CPWR
Center for Construction Research and Training

SAFETY PROTOCOL

Prevention through Design for Safety in Solar Installations

Hyun Woo Lee
John Gambatese
Chung Ho

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UNIVERSITY of WASHINGTON

Oregon State UNIVERSITY

PREAMBLE

This protocol provides guidance on applying Prevention through Design (PtD) to the design and installation of solar energy systems for small residential buildings. Seven PtD attributes with related design and installation issues are introduced, including roof materials, roof slopes, panel layouts, roof accessories, fall protection systems, lifting methods, and electrical systems. These attributes should be incorporated into the design documents of solar energy systems to improve the safety of solar workers during the installation processes.

ACKNOWLEDGEMENT

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A - INTRODUCTION

THIS PROTOCOL:

Provides	A guidance for application of Prevention through Design (PtD) into the design and installation of solar energy systems.
Applies	To existing residential buildings.
Addresses	Safety hazards and risk in the installation of solar energy systems.
Considers	Roof materials, roof slopes, roof accessories, roof layouts, fall protection systems, lifting methods, and electrical systems.

PREVENTION THROUGH DESIGN (PtD)

- Eliminates or reduces occupational safety and health hazards during the design process.
- Can be incorporated into the design of new processes, structures, equipment, tools, and work methods.

SAFETY FACTS

- Falls account for 35% of fatalities in construction (Wang et al. 2015).
- Almost 50% of construction fatalities and accidents are linked to design decisions (Behm 2005)

Prevention through Design (PtD) is "*the practice of* ***anticipating*** *and '****designing out****' potential occupational safety and health hazards and risks associated with* ***new processes, structures, equipment, or tools, and organizing work****, such that it takes into consideration the construction, maintenance, decommissioning, and disposal/recycling of waste material, and recognizing the business and social benefits of doing so*" (Schulte et al. 2008).

A - INTRODUCTION (cont.)

PtD APPLICATION PROCEDURE

Involved parties:	Project managers, designers, contractors, and safety personnel
Safety conditions:	Addressed in design documents (e.g. drawings, specs)
Safety enforcement:	Applied during installation processes

Basic steps

Step 1 Define the expected solar energy system.
Step 2 Review the design of the existing roof, evaluating how it impacts the solar panel layout and safety in solar installations (e.g. roof structures, roofing materials, roof accessories, roof layout).
Step 3 Review the solar energy system (e.g. panel layouts, roof access points, installation methods), including safety issues.
Step 4 Prepare initial design documents.
Step 5 Review the design and incorporate safety into the design and the design documents.
Step 6 Finalize the design documents.
Step 7 Safety personnel backcheck the design documents.
Step 8 Develop a safety implementation plan and enforce safety rules.

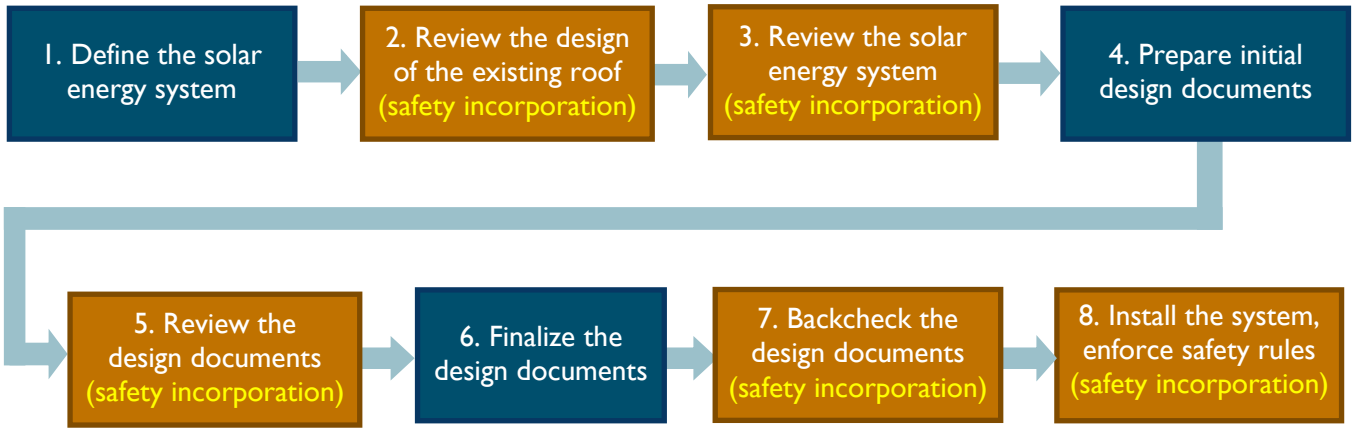

Fig. 1 PtD Implementation Procedure (adapted from Anderson & Galecka 2014)

B - PtD ATTRIBUTES

1. ROOFING MATERIAL

Roofing materials influence solar safety in different ways. While composite shingles present convenient installation conditions, metal roofs and cedar shakes pose high safety risks and hazards.

- Metal roofs, wood roofs, and roofs losing granular particles are slippery, especially when raining.
- Metal roofs increase the heat stress on hot days and glare under sunlight.
- Cedar shakes can crack or split when workers step on them.
- Concrete tiles are heavy, making it difficult to install connections for mounting systems.

Consider the following factors for roofing materials when designing solar panel layouts and installation methods.

Factors	Design suggestions
Roof Structures	Only install solar panels on structurally sound roofs that are unlikely to be damaged during the lifecycle of the solar energy systems. Structurally unsound roofs or damaged roofs should be upgraded before installing solar energy systems. If possible, include the layout of roof structures in the solar design documents.
Safety Anchors	Locate safety anchors along roof ridges whenever possible. *Composite shingle roofs:* Safety anchors should be located at any suitable areas in addition to roof ridges. *Metal roofs:* Safety anchors should be located only along metal roof ridge caps (if possible) to avoid roof leaks caused by connection holes.

B - PtD ATTRIBUTES

1. ROOFING MATERIAL (cont.)

Consider the following factors for roofing materials when designing solar panel layouts and installation methods.

Factors	Design suggestions
Installation Methods	*Wood roofs:* Include a recommendation in the design documents to use predrills to create pilot holes when connecting safety anchors and mounting systems with wood roof structures.
Personal Protective Equipment	*Wood roofs:* Include a recommendation in the design documents to use special working boots to avoid cracking wood tiles. *Roofs losing granular material:* Include a recommendation in the design documents to use special working boots with high slip resistance capacity. *Metal roofs:* Provide sunglasses and sufficient hydration for workers when working on sunny days.

Fig. 2 Lifting up composite shingles to inset connection plates

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2. ROOF SLOPE

Roof slope has a significant impact on solar safety. The steeper the roof, the more dangerous it is to install solar systems.

- Steeper roofs are more slippery, especially in the rain.
- Flat roofs can be slippery with the development of ponding and mosses
- Standing on steep roofs increases stress and pain in workers' ankles.
- Tools or materials slide along and drop from steep roofs more frequently.

Fig. 3 Installing connection brackets on a sloped roof.

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2. ROOF SLOPE

Consider the following factors regarding roof slope when designing solar panel layouts and installation methods.

Factors	Design suggestions
Safety Systems	*Steep roofs (slope > 4:12)*: Use either a guardrail system with toeboards, safety net system, or personal fall arrest system. *Low-slope roofs (slope ≤ 4:12)*: Use either a guardrail system, safety net system, personal fall arrest system, or a combination of warning line system and safety monitoring system.
Safety Anchors	More than 1 safety anchor should be installed for each worker for high steep roofs.
Working Platforms	*Low-slope roof and moderately-steep roofs:* Use the roof surface as a working platform. *High-slope roofs:* Use mechanical lifts as a working platform.
Installation Sequences	*Steep roof:* Install bottom racks first to serve as a support point for installing other racks.

OSHA 1926.500(b)(2): *Steep roof* means a roof having a slope greater than 4 in 12 (vertical to horizontal).

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3. ROOF ACCESSORIES

Roof accessories may present both advantages and disadvantages for solar safety. Solar designers should be fully aware of existing roof accessories and their impacts to safety during solar installations.

- Unprotected skylight openings may cause falling hazards.
- Roof accessories may cause tripping hazards, but can also serve as a backing object to keep materials from sliding along roof slopes.
- Chimneys may obstruct the movement of workers, but can also serve as an anchor point if they are structurally able to support a worker in a fall.

Fig. 4 This chimney obstructs the movement of the workers and reduces resistance capacity of the safety line

Fig. 5 This skylight and exhaust vent prevent installation materials from sliding, while the small drain vents pose high tripping hazards for the worker

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3. ROOF ACCESSORIES (cont.)

Consider the following factors regarding roof accessories when designing solar energy systems.

Factors	Design suggestions
Safety anchors	Chimneys should not be used as a safety anchor unless they are structurally attached to the building's structure and can support a worker in a fall. Locate safety anchors on both sides of dormers and chimneys in case these accessories obstruct the movement of the workers.
Fall from openings	Equip the workers with personal fall arrest systems, or install covers or guardrail systems for the openings. If using covers, ensure that they can support twice the load that may be imposed on them.
Solar panel layouts	Do not place solar panels on the top of skylights or chimneys.

Fig. 6 This solar energy system is divided into two arrays to avoid the existing chimney

OSHA 1926.501(b)(4)(i): Each employee on walking/working surfaces shall be protected from falling through holes (**including skylights**) more than 6 feet (1.8 m) above lower levels, by personal fall arrest systems, covers, or guardrail systems erected around such holes.

When cover is used, OSHA requires that:
OSHA 1926.502(i): ... covers shall be capable of supporting, without failure, at least twice the weight of employees, equipment, and materials that may be imposed on the cover at any one time.

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4. PANEL LOCATION

Choices about solar panel locations influence solar installation safety. Solar panel locations determine worker access areas, and decisions that facilitate or impede the movement of the workers.

- Locating solar panels over the entire roof and to the roof ridge makes it difficult to install safety anchors and to unhook from safety anchors.
- Covering the entirety of a roof with solar panels also impedes the ability of workers to perform maintenance after installation.

To allow access for fire fighters in case of an emergency, the International Fire Code (IFC 2012) requires clear access pathways and the clearances between solar panel edges and roof ridges.

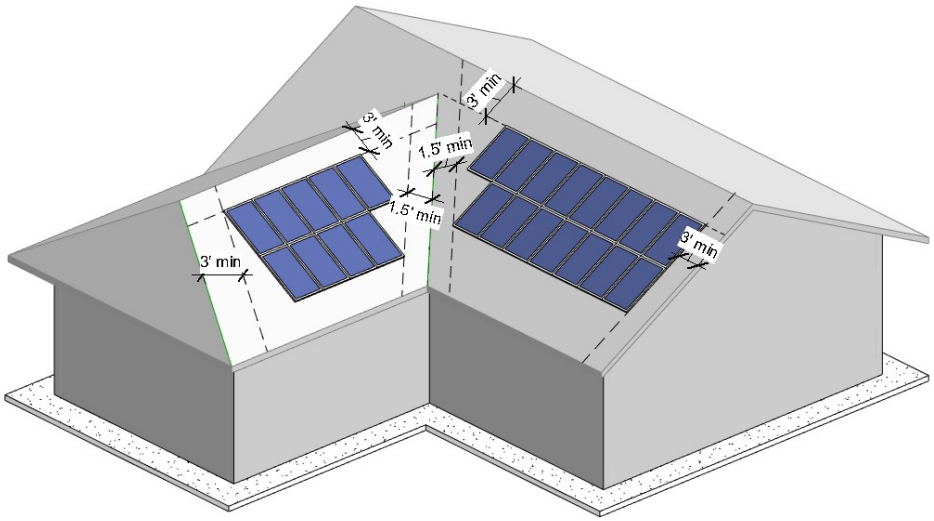

Fig. 7 Minimum clear access pathways and clearances between panels and roof ridges for residential building with roof hips and valleys

IFC 605.11.3.2.3 Residential buildings with roof hips and valleys. Panels/modules installed on residential buildings with roof hips and valleys shall be located no closer than 18 inches (457 mm) to a hip or valley where panels/modules are to be placed on both sides of a hip or valley. Where panels are to be located on only one side of a hip or valley that is of equal length, the panels shall be permitted to be placed directly adjacent to the hip or valley. (Exception: roof slopes ≤ 2:12).

IFC 605.11.3.2.4 Residential buildings with smoke ventilation. Panels/modules installed on residential buildings shall be located no higher than 3 feet (914 mm) below the ridge in order to allow for fire department smoke ventilation operations.

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4. PANEL LOCATION (cont.)

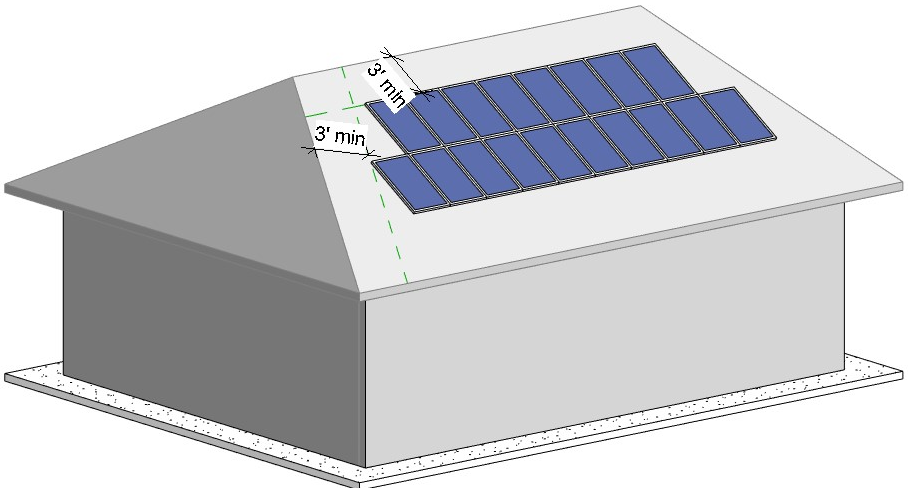

Fig. 8 Minimum clear access pathways and clearances between panels and roof ridges for a residential building with a hip roof

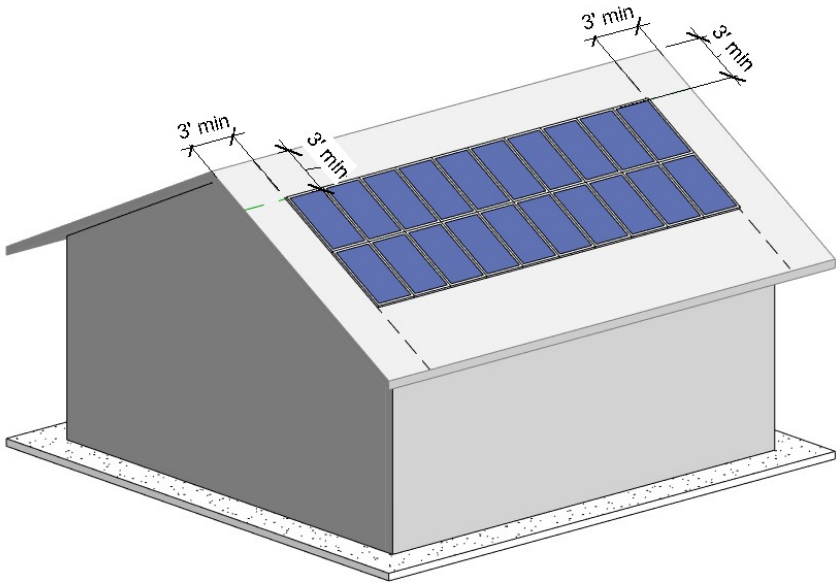

Fig. 9 Minimum clear access pathways and clearances between panels and roof ridges for a residential building with a single ridge

IFC 605.11.3.1 Roof access point. Roof access points shall be located in areas that do not require the placement of ground ladders over openings such as windows or doors, and located at strong points of building construction in locations where the access point does not conflict with overhead obstructions such as tree limbs, wires, or signs.

IFC 605.11.3.2.1 Residential buildings with hip roof layouts. Panels/modules installed on residential buildings with hip roof layouts shall be located in a manner that provides **a 3-foot-wide (914 mm) clear access pathway** from the eave to the ridge on each roof slope where the panels/modules are located. The access pathway shall be located at a structurally strong location on the building capable of supporting the live load of fire fighters accessing the roof. (Exception: roof slopes ≤ 2:12).

IFC 605.11.3.2.2 Residential buildings with a single ridge. Panels/modules installed on residential buildings with a single ridge shall be located in a manner that provides **two, 3-foot-wide (914 mm) access pathways** from the eave to the ridge on each roof slope where panels/modules are located (Exception: roof slopes ≤ 2:12).

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4. PANEL LOCATION (cont.)

Consider the following factors regarding solar panel locations when designing solar energy systems.

Factors	Design suggestions
Clear access pathways (for roof slopes > 2:12)	*Buildings with hip roofs:* Allow **a 3-feet-wide clear access pathway** from the eave to the ridge of each roof slope where panels are located. *Buildings with a single ridge:* Allow **two, 3-feet-wide clear access pathways** from the eave to the ridge of each roof slope where panels are located. *Buildings with hip roofs and valleys:* ♦ If panels are located on both sides of a hip or valley, locate the panels no closer than 18 inches from the hip or valley. ♦ If panels are located on only one side of a hip or valley that is of equal length, locate the panels directly adjacent to the hip or valley.
Clearances between panels and roof ridges	Do not place the panels higher than 3 feet below roof ridges, unless approved by the fire chief (for smoke ventilation).
Roof access points	Locate roof access points on the areas that do not require placing ground ladders over openings, such as windows and doors. Locate roof access points on areas that are structurally sufficient to support access.
Roof access areas	Allow sufficient areas for roof access and hoisting materials during installation.

IFC 605.11.3.1 Roof access point. Roof access points shall be located in areas that do not require the placement of ground ladders over openings such as windows or doors, and located at strong points of building construction in locations where the access point does not conflict with overhead obstructions such as tree limbs, wires, or signs.

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5. FALL PROTECTION SYSTEM

Multiple options can be used for fall protection, such as guardrail systems, safety net systems, and personal fall arrest systems. Panel layout design should facilitate the use of proper fall protection methods.

Figures 9 and 10 show examples of safety anchors that can be used for personal fall arrest systems. The maximum number of personal fall arrest systems attached to each safety anchor must be within the limit stated by the manufacturer.

Fig. 10 This project installed Hitchclips along the roof ridge to serve as safety anchors.

Fig. 11 This project installed Guardian bull ring anchors along the roof ridge.

OSHA 1926.501(b)(10): … each employee engaged in roofing activities on low-slope roofs, with unprotected sides and edges 6 feet (1.8 m) or more above lower levels shall be protected from falling by guardrail systems, safety net systems, personal fall arrest systems, or a combination of warning line system and guardrail system, warning line system and safety net system, or warning line system and personal fall arrest system, or warning line system and safety monitoring system. Or, on roofs 50-feet (15.25 m) or less in width (see Appendix A to subpart M of this part), the use of a safety monitoring system alone [i.e. without the warning line system] is permitted.

OSHA 1926.501(b)(11): … Each employee on a steep roof with unprotected sides and edges 6 feet (1.8 m) or more above lower levels shall be protected from falling by guardrail systems with toeboards, safety net systems, or personal fall arrest systems.

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5. FALL PROTECTION SYSTEM (cont.)

Consider the following factors regarding fall protection systems when designing solar energy systems

Factors	Design suggestions
Safety anchors	Safety anchors are normally located along roof ridges. Solar panels should not extend to roof ridges in order to comply with the International Fire Code (see Panel Layout Section) and allow for the installation of safety anchors. The maximum distance between two safety anchors should allow for the movement of workers within lanyard lengths. Install safety anchors on both sides of any obstruction on the roof, such as dormers, chimneys, and skylights. The obstruction can hinder the movement of workers who are wearing a fall arrest system.
Guardrail systems	For fall protection systems on a steep roof, guardrail systems must include toeboards.
Safety monitoring systems	Use a combination of safety monitoring systems and warning line systems for fall protection on low-sloped roofs. These can be in addition to using guardrail systems, safety net systems, and personal fall arrest systems. Low-sloped roofs having ≤ 50-foot width are permitted to use only a safety monitoring system for a fall protection system.

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6. LIFTING METHODS

Roof heights and panel sizes influence lifting methods. Consider the size and design of panel layouts when choosing a lifting method.

- The standard solar panel size for residential projects is 65"x39". The standard panel weight is about 40 lbs, within OSHA's manual lifting limit.
- OSHA regulations do not allow workers to carry solar panels while climbing on a ladder.
- OSHA regulations require workers to use at least one hand to grasp the ladder when progressing up and down the ladder
- Local codes may have stricter requirements. For example, Washington Administrative Codes requires that both hands must be free to hold on to the ladder while climbing or descending.

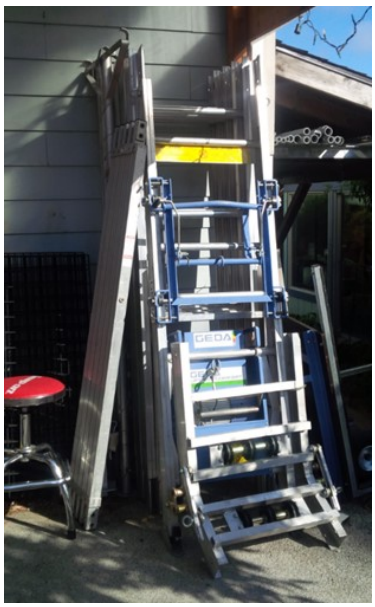

Fig. 12 Ladder hoists are recommended for panel lifting

Fig. 13 Ladder stabilization device

Fig. 14 Ladder with a ladder safety device

OSHA - Green Job: Solar panels should be lifted safely to the rooftops. Workers should never be allowed to climb ladders while carrying solar panels. Lifting equipment, such as ladder hoists, swing hoists, or truck-mounted cranes/conveyors, should be used wherever possible.

WAC - 296-876-40025 Climbing and Descending: (1) You must have both hands free to hold on to the ladder.

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6. LIFTING METHODS (cont.)

Consider the following factors for lifting solar panels when designing solar panel layouts and installation methods.

Factors	Design suggestions
Panel sizes	Design documents should include information about panel weights in relation to OSHA's manual lifting limit. Standard solar panels for residential projects should be selected whenever possible.
Panel layouts	Panel layouts should be designed to locate ladder access points at structurally strong areas and avoid the need to place ladders over openings, such as windows or doors.
Lifting methods	Use lifting equipment to lift solar panels to rooftops whenever possible. Do not climb the ladder while carrying solar panels.

*Fig. 15 Use of a ladder extension can make it safer to step off a ladder onto the elevated surface (*Source of the picture: Amazon.com)

OSHA 1926.1052(b)(21): Each employee shall use at least one hand to grasp the ladder when progressing up and/or down the ladder

OSHA 1926.1052(b)(22): An employee shall not carry any object or load that could cause the employee to lose balance and fall.

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7. ELECTRICAL SYSTEM

Electrical systems can create several safety hazards for workers. First and foremost, the power generated from solar energy systems can cause shock hazards for workers. In addition, electrical wires or conduits can create tripping hazards during installation.

Consider the following factors for electrical systems during the design phase:

Factors	Design suggestions
For safety during installation	Locate conduits, wiring systems, and raceways as close as possible to the ridge, hip, or valley, and from the hip or valley as directly as possible to the outside wall. Cautions is needed to ensure minimum clearance distances with existing overhead electrical lines
For safety during operation	Design the system to include rapid shutdown devices as required by the National Fire Code

IFC 605.11.1.2: Conduit, wiring systems, raceways for photovoltaic circuits shall be located as close as possible to the ridge or hip or valley, and from the hip or valley as directly as possible to outside wall to reduce trip hazard and maximize ventilation opportunity.

Fig. 16 Rapid shutdown device for a residential project

National Electrical Code 2017 NEC 690.12 : Rapid Shutdown of PV Systems on Buildings. PV system circuits installed on or in buildings shall include a rapid shutdown function to reduce shock hazard for emergency responders in accordance with 690.12(A) through (D).

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