

Inspector Guidelines for PV Systems

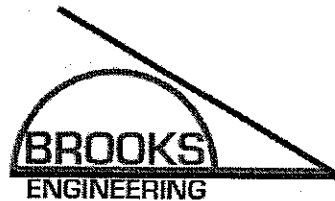
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Permit Guidelines for Small-Scale PV Systems	5
1) Basic site diagram identifying location of major components—not to scale.	5
2) One-line electric diagram showing all major field-installed electrical components, wire identification and sizing, and grounding.....	5
3) Major component information	5
a) Inverter information	5
b) Module information	5
c) Battery information (if used)	6
4) Array information	6
a) Number of modules in series, number of parallel source circuits, and total number of modules.....	6
b) Operating voltage (sum of series modules operating voltage in source circuit).....	7
c) Operating current (sum of parallel source circuit operating currents).....	7
d) Maximum system voltage [690.7]	7
e) Short-circuit current [690.8]	7
5) Wiring and Overcurrent Protection.....	8
a) Wire Type:	8
b) Conductor Ampacity:.....	8
6) Provisions for the photovoltaic power source disconnecting means:	12
7) Grounding	13
a) Equipment grounding conductor sizing [690.45]	13
b) System grounding conductor sizing.....	14
8) Array Mounting information.....	14
a) If array is roof mounted:	14
b) If array is ground mounted:.....	15
9) Costs of Permits	15
Inspection Guidelines for all PV systems	19
1) Equipment, conduit, and wiring installed according to approved plans	19
a) PV module model number matches plans and cut sheets	19
b) PV modules are properly grounded	19
c) Check that wiring is consistent with callouts on plans (number of modules)	20
d) Check that cable and conduit is properly supported	20
e) Where plug connectors are used for module wiring, inspect a sample of the connections to make sure that connectors are fully engaged.....	20
2) Structure attached according to plans and directions.....	20
3) Appropriate signs installed.	21
a) Sign construction:	21
b) Provide a sign identifying DC power system attributes at DC disconnect.....	21
c) Provide a sign identifying AC point of connection [690.54].....	21
d) Check that inverter matches callouts on one-line diagram.	21
e) Provide a sign identifying switch for alternative power system.	21
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.....	22

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 calculate 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/m², 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:

$V_{pmax} = 33 \text{ Volts}$

Number of modules in series = 10

$33 \text{ Volts} \times 10 = 330 \text{ Volts}$

- 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:

$I_{pmax} = 4.25 \text{ amps}$

Number of source circuits in parallel = 2

$4.25 \text{ amps} \times 2 = 8.5 \text{ amps}$

- d) Maximum system voltage [690.7]

Explanation: Maximum system voltage is calculated by multiplying the value of V_{oc} 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 $V_{oc} = 42.8 \text{ Volts}$

Number of Modules in Series = 10

Lowest temperature on record = 15°F (coeff. Of 1.13 from 690.7)

Maximum System Voltage = $42.8 \times 10 \times 1.13 = 484 \text{ Volts} < 600 \text{ Volts}$

- e) Short-circuit current [690.8]

Explanation: Short-circuit current is calculated by multiplying the value of I_{sc} 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:

$I_{sc} = 4.7 \text{ amps}$

Number of source circuits in parallel = 2

$4.7 \text{ amps} \times 2 \times 1.25 = 11.7 \text{ amps}$

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 70°C (158°F) in many locations. Module interconnection conductors are available with insulation rated for wet locations and a temperature rating of 90°C (194°F) 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/m²; maximum sustained irradiance= 1250 W/m²).*

From the example in Appendix One:

I_{sc} = 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

$I_{sc} = 4.7 \text{ amps}$

Maximum PV Source Circuit Current = $4.7 \text{ amps} \times 1.25 = 5.9 \text{ amps}$

Minimum Source Circuit Conductor Ampacity = $5.9 \text{ amps} \times 1.25 = 7.3 \text{ amps}$

- 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

$7.3 \text{ amps} \times 2 = 14.6 \text{ amps}$

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 17°C (30°F) 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 45°C (113°F), for rooftop sunlit conduit, the new ambient temperature is evaluated at 62°C (144°F). 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 ($12 \text{ amps} \times 1.25 = 15 \text{ amps}$) 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 ($125 \text{ amps} \times 1.2 = 150 \text{ amps}$; $150 \text{ amps} - 100 \text{ amp main breaker} = 50 \text{ amp PV breaker}$).

- 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 5b)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/ft². 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 40°C

_____ 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 90°C 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

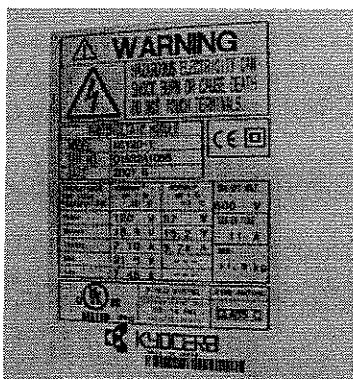


Figure 1 PV Module Listing Label

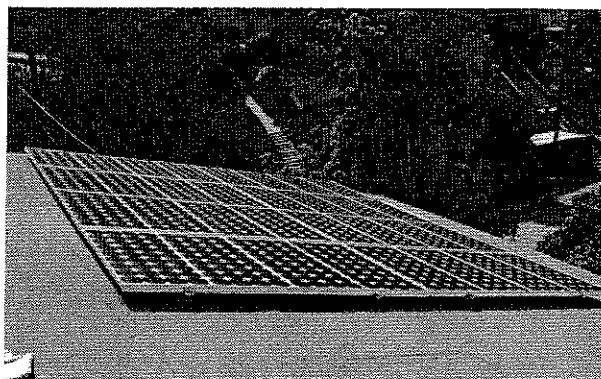


Figure 2 Verify Type and Number of Modules

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.

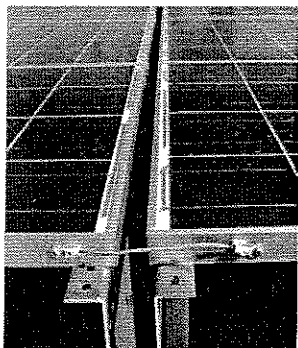


Figure 3 (incorrect) Improper lugs and conduit wire used

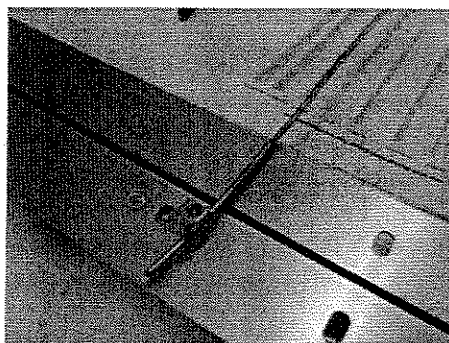


Figure 4 (correct) Shows continuous grounding conductor with stainless ground screw

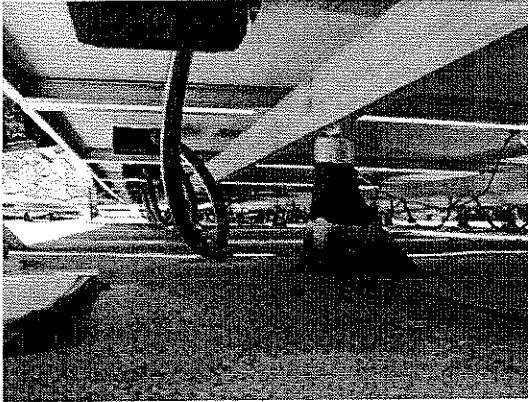


Figure 5 (incorrect) Flex exposed to physical damage

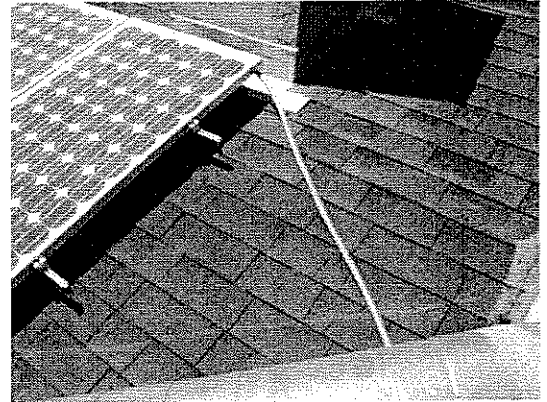


Figure 6 (incorrect) Flex conduit run without support

- 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

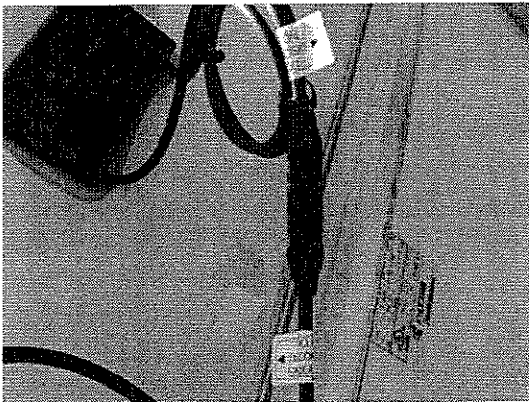


Figure 7 (incorrect) Connector loose and not supported on frame

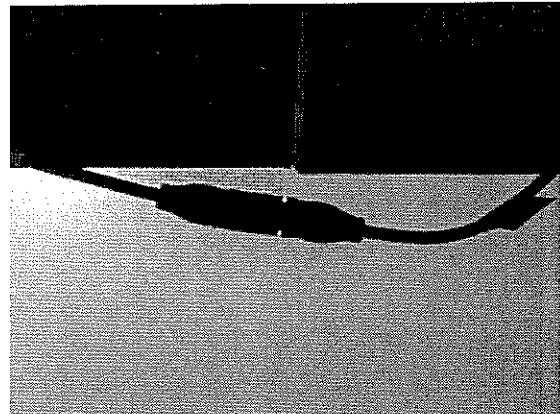


Figure 8 (incorrect) Connector loose

- 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)

21

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) Facilities with Utility Services and PV Systems. 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.

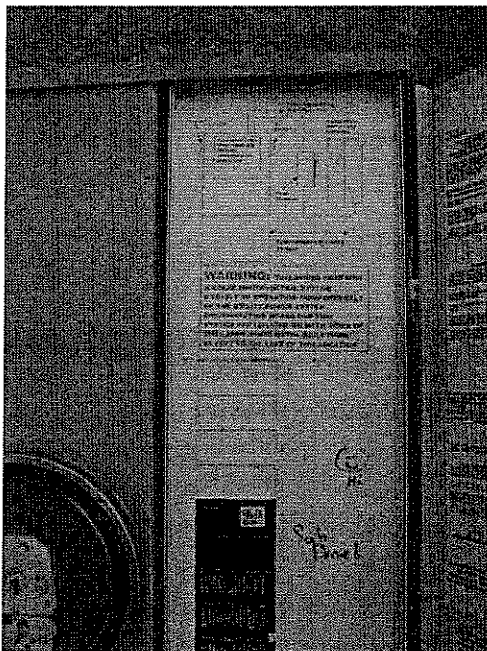


Figure 13 Sign at service entrance required by 702.8

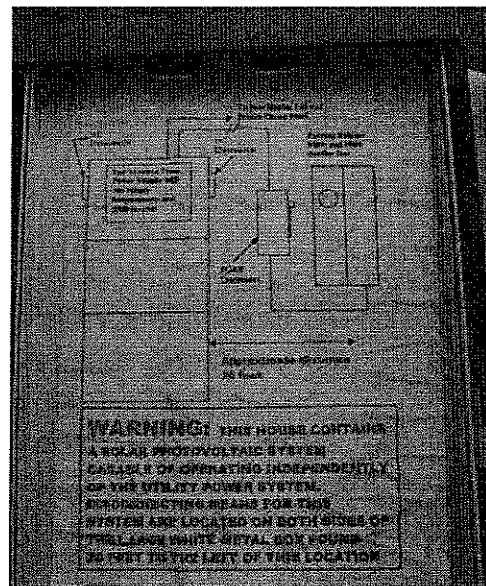


Figure 14 Close-up of sign for emergency personnel

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

<u>Yes</u>	Is a basic site diagram supplied with the permit package? Location of major equipment identified on plan.
<u>Yes</u>	Is a one-line diagram supplied with the permit package?
<u>Y</u>	Array configuration shown
<u>Y</u>	Array wiring identified
<u>Y</u>	Combiner/junction box identified
<u>Y</u>	Conduit from Array to PV Power Source Disconnect identified
<u>Y</u>	Equipment grounding specified
<u>Y</u>	Disconnect specified
<u>Y</u>	Conduit from disconnect to inverter identified
<u>Y</u>	Inverter specified
<u>Y</u>	Conduit from inverter to disconnect to panel identified
<u>Y</u>	System grounding specified
<u>Y</u>	Point of connection attachment method identified

Inverter Information

<u>Yes</u>	Are cut sheets provided for Inverter?
<u>SWR2500U</u>	Inverter model number
<u>Yes</u>	Is inverter listed for utility interactivity (see CEC list of Eligible Inverters)
<u>2500 Watts</u>	Maximum continuous output power at 40°C
<u>250-600 Volts</u>	Input voltage range of inverter

PV Module Information

<u>Yes</u>	Are cut sheets provided for PV modules?
<u>Yes</u>	Are the modules listed? (see CEC list of Eligible PV Modules)
<u>42.8 Volts</u>	Open-circuit voltage (Voc) from listing label
<u>600 Volts</u>	Maximum permissible system voltage from listing label
<u>4.7 Amps</u>	Short-circuit current (Isc) from listing label
<u>15 Amps</u>	Maximum series fuse rating from listing label

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

Array Information

<u>10</u>	Number of modules in series
<u>2</u>	Number of parallel source circuits
<u>20</u>	Total number of modules
<u>330 Volts</u>	Operating voltage (number of modules in series x module voltage at Pmax)
<u>8.5 Amps</u>	Operating current (number of parallel source circuits x module current at Pmax)
<u>484 Volts*</u>	Maximum system voltage (690.7)
<u>11.75 Amps*</u>	Short-circuit current (690.8)

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

*4.7 Amps $\times 1.25 \times 2 = 11.75$ Amps

Wiring and Overcurrent Protection

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

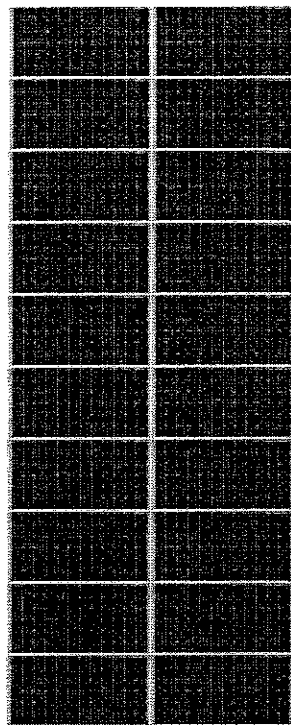
 Are the details of the array supports, framing members,
 and foundation posts and footings provided

 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?

PV Array (20, 140-Watt PV modules in two series strings of 10 modules—notes 1&2)

3/4" EMT Conduit with two #10 AWG, THWN conductors and a #10 AWG, THWN equipment grounding conductor (for all conduit from rooftop combiner to PV Power Source Disconnect)



Approximate distance from rooftop box to switch is 75 feet

4"x8"x4" NEMA 4 Combiner/Junction Box (note 3)

1/2" LFNC Conduit with two #10 AWG, THWN conductors and a #10 AWG, THWN equipment grounding conductor

1/2" LFNC Conduit with two #12 AWG, THWN conductors, a #12 AWG, THWN equipment grounding conductor and a #8 AWG, THWN DC circuit grounding conductor (for all conduit from Inverter to Main Service Panel)

PV Power Source Disconnect (note 4)

DC/AC Inverter (notes 5, 6, & 7)

PV Output Meter (note 8)

Inverter Output Disconnect (note 9)

Utility Disconnect (note 10)

Main Service Panel (note 11)

Utility

- 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

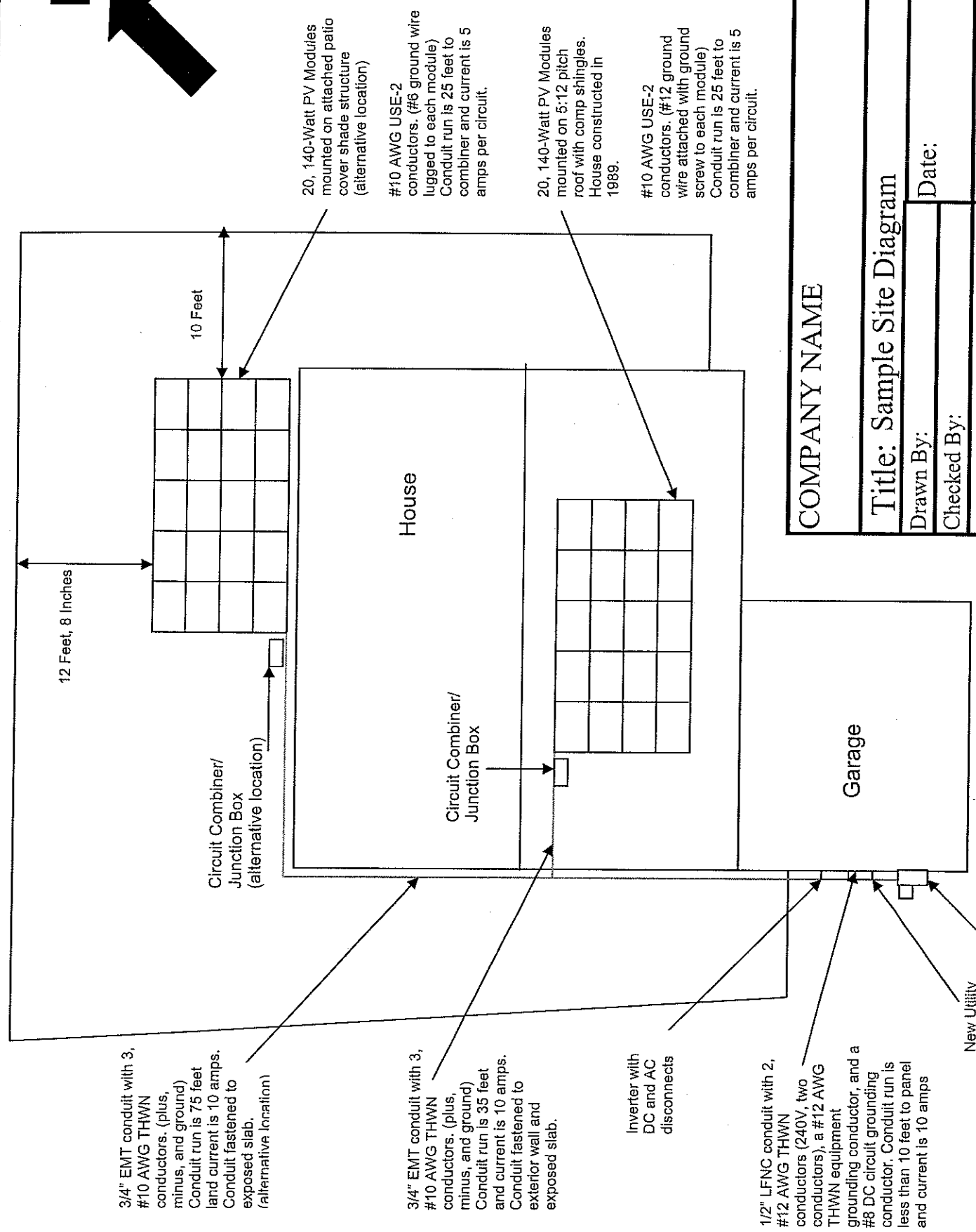
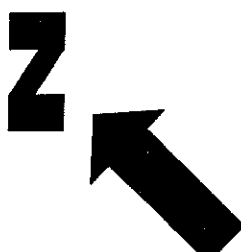
Drawn By: _____ Date: _____

Checked By: _____

Scale: NTS

Material: _____

DWG NO. EX-1
Related Dwg: EX-2



12 Feet, 8 Inches

10 Feet

House

Garage

Circuit Combiner/
Junction Box

Circuit Combiner/
Junction Box
(alternative location)

3/4" EMT conduit with 3,
#10 AWG THWN
conductors. (plus,
minus, and ground)
Conduit run is 75 feet
and current is 10 amps.
Conduit fastened to
exposed slab.
(alternative location)

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.

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

New Utility
Disconnect

Existing Main Service Panel

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.

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.

COMPANY NAME

Title: Sample Site Diagram

Drawn By:

Date:

Checked By:

Scale: NTS

Material:

DWG NO. EX-2
Related Drawings: EX-1