MODEL INSPECTION CHECKLIST

FOR ROOFTOP PV SYSTEMS

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Introduction to IREC's Model Inspection Checklist for Rooftop PV Systems

The Interstate Renewable Energy Council, Inc. (IREC) is pleased to release this *Model Inspection Checklist for Rooftop Photovoltaic (PV) Systems* for use by municipalities across the United States. In evaluating methods for improving the permitting process for rooftop solar systems, IREC is focused on developing tools that offer benefits to both municipal staff and solar installers. Adoption of an inspection checklist falls easily into this category.

For municipalities, an inspection checklist can serve a variety of important functions. First, it can serve as a supplementary educational tool for new or experienced inspectors to ensure they are aware of the host of code requirements that must be verified on-site during the inspection. It can also increase the consistency of inspections, by both a single inspector, as well as different inspectors working for the jurisdiction. Consistent inspections ensure high-quality, safe installations and also reduce conflict with installers, who may complain when they perceive that inspectors provide different results. The municipality can also use an inspection checklist as a tool for highlighting particular issues that seem to be repeatedly problematic for installers. For example, a checklist could contain a section for "common mistakes" which could highlight particular issues for both installers and inspectors to verify.

For installers, a checklist can help to prepare them for the inspection in advance, reducing the number of items that might need to be addressed afterward. This saves both the installer's and municipality's time and resources by reducing the number of re-inspections that would otherwise be required. As with inspectors, the inspection checklist can help to educate and refresh installers about the number of requirements they must meet, and to help inform and remind them of what inspectors will be looking for. For new installers or those new to the jurisdiction, who may not be as familiar with the code requirements, a checklist can be particularly valuable tool. A checklist can reduce the number of times inspectors have to do on-site education of new installers.

As code requirements change and municipalities adopt unique local rules, an inspection checklist can act as a key tool for highlighting those changes. A checklist can be easily updated over time to include new requirements. In addition to identifying rule changes, if the municipality has a particular interpretation of a code requirement that is sometimes applied differently, it can highlight its interpretation in its inspection checklist.

Despite the potential value of an inspection checklist, IREC realizes that many municipalities do not have the time to invest in creating a checklist from scratch. This Model Checklist is a nationally applicable template; it is intended to serve as an easy starting point for municipalities. Recognize, however, it will likely need some modification to match specific state and local code requirements.

In order to make this Model useful to as many jurisdictions as possible, IREC has drafted the requirements using relevant national code sections that are generally used as a starting point for state and local codes across the United States. It is not essential for a checklist to contain citations to each code section, as long as the requirements are accurately described. The citations may help resolve or head off disputes when an installer or inspector is unclear about the origin of the requirement or its exact wording. It

is our hope that in most states identifying the equivalent state code sections should be a relatively simple process. In addition, it is important for jurisdictions to add any unique state or local requirements that do not exist in the national codes utilized by IREC. It is also possible that a state body could choose to offer a statewide inspection checklist based on this Model that includes all the relevant state code requirements in order to save time for municipalities. Alternately, municipalities in a region may pool their resources to add the local code requirements to this Model.

It is important to note that an inspection checklist *is not* a replacement for careful review and understanding of the actual code requirements. A checklist is merely intended to act as an abbreviated tool, which can be used on-site for verification of compliance with code requirements and as a quick reference guide to help inspectors quickly find the correct code sections. Where there is a question about the actual language of the code section or the specificity of the requirement, both inspectors and installers should look up the code sections rather than relying on any inspection checklist.

The Model Inspection Checklist for Rooftop PV Systems was developed after reviewing existing checklists that have been created by leading jurisdictions across the United States. IREC incorporated the best components of each of these checklists and then worked with Don Hughes, Senior Electrical Inspector with Santa Clara County, California, to identify the relevant code requirements and add the citations. We also incorporated suggestions from numerous jurisdictions that have attended workshops on permitting reform hosted by IREC. Finally, this document was peer-reviewed by qualified inspectors and building code officials from across the country, and by UL representatives. The reviewers provided helpful feedback on the code requirements and other considerations regarding how checklists are implemented.

IREC is hopeful that this Model Inspection Checklist will act as a valuable resource for municipalities. IREC welcomes comments and suggestions about the content and implementation of the Model checklist by municipalities and installers.

IREC is grateful to the following individuals for their assistance in providing comments on the development of this Model: John K. Taecker, Gary Goodell, Jeff Fecteau, and Boris Sursky.

For additional IREC resources on Solar PV Inspections, please see:

Field Inspection Guidelines for PV Systems, prepared by Bill Brooks for IREC, June 2010, available at: http://irecusa.org/wp-content/uploads/2010/07/PV-Field-Inspection-Guide-June-2010-F-1.pdf

S*haring Success: Emerging Approaches to Efficient Rooftop Solar Permitting*, May 2012, available at: http://www.irecusa.org/wp-content/uploads/FINAL-Sharing-Success-w-cover-revised-final052012.pdf

Simplifying the Solar Permitting Process: Residential Solar Permitting Best Practices, IREC and the Vote Solar Initiative, September 2013, available at: http://www.irecusa.org/wp-content/uploads/2013/09/expanded-best-practices.pdf

The Interstate Renewable Energy Council, Inc. Model Inspection Checklist for Rooftop Photovoltaic (PV) Systems

All National Electrical Code (NEC) references are to both the 2008 and 2011 versions unless otherwise noted. All International Residential Code (IRC), International Building Code (IBC) and International Fire Code (IFC) references are to the 2012 versions unless otherwise noted.

Section 1: PV Array Configuration

- ☐ Module manufacturer, make, model, and number of modules match the approved plans. (2009 & 2012 IBC 107.4)
- ☐ PV modules are listed to UL 1703. (NEC 110.3, 690.4 & IBC 1509.7.4) NOTE: AC modules need to be listed to UL 1703 and UL 1741.
- ☐ DC modules are properly marked and labeled. (NEC 110.3, 690.4(D) & 690.51)
- ☐ AC modules are properly marked and labeled. (NEC 110.3, 690.4(D) & 690.52)
- ☐ Modules are attached to the mounting structure according to the manufacturer's instructions and the approved plans. (NEC 110.3(B), 2009 & 2012 IBC 107.4)
- ☐ Roof penetrations are flashed and counter-flashed. (2009 & 2012 IBC Chapter 15 & 2012 IRC Chapter 9)
- ☐ PV modules are in good condition (i.e., no broken glass or cells, no discoloration, frames not damaged, etc.). (NEC 110.12(B))
- ☐ Residential one and two family dwelling limited to maximum PV system voltage of 600 volts. (NEC 690.7)
- ☐ Rooftop systems are designed in accordance with the IBC. (2012 IBC 1509.7)
- ☐ Roof access points, paths and clearances need to comply with the IFC. (IFC 605.11.3.1 - 605.11.3.3.3)

Section 2: Grounding

- ☐ A complete grounding electrode system is installed. (NEC 690.47(A) & (B))
- ☐ Modules are grounded in accordance with manufacturer's installation instructions using the supplied hardware or listed equipment specified in the instructions and identified for the environment, and using the grounding point identified on the module and in the manufacturer's instructions. (NEC 690.43 & 110.3(B))
- ☐ Properly sized equipment grounding conductor is routed with the circuit conductors. (NEC 690.45, 250.134(B) & 300.3(B))

- ☐ AC and DC grounding electrode conductors are properly connected. Separate electrodes, if used, are bonded together. (NEC 690.47, 250.50 & 250.58)

- ☐ Bonding fittings are used on concentric/eccentric knockouts with metal conduits for circuits over 250 volts. (NEC 250.97) (*see also* exceptions 1 through 4)

- ☐ Bonding fittings are used for ferrous metal conduits enclosing grounding electrode conductors. (NEC 250.64(E))

Section 3: Wire Management

- ☐ Wires are secured by staples, cable ties, straps, hangers or similar fittings at intervals that do not exceed 4.5 feet. (NEC 334.30 & 338.12(A)(3))

- ☐ Wires are secured within 12 inches of each box, cabinet, conduit body or other termination. (NEC 334.30 & 338.12(A)(3))

- ☐ Cable closely follows the surface of the building finish or of the running boards. (2011 NEC 690.4(F) & IFC 605.11.2) NOTE: see Section 12 below for additional guidance on routing of conductors for fire fighter safety concerns.

- ☐ Exposed single conductors, where subject to physical damage, are protected. (NEC 230.50(B) & 300.5(D))

Section 4: Conductors

- ☐ Exposed single conductor wiring is a 90C, wet rated and sunlight resistant type USE-2 or listed PV wire. (NEC 690.31(B)) If the wiring is in a conduit, it is 90C, wet rated type RHW-2, THWN-2, or XHHW-2. (NEC 310.15)

- ☐ Exposed single conductors used for ungrounded (transformerless) systems are listed and identified as "PV wire." (NEC 690.35(D)(3)) For other conductor requirements for ungrounded systems see NEC 690.35(D).

- ☐ Conductor insulation is rated at 90C to allow for operation at 70C+ near modules. (NEC 310.15)

- ☐ Where conductors or cables are installed in conduits exposed to direct sunlight on or above rooftops, correction factors for ambient temperature adjustments are applied. (2008 NEC 310.15(B)(2)(c) & 2011 NEC 310.15(B)(3)(c))

- ☐ Grounded conductor is identified white or grey. (NEC 200.6)

- ☐ Open conductors are secured and protected. (NEC 338.12(A)(3) & 334.30)

- ☐ Conductors are not in contact with the roof surface. (NEC 334.30)

- ☐ DC conductors inside a building are in a metal raceway or MC metal-clad cable that complies with 250.118(10), or metal enclosures. (NEC 690.31(E))

- ☐ If more than one nominal voltage system conductor is installed in the raceway, permanent identification and labeling is required. (NEC 200.6(D) & 210.5(C))

- ☐ For underground conductor installations, the burial depth is appropriate and warning tape is in place. (NEC 300.5(D)(3) & Table 300.5)

- ☐ Aluminum is not placed in direct contact with concrete. (NEC 250.120(B) & 110.11)

- ☐ DC source circuit conductors are rated at 1.25 x 1.25 = 156% short-circuit (ISC) current from modules. NOTE: The module ISC x number of combined strings, if strings are combined. When DC source circuits (strings) are connected in parallel the short circuit current multiplies and PV output conductors from combined strings need to be sized appropriately. (NEC 690.8(1) & (B)(1))

- ☐ PV circuit and premises wiring is separated. (NEC 690.4(B))

- ☐ PV system conductors shall be grouped and identified. (2011 NEC 690.4(B))

Section 5: Overcurrent Protection

- ☐ Overcurrent devices in the DC circuits are listed for DC operation. (NEC 110.3(A), (B) & 690.9(D))

- ☐ DC source circuit overcurrent protection devices are rated at 1.25 x 1.25 = 156% short-circuit (ISC) current from modules. NOTE: The module ISC x number of combined strings, if strings are combined. When DC source circuits (strings) are connected in parallel the short circuit current multiplies DC over-current protective devices need to be sized appropriately. (NEC 690.8(B)(1))

- ☐ Inverter output circuit overcurrent protection device (point of connection to AC system breaker) is sized based on the maximum inverter output current x 125%. (NEC 690.8(A)(3) & 690.8(B)(1))

- ☐ Overcurrent protection is required for the PV source circuit (modules and parallel connected modules), PV output circuit (conductors between source circuits and inverter), inverter output circuit, battery circuit conductors and equipment. (NEC 690.9(A))

- ☐ Where three or more strings are combined, a listed combiner box (UL1741) is used and fuses are required. When DC source circuits (strings) are connected in parallel, the current through a failed circuit can be the sum of the current connected from the other strings, therefore special consideration must be taken to ensure the sum of the total number of strings minus one does not exceed the module manufacturers series fuse rating, or conductor ampacity. (NEC 110.3(B), 690.9(A)) NOTE: there are a few exceptions where the module has a higher series fuse rating and a low ISC rating.

- ☐ When a back-fed breaker is used as a utility interconnection means, the breaker does not read “line and load.” (2008 NEC 690.64(B)(5) & 2008 & 2011 NEC 110.3(B), 705.12(D)(5))

- ☐ PV interconnect breaker is located at the opposite end of the buss from the feeder connection, unless using 100% rated equipment. (2008 NEC 690.64(B)(7), 705.12(D)(7) & 2011 NEC 705.12(D)(7))

Section 6: Electrical Connections

- ☐ Crimp on terminals are listed and installed using a listed tool specified for use in crimping those specific crimps. (NEC 110.3(B) & 110.14)
- ☐ Pressure terminals are listed for the environment and tightened to manufacturer recommended torque specifications. (NEC 110.11, 110.3(B) & 110.14)
- ☐ Connectors are listed for the voltage of the system and have appropriate temperature and ampere ratings. (NEC 110.3(B) & 110.14)
- ☐ Twist on wire connectors are listed for the environment (i.e. wet, damp, direct burial, etc.) and installed per manufacturer's instructions. (NEC 110.11, 110.3(B), 110.14 & 300.5(B))
- ☐ Power distribution blocks are listed. (NEC 690.4 & 2011 NEC 314.28(E))
- ☐ Terminals containing more than one conductor are listed for multiple conductors. (NEC 110.14(A) & 110.3(B))
- ☐ Connectors and terminals used for fine strand conductors are listed for use with such conductors. (NEC 110.14(A) & 110.3(B))
- ☐ Connectors that are readily accessible and operating at over 30 volts require a tool for opening. (NEC 690.33(C))
- ☐ Module connectors are tight and secure. (NEC 110.3(B) & 110.12)
- ☐ Wiring and connections of inverters, PV source circuits, battery connections, etc., and all interconnections are performed by qualified personnel. (2011 NEC 690.4(E))

Section 7: Charge Controllers

- ☐ Charge controller is listed to UL Standard 1741. (NEC 110.3 & 690.4(D))
- ☐ Exposed energized terminals are not readily accessible. (NEC 110.27)
- ☐ Diversion charge controllers that are used as the sole means of regulating charging of batteries have a second independent means of control to prevent overcharging. (NEC 690.72(B)(1))

Section 8: Disconnects

- ☐ Disconnects used in DC circuits are listed for DC operation. (NEC 110.3)

- ☐ Disconnects are installed for all current carrying conductors of the PV source. (NEC 690.13 - 690.14)

- ☐ Disconnects are installed for the PV equipment. NOTE: For inverters and other equipment that are energized from more than one source, the disconnecting means must be grouped and identified. (NEC 690.15)

- ☐ Disconnects and overcurrent protection are installed for all ungrounded conductors in ungrounded (transformerless) PV power systems. (NEC 240.15 & 690.35)

Section 9: Inverters

- ☐ Inverters are listed to UL 1741. (NEC 690.4(D)) NOTE: grid-tied system inverters need to be identified for use in interactive power systems.

- ☐ Point of connection is at a dedicated breaker or disconnect. (2008 NEC 690.64(B)(1), 705.12(D)(1) & 2011 NEC 705.12(D)(1))

- ☐ Total rating of the overcurrent devices supplying equipment does not exceed 120% of the equipment rating. (2008 NEC 690.64(B)(2), 705.12(D)(2) & 2011 NEC 705.12(D)(2))

- ☐ Listed AC and DC disconnects and overcurrent protection are grouped and identified. (NEC 690.15)

- ☐ No multi-wire branch circuits are installed where single 120-volt inverters are connected to 120/240-volt load centers. (NEC 690.10(C))

- ☐ The plastic barrier is re-installed between the AC, DC wiring and communication wires. (NEC 110.3(B) & 110.27)

Section 10: Batteries

- ☐ Storage batteries for dwellings have the cells connected to operate at less than 50 volts. (NEC 690.71(B)(1))

- ☐ Live parts of battery systems for dwellings are guarded to prevent accidental contact by persons or objects. (NEC 690.71(B)(2))

- ☐ Flexible battery cables are listed RHW or THW, 2/0 minimum for battery cell connections. (NEC 690.74) NOTE: welding cables, marine, locomotive (DLO), and automotive cables do not meet the current Electrical Code requirements. (NEC 110.3(A) & (B))

- ☐ Flexible battery cables do not leave the battery enclosure. (NEC 690.74 & 400.8)

- ☐ Flexible, fine strand cables are only be used with terminals, lugs, devices, and connectors that are listed and marked for such use. (NEC 690.31(F), 690.74, 110.3(B) & 110.14)

- ☐ High interrupt, listed, DC rated fuses or circuit breakers are used in battery circuits. The AIC is at least 20,000 amps. (NEC 690.71(C) & 110.9)

- ☐ Cables to inverters, DC load centers, and/or charge controllers are in a conduit. (NEC 690.31(A) & 690.31(E))

- ☐ Conduits enter the battery enclosure below the tops of the batteries. NOTE: this is to avoid accidental ventilation of gases into electrical equipment where sparks may occur. Follow battery enclosure manufacturer's instructions for venting and conduit locations. (NEC 110.3(B), 480.9(A) & 480.10)

- ☐ A disconnect means is provided for all ungrounded conductors derived from a stationary battery system over 30 volts. (NEC 480.5 & 690.15) NOTE: see NEC 690.71(E) for additional service disconnecting means requirements for series connected battery circuits.

- ☐ Area is well ventilated and the batteries are not installed in living areas. (NEC 408.9(A) & 408.10)

Section 11: Signs and Labels

- ☐ All interior and exterior DC conduit, enclosures, raceways, cable assemblies, junction boxes, combiner boxes, and disconnects are marked. (IFC 605.11.1 & 2011 NEC 690.31(E)(3))

- ☐ The markings on the conduits, raceways and cable assemblies are every 10 feet, within one foot of all turns or bends and within one foot above and below all penetrations of roof/ceiling assemblies, walls and barriers. (IFC 605.11.1.4)

- ☐ Marking is placed adjacent to the main service disconnect in a location clearly visible from where the disconnect is operated. (IFC 605.11.1.3)

- ☐ The markings say “WARNING: PHOTOVOLTAIC POWER SOURCE” and have 3/8 inch (9.5 mm) minimum-sized white letters on a red background. The signs are made of reflective weather resistant material. Self-adhesive signs are available from suppliers. (IFC 605.11.1.1, 605.11.1.2 & 2011 NEC 690.4(E)(3))

- ☐ Where PV circuits are embedded in built-up, laminate, or membrane roofing materials in roof areas not covered by PV modules and associated equipment, the location of circuits shall be clearly marked. (2011 NEC 690.4(F))

- ☐ Labels are phenolic where exposed to sunlight. Labels required on conduit are permanent, weather resistant and suitable for the environment. Labels have a red background with white lettering. The following labels are required as applicable:

Table: Signage Requirements for PV systems

Code Section	Location of Label	Text
NEC 690.5(C)	Utility-interactive inverter & battery enclosure	WARNING: ELECTRIC SHOCK HAZARD IF A GROUND FAULT IS INDICATED, NORMALLY GROUNDED CONDUCTORS MAY BE UNGROUNDED AND ENERGIZED
NEC 690.35(F)	All enclosures with ungrounded circuits or devices which are energized and may be exposed during service	WARNING: ELECTRIC SHOCK HAZARD. THE DC CONDUCTORS OF THIS PHOTOVOLTAIC SYSTEM ARE UNGROUNDED AND MAY BE ENERGIZED.
NEC 690.14(C)(1)	On the main service when DC wiring is run through the building and the DC disconnect is located other than at the main service	DC DISCONNECT IS LOCATED….
NEC 690.14(C)(2)	On the AC and DC disconnects	PHOTOVOLTAIC SYSTEM DISCONNECT
NEC 690.53	On the DC disconnects	OPERATING CURRENT ___ OPERATING VOLTAGE ___ MAXIMUM SYSTEM VOLTAGE ___ SHORT CIRCUIT CURRENT ___
NEC 690.54	At interactive points of interconnection, usually the main service	RATED AC OUTPUT CURRENT ___ AMPS NORMAL OPERATING AC VOLTAGE ___ VOLTS
NEC 690.56(B)/ 690.14(D)(4), 705.10 2011 NEC 690.4(H)	At the electrical service and at the PV inverter if not at the same location	A directory providing the location of the service disconnecting means and the photovoltaic system disconnecting means
NEC 690.17	On the DC disconnect and on any equipment that stays energized in the off position from the PV supply	WARNING! ELECTRIC SHOCK HAZARD. DO NOT TOUCH TERMINALS. TERMINALS ON BOTH THE LINE AND LOAD SIDES MAY BE ENERGIZED IN THE OPEN POSITION.
NEC 690.64(B)(7)	Inverter output OCPD	WARNING: INVERTER OUTPUT CONNECTION DO NOT RELOCATE THIS OVERCURRENT DEVICE.

Code Section	Location of Label	Text
Common Utility Requirement	At the main electrical service when a supply side tap is used	CAUTION! SUPPLY SIDE TAP. OPEN AND LOCK AC PV DISCONNECT BEFORE REMOVING METER.
NEC 690.55	Battery enclosure	MAXIMUM OPERATING VOLTAGE, EQUALIZATION VOLTAGE POLARITY OF GROUNDED CONDUCTORS
When approved by the AHJ through NEC load calculations. NOTE: this is for a reduction of the existing main breaker to facilitate the added PV OCPD. There are no exceptions to 690.64 (B)(2) and 705.12 (D)(2) for the sum of OCPDs exceeding 120% of bus rating, even based on calculations. The main breaker may not be reduced below minimum requirements of NEC 230.79.	Main electric service	MAXIMUM MAIN BREAKER SIZE: XXX AMPS
IFC 605.11.1.4	On conduit, raceways, and enclosures, mark every 10 feet, at turns, above/below penetrations	WARNING: PHOTOVOLTAIC POWER SOURCE

Section 12: Fire Safety

- ☐ Rooftop mounted PV panels and modules have the proper fire classification rating. (IBC 1509.7.2)
- ☐ Rooftop DC Conduits are located as close as possible to the ridge or hip or valley and from the hip or valley as directly as possible to an outside wall to reduce trip hazards and maximize ventilation opportunities. (IFC 605.11.2)
- ☐ Conduit runs between sub arrays and to DC combiner boxes are installed in a manner that minimizes total amount of conduit on the roof by taking the shortest path from the array to the DC combiner box. (IFC 605.11.2)
- ☐ DC Combiner Boxes are located so that conduit runs are minimized in the pathways between arrays. (IFC 605.11.2)
- ☐ DC wiring in enclosed spaces in buildings is installed in metallic conduit or raceways. Conduit runs along the bottom of load bearing members. (IFC 605.11.2 & 2011 NEC 690.4(F))

- ☐ DC wiring methods shall not be installed within 25cm (10”) of the roof decking or sheathing except where directly below the roof surface covered by the PV modules and associated equipment. (2011 NEC 690.31(E)(1))

- ☐ All roofs have an access point that does not place ground ladders over openings such as windows or doors, are located at strong points of building construction, and in locations where the access point does not conflict with overhead obstructions such as tree limbs, wires, or signs. (IFC 605.11.3.1)

- ☐ Roofs with slopes greater than 2:12 have solar panel layouts that meet the following criteria: (some exceptions apply, see diagrams in IFC)

    - Hip Roofs: Panels/modules are located so that there is a 3-foot wide clear access pathway from the eave to the ridge on each roof slope where panels/modules are located. (IFC 605.11.3.2.1)

    - Hips and Valleys: If panels/modules are placed on both sides of a hip or valley they are located no closer than 18 inches to a hip or valley. If the panels are located on only one side of a hip or valley that is of equal length, then the panels can be placed directly adjacent to the hip or valley. (IFC 605.11.3.2.3)

    - Single Ridges: Panels/modules are located so that there are two 3-foot wide access pathways from the eave to the ridge on each roof slope where there are panels/modules installed. (IFC 605.11.3.2.2)

    - Ridges: Panels/modules are located no higher than 3 feet from the top of the ridge in order to allow for fire department smoke ventilation operations. (IFC 605.11.3.2.4)

    - Access pathways are located at a structurally sound location capable of supporting the load of fire fighters accessing the roof. (IFC 605.11.3.2.1)