美國電工法規所規範之 PV Rapid Shut Down介紹

2020-11-18 | Richard Lee

Biography

- Richard Lee
- Staff Engineer (since 2003/06)
- Power supply / EV Charger / PV Inverter product safety evaluation

Agenda and Objective

I. Basic Introduction

II. PV Rapid Shutdown & PV Hazard Control

Participate have roughly idea about PV rapid shut down

Basic Introduction

2014 NEC - 690.12 PV Rapid Shutdown

This PVRS system is intended to be used by fire fighters to reduce electric shock hazards of working around an electrically live PV array and its wiring. This article is intended to establish a safe perimeter around a PV array via functions such as an output disconnect or a function that attenuates or limits the PV array output power to a low level.

PV Output

- 30V
- 10 Seconds

Perimeter

- More than 10ft (3 m) from PV array; or
- 5ft (1.5 m) into building

When 690.12 was developed there were no standards for PV Rapid Shutdown Equipment.

What is a CRD?

- Certification Requirement Decision (CRD)
- Establishes published set of requirements to address the technical safety concerns in the absence of existing published requirements.
- Upon publication the CRD is required to be submitted to the STP for review and comment with intention to be included into the published standard.

PV Rapid Shutdown
&
PV Hazard Control

2014 10 ft Boundary

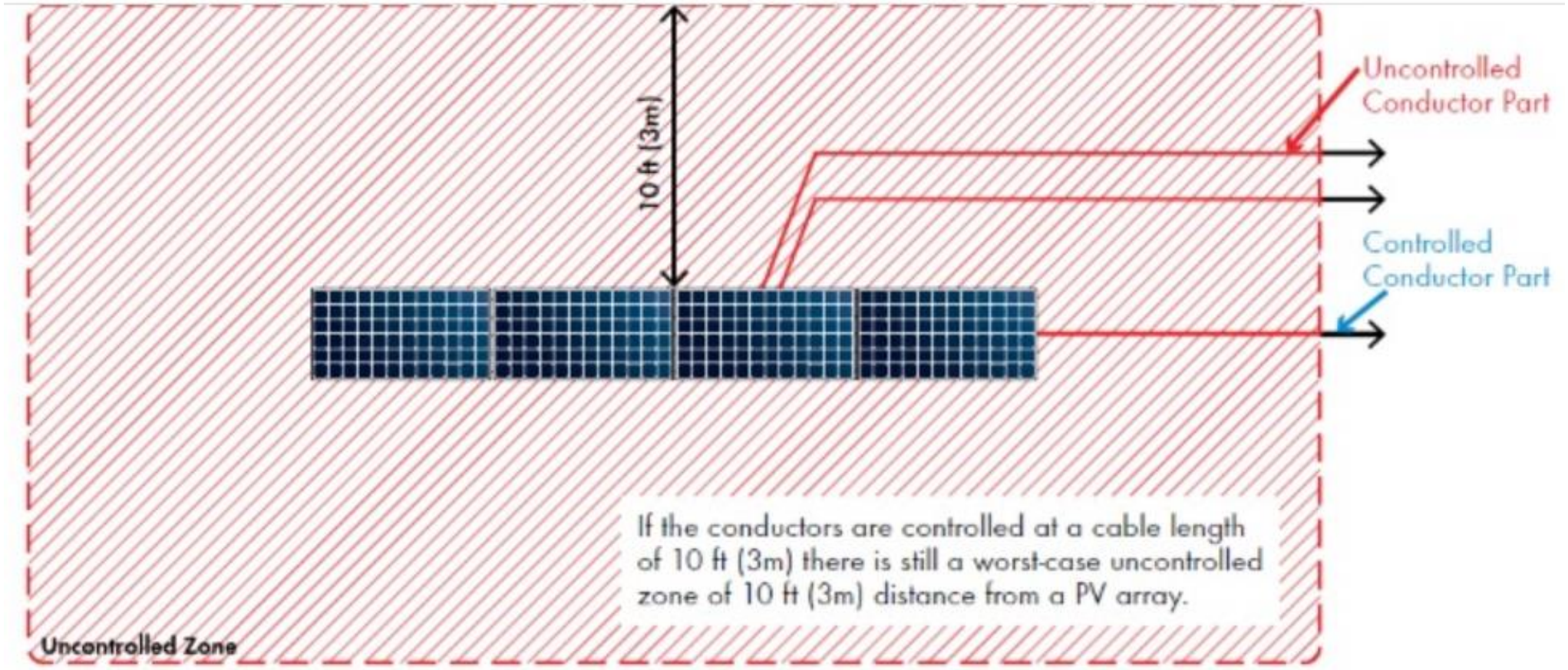
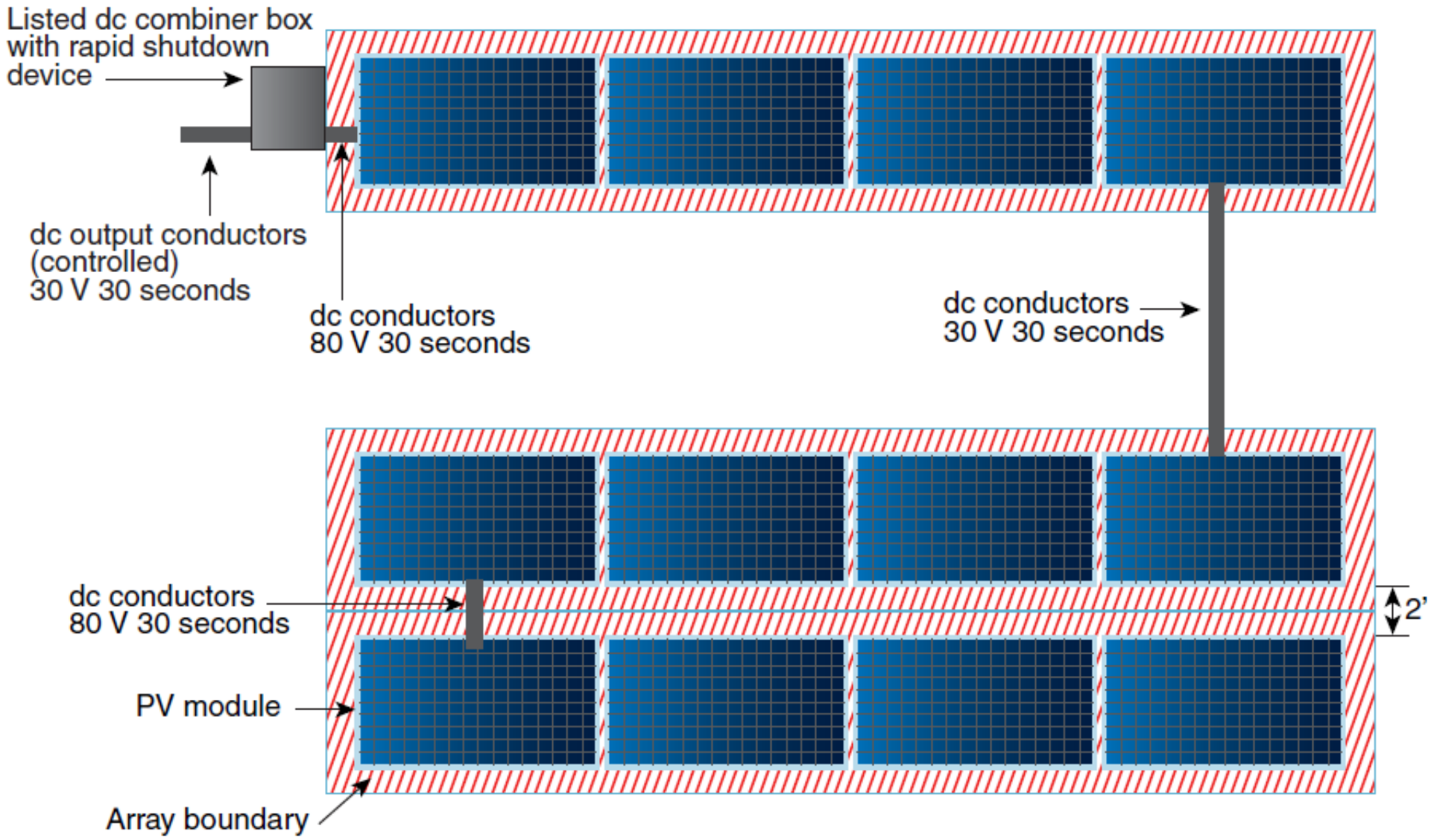


Figure 1: 2014 NEC Rapid Shutdown requires a "10-foot rule" for controlled conductors.

2017 1 ft Boundary (30 Seconds not 10 Seconds)



UL1741 Requirements for PVRS Published Dec 22, 2017

Construction

- Protection of Emergency Personnel
- Electrical Isolation Systems (EIS)
- Initiators, Status Indicators and Reset Devices
- Functional Safety is required for hardware and software
- Ratings, Markings and Instructions.

Performance / Testing

- PVRSS that Include PV Disconnect Functionality
- Operational Tests PVRSS (Verify levels Controlled Conductors)
- Verification Testing of PVRSS at Rated Extremes
- Power Supply Ride Through Inverters Certified as PVRSE
- Other equipment rated as PVRSE
- Functional Safety Testing
- Environmental Stress Testing (based on UL991)

Environmental Stress Testing (based on UL 991)

- Overvoltage/Undervoltage
- Power Supply Dips and Short Interruption
- Transient Overvoltage (Surge)
- Voltage Variation
- Electrical fast Transient/burst
- Signal Circuit fast transient
- Radiated immunity (EMI)
- Digital equipment modulation
- Keying interference
- ESD
- Electric Field
- Magnetic Field
- Composite Operational and Thermal Cycling
- Shipping and storage
- Thermal and Humidity cycling
- Dust
- Vibration and Jarring

Problem Define

1. **What are We Protecting Against?**

   What are the hazards for firefighters (FF) working in and around PV arrays?

2. **How do We Prevent It?**

   How do we keep firefighters out of hazardous current paths?

UL Standard to Address PV Array Protection Related to Rapid Shutdown

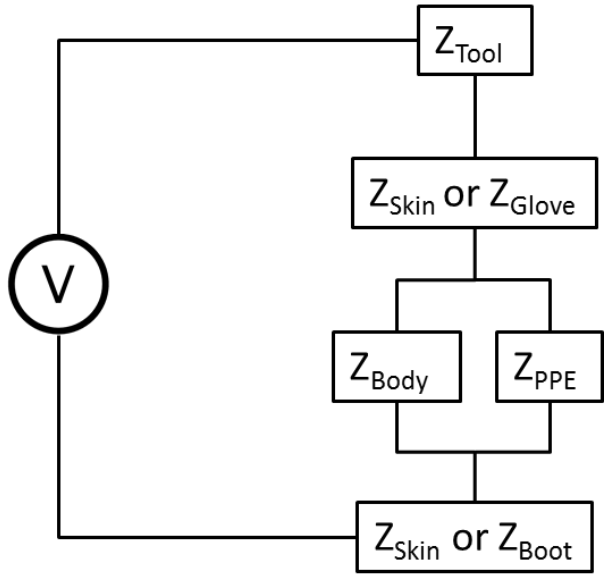
- There is significant agreement and support from PV industry and fire fighters to develop a new consensus safety standard to address PV Rapid Shutdown Array protection.

- While this effort can start and make good progress is critical that we do not make the same mistake again and assume we know the solution to an unknown question.

- We need research to guide this effort!

Fire Fighter (FF) Body Model Impedance

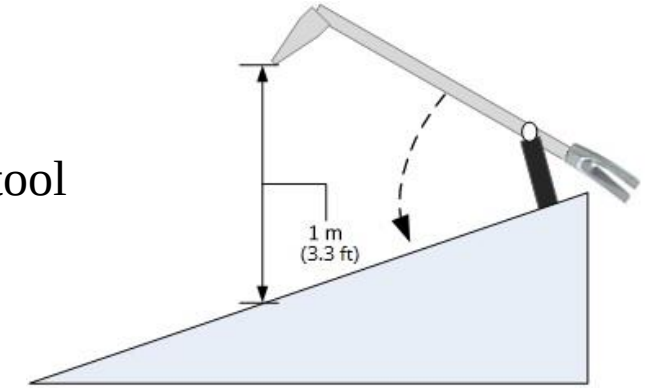
1. Document Search
2. Modeling/Simulation
3. FF PV interactions and exposures to current flow
4. Wet – water, sweat, sea water
5. Actual measurements of FF PPE
   - Do wet FF PPE provide shock protection or make it worse?



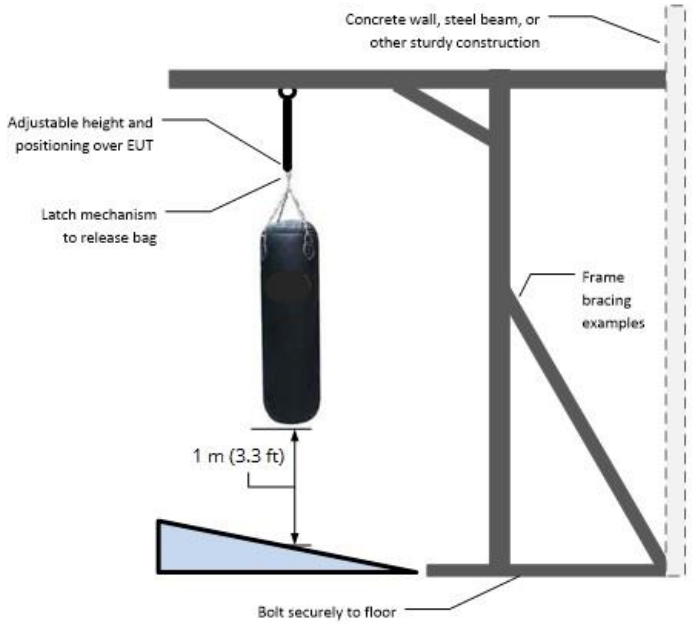
6. Account for common FF tools
7. Expanding on the existing data IEC/TS 60479-1 and other standards, to account for;
   - PPE clothing
   - Tools
   - Other relevant factors
8. These could be evaluated with other variables:
   - PPE moisture
   - Skin moisture
   - Anatomical factors

PVHC System Conditioning - Potential Damage From Fire Fighter Operations

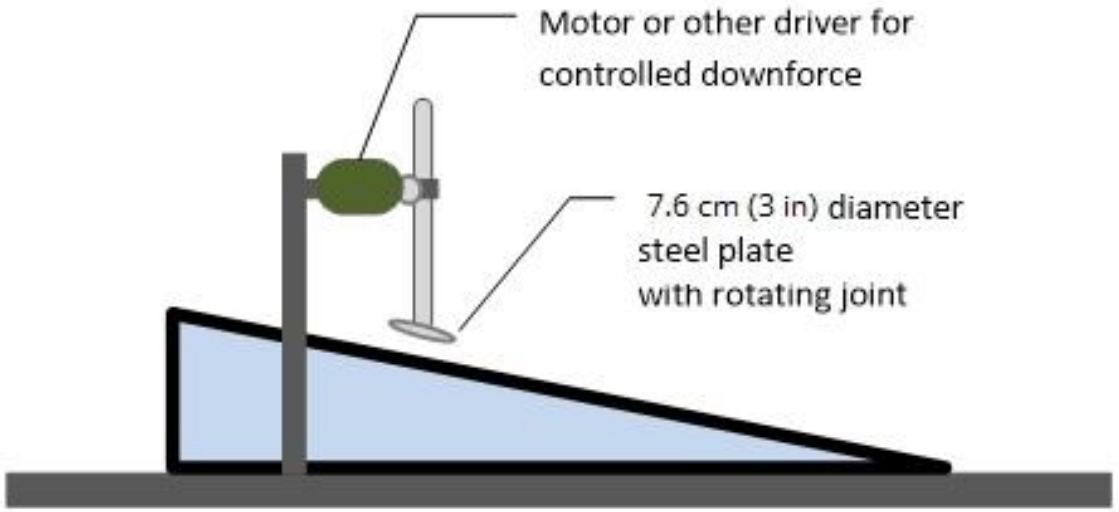
1. Damage from firefighter tool



2. Damage from falling firefighter

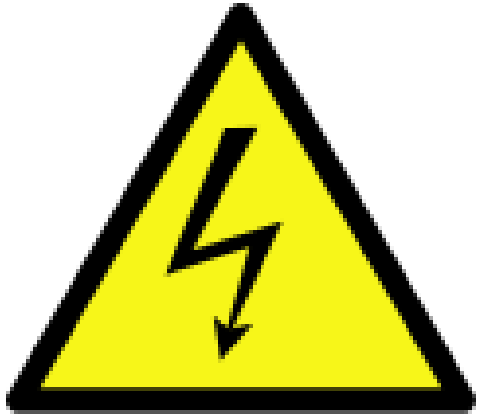


3. Damage from firefighter step, walk or crawl



PVHC - It Is About the Current and Not Just the Voltage

While limiting voltage is one means to reduce electric shock hazards there are many other ways to reliably reduce shock hazards. This new UL3741 standard will provide an evaluation program that is based upon engineering and science so we can keep fire fighters out of hazardous current paths



Direct Current Thresholds

Physiological Effects (DC)	Men	Women	Children
Perception (Wet)	4 mA	2.5 mA	2 mA
Inability to Let Go (Wet)	60 mA	40 mA	30 mA
Inability to Let Go (Dry)	120 mA	80 mA	60 mA
Ventricular Fibrillation (Wet)	226 mA	150 mA	113 mA

* The limits for children has been historically used to establish the electrical shock threshold for safety standards. Understand there are no children firefighters, they are listed for reference.
* Perception and inability of let-go is derived from research work of Dalziel; Ventricular fibrillation is derived based on the IEC 60479-1.
* Ventricular Fibrillation (Wet) limits were calculated from the DC values in accordance with IEC 60479-1.

The 2020 NEC 690.12 is being Revised and Coordinated with UL 3741

(2) Inside the Array Boundary.
The PV system shall comply with one of the following:

(1) Provide shock hazard control for emergency responders through the use of a PV Hazard Control means listed for the purpose. The hazard control components shall be installed and used in accordance with the instructions included with the listing or field labeling. ~~The PV array shall be listed or field labeled as a rapid shutdown PV array. Such a PV array shall be installed and used in accordance with the instructions included with the rapid shutdown PV array listing or field labeling.~~

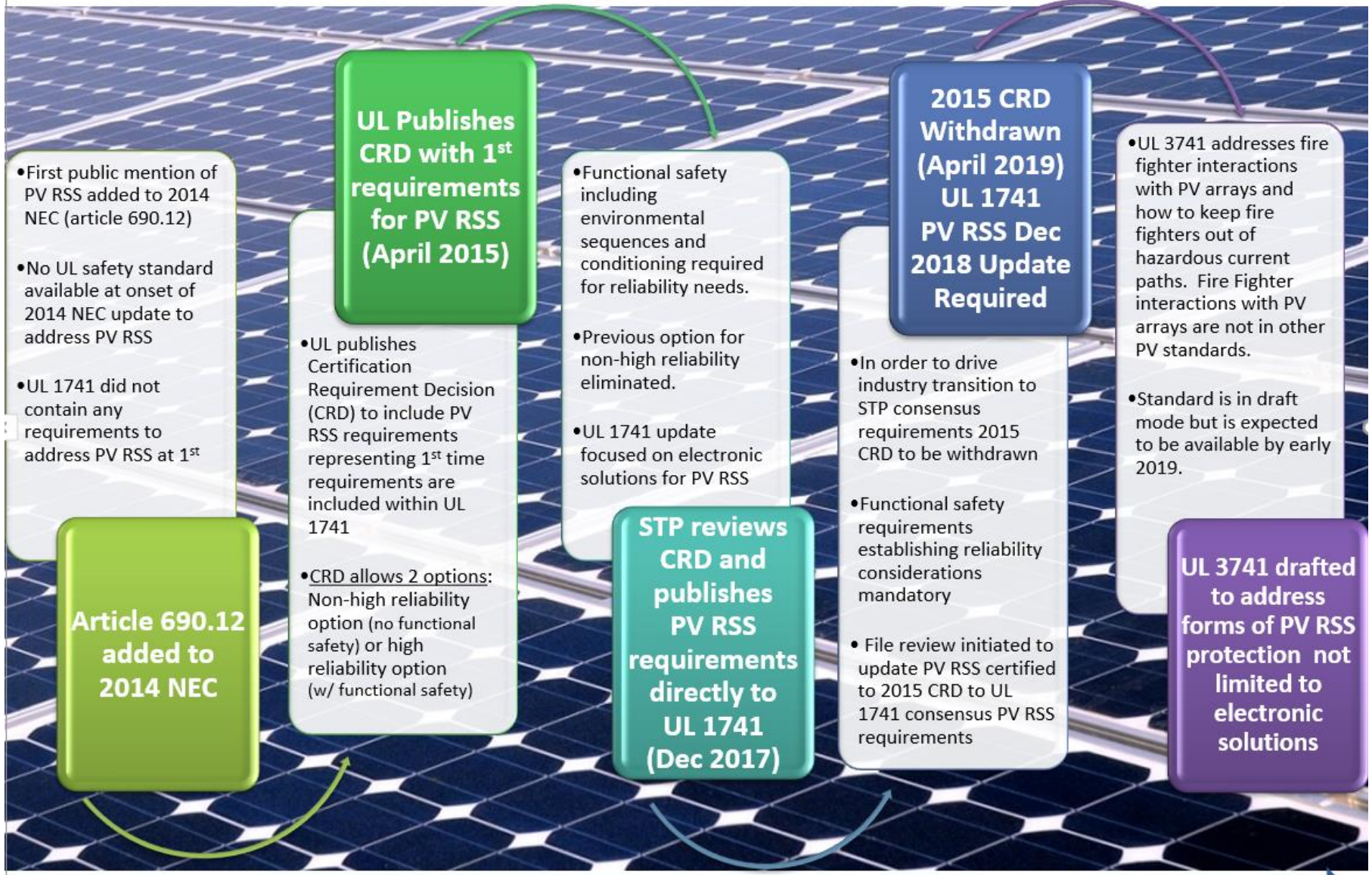
Informational Note: A listed or field labeled ~~rapid shutdown PV array is evaluated as an assembly or system~~ PV hazard control system may be comprised of either an individual piece of equipment that fulfills the necessary functions, or multiple pieces of equipment coordinated to perform the functions as described in the installation instructions to reduce the risk of electric shock hazard within a damaged PV array ~~during emergency response operations~~for fire fighters. ~~as defined in the installation instructions to reduce but not eliminate risk of electric shock hazard within a damaged PV array during fire fighting procedures. These rapid shutdown PV arrays are designed to reduce shock hazards by methods such as limiting access to energized components, reducing the voltage difference between energized components, limiting the electric current that might flow in an electrical circuit involving personnel with increased resistance of the conductive circuit, or by a combination of such methods.~~

(2) Controlled conductors located inside the boundary ~~or not more than 1 m (3 ft) from the point of penetration of the surface of the building~~ shall be limited to not more than 80 volts within 30 seconds of rapid shutdown initiation. Voltage shall be measured between any two conductors and between any conductor and ground.

(3) PV arrays with no exposed wiring methods, no exposed conductive parts, and installed more than 2.5 m (8 ft) from exposed grounded conductive parts or ground. ~~shall not be required to comply with 690.12(B)(2).~~

~~The requirement of 690.12(B)(2) shall become effective January 1, 2019.~~

The Evolution of PV Rapid Shutdown Systems & Equipment Standards & Certification Requirements



Where are we now?

- The NEC is adopted locally by US states and cities so there are many jurisdictions across the US that are using editions of the NEC that are one, two or three editions old.
- While some jurisdictions will adopt the 2020 NEC following its publication others will still be using the 2017, 2014 and 2011 NEC editions.
- UL1741 Listed PV rapid shutdown equipment makes it easy for AHJ inspectors to accept PV installations.
- Equipment certified to the PVRS UL1741 CRD can comply with the 2014 and 2017 NEC, but equipment will need to be certified to the new UL1741 requirements including functional safety for acceptance under UL3741 and the 2020 NEC.

NEC® in Effect

7/1/2020

2020 NEC® - 4

2017 NEC® - 31

2014 NEC® - 9

2008 NEC® - 3

County/Municipality NEC® regulation only - 3

Thanks for your time and participate