Inspector Guidelines for PV Systems

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of the
Pace University Law School Energy Project

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Version 2.1
March 2006

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Introduction:

This report provides some background to the Inspector Guidelines that follow. This work is part of the Renewable Energy Technology Analysis Project of the Pace Law School Energy Project, funded by the U.S. Department of Energy. These guidelines provide a framework for the permitting and inspection of PV systems. There are two separate guidelines since jurisdictions normally treat the process in two steps. First is the plan check stage where the information is reviewed for accuracy and completeness. Second is the field inspection stage where the installation is reviewed for compliance with the approved plans.

Why do we need Inspector Guidelines in the first place?

There are some jurisdictions throughout the United States that do not require much in the way of documentation to pull permits, and may not do a careful review of the completed installation. However, there are quite a few jurisdictions that require varying levels of documentation and may have a tendency to impose restrictions that go beyond national codes and standards for PV systems. Both of these situations present a problem to the PV industry at large.

The situation where there is little scrutiny is problematic because installers that cut corners will be allowed to continue to do shoddy work without proper enforcement of the codes. Cutting corners with PV installations can have drastic consequences from both a performance and safety point of view. In either case, the PV industry will ultimately end up with the consequences of systems that do not meet minimum standards. Adverse public relations caused by poorly installed solar thermal systems is a problem the solar industry still struggles with 15-20 years after the systems were installed. A guideline will give local jurisdictions standardized approach to review installations and help them identify poor workmanship.

Excessive controls/regulatory requirements can also be a problem. PV installers are often distressed when exposed to varying requirements with each jurisdiction. These variations are often caused by the lack of understanding or perceived risk on the part of the local jurisdiction. Building Officials who are unfamiliar with PV use their experience to develop requirement they believe are adequate for PV systems. These requirements can vary significantly from one jurisdiction to another. Much of the concern from the installing community is that if every jurisdiction adopts slightly different requirements, meeting varying requirements adds cost to PV systems installations that a standardized approach could avoid. A guideline provides a broadly recognized outline that provides the jurisdiction with clearly defined examples of code compliance. It also saves significant time and effort by not having to research and draft an original set of guidelines. The end result for the installer is a predictable process with uniform enforcement of code requirements.

What are the objectives of the guidelines?

The overarching objective of the guidelines is to facilitate the installation of safe PV systems at a minimum of cost and effort for the inspector and the installer. The guidelines were written from the viewpoint that all PV systems installed for residential or commercial use should fundamentally include proper documentation, proper structural attachments, and proper wiring methods. When installations fail to meet these basic requirements, those systems are detrimental to the long-term health and safety of the PV industry. Setting proper standards also makes it more difficult for “fly-by-night” installers to steal business from legitimate contractors because there is less opportunity to cut corners. The PV industry should take notes from several other industries that have dealt with similar problems and strongly support the development and enforcement of codes and standards.

What is the basic approach used to develop the guidelines?

These guidelines were developed using the practical experience of many quality installers and inspectors throughout California and the rest of the nation. California is used for much of the feedback because there are well over 15,000 PV systems in that state that have been permitted and inspected in the past few years. This represents a significant knowledge base that was previously unavailable. Inspectors in California are now familiar with PV installations because many have been exposed to a dozen or more installations. A few inspectors have reviewed over 100 installations.

This experience base, coupled with the codes and standards that govern these systems, provide the basis for these guidelines. The approach is to establish a set of best practices that will ensure that the public safety is preserved when an installation meets these guidelines. There may be local code variations for issues such as wind loading or seismic concerns, but most of the items are generic to all well-installed systems. The guidelines may be viewed as a minimum standard, but they should be sufficient for the majority of systems.

Who will benefit from these guidelines?

This project focuses specifically on the local jurisdictions that are responsible for the review of PV system installations. Because of the size and cost of systems, and the safety issues involved, many regions of the country will require that a permit be initiated to carry out the installation, and a field inspection be made of the finished installation to ensure the public safety is preserved. An equally import beneficiary of these guidelines are the installers. By understanding the guidelines by which installations will be measured, the installer can more readily prepare to meet those requirements.

What are the next steps needed to propagate these practices?

Guidelines are different from codes in that guidelines normally do not carry the weight of law. It is important that influential building officials and chief electrical inspectors in several regions of the U.S. review these guidelines, understand what is proper for PV installations, provide feedback to the guidelines, and ultimately adopt them for their own jurisdictions. If several prominent building officials adopt these guidelines, others who respect the judgment of those building officials may also adopt them. Most local jurisdictions are committed to the education of their staff to address those issues of particular concern in their region. We hope that the savings in time and effort produced by effective guidelines will result in their widespread adoption, making such practices standard.

Guideline 1:

Permit Guidelines for Small-Scale PV Systems

1) Basic site diagram identifying location of major components—not to scale.

   This is a simple diagram to show where the equipment is located. This can be a zone clearance plot plan with the equipment clearly shown and identified on the plan. If PV array is ground-mounted, clearly show that system will be mounted within allowable zoned setbacks. See example EX-2 in appendix for reference.

2) One-line electric diagram showing all major field-installed electrical components, wire identification and sizing, and grounding.

   This diagram needs to have sufficient detail to call out the electrical components, the wire types and sizes, number of conductors, and conduit type and size where needed. This will typically include detailed module information, series/parallel configuration of modules, details of the Photovoltaic Output Circuit, wire type and size of module wiring, type and size of any junction or combiner boxes, approximate length of conductors in PV array, approximate length of conductors from junction box to the photovoltaic power source disconnecting means. Other important information includes equipment grounding of the PV array and system grounding of the inverter. It will also include specific information on the PV inverter and all associated wire in and out of the inverter. The utility disconnect (if required by the utility) type and location should also be called out on the diagram and the means of connection to the building electrical system. See example EX-1 in appendix for reference.

3) Major component information
   a) Inverter information
      i) Model number and manufacturer's "cut sheets" for the specific model.
      ii) Listing. Is the inverter listed by a Nationally Recognized Testing Laboratory (NRTL) to UL Std.1741 and labeled "Utility-Interactive"? If the utility-interactive labeling is not provided, does the unit comply with the requirements of IEEE Std. 929-2000 as verified the instruction manuals validated by the listing agency. For a current list of compliant inverters, visit the California Energy Commissions website, http://www.consumerenergycenter.org/cgi-bin/eligible_inverters.cgi. Some NRTLs have current listing information online as well.
      iii) Maximum continuous output power at 40°C
      iv) DC input voltage range
      v) AC output voltage range

   b) Module information
      i) Manufacturer's "cut sheets" for the specific model.
      ii) Listing. The module should be listed to UL 1703. For a current list of modules that are listed to UL 1703, visit the California Energy Commission's website, http://www.consumerenergycenter.org/cgi-bin/eligible_pvmodules.cgi.

Explanation: *This module information is particularly important since it is used to calculate several current and voltage parameters required by the National Electrical Code (NEC). Listing information is necessary for NEC testing requirements [90.7, 100,110.3]. (Numbers in brackets refer to sections in the 2002 NEC throughout this document.)*

iii) Open-circuit voltage (Voc)
Explanation: *Voc is needed to calculated maximum system voltage specified in NEC 690.7.*

iv) Maximum permissible system voltage
Explanation: *Maximum permissible system voltage (often 600 Vdc) is needed to show that the NEC 690.7 voltage does not exceed this value.*

v) Short-circuit current (Isc)
Explanation: *Isc is needed to calculate short-circuit current specified in NEC 690.8.*

vi) Maximum series fuse rating
Explanation: *Maximum series fuse rating is needed to ensure that the proper overcurrent protection is provided for the modules and array wiring.*

vii) Maximum power (Pmax) at Standard Test Conditions (STC, 1000W/m^2, 25°C cell temp)
Explanation: *Maximum power at STC specifies the rated power of the PV module under simulated conditions.*

viii) Operating voltage (Vpmax)
Explanation: *Vpmax is needed to calculate system operating voltage. This is the voltage of the module when operating at Pmax and STC.*

ix) Operating current (Ipmax)
Explanation: *Ipmax is needed to calculate system operating current. This is the current of the module when operating at Pmax and STC.*

c) Battery information (if used)

x) Manufacturer's "cut sheets" for the specific model.

xi) Nominal battery voltage for the system (Vbat)
Explanation: *This is 2 Volts per cell for lead-acid batteries. A 24-cell lead-acid battery would have a nominal voltage of 48 volts.*

4) Array information

a) Number of modules in series, number of parallel source circuits, and total number of modules.
Explanation: *Four items related to the PV array must be calculated and posted on a sign at the PV Power Source disconnect. The first item (i) characterizes the array design and provides the information necessary to calculate the four items needed to produce proper array identification for a sign required at the site.*

From Example in Appendix One:

Number of modules in series = 10
Number of parallel source circuits = 2
Total number of modules = 10 x 2 = 20

b) Operating voltage (sum of series modules operating voltage in source circuit)
   Explanation: *Operating voltage is found by multiplying the module voltage at maximum power by the number of modules in a series string.*
   From the example in Appendix One:
   Vpmax = 33 Volts
   Number of modules in series = 10
   33 Volts x 10 = 330 Volts

c) Operating current (sum of parallel source circuit operating currents)
   Explanation: *Operating current is found by multiplying the module current at maximum power for a module series string by the number of source circuits in parallel.*
   From the example in Appendix One:
   Ipmax = 4.25 amps
   Number of source circuits in parallel = 2
   4.25 amps x 2 = 8.5 amps

d) Maximum system voltage [690.7]
   Explanation: *Maximum system voltage is calculated by multiplying the value of Voc on the listing label by the appropriate value on Table 690.7 in the NEC, and then multiplying that value by the number of modules in a series string. The table in the NEC is based on crystalline silicon modules and uses coldest expected temperature at a site to derive the correction factor. Some modules do not have the same temperature characteristics as crystalline silicon so the manufacturer's instructions must be consulted to determine the proper way to correct voltage based on coldest expected temperature. A conservative estimate for coldest expected temperature is the lowest recorded temperature at a location. An engineering evaluation may show that maximum voltage is less than this method suggests. If sufficient substantiation accompanies this evaluation, a lesser value for maximum system voltage should be allowed.*
   From the example in Appendix One:
   Module Voc = 42.8 Volts
   Number of Modules in Series = 10
   Lowest temperature on record = 15°F (coeff. Of 1.13 from 690.7)
   Maximum System Voltage = 42.8 x 10 x 1.13 = 484 Volts < 600Volts

e) Short-circuit current [690.8]
   Explanation: *Short-circuit current is calculated by multiplying the value of Isc on the listing label by the number of source circuits operating in parallel, then multiplying this value by 125% to account for extended periods of sunlight above the tested solar intensity (rated irradiance= 1000 W/m^2; maximum sustained irradiance= 1250 W/m^2).*
   From the example in Appendix One:
   Isc = 4.7 amps
   Number of source circuits in parallel = 2
   4.7 amps x 2 x 1.25 = 11.7 amps

5) Wiring and Overcurrent Protection

a) Wire Type:

PV module interconnections should be 90°C wet-rated conductors. Allowable wire types are as follows:

- USE-2 single conductor cable for exposed applications
- Type TC multiconductor cable for exposed applications with THWN-2 or XHHW-2 or RHW-2 or equivalent 90°C wet-rated conductors in the cable.
- Type THWN-2 or XHHW-2 or RHW-2 or equivalent 90°C wet-rated conductors in high temperature conduit (conduit rated for a minimum of 75°C wet conditions).

  Explanation of need for high temperature wiring:

  Typical temperature for PV modules in full sun at 20°C outdoor temperature is 50°C. This is a 30°C rise above outdoor temperatures. On the hottest day of the year, outdoor temperatures can reach 40-45°C in many locations throughout the United States. This means that the PV module will be operating at 75°C on the hottest day of the year (45°C+30°C =75°C). 75°C wire is insufficient for connection to a hot PV module under this condition and conduit rated for a minimum of 75°C wet conditions is necessary to contain wires that must be in conduit.

  To further support the concern over the high temperature of PV modules, a new fine print note has been added to the 2005 NEC.

  690.31 (A) FPN: Photovoltaic modules operate at elevated temperatures when exposed to high ambient temperatures and to bright sunlight. These temperatures may routinely exceed 70ºC (158ºF) in many locations. Module interconnection conductors are available with insulation rated for wet locations and a temperature rating of 90ºC (194ºF) or greater.

b) Conductor Ampacity:

Correct maximum current and ampacity calculations should be provided for each circuit. (Ampacity of conductors must be sufficient for application)

i) The maximum PV source circuit current is the sum of parallel module rated short circuit currents multiplied by 125 percent [690.8(A)(1)]. Explanation: *The 125 percent increase over the rated short circuit current is to account for sustained periods when the sun's intensity (irradiance) can be 25% greater than the rated irradiance. (rated irradiance= 1000 W/m^2; maximum sustained irradiance= 1250 W/m^2).*

From the example in Appendix One:

Isc = 4.7 amps

4.7 amps x 1.25 = 5.9 amps

ii) The minimum source circuit conductor ampacity is 125 percent of the maximum PV source circuit current [690.8(B)(1)].

Explanation: *The 125 percent increase over the maximum PV Source Circuit current is to account for the standard listing of wire to 80% of maximum circuit current for continuous duty.*

Example from Appendix One:

Minimum ampacity calculation
Isc = 4.7 amps
Maximum PV Source Circuit Current = 4.7 amps x 1.25 = 5.9 amps
Minimum Source Circuit Conductor Ampacity = 5.9 amps x 1.25 = 7.3 amps

iii) Minimum photovoltaic output circuit conductor ampacity is the sum of the maximum current of the parallel source circuits [690.8(B)(1)] times 1.25.

Explanation: *Paralleled currents add together. The 125 percent increase over the PV output circuit current is to account for the standard listing of wire to 80% of maximum circuit current for continuous duty.*

From the example in Appendix One:

Minimum Source Circuit Conductor Ampacity = 7.3 amps
Number of source circuits in parallel = 2
7.3 amps x 2 = 14.6 amps

Calculating ampacity of conductors used for the PV output circuit can be an involved process. If more than three current carrying conductors are installed in the conduit, Table 310.15(B)(2)(a) is used to adjust the conductor ampacity. If more than 10% of the circuit, or 10 feet of the circuit is in conduit in direct sunlight, Article 310.10 has a new fine print note in the 2005 NEC.

310.10 FPN No. 2: Conductors installed in conduit exposed to direct sunlight in close proximity to rooftops have been shown, under certain conditions, to experience a temperature rise of 17ºC (30ºF) above ambient temperature on which the ampacity is based.

This note instructs the installer to increase the apparent ambient temperature correction factor used in Table 310.16. For instance, should the maximum ambient temperature be 45ºC (113ºF), for rooftop sunlit conduit, the new ambient temperature is evaluated at 62ºC (144ºF). This has a dramatic impact on the allowable ampacity of a conductor.

iv) Minimum inverter output circuit conductor ampacity must be equal or greater than the inverter continuous output current rating times 1.25.

Explanation: *The inverter output circuit current is calculated from the maximum continuous power rating at nominal AC voltage. The 125 percent increase over the maximum Inverter Output Circuit current is to*

account for the standard listing of wire to 80% of maximum circuit current for continuous duty.
From the example in Appendix One:
Inverter continuous output rating = 2500 Watts
Minimum inverter voltage = 211 Volts
Maximum operating current = 2500 Watts / 211 Volts = 12 Amps
Min. Inverter Output Circuit ampacity = 12 Amps x 1.25 = 15 Amps

c) Overcurrent protection: Necessary fuses or circuit breakers must be properly sized and specified for each circuit.

i) Source circuit overcurrent protection must be sized so that both the PV module and the conductor from the module to the overcurrent device are properly protected [690.9 (A), 240.20 (A)]. PV modules must be protected so that the maximum series fuse rating, printed on the listing label, is not exceeded. It is important to note that even though the listing label states "fuse" rating, a more accurate term would be the "maximum series overcurrent protection" rating since either a fuse or a circuit breaker may be used to satisfy this listing requirement. The module may be protected either by installing fuses or circuit breakers in a series string of modules or by the design of the PV system.

Inverters listed with a Maximum utility back feed current that is well above 1 amp (typically equal to the maximum allowable output overcurrent protection) must be assumed to provide back feed current to the PV array. Each source circuit must have overcurrent protection that is greater than or equal to the minimum PV Source Circuit current rating and less than or equal to the maximum series fuse rating.
Explanation: *For an array with a minimum source circuit current rating of 7.3 amps and a maximum series fuse rating of 15 amps, The minimum fuse rating would be 8 amps (next larger fuse rating above 7.3 amps) and the maximum would be 15 amps.*

For an inverter listed with a Maximum utility back feed current that is zero, or well under 1 amp (e.g. Fronius IG 5100), two source circuits can be connected to the inverter without requiring overcurrent protection on either circuit.
Explanation: *If an array is connected to a non-back feeding source containing two strings in parallel, the maximum current in a string is equal to the current from the other string in parallel. If the maximum current of each string is 5.9 Amps, then the maximum current at any PV module is 5.9 Amps and the maximum series fuse rating of the module will never be exceeded.*

ii) Battery (if used) overcurrent protection must have a sufficient voltage and ampere-interrupt rating (AIR) to withstand the operating conditions of the battery system. [NEC 690.9 (D)]

   Explanation: *Batteries can produce thousands of amps of current during a short circuit. The overcurrent protection must be able to operate properly at the highest voltage produced by the battery and while exposed to the full the short circuit current supplied by the battery.*

iii) Inverter Output Circuit overcurrent protection should be sized and protected according the manufacturers directions. The circuit and corresponding overcurrent protection should be sized at a 125% of the maximum continuous output of the inverter [NEC 215.3 Overcurrent for Feeder Circuits]. The inverter may also have a maximum allowable overcurrent requirement.

   Explanation: *For instance, the SMA SWR2500U has a maximum continuous output of 12 amps and a maximum allowable overcurrent protection of 15 amps. This means that the minimum allowable overcurrent is 15 amps (12 amps x 1.25 = 15 amps) and a maximum of 15 amps.*

iv) NEC 690.64 (B) covers the requirements for Point of Connection of the PV inverter to the building electrical system. The most common method of connection is through a dedicated circuit breaker to a panel busbar. The allowable size of the supply breaker depends on whether or not the facility is a dwelling. If the building is a dwelling, the sum of the supply breakers feeding the busbar of a panel can be up to 120% of the busbar rating. Non-dwelling facilities do not allow the sum of the supply breakers to exceed the busbar rating.

   Explanation: *A dwelling with a service panel containing a 100-amp busbar and a 100-amp main breaker will allow breakers totaling 120% of the busbar rating (120-amps). Since the main breaker is 100 amps, the PV breaker can be up to 20 amps without exceeding the 120% allowance. For a service panel with a 125-amp busbar and a 100-amp main breaker, this provision will allow up to a 50 amp breaker (125 amps x 1.2 = 150 amps; 150 amps – 100 amp main breaker = 50 amp PV breaker).*

v) A new provision in the 2005 NEC clarifies the fact that dedicated circuit breakers backfed from listed utility-interactive inverters do not need to be individually clamped to the panelboard bus bars. This has always the case, but many inspectors have employed the provisions of NEC 408.36(F) that the breaker be secured in place by additional fastener. Utility-interactive inverters do not require this fastener since they are designed to shut down immediately should the dedicated breaker become disconnected from the bus bar under any condition.

NEC 690.64 (B) covers the requirements for Point of Connection of the PV inverter to the building electrical system. The most common method of connection

6) Provisions for the photovoltaic power source disconnecting means:

The 2005 NEC states in 690.14(C)(1), "Location. The photovoltaic disconnecting means shall be installed at a readily accessible location either outside of a building or structure or inside nearest the point of entrance of the system conductors. The photovoltaic system disconnecting means shall not be installed in bathrooms."

i) Readily accessible—Article 100 states, "*Accessible, Readily (Readily Accessible). Capable of being reached quickly for operation, renewal, or inspections without requiring those to whom ready access is requisite to climb over or remove obstacles or to resort to portable ladders, and so forth.*
ii) Readily accessible provision is primarily for emergency operation. If the disconnect is not mounted in close proximity of the service entrance disconnect (usually within 10 feet of the meter location or service disconnect switch), then a diagram or directory must be provided to clearly identify where the disconnect is located.
iii) A rooftop disconnect on a residential roof will normally not qualify as a readily accessible disconnect.

A new exception to this requirement has been added to provide additional clarification for residential and building integrated PV systems. This exception reads:

"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) states:

"**(E) Direct-Current Photovoltaic Source and Output Circuits Inside a Building**. Where direct current photovoltaic source or output circuits of a utility-interactive inverter from a building-integrated or other photovoltaic system are run inside a building or structure, they shall be contained in metallic raceways or enclosures from the point of penetration of the surface of the building or structure to the first readily accessible disconnecting means. The disconnecting means shall comply with 690.14(A) through 690.14(D)."

Although metal-clad cable is not specifically called out in 690.31(E), many jurisdictions consider installations with metal-clad cable as meeting the intent of this new provision. Note that this new section specifically mentions building-integrated systems. The way the 2002 NEC was written, a roof-integrated PV system cannot reasonably comply the 690.14(C)(1) as written.

Those jurisdictions that remain on the 2002 NEC need to consider two alternative approaches to the provisions of 690.14(C)(1).

Suggested alternative approaches:

(1) Follow the new exception in the 2005 NEC and require that all wiring once within the building be installed in metallic raceways or enclosures, or metal-clad cable from the point of penetration of the building to the first readily accessible disconnecting means.

(2) Consider applying the requirements of NEC 440.14 for Air-Conditioning and Refrigerating Equipment only requires that the disconnect be "readily accessible from the air conditioning or refrigerating equipment." Following this provision would require a clearly marked rooftop disconnect that can be easily operated by emergency personnel on the roof with an appropriate sign at the service entrance providing (1) a warning of voltage, (2) how to shut down system prior to getting on roof, and (3) location of disconnect on the roof.

7) Grounding

The NEC requires [690.41] that all systems operating above 50 volts have one conductor referenced to ground unless the system complies with the requirements of 690.35 for ungrounded PV arrays.

Some inspectors have insisted upon the grounding connection point of the array to be near the array since the fine print note in 690.42 states "FPN: Locating the grounding connection point as close as practicable to the photovoltaic source better protects the system from voltage surges due to lightning." Although this may be an accurate statement, changing the grounding location necessitates that inverter be moved to the grounding location since many inverters require that the array be grounded in the inverter. There are many reasons why moving the inverter away from the service entrance is not good design and these reasons generally outweigh any lightning protection benefits received by grounding the system conductors near the array.

The code also requires that all exposed non-current-carrying metal parts of module frames, equipment, and conductor enclosures be grounded regardless of system voltage [690.43].

a) Equipment grounding conductor sizing [690.45]

The size of the equipment grounding conductor is dependent on whether the system has ground fault protection (GFP) equipment or not. The provisions for GFP equipment are stated in 690.5. Many residential inverters have GFP equipment integral to the inverter and require that the PV array be grounded at the inverter only.

i) Systems without ground fault protection equipment

The NEC requires that equipment grounding conductors for systems without GFP equipment be sized for 125% of circuit short circuit current [690.45] (calculated in 5)b)i) in this guide). The shortcut method of sizing this conductor is simply to size the equipment grounding conductor the same size as the current carrying conductors. Calculating 125% of circuit Isc may produce a conductor size that is one size smaller than the current carrying conductors, but that must be calculated for confirmation.

ii) Systems with ground fault protection equipment
Size equipment grounding conductor according to NEC Table 250.122.

b) System grounding conductor sizing

i) AC System
Size grounding electrode conductor according to NEC Table 250.66

iii) DC System
Size grounding electrode conductor according to NEC 250.166. This results in a minimum size of 8 AWG.

8) Array Mounting information

Provide information on weight of array (pounds per square foot). This includes the weight of the modules and all panelizing hardware (e.g. modules, rails and associated hardware).

a) If array is roof mounted:

Provide information on roof structure(s) construction (truss or rafter size and spacing) and roofing material.

i) Is the weight distribution of the system greater than 5 lbs. per square foot? If yes, engineering calculations may be required.

ii) Is the roof structure more than 30 years old? If yes, specify rafter or truss size and spacing—engineering calculations may be required if non-standard.
Explanation: *Subpoint (i) refers to the broad inspection practice that allows additional layers of comp shingles as long as the weight is limited to no more than an additional 5 lbs/ft^2. This provides a conservative structural weight threshold without the need for a structural engineer to review the roof structure. Subpoint (ii) refers to the fact that the code enforcement of roof structural elements has been much more consistent across the United States in the last 30 years. However, there may be many local jurisdictions who have been carefully reviewing roof structures for a much longer period of time. The local jurisdiction should consider extending this limit based on the period that roofs have been consistently inspected.*

iii) Identify roofing type (e.g. comp shingle, masonry tile, shake, etc…)

iv) Provide engineering details of PV panel mounting attachment to the roof-framing members. Several well-engineered mounting systems are now available for installers to use. These designs often include detailed engineering specifications and details. Installers who use their own designs will need to provide their own details and engineering calculations with their design.

v) Identify method of sealing roof penetrations (e.g. flashing, sealed with urethane caulk, etc…)

b) If array is ground mounted:

i) Show array supports, framing members, and foundation posts and footings.
ii) Provide information on mounting structure(s) construction. If the mounting structure is unfamiliar to the local jurisdiction and is more than six (6) feet above grade, it may require engineering calculations.
iii) Show detail on module attachment method to mounting structure.

9) Costs of Permits

Each jurisdiction may have different internal costs structures and approaches to working with solar PV systems. The following section is provided as a suggestion in developing the cost structure for a local jurisdiction.

Costs for permits are often based on the overall project cost. This works well for many conventional projects because this accurately represents the scale of the project. However, with a PV installation, the equipment costs are much higher than with other projects of similar scope. It is therefore recommended that an alternative permit fee scale be used for PV system installations. The scope of a PV installation is similar to that of installing a retrofitted residential HVAC system. The permitting costs for a PV system should be similar to those for an HVAC system.

Although initial plan review and field inspection costs may be slightly higher for the first few systems, those costs should reduce as the local jurisdiction becomes familiar with the installations. A subdivision of more than 10 units should be considered for an additional fee reduction based on the repetitive nature of the reviews. A suggested fee schedule is as follows:

Small PV system (up to 4 kW): $75 - $200
Large PV system (up to 10 kW): $150 - $400

For systems above 10 kW, consider a permit cost of $15 - $40 per kW.

Worksheet for PV System Plan Check

Supplied Diagrams

__________________ Is a basic site diagram supplied with the permit package?
Location of major equipment identified on plan.

__________________ Is a one-line diagram supplied with the permit package?

- __________________Array configuration shown
- __________________Array wiring identified
- __________________Combiner/junction box identified
- __________________Conduit from Array to PV Power Source Disconnect identified
- __________________Equipment grounding specified
- __________________Disconnect specified
- __________________Conduit from disconnect to inverter identified
- __________________Inverter specified
- __________________Conduit from inverter to disconnect to panel identified
- __________________System grounding specified
- __________________Point of connection attachment method identified

Inverter Information

__________________ Are cut sheets provided for Inverter?

__________________ Inverter model number

__________________ Is inverter listed for utility interactivity (see CEC list of Eligible Inverters)

__________________ Maximum continuous output power at 40ºC

__________________ Input voltage range of inverter

PV Module Information

__________________ Are cut sheets provided for PV modules?

__________________ Are the modules listed? (see CEC list of Eligible PV Modules)

__________________ Open-circuit voltage (Voc) from listing label

__________________ Maximum permissible system voltage from listing label

__________________ Short-circuit current (Isc) from listing label

__________________ Maximum series fuse rating from listing label

__________________ Maximum power at Standard Test Conditions (Pmax on Label)

__________________ Voltage at Pmax from listing label

__________________ Current at Pmax from listing label

Array Information

__________________ Number of modules in series

__________________ Number of parallel source circuits

__________________ Total number of modules

__________________ Operating voltage
(number of modules in series x module voltage at Pmax)

__________________ Operating current
(number of parallel source circuits x module current at Pmax)

__________________ Maximum system voltage (690.7)

__________________ Short-circuit current (690.8)

Wiring and Overcurrent Protection

__________________ Wire type is 90ºC wet rated

__________________ Conductor ampacities are sufficient

- __________________Maximum PV source circuit current
- __________________Minimum PV source circuit conductor ampacity
- __________________Minimum PV output circuit conductor ampacity
- __________________Minimum inverter output circuit conductor ampacity

__________________ Source Circuit overcurrent protection is sufficient

- __________________If inverter is not listed for no backfeed current, does each source circuit have overcurrent protection in compliance with the listed maximum series fuse?
- __________________If inverter is listed for no backfeed current, overcurrent protection is not necessary if only two parallel strings are connected to the inverter.

__________________ Overcurrent protection on Inverter Output Circuit is sufficient

__________________ Point of connection meets provisions of NEC 690.64.

- __________________Point of connection panel busbar rating

Roof Information (for rooftop systems)

__________________ Are the conductors from the PV Array run through the house?
If yes, what method will be used to address the protection issues?

__________________ Weight of array for rooftop systems
(pounds per square foot--include mounting hardware)

__________________ Age of building (roof structure)
(If building is under 30 years old and array weight is less than 5 lb/sq.ft., then engineering calcs unnecessary for roof loading)

__________________ If roof structure is over 30 years old, describe structural elements:
Rafters:
__________________ Size of rafters (e.g. 2"x6")
__________________ Span of rafters (e.g. 14')
__________________ Spacing of rafters (e.g. 24")

__________________ Identify roofing type (e.g. comp shingle, masonry tile, shake, etc…)

__________________ Is the detail of PV panel mounting attachment to the roof-framing members provided?
__________________ Identify method of sealing roof penetrations
(e.g. flashing, sealed with urethane caulk, etc…)

Ground Mounting Structure (for ground-mounted structures)

__________________ Weight of array
(pounds per square foot--include mounting hardware)
__________________ Are the details of the array supports, framing members, and foundation posts and footings provided
__________________ Is the information on mounting structure(s) construction provided?
(If the mounting structure is unfamiliar to the local jurisdiction and is more than six feet above grade, it may require engineering calculations.)
__________________ Is the detail on module attachment method to mounting structure provided?

Guideline 2:

Inspection Guidelines for all PV systems

1) Equipment, conduit, and wiring installed according to approved plans.
   At a minimum, a copy of the one-line diagram and the plot plan should be available at the site for the inspector’s use during field inspection. If any variations exist between the reviewed plans and the site installation, those changes should be noted on those drawings along with any necessary explanation as to why adjustments were made to the plans. If substantial changes are found in the field installation, the as-built changes may need to be referred back to plan review to ensure code compliance.

   Field Inspection Checklist for electrical one-line:

   a) PV module model number matches plans and cut sheets

Figure 1 PV Module Listing Label

Figure 2 Verify Type and Number of Modules

   b) PV modules are properly grounded
      Modules should be grounded with lugs or equipment grounding screws on each module and mounting rails or some equivalent grounding method. Equivalent grounding could be stainless or bi-metallic star washers bonding anodized aluminum module frames to roof-mounted rails and attaching grounding wire to a lug on the rails. Another method is to attach a bonding wire from each module to a lug on the rails with the grounding wire attached to a lug on rails.

Figure 3 (incorrect) Improper lugs and conduit wire used

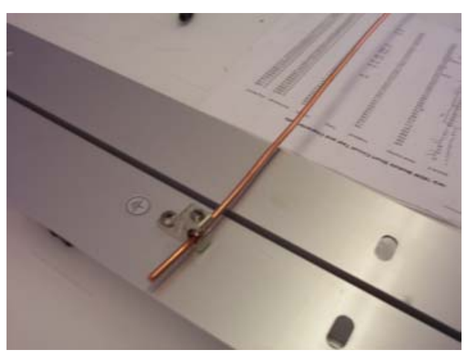


Figure 4 (correct) Shows continuous grounding conductor with stainless ground screw

Figure 5 (incorrect) Flex exposed to physical damage

Figure 6 (incorrect) Flex conduit run without support

c) Check that wiring is consistent with callouts on plans (number of modules)

d) Check that cable and conduit is properly supported

e) Where plug connectors are used for module wiring, inspect a sample of the connections to make sure that connectors are fully engaged

Figure 7 (incorrect) Connector loose and not supported on frame

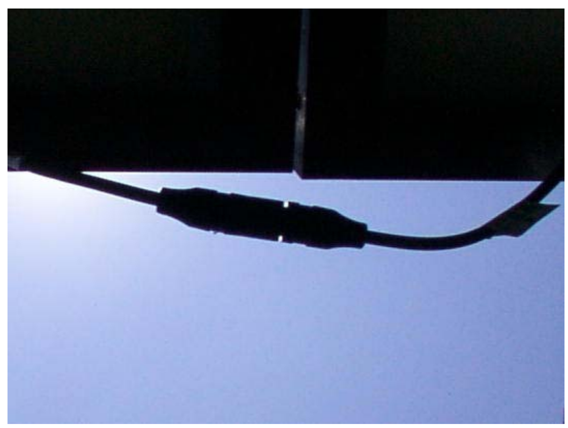


Figure 8 (incorrect) Connector loose

2) Structure attached according to plans and directions.

The plans should have a detail of the structural attachment. The field inspector should review the field structural attachment to confirm that it matches the supplied detail. Inspector should confirm that the modules are firmly attached to the

Figure 9 Flashed Penetration (correct)

structure by firmly pulling up on the modules at several locations (installers can miss structural members with their lag screws).

3) Appropriate signs installed.

a) Sign construction:

The signs should be of sufficient durability to withstand the environment involved. For outdoor signs, the sign should be either metal or plastic with engraved or machine printed letters, or electro-photo plating, in a contrasting color to the sign background. Plexiglas-covered paper or laminated paper directories are also acceptable provided that the signs are sufficiently protected from the environment involved. The signs or directories shall be attached to the electrical equipment or located adjacent to the identified equipment.

b) Provide a sign identifying DC power system attributes at DC disconnect [690.53. Photovoltaic Power Source]. This sign must include:
   i. Operating current (provided in initial plan review--sum of parallel source circuit operating currents)
   ii. Operating voltage (provided in initial plan review--sum of series modules operating voltage in source circuit)
   iii. Maximum system voltage [690.7]
   iv. Short-circuit current [690.8]

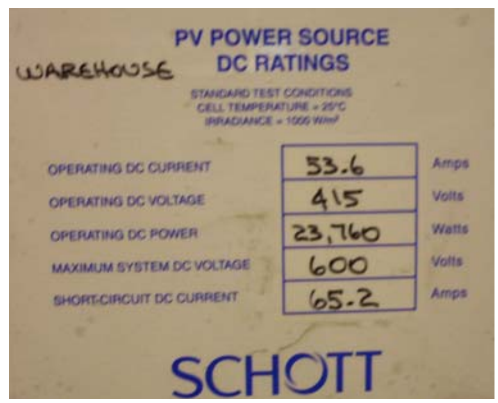


Figure 10 PV Power Source Sign

c) Provide a sign identifying ac point of connection [690.54]. This sign must include:
   i. Maximum ac operating current
   ii. Operating voltage (120, 208, 240, or 480 Volts)

d) Check that inverter matches callouts on one-line diagram.

e) Provide a sign identifying switch for alternative power system.

Figure 11 Inverter Listing Label

A sign should be mounted on or next to the PV system disconnecting means with the words to the effect of “PV System Disconnect” in a minimum of 3/8” high letters. If this disconnect is not located at the service disconnect, follow the requirement in NEC 690.56 (B):

Figure 12 PV System Disconnect Signs

NEC 690.56 (B) <u>Facilities with Utility Services and PV Systems</u>. Buildings or structures with both utility service and a photovoltaic system shall have a permanent plaque or directory providing the location of the service disconnecting means and the photovoltaic system disconnecting means, if not located at the same location.

f) If system includes an Optional Standby System, provide a sign at the main service disconnect [702.8] notifying the type and location of the optional standby system.

   The primary purpose for this sign is to identify location of disconnects for a system supplying power to a building in addition to the utility service.

Figure 13 Sign at service entrance required by 702.8

Figure 14 Close-up of sign for emergency personnel

Worksheet for PV System Field Inspection

One-line diagram comparison

________ Is a one-line diagram available at the site?

  ________ PV module model number matches plans and cut sheets

  ________ PV modules are properly grounded with lugs on each module or equivalent grounding method

  ________ PV array wiring is consistent with plans (# of modules)

  ________ Check that cable and conduit is properly supported

  ________ Where plug connectors are used for module wiring, inspect a sample to make sure that connectors are fully engaged

  ________ Inverter model number matches plans and cut sheets

Structural Attachment of Array

________ Confirm that footings and support structure match the supplied detail.

________ Confirm that module attachment matches the supplied detail.

PV System Signs

________ Do signs have sufficient durability to withstand the environment?

________ Sign Identifying Photovoltaic Power Source (at DC disconnect)

  ________ Operating current (provided in initial plan review)

  ________ Operating voltage (provided in initial plan review)

  ________ Maximum system voltage (690.7)

  ________ Short-circuit current (690.8)

________ Sign identifying AC point of connection (690.54)

  ________ Maximum operating current (provided in initial plan review)

  ________ Operating AC voltage (provided in initial plan review)

________ Sign identifying switch for alternative power system

________ Sign at the main service disconnect (702.8) notifying the type and location of the optional standby system

APPENDIX:

EXAMPLE SUBMITTAL

(cutsheets for products in separate attachments)

Worksheet for PV System Plan Check

Supplied Diagrams

___Yes___ Is a basic site diagram supplied with the permit package?
Location of major equipment identified on plan.

___Yes___ Is a one-line diagram supplied with the permit package?

- ___Y___ Array configuration shown
- ___Y___ Array wiring identified
- ___Y___ Combiner/junction box identified
- ___Y___ Conduit from Array to PV Power Source Disconnect identified
- ___Y___ Equipment grounding specified
- ___Y___ Disconnect specified
- ___Y___ Conduit from disconnect to inverter identified
- ___Y___ Inverter specified
- ___Y___ Conduit from inverter to disconnect to panel identified
- ___Y___ System grounding specified
- ___Y___ Point of connection attachment method identified

Inverter Information

___Yes___ Are cut sheets provided for Inverter?

___SWR2500U___ Inverter model number

___Yes___ Is inverter listed for utility interactivity (see CEC list of Eligible Inverters)

___2500 Watts___ Maximum continuous output power at 40ºC

___250-600 Volts___ Input voltage range of inverter

PV Module Information

___Yes___ Are cut sheets provided for PV modules?

___Yes___ Are the modules listed? (see CEC list of Eligible PV Modules)

___42.8 Volts___ Open-circuit voltage (Voc) from listing label

___600 Volts___ Maximum permissible system voltage from listing label

___4.7 Amps___ Short-circuit current (Isc) from listing label

___15 Amps___ Maximum series fuse rating from listing label

140 Watts	Maximum power at Standard Test Conditions (Pmax on Label)
33 Volts	Voltage at Pmax from listing label
4.25 Amps	Current at Pmax from listing label

Array Information

10	Number of modules in series
2	Number of parallel source circuits
20	Total number of modules
330 Volts	Operating voltage (number of modules in series x module voltage at Pmax)
8.5 Amps	Operating current (number of parallel source circuits x module current at Pmax)
484 Volts*	Maximum system voltage (690.7)

*assuming minimum expected temperature of 15F- 42.8V x 1.13 x 10 = 484 Volts

11.75 Amps*	Short-circuit current (690.8)

*4.7 Amps x 1.25 x 2 = 11.75 Amps

Wiring and Overcurrent Protection

Yes	Wire type is 90ºC wet rated
Yes	Conductor ampacities are sufficient
5.9 Amps	Maximum PV source circuit current
7.3 Amps	Minimum PV source circuit ampacity
14.6 Amps	Minimum PV output circuit ampacity
15.0 Amps	Minimum inverter output circuit ampacity
Yes	Source Circuit overcurrent protection is sufficient
N/A	If inverter is not listed for no backfeed current, does each source circuit have overcurrent protection in compliance with the listed maximum series fuse?
Y	If inverter is listed for no backfeed current, overcurrent protectio is not necessary if only two parallel strings are connected to the inverter.
Yes -15 Amps	Overcurrent protection on Inverter Output Circuit is sufficient
Yes	Point of connection meets provisions of NEC 690.64.
125 Amps	Point of connection panel busbar rating

Roof Information (for rooftop systems)

No ________ Are the conductors from the PV Array run through the house?
If yes, what method will be used to address the protection issues?

3 lbs/sq. ft.* ________ Weight of array for rooftop systems
(pounds per square foot--include mounting hardware)

*module is 2.67 lbs/sq. ft. and hardware is less than 0.3 lbs/sq. ft.

8 years ________ Age of building (roof structure)
(If building is under 30 years old and array weight is less than 6 lb/sq.ft., then engineering calcs unnecessary for roof loading)

N/A ________ If roof structure is over 30 years old, describe structural elements:
Rafters:
________ Size of rafters (e.g. 2"x6")
________ Span of rafters (e.g. 14')
________ Spacing of rafters (e.g. 24")

comp shingle ________ Identify roofing type (e.g. comp shingle, masonry tile, shake, etc…)

Yes ________ Is the detail of PV panel mounting attachment to the roof-framing members provided?

sealed with urethane Identify method of sealing roof penetrations
(e.g. flashing, sealed with urethane caulk, etc…)

Ground Mounting Structure (for ground-mounted structures)

N/A ________ Weight of array
(pounds per square foot--include mounting hardware)

________ Are the details of the array supports, framing members, and foundation posts and footings provided

________ Is the information on mounting structure(s) construction provided?
(If the mounting structure is unfamiliar to the local jurisdiction and is more than six feet above grade, it may require engineering calculations.)

________ Is the detail on module attachment method to mounting structure provided?

Worksheet for PV System Field Inspection

One-line diagram comparison

___Y___ Is a one-line diagram available at the site?

- ___Y___ PV module model number matches plans and cut sheets
- ___Y___ PV modules are properly grounded with lugs on each module or equivalent grounding method
- ___Y___ PV array wiring is consistent with plans (# of modules)
- ___Y*___ Check that cable and conduit is properly supported

  *Contractor fixed three places with insufficient support
- ___Y___ Where plug connectors are used for module wiring, inspect a sample to make sure that connectors are fully engaged
- ___Y___ Inverter model number matches plans and cut sheets

Structural Attachment of Array

___Y___ Confirm that footings and support structure match the supplied detail.

___Y___ Confirm that module attachment matches the supplied detail.

PV System Signs

___Y___ Do signs have sufficient durability to withstand the environment?

___Y___ Sign Identifying Photovoltaic Power Source (at DC disconnect)

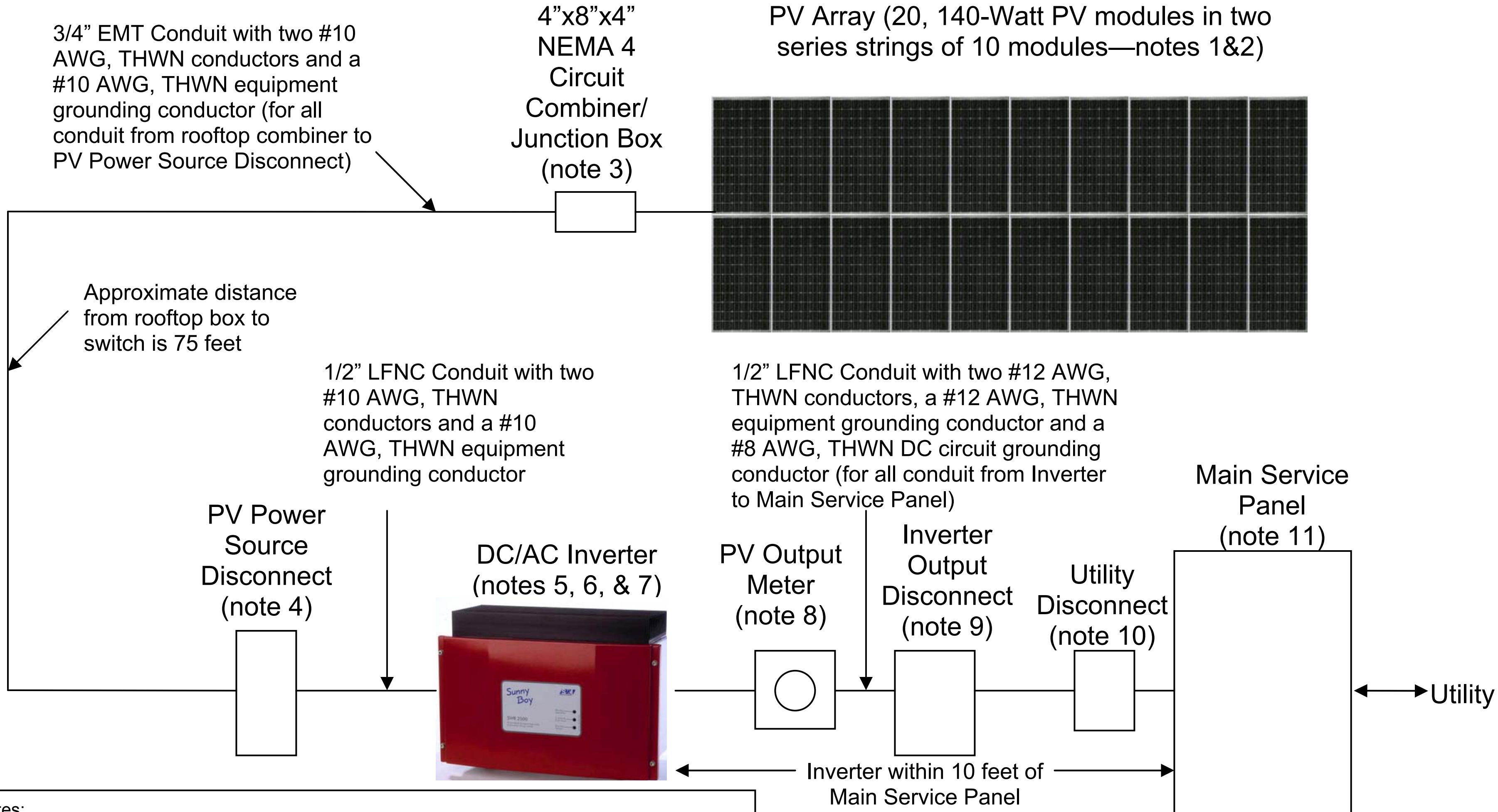
- ___Y___ Operating current (provided in initial plan review)
- ___Y___ Operating voltage (provided in initial plan review)
- ___Y___ Maximum system voltage (690.7)
- ___Y___ Short-circuit current (690.8)

___Y___ Sign identifying AC point of connection (690.54)

- ___Y___ Maximum operating current (provided in initial plan review)
- ___Y___ Operating AC voltage (provided in initial plan review)

___Y___ Sign identifying switch for alternative power system

__N/A__ Sign at the main service disconnect (702.8) notifying the type and location of the optional standby system



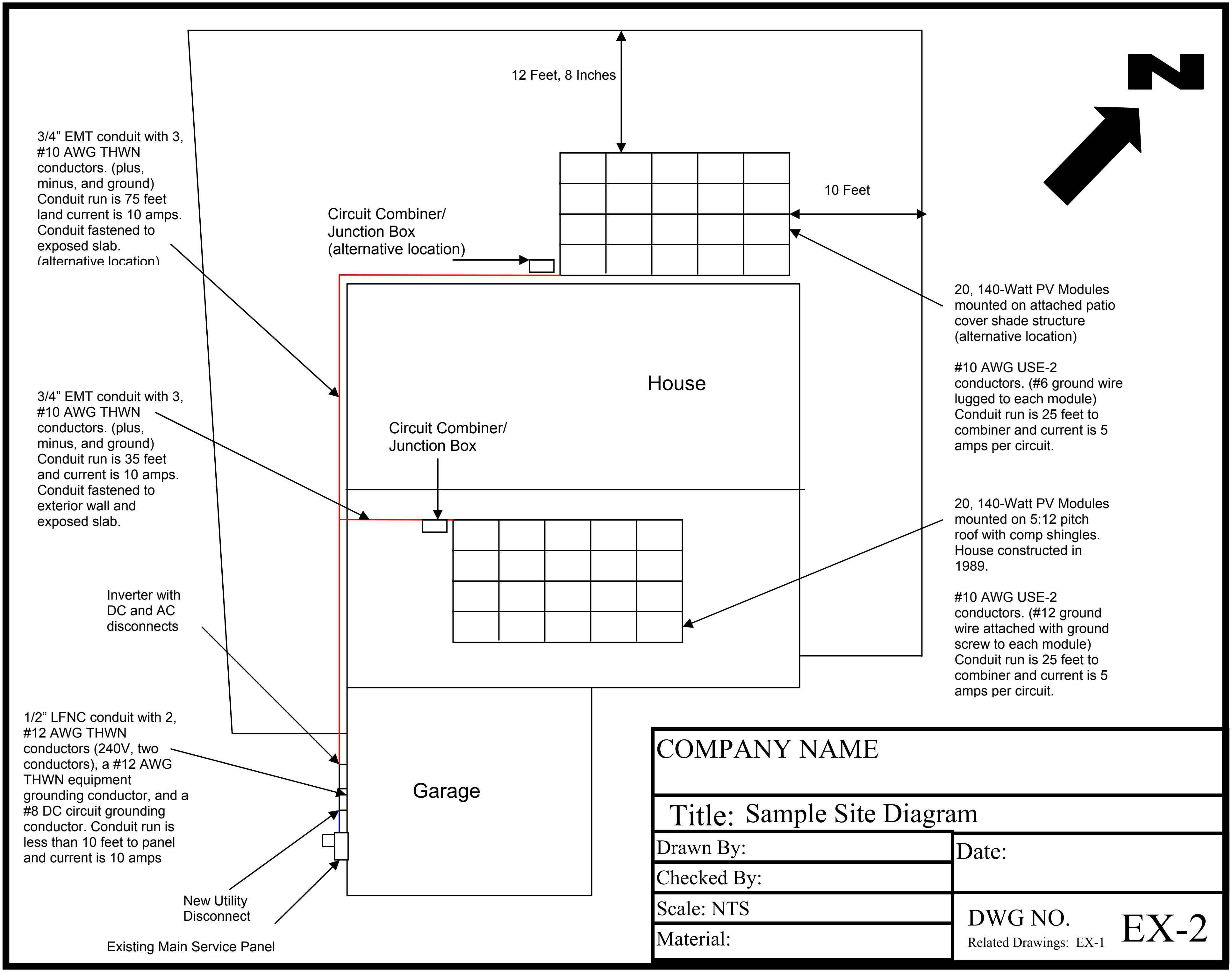
Notes:

1. PV Array contains two parallel strings of 10, 140-Watt Modules in series (20-modules)
2. PV Array wiring to combiner is #10 AWG USE-2 with factory-installed MC connectors to interface with modules.
3. PV Array Combiner/Junction box provides transition from array wiring to conduit wiring.
4. PV Power Source Disconnect (unfused) rated at 30-amps, 600-Vdc, NEMA 3R Rainproof.
5. Ground-Fault Protection provided in DC/AC Inverter.
6. DC/AC Inverter is SB2500UL model rated at 2.5 kW AC output and is rated to provide 10.4 amps at 240-Volts at 40°C.
7. Inverter is Listed to UL-1741 "Utility-Interactive"
8. PV Output Meter is Form 2S kWh meter with cyclometer register (easy-read).
9. Inverter Output Disconnect rated at 30-amps, 240Vac, NEMA 3R. (needed only if Utility Switch not within view of inverter)
10. Utility Switch is visible open, lockable in open position, 240-Vac, 30-amp switch.
11. 100-Amp Main Service Panel with 15-Amp Two-Pole Circuit Breaker for Interactive Point of Connection (up to 20-amp allowed for 100 amp busbar—NEC 690.64(B)(2) exception)
12. Equipment grounding conductors on AC- and DC-side sized according to NEC 250.122.
13. Negative pole of PV array referenced to ground at the Inverter.
14. All grounds connected to main service ground in Main Service Panel.

COMPANY NAME

Title: Sample One-Line Diagram for PV System

Drawn By:	Date:
Checked By:	
Scale: NTS	DWG NO. EX-1 Related Dwgs: EX-2
Material:	


12 Feet, 8 Inches
10 Feet
3/4” EMT conduit with 3, #10 AWG THWN conductors. (plus, minus, and ground) Conduit run is 75 feet land current is 10 amps. Conduit fastened to exposed slab. (alternative location)
Circuit Combiner/ Junction Box (alternative location)
20, 140-Watt PV Modules mounted on attached patio cover shade structure (alternative location)
#10 AWG USE-2 conductors. (#6 ground wire lugged to each module) Conduit run is 25 feet to combiner and current is 5 amps per circuit.
House
3/4” EMT conduit with 3, #10 AWG THWN conductors. (plus, minus, and ground) Conduit run is 35 feet and current is 10 amps. Conduit fastened to exterior wall and exposed slab.
Circuit Combiner/ Junction Box
20, 140-Watt PV Modules mounted on 5:12 pitch roof with comp shingles. House constructed in 1989.
#10 AWG USE-2 conductors. (#12 ground wire attached with ground screw to each module) Conduit run is 25 feet to combiner and current is 5 amps per circuit.
Inverter with DC and AC disconnects
1/2” LFNC conduit with 2, #12 AWG THWN conductors (240V, two conductors), a #12 AWG THWN equipment grounding conductor, and a #8 DC circuit grounding conductor. Conduit run is less than 10 feet to panel and current is 10 amps
Garage
New Utility Disconnect
Existing Main Service Panel
COMPANY NAME
Title: Sample Site Diagram
Drawn By:
Date:
Checked By:
Scale: NTS
Material:
DWG NO.
Related Drawings: EX-1
EX-2