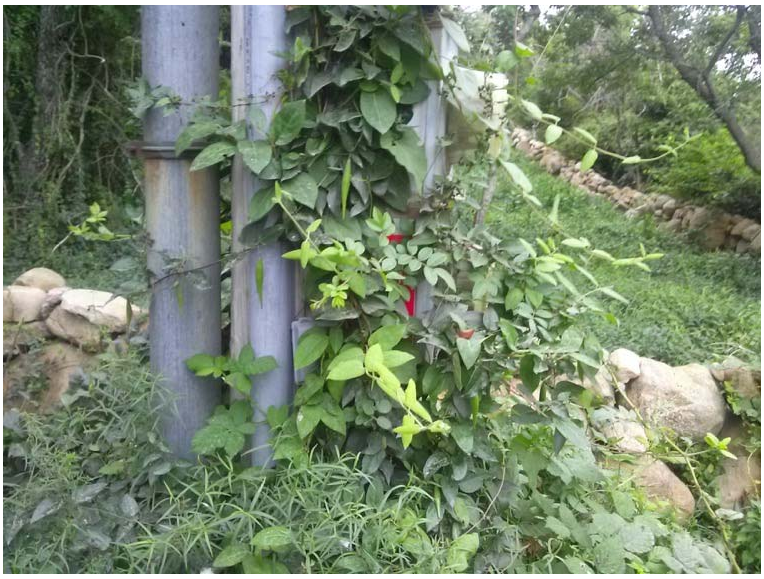
129

Identification or Labeling Requirements for Disconnecting Equipment- THE DIRECTORY



130

Identification or Labeling Requirements for Disconnecting Equipment- THE DIRECTORY



131

Identification or Labeling Requirements for Disconnecting Equipment- THE DIRECTORY

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Identification or Labeling Requirements for Disconnecting Equipment

PV (DC) Disconnecting Means

Each PV (DC) system disconnecting means shall be permanently marked to identify it as a PV system disconnecting means.

Photo courtesy of Bill McGovern

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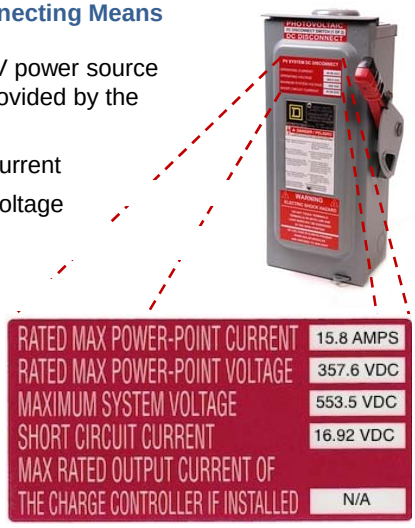
Identification or Labeling Requirements for Disconnecting Equipment

PV (DC) Disconnecting Means

A permanent label for the direct-current PV power source indicating items (1) through (5) shall be provided by the installer at the PV disconnecting means:

- (1) Rated maximum power-point current
- (2) Rated maximum power-point voltage
- (3) Maximum system voltage
- (4) Short-circuit current
- (5) Maximum rated output current of the charge controller *(if installed)*

Charge Controller Indicates a Battery Backed up System!!!!



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Battery Disconnecting Means

Marking or Label

Battery Disconnect Breaker: The largest breaker on a battery system's power panel (which is by the inverter).

This breaker shuts down the system entirely. The circuits on the emergency electrical panel are live even when the main service is disconnected.

Battery powered backup circuits on separate electrical (emergency) panel.

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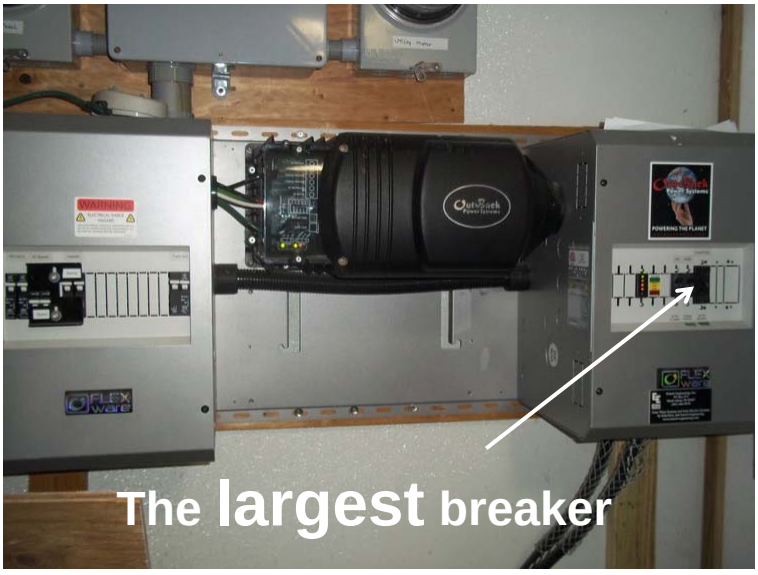
Battery Disconnecting Means



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Battery Disconnecting Means

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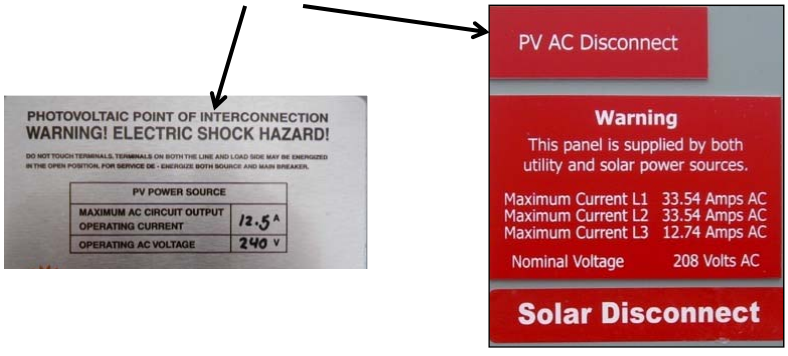
Identification or Labeling Requirements for Disconnecting Equipment

AC Disconnecting Means

All interactive system(s) points of interconnection with other sources shall be marked at an accessible location at the disconnecting means as a power source and with the rated ac output current and the nominal operating ac voltage.



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Agenda

1. Basic Facts and Safety Overview
2. Fire Safety Code Discussion
3. Information Systems and How They are Used
4. How Do Solar Electric Systems Work?
5. System Types and Schematic Representation
6. Site Plans and Identification of Components
7. **How to Identify and Disable Different Solar Electric Systems**
8. Worksheets for System Type Identification

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How to Identify and Disable Different Solar Electric Systems

System Types

I. On Grid
   1. Micro-inverter
   2. String inverter
   3. Industrial or Utility Central Inverter
   4. w/ Battery Backup

II. Off Grid

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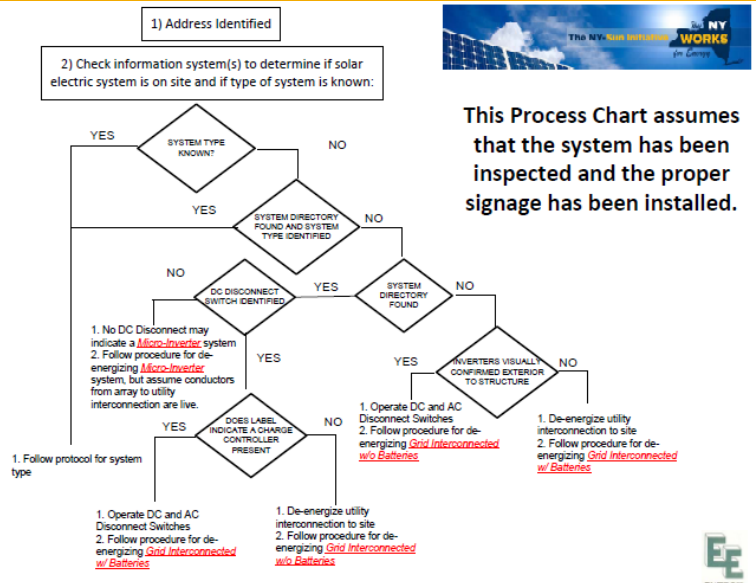
How to Identify and Disable Different Solar Electric Systems



This Process Chart assumes that the system has been inspected and the proper signage has been installed.

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I. On Grid
1. Micro Inverter

MICROINVERTER SYSTEM

DC circuits are from the solar modules to the inverter.
DC circuits are energized whenever solar modules are exposed to sunlight.

DC circuits are usually limited to directly under the solar modules for microinverter systems as the inverter is often attached to the module or to the rack which is directly underneath the module.

De-energizing ac power to the building will disconnect utility energy from the disconnecting point to the solar modules.

The ac disconnecting point may be
1) Utility meter
2) Labeled solar electric system disconnect switch
3) Labeled solar electric system breaker in a main or subpanel

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I. On Grid
1. Micro Inverter

DISCONNECTING SEQUENCE

1. Look for the System Directory. Usually located at the building's main service disconnecting point.
2. Disconnect utility power to building.
3. AC conductors from utility to disconnecting point are energized.
4. Avoid DC conductors immediately underneath the solar modules.

Normally energized when sunlight is present

De-energized if disconnect between the power source (utility or solar) and equipment is disconnected in off position

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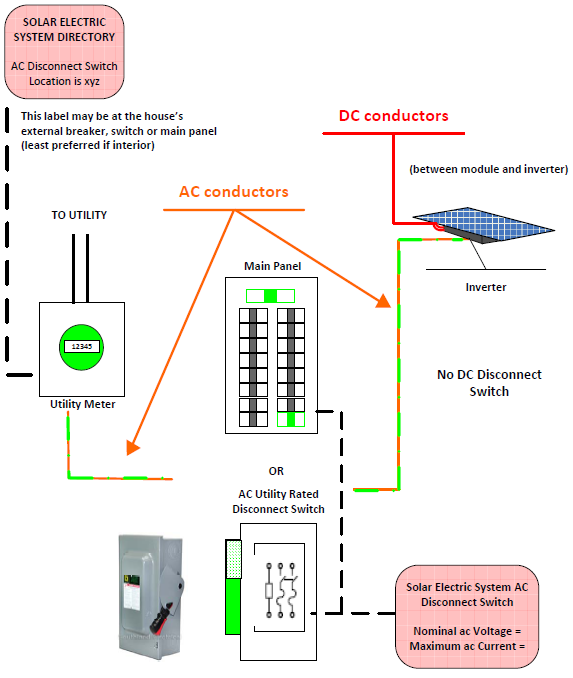

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I. On Grid
2. String Inverter

GRID INTERCONNECTED WITHOUT BATTERY

DC circuits are from the solar modules to the inverter.
They normally are in metallic conduit.
DC circuits are energized whenever solar modules are exposed to sunlight.

Operating the dc disconnection switch will de-energize from that point to the inverter. It will NOT de-energize from that point back to the solar modules.

De-energizing ac power to the building will de-energize the ac circuit from the disconnecting point to the inverter.

The ac disconnecting point may be
1) Utility meter
2) Labeled solar electric system disconnect switch
3) Labeled solar electric system breaker in a main or subpanel.

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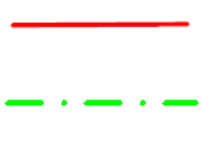
I. On Grid
2. String Inverter

DISCONNECTING SEQUENCE

1. Look for the System Directory. Usually located at the building's main service disconnecting point.
2. Disconnect utility power to building and operate dc Disconnect Switch.
3. AC conductors from utility to disconnecting point are energized.
4. Avoid dc conductors immediately underneath the solar modules to the dc disconnect switch.



Energized when sunlight is present

De-energized if disconnect between the power source (utility or solar) and equipment is disconnected in off position

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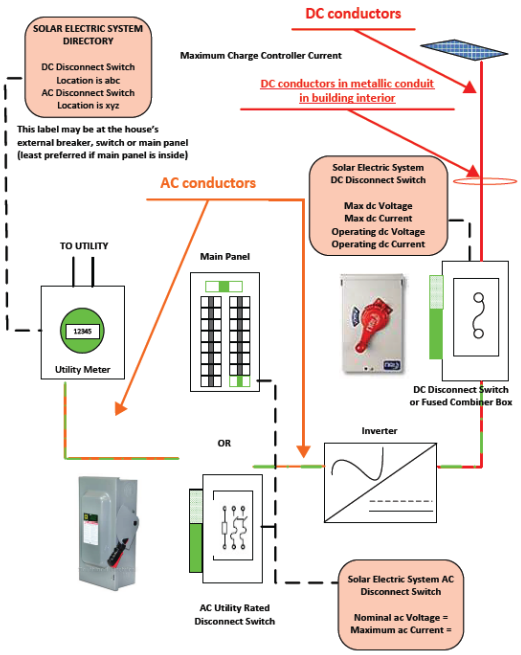
GRID INTERCONNECTED WITHOUT BATTERY



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I. On Grid
3. Industrial or Utility Central Inverter

UTILITY INTERCONNECTED

DC circuits are from the solar modules to the many combiner boxes before going on to the inverter. They normally are in metallic pv PVC conduit.
DC circuits are energized whenever solar modules are exposed to sunlight.

De-energizing ac power to the building will NOT de-energize the ac circuit from the disconnecting point to the inverter.
In fact, a building may not even be on site.

De-energizing the ac disconnecting means will de-energize the ac circuit from the disconnecting point to the inverter.

The ac disconnecting point will be
1. Labeled solar electric system disconnect switch
This switch will most likely be protected by a fence, locked enclosure, or some other barrier.

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I. On Grid
3. Industrial or Utility Central Inverter

DISCONNECTING SEQUENCE

1. Look for the System Directory. Usually located at the building's main service disconnecting point.
2. Disconnect utility power to Inverter, and operate dc Disconnect Switch.
3. AC conductors from utility to disconnecting point are energized.
4. AC conductors from disconnecting point to Inverter are energized unless disconnect is in OFF position.
5. Avoid DC conductors from the solar modules to the dc Disconnect Switch.

Energized when sunlight is present

De-energized if disconnect between the power source (utility or solar) and equipment is disconnected in off position

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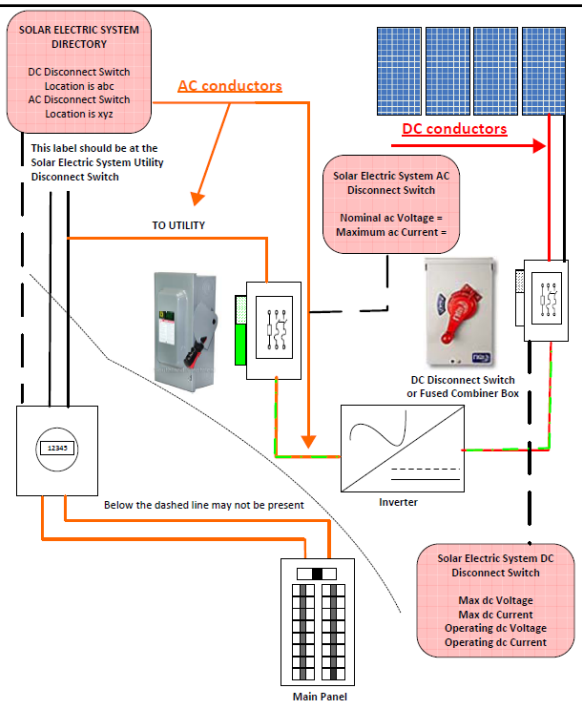

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I. On Grid
4. With Battery Backup

GRID INTERCONNECTED WITH BATTERY

DC circuits are from the solar modules to the inverter. They normally are in metallic or PVC conduit. DC circuits are energized whenever solar modules are exposed to sunlight.

De-energizing ac power to the building will de-energize the ac circuit from the disconnecting point to the inverter.

The ac disconnecting point may be
1) Utility meter
2) Labeled solar electric system disconnect switch
3) Labeled solar electric system breaker in a main or subpanel

HOWEVER, turning off the ac disconnecting point will NOT DE-ENERGIZE the inverter's emergency power circuit.
This circuit powers the building's important electrical systems such as: furnace, well, computers, refrigeration, etc.

These circuits are often grouped together in a separate solar electric panel. These circuits are energized until the inverter is turned off, which is accomplished by turning off the battery power switch to the inverter [BATTERY SHUT DOWN BREAKER].

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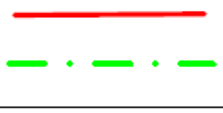
DISCONNECTING SEQUENCE

1. Look for the System Directory. Usually located at the building's main service disconnecting point.
2. Disconnect utility power to building, and operate DC Disconnect Switch.
3. AC conductors from utility to disconnecting point are energized unless meter is pulled.
4. AC conductors from Inverter to Battery Powered Panel are energized unless INVERTER SHUT DOWN BREAKER is OFF.
5. Avoid DC conductors immediately underneath the solar modules to the DC Disconnect Switch.



Energized when sunlight is present

De-energized if disconnect between the power source (utility or solar) and equipment is disconnected in off position

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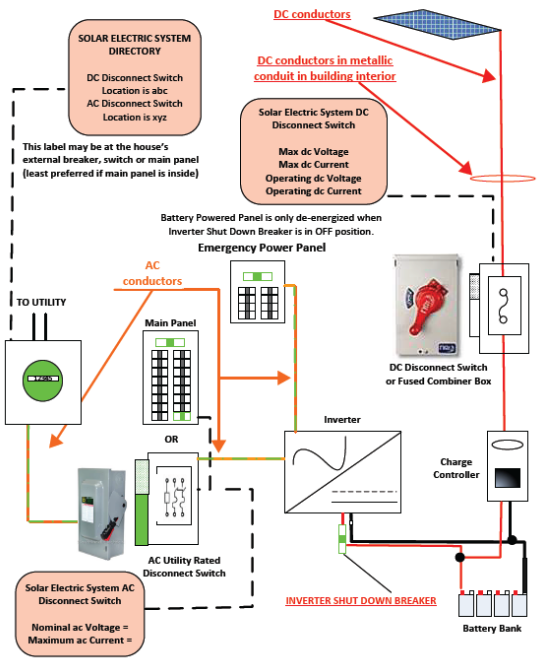
GRID INTERCONNECTED WITH BATTERY



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II. Off Grid

GRID ISOLATED WITH BATTERY

DC circuits are from the solar modules to the inverter.
They normally are in metallic conduit.
DC circuits are energized whenever solar modules are exposed to sunlight.

There is no utility interconnection, however, there may be a generator interconnection. De-energizing ac power to the building will de-energize the ac circuit from the disconnecting point to the inverter.

The ac disconnecting point may be:
1) Labeled generator disconnect switch

HOWEVER, this switch will NOT DE-ENERGIZE the inverter's emergency power circuit. This circuit powers the entire building. These circuits are energized until the inverter is turned off, which is accomplished by turning off the battery power switch to the inverter [BATTERY SHUT DOWN BREAKER].

In rare cases, there may be DC circuits usually emanating from a dc subpanel. Turning off the battery shut down breaker to the Inverter will NOT DE-ENERGIZE the dc circuits. They are powered directly from the battery. The electric panel's main breaker must be turned off.

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DISCONNECTING SEQUENCE

1. Look for the System Directory. Usually located at the building's main service disconnecting point.
2. AC conductors from inverter to Battery Powered Panel are energized unless INVERTER SHUT DOWN BREAKER (BATTERY BREAKER) is OFF.
3. Avoid dc conductors immediately underneath the solar modules to the dc disconnect switch.
4. If a dc subpanel is present, the dc conductors to this panel usually are energized directly off the battery. If there is no disconnecting switch or breaker between the battery and the subpanel, turning off the subpanel is only way to de-energize the dc subpanel. The conductors between the battery bank and the dc subpanel will still be energized.

Energized when sunlight is present

De-energized if disconnect between the power source (utility or solar) and equipment is disconnected in off position

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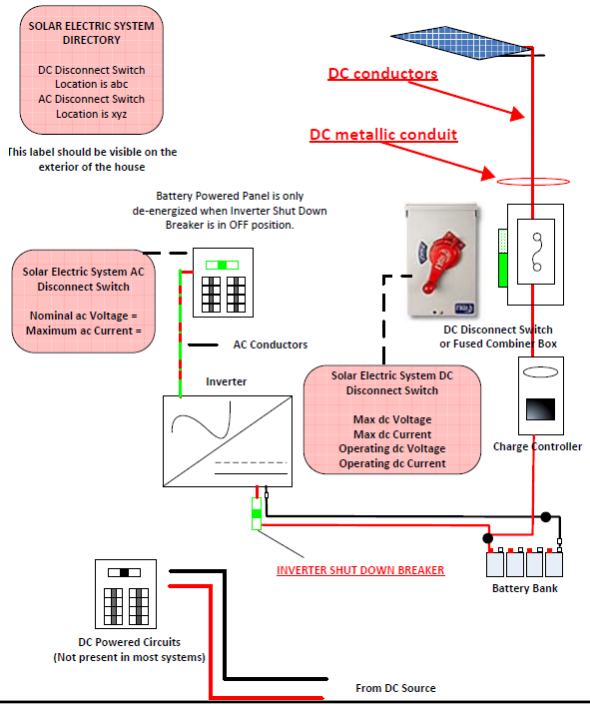

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Time for a Little Quiz

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Conclusion

Quiz Discussion

Course Material Discussion

Feedback for Future Reference

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Available Training Topics

Creating and Implementing Your Solarize Campaign

Expanding Commercial Solar With a PACE Program

Introduction to Shared Solar

Introduction to Solar Policy Workshop

Land Use Planning for Solar Energy

Safety and Fire Considerations for Solar PV

Solar Procurement for Local Governments

Solar PV for Engineers and Architects

Solar PV Permitting and Inspection Methods

Streamlining Solar Permitting

Zoning for Solar Energy

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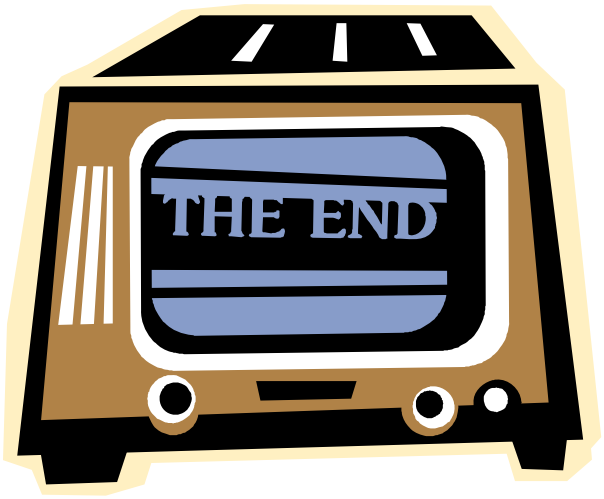

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