Farmington City

Commercial Solar Photovoltaic (PV) System (600v or less) Plan Review

(Revised 10/1/12)

BUILDING ADDRESS____

SUBDIVISION____LOT___________

OWNER'S NAME____

CONTRACTOR____

This checklist is compiled for plan checking purposes for commercial solar photovoltaic (PV) systems rated 600 volts or less (this includes bipolar arrays where both the positive sub-array and the negative sub-array each produce a maximum of 600volts at the coldest possible outside temperature). The information contained herein is compiled from the *2011 National Electrical Code (NEC), 2009 International Building Code (IBC), 2009 International Fire Code (IFC), 2009 International Mechanical Code (IMC),* manufacture and PV industry standards, and **Farmington City** requirements. This checklist is not intended to indicate any change in any code or ordinance by inference or omission.

Items circled on this checklist shall be corrected on the plans and the requested information shall be provided before a permit shall be issued. This checklist shall be attached to and become a part of the approved plans. Next to the item circled, put the page number of the plans or submitted info where the corrections were made.

Items checked on this checklist shall be corrected during construction and installation.

1. Site plan shall contain the following information:

- **1.1** On the site plan, show the location of the following: the building relative to property lines, all PV modules, inverter(s), PV system disconnects, batteries (if used), and other associated PV equipment on the property.
- **1.2** If modules are going to be mounted on a detached structure, provide the size of the structure and distances to property lines in addition to all PV system components.
- **1.3** Additional comments:_______________________________________

____

____

____

____

2. <u>Module System Mounting</u> shall meet the following requirements:

2.1 If modules are going to be <u>mounted on the roof</u> the following must be provided:

2.1.1 Note the type of roof on the building (flat or pitched), and also note the type of roof covering.

2.1.2 Provide the fire classification of the modules that are to be installed on the roof. The fire classification of the modules must meet the minimum roof assembly classification requirements of section 1505 in the *IBC*. The modules must be tested in accordance with ASTM 108 or UL 790. *IBC* 1505.1

2.1.3 Provide mounting system info that shows the system is listed for the mounting of PV modules on the roof. The mounting system must be compatible with the type of roof covering on the building.

2.1.4 The mounting system manufacture requirements must be submitted and all connections, support sizes, and support spacing noted. Please also note the weight of all supports and modules.

2.1.5 An engineer analysis must be provided to show that the support system (with modules installed) is designed for, and will be able to handle: **3 second wind gusts up to 150 mph in exposure B, snow loads of at least 30 psf, and be designed for seismic design category D**. An engineer analysis of the roof must also be provided to show that the building's existing roof <u>and</u> rafters can safely support all new loads. All applicable code requirements of the *2009 IBC* must be met. Notice: depending on the type of occupancy category (*IBC* 1604.5) of the building or structure, the seismic, wind, and snow loads figured may need to be increased as per chapter 16 (Structural Design) in the 2009 *IBC*.
Note: An engineer analysis, as noted above, *may* not be required if the **Farmington City** Building Official or plans examiner deems the information provided for plan review is adequate in showing that all applicable code requirements will be met.

2.1.6 Provide information on how all roof penetrations (supports, J-boxes, conduit etc…) are going to be properly flashed. Mounting of supports and roof flashings must be compatible with the roof covering.

2.1.7 PV modules cannot be installed over or block any attic vents, plumbing vents, furnace or water heater vents etc. Modules or supports cannot be installed over or block any access doors, removable covers on equipment, or any other piece of equipment or portion of the building that is required to be readily accessible. PV modules also cannot be located in any equipment working spaces.

2.2 If modules are going to be <u>mounted on a detached structure</u> the following must be provided:

2.2.1 A structural plan detailing how the structure is to be built and noting how all associated requirements of the code will be met (for example: square footage, footings, foundation, supports, bracing, connectors, snow loads, wind loads etc..).

2.2.2 If a manufactured structure designed for the mounting of PV modules is going to be used, then a complete set of manufacture instructions must be provided and all requirements followed.

2.2.3 The structure with modules installed must be designed to handle **3 second wind gusts of up to 150 mph in exposure B, snow loads of at least 30 psf, and also be designed per seismic design category D.** All applicable code requirements of the *2009 IBC* must be met.

2.3 Additional comments:____

____
____
____
____
____
____
____
____

3. Electrical System Analysis:

3.1 The Building Official or plans examiner may determine that detailed plans and an electrical analysis of both the building's existing electrical system and also the new photovoltaic electrical system is required in order to determine that the new PV system will be compatible with and not adversely affect or overload the existing electrical system in any way. The electrical analysis and engineering, if required, must be prepared by a qualified licensed electrical engineer.

3.2 The electrical analysis, if required, shall also address available fault current. All new or existing devices and equipment must be rated for the available fault current that they could be subjected to, *NEC* 110.9 and 110.10.

3.3 Additional comments:____

____
____
____
____
____
____

4. Single-Line or Three-Line Diagram

The one-line or three-line diagram must contain the following:

4.1 Indicate the type of system that is being installed: A standard system with modules connected in series having a single inverter, a bipolar system having both a positive sub-array and a negative sub-array connecting to a single inverter, a micro inverter system where each PV module has its own micro inverter, or AC modules (AC modules have a micro inverter installed inside each module at the factory). Also indicate if it's an ungrounded system (if applicable).

4.2 Show the exact number and layout of the modules and how they are connected together (in series or parallel).

4.3 Show all PV system components like: J-boxes, combiner box, inverter, all disconnects, and other equipment like charge controllers and batteries if used. Indicate where all the components will be located in or on the building.

4.4 Indicate the location of and what type of electrical panelboard or switchgear that the PV system will tie into: to a sub-panel or switchgear located remote from the building's electrical service equipment, or to the building's main electrical service panelboard or switchgear. Show the amperage rating of that panel or switchgear, the amperage rating of its busbars, the rating of the main breaker or fuses protecting that panel or switchgear, and which breaker slot on its busbar(s) will the PV tie-in-breaker be located.

Note: The PV tie-in-breaker must be located at a breaker slot at the end of the panelboard or switchgear's busbar(s) opposite from where that panel or switchgear receives it utility source power if the 120% allowance rule of *NEC* 705.12(D)(1) and (D)(7) is going to be utilized. **(see also section 8.10 in this plan check for more details)**

4.5 All PV systems backfeed the building's main electrical service equipment regardless of where on the buildings's electrical system the PV circuits will be connected; because of this please note what type of electrical service equipment it is, the name of the manufacture, model #, and which breaker slot in the service equipment the backfed breaker will be located. Please also provide a picture of the service equipment with the front panel door(s) open, and pictures of interior labels if possible (due to safety concerns removing covers exposing live connections or parts is **NOT** required). Detailed panel manufacture diagrams and info can be submitted in lieu of pictures. Please see section 8.10 in this plan check for more information and requirements.

4.6 Show all wire sizes, types, and if copper or aluminum. Please also include info for the size of existing conductors that feed the electrical panel(s) being tied into or that feed *any* electrical panel that will be backfed by the PV system.

4.7 Show the size of each existing main breaker(s) protecting any panel that will be backfed by the new PV or battery system.

4.8 Indicate on plans where in or on the building each group of circuit conductors will be ran. If circuit conductors at the PV array are exposed outside, wires must be type USE-2 or listed "PV" conductors (*NEC* 690.31 B). Wires installed outside (even if in conduit) must be listed for wet locations (*NEC* 300.9). All wires are strongly recommended to be rated 90°C (for example: USE-2, RHW-2, THWN-2, and XHHW-2) due to deration issues.

4.9 Show conduit types, sizes, how many conductors will be in each conduit, and how high off of the roof surface will conduit be installed.

4.10 Note that any **DC** circuits that penetrate and enter the building will be ran in metal conduit or be MC cable (if protected) until the first readily accessible disconnect is reached. *NEC* 690.31(E)

4.11 Show the ratings of all fuses and breakers.

4.12 Bipolar systems:

4.12.1 Show on plans how and where the conductors of both the positive and negative sub-arrays will each be installed. Also note that that the positive sub-array circuit conductors will be installed in separate conduits and enclosures than the negative sub-array circuit conductors.

4.12.2 Show where the neutral (grounded) conductors are going to be ran to: directly to the bipolar inverter, or to a detached accessory box that is listed and designed for the connection of the neutral (grounded) conductors to a ground reference (either method must be as per the PV inverter manufacture's requirements).

4.13 Additional comments:____

____
____
____
____
____
____
____
____
____
____

5. PV Module Information:

5.1 All photovoltaic (PV) modules, including building-integrated PV (BIPV) modules, must be listed as per UL 1703, and be installed as per manufacture's requirements. *NEC* 690.4 (D)

5.2 Module manufacture spec sheets must be provided giving the rated Watts (Pmp), rated Volts (Vmp), rated Amps (Imp), open circuit voltage (Voc), and short circuit current (Isc) of each module **(Must use STC ratings)**.

5.3 Building-integrated PV (BIPV) modules must be compatible with and have the equivalent strength and durability of that as is required for the type of exterior covering system they are installed with.

5.4 Additional comments:____

____
____
____
____

6. <u>Total System Power:</u> This section applies only to systems where PV modules are **connected in series** with one or more strings of modules connecting to a single inverter (<u>non</u>-micro inverter systems). This section also applies to <u>bipolar PV systems</u>. Note: More than one of these types of systems can be combined together at the output circuits of the inverters if all requirements of the *NEC* are met.

- **6.1** Provide the **total system <u>DC</u>** rated Wattage (Pmpp), rated Voltage (Vmpp), rated Amperage (Impp), max open circuit voltage (Voc) that has also been increased for coldest outside temperature (see *NEC* 690.7), and the max short circuit current (Isc). **<u>Must use STC ratings only</u>**.
- **6.2** The total system open circuit voltage (Voc), figured for the coldest possible outside temperature, cannot exceed the voltage rating of the inverter, wiring, terminations, or any other equipment that is part of the system. *NEC* 690.7
  Note: For bipolar systems, the system voltage is permitted to be the larger of either the positive sub-array voltage or the negative sub-array voltage and it is not required to add both sub-array voltages together to figure the total system voltage <u>as long as all requirements</u> of *NEC* 690.4(G) and 690.7(E) are met.
- **6.3** Additional comments:____

____
____
____
____
____

7. <u>Inverter(s):</u>

- **7.1** If the PV system is going to tie into the building's electrical system, provide manufacture's info showing that the PV inverter(s) is/are the "utility interactive" type having anti-islanding protection, and be listed as meeting **UL 1741** (*NEC* 690.4 (D) and 690.60- 690.61).
- **7.2** All <u>PV</u> inverters must be equipped with a ground fault protection device (GFPD) unless each equipment grounding conductor is sized with an allowable ampacity of at least two times the temperature and conduit fill corrected ampacity of the ungrounded ("hot") conductors that it is ran with. A listed detached GFPD is permitted to be used if one is not provided as part of the inverter and must be installed as per manufacture's instructions. *NEC* 690.5 (see also 11.3.3 in this plan check)
- **7.3** Any PV system with **DC** circuits on or penetrating a building operating at 80 volts or more must be protected by a listed DC arc-fault circuit interrupter (AFCI) that is the "PV" type, or have other components listed to provide equivalent protection, *NEC* 690.11. This device is permitted to be a detached device if not provided as part of the inverter and if installed as per manufacture's requirements. Note: Micro inverter systems available at this time do not meet this criteria and are <u>not</u> required to have AFCI protection.

7.4 Full inverter manufacture installation instructions are required to be submitted for review. In addition to the full installation instructions, the following must also be provided:

7.4.1 If a **series connected PV module system** with one or more strings of modules is going to be installed, the manufacture spec sheets or installation instructions must show the following:

a. The maximum allowable voltage, and wattage (produced by the PV array or batteries) that the inverter can safely handle.

b. The maximum allowable current (amps) from each string (source circuit) or from each PV output circuit connecting to the inverter.
Note: see also 8.1.1 and 8.1.2 for more info on source circuits and PV output circuits.

c. The inverter's maximum continuous **AC** output current (amps), and voltage.

d. How many strings (source circuits) can be combined together inside of the inverter, or for larger systems, how many PV output circuits can be combined together inside of the inverter.

e. If each string (source circuit) or PV output circuit is protected by a fuse internal of the inverter please show the rating of each fuse.

f. Please also provide manufacture's info on whether the inverter allows backfeed or not.

7.4.2 If a **bipolar PV system** (a system with both a positive sub-array and a negative sub-array each connecting separately to a single inverter) is going to be installed, the manufacture spec sheets or installation instructions must show the following:

a. The total allowable wattage combined from both the positive sub-array and negative sub-array that the inverter can safely handle.

b. The total allowable voltage from each separate sub-array (positive sub-array and negative sub-array) that the inverter can safely handle.

c. The total allowable current (amps) from each ungrounded ("hot") conductor of PV output circuits connecting to the inverter.
Note: see also 8.1.2 for more info on PV output circuits.

d. The inverter's maximum continuous **AC** output current (amps), and voltage.

e. How many PV output circuits can be combined together inside of the inverter.

f. If each PV output circuit is protected by a fuse internal of the inverter please show the rating of each fuse.

g. Please also provide manufacture's info on whether the inverter allows backfeed or not.

7.4.3 If a **micro inverter system or an AC module system** is going to be installed, the manufacture spec sheets or installation instructions must show the following:

a. How many micro inverters can be connected together on a single circuit and show the allowable maximum rating of the double- pole or three-pole PV tie-in-breaker that the circuit will connect to.

b. The inverters' rated AC output current (amps), and voltage.

7.5 Additional comments:____

____
____
____
____
____
____

8. <u>Circuit Conductors and Overcurrent Protection</u>: Sections **8.1** and **8.2** apply only to the types of systems noted. Sections **8.3 through 8.12** apply to <u>all</u> types of PV and electrical systems.

8.1 **Series connected PV module systems** (**non**-micro inverter systems). This section also applies to **bipolar PV systems**.

8.1.1 The PV string or "<u>source circuit</u>" conductors' ampacity and breaker or fuse rating must meet *NEC* 690.8 (A)(1), (B)(1) and (B)(2).

Start by taking the modules short circuit current (Isc) using the module manufacture's Standard Testing Conditions (STC) rating and multiply that current (amps) by 1.25, *NEC* 690.8 (A)(1).

Note: For a string of modules connected <u>in series</u>, the short circuit current (Isc) from each module <u>do not</u> add together, but the current (amps) stays the same for the whole source circuit. After the 1.25 has been applied to the initial Isc rating of the modules, <u>multiply again</u> by 1.25 to determine the conductor ampacity (if no ampacity adjustment or correction is needed) and overcurrent protection device (fuse or breaker) rating, *NEC* 690.8 (B)(1) and (B)(2). If the final figured current does not correspond to a standard fuse or breaker size, use the next size up, *NEC* 240.4 (B).

If conductors require ampacity adjustments or correction due to conduit fill, conduit exposed to sunlight on roof, or ambient temp. see section 690.8 (B)(2) in the *NEC* (see also 8.3 in this plan check).

The string circuits (source circuits) may not be required to be protected by a fuse or breaker when only 2 strings (small PV systems) are combined together at an inverter <u>and</u> if the inverter does <u>not</u> allow backfeed from the AC side to flow to the DC side of the inverter. *NEC* 690.9 (A)

Note: the string or "source circuit" is the circuit between the PV modules and a combiner box if a detached combiner box is used, or the circuit between the modules and inverter if a detached combiner box is *not* used.

8.1.2 <u>The PV output circuit</u> (the circuit between a combiner box and the inverter) conductors' ampacity and breaker or fuse rating must meet *NEC* 690.8(A)(2), (B)(1) and (B)(2).

Start by simply adding all the strings (source circuits) short circuit currents (Isc) that will be combined together at a combiner box. Take the total added currents and multiply by 1.25, *NEC* 690.8(A)(2). Now take the current and <u>multiply again</u> by 1.25 to size the PV output conductors and overcurrent protection device (fuse or breaker). If the final figure does not correspond to a standard fuse or breaker size, use the next size up.

See section 690.8(B)(2) in the *NEC* and 8.3 in this plan check if ampacity adjustment or correction of conductors is needed due to conduit fill, conduit exposed to sunlight on roof, or for ambient temp.

If more than one PV output circuit (a large system with multiple combiner boxes) will be ran to the inverter, an overcurrent protection device is required to protect <u>each</u> PV output circuit's ungrounded ("hot") conductor and be located inside of or directly next to the inverter. Overcurrent protection for a PV output circuit may not be needed if the following conditions are met: each string (source circuit) is protected by its own fuse or breaker, there is only one PV output circuit that connects to the inverter, the PV output wires are sized to handle the combined short circuit currents (Isc) from all strings (source circuits), and the inverter does <u>not</u> allow backfeed. *NEC* 690.9(A).

Note: if string conductors (source circuit conductors) tie directly into the inverter and are not combined in a detached combiner box, then the system will <u>not</u> have a PV output circuit.

8.1.3 Breakers or fuses protecting **DC** circuits must be listed for **DC** use and be rated for the maximum cold temperature voltage (Voc) on that circuit. *NEC* 690.9(D) and 690.7

8.1.4 All DC grounded or neutral conductors must be sized same as ungrounded ("hot") conductors as noted in this section.

8.1.5 The inverter's **AC** output circuit (the circuit between the inverter and the tie-in-breaker at the building's electrical panel) conductors' ampacity and breaker or fuse rating must meet *NEC* 690.8(A)(3), (B)(1) and (B)(2).

Simply take the inverter's continuous **AC** output current rating and multiply by 1.25 (only once). If the final figured current does not correspond to a standard fuse or breaker size, use the next size up.

The size of the breaker should also meet the inverter manufacture's requirements. If the conductors must have their ampacity adjusted or corrected due to conduit fill, conduit exposed to sunlight on roof, or ambient temp. see *NEC* 690.8 (B)(2) and 8.3 in this plan check.

8.1.6 When a **bipolar PV system** is going to be installed, all source circuits and PV output circuits for the positive sub-array must be installed in separate raceways and enclosures than source circuits and PV output circuits from the negative sub-array until connecting to the inverter (or connecting to other listed devices specifically designed for the bipolar system and installed as per manufacture's instructions). *NEC* 690.4 (G)

8.2 Micro inverter and AC module systems.

8.2.1 All manufacture instructions must be followed when installing a micro inverter or AC module system.

8.2.2 Provide manufacture specs giving the maximum number of inverters that can be parallel connected together on a single circuit, the recommended AC output conductor size, and the required breaker or fuse rating. The total combined AC output current (amps) from all the connected micro inverters on a single circuit cannot exceed 80% of the rating of the breaker (no more than 12 amps on a 15 amp breaker or 16 amps on a 20 amp breaker). *NEC* 690.8(A)(3), (B)(1) and (B)(2).

8.3 All conductors for **any** electrical system must be installed within their temperature range based on ambient temperature or the conductor's ampacity (as per *NEC* table 310.15(B)(16)) must be corrected and adjusted for the conditions of use. If more than 3 current carrying conductors will be ran in the same conduit, the ampacity of the wires must be adjusted as per *NEC* table 310.15(B)(3)(a). If wires are ran in conduit exposed to sunlight on top of the roof, the wire's ampacity must be adjusted further as per 2011 *NEC* table 310.15(B)(3)(c), and table 310.15(B)(2)(a).

8.4 All PV source circuits, PV output circuits, and inverter AC output circuits must each be identified separately from one another by an approved marking or color coded tape at all points of terminations, connections, and splice points. All conductors from different PV systems entering the same enclosures must be grouped separately. *NEC* 690.4(B)(1-4)

8.5 Any conduits, enclosures, or MC cable that contain **DC** circuits shall be marked with the wording "Photovoltaic Power Source." The markings shall be provided at every enclosure, every 10 feet along the conduit or MC cable, and at each side of where the conduit or cable passes through a wall, floor, or other partitions. The markings shall be permanently affixed and visible after installation. *NEC* 690.31(E)(3-4)

8.6 Any **DC** circuits that are ran in an attic must be installed at least 10 inches or more below the roof deck unless installed directly under the PV modules. *NEC* 690.31(E)(1)

8.7 Any DC circuits installed inside of a building must be routed along structural members such as beams, rafters, trusses, and columns where possible. Where circuits are imbedded in built-up, laminate, or membrane roofing in roof areas not covered by PV modules and associated equipment, the location of the circuits shall be clearly and permanently marked. *NEC* 690.4(F)

8.8 The voltages of any DC circuits that feed DC utilization equipment must meet the requirements of *NEC* 210.6. *NEC* 690.7(B)

8.9 All conductors (both AC and DC circuits) that are readily accessible or subject to damage must be protected (in conduit). *NEC* 690.31(A) and 300.4

8.10 PV point of connection breaker(s). This section also applies to any breakers, conductors, or equipment that are backfed from a PV and/or battery system.

8.10.1 All panel busbars and conductors in the building's electrical system that are backfed by the PV system must comply with a, b, c, and d.

Important: A PV system that is tied into a sub-panel not only effects the panel it is being connected to, but also <u>every</u> additional panel and conductors that are backfed all the way back to the electrical service equipment, and compliance with all of *NEC* 690.64 (2011 *NEC* 705.12(A) & (D)) is required for <u>all</u> panel busbars and conductors being backfed from the PV system (see also 705.12(D)(7) for panels in series).

Notice: For compliance with **b or c**: the building's <u>existing electrical loads</u> calculated per article 220 in the *NEC* cannot exceed the following: the rating of the panel being tied into (*NEC* 408.30), the ampacity of the panel's feeder wires (*NEC* 215.2 A 1), and the rating of the breaker protecting the feeder wires (*NEC* 215.3). A calculated load may be required to show that this is the case.

a. If the PV system is going to backfeed the building's electrical service box **on the supply side** (utility side) of the building's main service breaker(s), then the rating of the PV tie-in-breaker cannot exceed the rating of the service equipment busbars or the ampacity of the utility service conductors. For example: if the service equipment busbars are rated for 400 amps and the utility <u>service</u> conductors are also rated for 400 amps, then up to a 400 amp PV tie-in-breaker could backfeed the service equipment **if** the busbars in the equipment would allow that size of a breaker to be connected to them without violating the listing of the equipment (see service equipment manufacture's limitations) **<u>and</u>** if the busbars are on the **service** side (utility side) of the building's main service breaker(s). *NEC* 690.64, 705.12(A), and 230.82(6)

NOTE: IF THE SERVICE SIDE CONNECTION IS GOING TO BE MADE BY TAPPING THE SERVICE CONDUCTORS, THE POWER COMPANY MUST GIVE FULL PERMISSION BEFORE DOING SO.

b. If the PV tie-in-breaker(s) are going to backfeed any panel **on the load side** (building side) of the building's main service breaker(s) **and** the backfed breaker(s) are located at the end of the panel's busbars, opposite to the main feeder wire connections to that panel, then the sum of the PV tie-in-breaker rating (or the combined rating of multiple PV tie-in-breakers if used) and the panel's main breaker rating cannot exceed **120%** of the rating of the panel being backfed. For example: if a 100 amp rated panel is protected by a 100 amp main breaker, then a 20 amp PV backfed breaker is allowed to backfeed that panel if the backfed breaker is located at the end of the busbars. Or for another example: if a 400 amp rated panel is protected by a 400 amp main breaker, then up to an 80 amp PV backfed breaker is allowed to backfeed that panel if located at the end of the panel's busbars.
NEC 705.12(D)(2) and (D)(7)

c. If the PV tie-in-breaker(s) are going to backfeed any panel **on the load side** of the building's main service breaker and the PV backfed breaker cannot be located at the end of the panel's busbar opposite of the feeder connection to that busbar, then the combined ratings of the PV backfed breaker(s) and the rating of the main breaker protecting that panel cannot exceed **100%** of the rating of that panel. For example: if the panel being tied into is rated for 100 amps and is protected by a 100 amp main breaker, in order for a 30 amp PV tie-in-breaker to backfeed the panel, the main breaker protecting the panel must be reduced down to 70 amps (30+70=100), and assuming that the building's existing electrical loads on that panel (calculated as per *NEC* 220) do not exceed the rating of the new 70 amp main breaker. *NEC* 705.12(D)(7)

d. Conductor protection. The sum of the ratings of all overcurrent protection devices supplying power to any conductor (from multiple power sources) cannot exceed 120% of the rating of the conductor. For example: If we have feeder conductors that are rated at 100 amps and protected from utility fault and overcurrents by using a 100 amp breaker, then that same feeder wire that is going to also be backfed by a PV system can only have a 20 amp PV tie-in-breaker backfeed the wire (the combined ratings of overcurrent devices supplying power to a conductor (wire) cannot exceed 120% of the rating of that conductor). *NEC* 705.12(D)(2) (see also 705.12(D)(7) for panelboards in series).

8.10.2 Feeder taps. If a feeder tap is going to be performed in order to tie the PV system into the building's electrical system, the following must be submitted or noted on the plans and complied with during installation:

a. The PV breaker or fuses must be located **immediately next to** where the PV conductors (the inverter AC output circuit) tap the feeder wires (the feeder tap distance rules of section 240.21(B) in the *NEC* were not designed for PV systems and should not be used).

b. The sum of the ratings of all breakers feeding (from multiple sources of power) the conductors being tapped cannot exceed **120%** of their rating.
Note: the 120% rule can only be utilized if the building's existing electrical loads on the feeder conductors do not exceed the ampacity of the feeder conductors (*NEC* 215.2(A)(1)) or the feeder conductors' breaker or fuse rating. A load calculation (based on article 220 in the *NEC*) may need to be submitted showing that this is the case. *NEC* 705.12(D)(2) and (D)(7)

8.10.3 Ground fault protected main breakers (GFPD) or arc-fault circuit interupter (AFCI) breakers being backfed by a PV system must be listed for backfeeding or the PV and/or battery system must connect to the electrical system ahead (on the line side) of that breaker. *NEC* 705.12 (D)(3)

8.10.4 Any connections in any electrical equipment must not violate the listing of the equipment or any portion thereof, and must be as per manufacture's instructions and requirements.

8.11 Transformers. Unless a transformer is rated for the maximum continuous output current (amps) from the PV and/or battery inverter on the side of the transformer connected towards the output of the inverter, the transformer shall have overcurrent protection on the side of the transformer connected towards the output of the inverter in accordance with 450.3 by considering first one side of the transformer, then the other side of the transformer, as the primary, *NEC* 690.9(B).
Note: If a new transformer is going to be installed somewhere on the AC side of the inverter, it must be installed just like any other transformer in an electrical system and all applicable *NEC* code requirements apply.

8.12 Additional comments:____

____

9. Disconnects

9.1 A main PV system disconnect is required to be able to completely disconnect the PV system from the building's electrical system and must be located at a readily accessible location on the outside of the building or nearest point of entrance of the PV system conductors into the building. If the disconnect is located further inside the building from the nearest point of entrance of any **DC** circuit conductors, then those conductors must be installed in **metal conduit** or be **MC cable** until the first readily accessible disconnect is reached. *NEC* 690.14(C) and 690.31(E)

9.2 Equipment such as inverters, batteries, and charge controllers for batteries all require disconnects to be able to shut off all sources of power to the equipment. For example: an inverter must have a DC disconnect to be able to disconnect the PV power source to the inverter and must also have an AC disconnect to be able to disconnect the utility power source to the inverter. If batteries are installed, the inverter must be able to be disconnected from them as well. **If multiple disconnects for a piece of equipment are required, then they must be grouped together in the same area**. *NEC* 690.15

9.3 Fuses are required to be able to be disconnected from all sources of power provided to them. Note: For larger fuses, this would require disconnects on each side of the fuse, and should be located in close proximity to the fuse (see *NEC* 690.16(B) for exception). For smaller DC fuses, the disconnecting means is permitted to be the fuse holders if the holders are listed and permitted to be used as a disconnect and the fuse holders are the "finger safe" type and do not have any exposed current carrying metal parts when changing the fuses. *NEC* 690.16

9.4 When fuses are to be used for any 240v **AC** circuits, or 3 phase **AC** circuits, provide information showing that the disconnecting means for the fuses protecting the circuit is simultaneous. *NEC* 210.4(B)

9.5 Additional comments:____

____

10. Equipment and Connectors

10.1 Provide manufacture info showing that inverters (UL 1741), PV modules (UL 1703), AC modules (UL 1703 and 1741), combiner boxes (UL 1741), and charge controllers (UL 1741) for batteries used in a PV system are all indentified and listed for the application. *NEC* 690.4(D)

10.2 Provide info showing that all equipment is listed and rated for wet locations and is listed as "rain tight" if installed outdoors. *NEC* table 110.28

10.3 Provide info showing all equipment is listed and rated for the **type** of voltage (AC or DC), the maximum **amount** of voltage (Voc that has been increased for the coldest possible outside temperature), and the maximum amount of short circuit current (Isc) that it could be subjected to. *NEC* 110.3 and 110.4

10.4 If fine stranded conductors are going to be installed only terminals, lugs, devices, and connectors that are listed and marked for such use can be installed. *NEC* 690.31(F) and 110.14
Note: All connectors for fine stranded conductors must also meet UL 486 A&B.

10.5 Equipment or wiring installed in a hazardous (classified) location shall comply with the applicable requirements of sections 500 through 516 in the *NEC*, *NEC* 690.3 (exception).

10.6 Additional comments:____

____

____

____

____

____

11. <u>Grounding</u>

11.1 Equipment bonding:

11.1.1 All metal parts of all modules, module supports, system equipment, and enclosures shall be bonded together and connected to the grounding system. Provide detailed info on the types of connectors and/or devices that will be used for bonding modules, supports, and boxes to the equipment grounding conductor. All devices used for bonding frames of PV modules or other equipment to the grounding system must be listed and identified for the purpose. *NEC* 690.43

11.1.2 Provide info showing that the metallic mounting structures (rails, supports etc.) for the PV modules that are also going to be used for grounding purposes are identified as equipment grounding conductors or shall have identified bonding jumpers connected between each separate metallic section and be bonded to the grounding system. *NEC* 690.43(C)

11.1.3 Lugs for bonding aluminum rails and modules must be listed for outdoor use and also for bonding PV rails and modules. Burndy CL50.1TN lugs, ILSCO GBL4 DBT lugs, and WEEBL 6.7 lug and clip assemblies are all ok for this purpose *if* installed per manufacture requirements. Must provide info on any other types of connectors if used.

11.2 **DC** system grounded conductor:

Note: Either the positive conductor or the negative conductor that is connected to earth by the grounding electrode conductor, is considered as the grounded conductor of a DC system.

11.2.1 All grounded conductors must be isolated from ground except at the point where the conductor is connected to the ground bonding point (which is usually located in the inverter at the GFPD for PV systems), *NEC* 690.42. Note: see also the informational note in section 690.47(C) in the 2011 *NEC* for clarification.

11.2.2 Grounded conductor marking. Grounded conductors of size #4 AWG or larger shall be identified at the time of installation by distinctive white marking at all terminations (this also applies to grounded conductors smaller than #4 AWG if the conductors are USE or "PV type" conductors installed at the PV array). All other grounded conductors than those mentioned must be marked white or grey as per *NEC* 200.6(A). See *NEC* 200.6(A) and (B) for full requirements.

11.3 Equipment grounding conductors: *NEC* 690.43

11.3.1 Equipment grounding conductors shall be ran with the associated circuit conductors when those conductors leave the vicinity of the PV array. *NEC* 690.43(F)

11.3.2 Show the size of all equipment grounding conductors on plans. Equipment grounding conductors shall be sized per *NEC* table 250.122 based on the size of the fuse or breaker protecting the circuit. If there isn't a breaker or fuse used in a circuit, an assumed breaker or fuse rating (sized per *NEC* 690.8(B)) shall be used for sizing the equipment grounding conductors. *NEC* 690.45(A)

11.3.3 If no ground fault protection device (GFPD) for the **DC** system is provided, each equipment grounding conductor must have an ampacity of at least two times the conduit fill and temperature corrected ampacity of the conductors it is associated or installed with. *NEC* 690.45(B)

11.4 Grounding electrode conductors: *NEC* 690.47

11.4.1 Show the grounding electrode conductor on plans. A grounding electrode conductor must originate at the grounding electrode conductor connection point located on or inside of the inverter(s) (for PV systems), and ran to the building's grounding electrode per one of the methods listed in 2011 *NEC* 690.47(C)(1-3). If the building's grounding electrode(s) are not accessible then the grounding electrode conductor can be ran to the building's electrical service equipment to connect to the grounding terminal bar. Note: If it can be verified that the building steel is used as the building's grounding electrode, or if the building steel is connected to another grounding electrode in an approved manner, the **DC** grounding electrode conductor may be permitted to connect to the building steel instead of running it to the service equipment, *NEC* 250.68(C)(2).

11.4.2 Show the size of the PV grounding electrode conductor on plans. The grounding electrode conductor must be sized per *NEC* 250.166 based on the size of the largest **DC** conductor feeding the inverter. However, the grounding electrode conductor does not have to be larger than #6 copper if connecting to a ground rod, or #4 copper if connecting to a Ufer. If the <u>equipment grounding conductor</u> from the inverter(s) to the existing **AC** electrical service equipment is <u>also</u> going to be used for the PV system grounding electrode conductor, then the larger required size of either 250.122 or 250.166 must be used (note: please also read section 11.4.3 regarding equipment grounding conductors also being used as grounding electrode conductors). 2011 *NEC* 690.47(C)(1-3)

11.4.3 The grounding electrode conductor(s) must be installed per *NEC* 250.64(E). **Notice**: Section 250.64(E) makes it very difficult to use **AC** equipment grounding conductors as also the PV system grounding electrode conductor due to the fact that the conductor must be bonded every time the conductor enters, *and bonded again*, when it leaves a ferrous metal (containing iron) conduit or enclosures. The grounding electrode conductor must also remain continuous or be irreversibly spliced.
NEC 690.47(C)(3), 250.64(E), and 250.64(C)(1)

11.5 Ground wire protection. Indicate how the equipment grounding conductors <u>and</u> the grounding electrode conductor will be ran and protected from damage. If grounding conductors are exposed then a minimum of #6 copper conductors must installed. All grounding conductors must be protected from damage or be installed in conduit.
NEC 690.46, 250.120(C), and 250.64(B)

11.6 Grounding electrodes:

11.6.1 Note on plans the type of grounding electrode the PV system's grounding electrode conductor will be connecting to. If no grounding electrodes are accessible, note that the grounding electrode conductor will be ran to the building's electrical service equipment to connect to the AC grounding terminal bar. The grounding electrode conductor may also connect to the building steel if it can be verified that the building steel is used as the building's grounding electrode or if the building steel is connected to another grounding electrode in an approved manner, *NEC* 250.68(C)(2). Grounding electrodes are required to be one of the types given in *NEC* 250.52.

11.6.2 Note on plans if a new grounding electrode is going to be installed for the PV system. Any new grounding electrodes must be bonded to the building's existing grounding electrode(s) to form a grounding electrode system. *NEC* 250.50 and 690.47(C)(1)

11.7 Transformers and other equipment must be installed and grounded as per *NEC* requirements, per the listing of the equipment, and per manufacture's instructions.

11.8 Additional comments:____
____
____
____
____
____
____
____

12. Signage

12.1 Signs at the building's utility electrical service panel:

12.1.1 A sign is required at the service panel stating that the building has a PV system as an additional power source. *NEC* 705.10

12.1.2 A sign is required at the building's service box giving the location of the main PV system disconnect(s), or main disconnect(s) of any other power production system if the disconnect(s) are not located next to the utility service box. *NEC* 690.4(H) and *NEC* 705.10

12.2 Signs at main system disconnect(s):

12.2.1 A sign is required at the main PV system disconnect (and at any other power production main system disconnect) labeling it as such. *NEC* 690.14(C)(2)

12.2.2 If a **series connected module PV system** or a **bipolar PV system** is being installed, a sign is required at the main PV system disconnect (usually at the inverter) giving the total **DC** system **STC** rated max current (Impp), the rated max voltage (Vmpp), the open circuit voltage (Voc) which has been increased for coldest possible outside temperature, short circuit current (Isc), and the rated max output of a battery charge controller (if a charge controller is installed), *NEC* 690.53. See also section 6 in this plan check for more info. Note: this section does not apply to micro-inverter or AC module systems.

12.2.3 Any PV system employing battery storage must also have a sign giving the max operating voltage (including any equalization voltage), and the polarity of the grounded circuit conductor (positive or negative). *NEC* 690.55

12.3 Signs at the interconnection point (tie-in-point) between the PV system and the building's electrical system:

12.3.1 A sign is required at the PV tie-in-breaker location giving the rated **AC** output current (amps) and voltage of the inverter(s). *NEC* 690.54

12.3.2 A sign is required at the PV tie-in-breaker if the breaker is located at the end of the panel, opposite of the panels main feeder wire connections and the 120% rule of *NEC* 705.12(D)(2) and (D)(7) is utilized (previously 690.64(B)(2) and (B)(7) in the 2008 *NEC*).

12.4 Signs at equipment:

12.4.1 Where all terminals of any disconnecting means may be energized in the open position, a warning sign shall be mounted on or adjacent to the disconnecting means and state the following: "WARNING ELECTRIC SHOCK HAZARD. DO NOT TOUCH TERMINALS. TERMINALS ON BOTH THE LINE AND LOAD SIDES MAY BE ENERGIZED IN THE OPEN POSITION." *NEC* 690.17

12.4.2 When a <u>bipolar PV system</u> is to be installed, a sign is required at the inverter and equipment stating: "WARNING BIPOLAR PHOTOVOLTAIC ARRAY. DISCONNECTION OF NEUTRAL OR GROUNDED CONDUCTORS MAY RESULT IN OVERVOLTAGE ON ARRAY OR INVERTER." *NEC* 690.7(E)

12.5 Additional comments:____

____

____

____

____

13. <u>Battery Backup Systems</u> (These requirements, where applicable, shall be in addition to those already covered in this plan review.)

13.1 Inverter:

13.1.1 Detailed manufacture installation instructions and requirements for the inverter or a listed PV center (if used) must be submitted for plan review and all requirements must be followed when installing the system.

13.1.2 Provide manufacture's info that the inverter is specifically designed and listed for its use.

13.1.3 Provide manufacture's info indicating that the battery inverter is listed as being "utility interactive" meeting UL 1741 if grid tied. *NEC* 690.60, 690.61 and 705.40

13.1.4 Show that a ground fault protection device (GFPD) is provided for the DC photovoltaic (PV) system **<u>if</u>** the PV system and the battery system share the same inverter(s), *NEC* 690.5. If <u>no</u> ground fault protection device (GFPD) for the DC portion of the PV system is provided, each equipment grounding conductor must have an ampacity of at least two times the conduit fill and temperature corrected ampacity of the conductors it is associated or installed with, *NEC* 690.45(B) (see also section 11.3.3 in this plan check). Note: Only the DC portion of the <u>PV system</u> requires ground fault protection (GFPD), not battery systems that use separate inverter(s) than the PV system.

13.1.5 Any <u>**PV systems**</u> with **DC** circuits on or penetrating a building operating at 80 volts or more must be protected by a listed DC arc-fault circuit interrupter (AFCI) that is the "PV type" or have other components listed to provide equivalent protection, *NEC* 690.11. Note: Only the DC portion of the <u>PV system</u> requires arc-fault protection (AFCI), not battery systems that use separate inverter(s) than the PV system.

13.1.6 Provide information showing the maximum allowable voltage and amperage from the PV array and/or the batteries that the inverter(s) can safely handle.

13.1.7 The inverter's **AC** output circuit conductors and overcurrent protection device must be sized as per *NEC* 690.8(A)(3), (B)(1), and (B)(2). Note for sizing PV source circuits and PV output circuits see sections 8.1.1 and 8.1.2 in this plan check.

13.1.8 The AC output circuit overcurrent device (as noted in 13.1.7) shall be located at the output of the <u>stand alone or battery backup</u> inverter, *NEC* 690.10(B). If this overcurrent device is a plug-in type breaker, it must be secured in accordance with *NEC* 408.36 (secured in place by an additional fastener that requires other than a pull to release the breaker from the panel busbars), *NEC* 690.10(E).

13.2 Batteries:

13.2.1 Indicate what types of batteries are going to be installed and also note if they are the flooded/vented type or sealed type.

13.2.2 Provide info that the battery type is compatible with the inverter and also that the inverter or charge controller(s) will <u>not</u> "equalize" or overcharge sealed batteries.

13.2.3 Show on plans how many batteries are to be installed, how they are connected (in series or parallel), the voltage of each battery, and the total battery bank voltage.
An example of a 48 volt battery system would be four-12 volt batteries connected in series <u>per string</u> (more than one string can be parallel connected together if the total battery system amp-hours is within the limits of the inverter).

13.2.4 Show the size of conductors (wires) from the batteries to the inverter and also the rating of the overcurrent device protecting those conductors. The size of conductors from the battery bank to the inverter must be as per *NEC* 690.8(A)(4) and (B)(2), and the breaker or fuse rating protecting the conductors as per *NEC* 690.8(A)(4) and (B)(1).
Note: the formula for figuring the max current of 690.8(A)(4) is taking the inverter's rated continuous **AC** <u>output</u> wattage and dividing it by the lowest battery voltage that can sustain that wattage and also by dividing by the inverters AC to DC conversion

efficiency %. For example: 5,000 watts ÷ 44 volts ÷ .85= 133.68 amps. Then the conductors' ampacity and the rating of the fuse or breaker are figured by increasing the 133.68 amps by 125%, which is 167.1 amps. The next size up fuse or breaker would be 175 A. The size of the conductors would be based on 167.1 amps if **no** conductor ampacity correction or adjustment is required (see also 13.2.6 for minimum conductor size).

13.2.5 Provide information to show that the batteries' overcurrent protection device(s) protect all other equipment in the system from any overcurrent from the batteries and also be rated for the available short circuit current that could be produced by the batteries. These breakers or fuses must be located **<u>as close as possible</u>** to the batteries (maximum of 4 or 5 feet is usually required by the manufacture, but closer is better) and cannot be in a different room than the batteries. *NEC* 690.71(C), 240.21(H), and 480.5

13.2.6 If flexible (fine stranded) cables are going to be used to connect the batteries together, then a minimum of 2/0 copper conductors must be used and be listed for "hard-service" and be identified as moisture resistant. The cables can only be installed to interconnect the batteries and ran from the batteries to a nearby junction box where there they must be connected to an approved wiring method. *NEC* 690.74

Important: Flexible, fine-stranded cables must be terminated with terminals, lugs, devices, and connectors that are listed for such and must also meet UL 486 A&B. Consult manufacture of all equipment involved with the fine stranded conductors and provide detailed info on listing and installation requirements of that equipment.

13.2.7 Working space must be provided per *NEC* 110.26 around battery enclosure(s) and all equipment, *NEC* 480.9(C). Batteries cannot be installed in other equipment working areas.

13.2.8 Battery ventilation:

a. Provide information on how the battery enclosure will be ventilated. *NEC* 480.9(A) requires "provisions to be made for sufficient diffusion and ventilation of the gases from the battery to prevent the accumulation of an explosive mixture" (see manufacture's recommendations). Note: The 2011 *NEC*, 2009 *IMC*, or 2009 *IFC* do not specifically require *mechanical* ventilation to be provided for smaller battery systems, but may be required if no other ventilation options exist. The battery manufacture's recommendations should always be followed. See also section 13.2.12 for large battery system requirements.

b. The conduit for the battery conductors must enter the enclosure at a point lower than the tops of the batteries and must be sealed to prevent hydrogen gas from entering the conduit.

13.2.9 If a battery system over 48 volts is going to be installed, and flooded/vented batteries are used, the batteries cannot be installed on or within conductive cases or racks, *NEC* 690.71(D). This requirement does not apply to VRLA or other types of sealed batteries.

13.2.10 If a battery system over 48 volts is going to be installed, all requirements of *NEC* 690.71(E) and (F) (battery disconnect requirements) must be followed.

13.2.11 If an ungrounded battery system <u>over</u> 48 volts is going to be installed, all requirements of 690.71(G) must be followed.

13.2.12 Large Battery Systems.

Large stationary storage battery systems having an electrolyte capacity of more than 50 gallons for flooded lead-acid, nickel cadmium and valve regulated lead-acid (VRLA) batteries, or over 1,000 lbs. for lithium-ion and lithium polymer batteries, used for facility standby power, emergency power, or uninterrupted power supply shall comply with <u>all</u> of section 608 and 907.2.23 in the 2009 *International Fire Code (IFC)*, and sections 502.4 and 502.5 in the 2009 *International Mechanical Code (IMC)*. Note: the same wording of 907.2.23 *IFC* also appears in section 907.2.23 in the 2009 *International Building Code (IBC)*.

13.3 Charge controllers:

13.3.1 Provide manufacture's installation requirements and specifications for the charge controller(s). Charge controllers are required for battery backup systems to regulate the charge of the batteries, *NEC* 690.72(A). Note: charge controller should also be listed to meet UL 1741.

13.3.2 One or more charge controller(s) are required to prevent over charging and excessive discharging of the batteries. There must be a charge controller between the batteries and any source of power (utility, generator, PV, wind turbine etc.) that is directly connected to the batteries in order to control the charge of the batteries (this may sometimes require multiple charge controllers). *NEC* 690.72

13.3.3 When buck/boost charge controllers and other DC to DC power converters that increase or decrease the output current or output voltage with respect to the input current and input voltage are installed, the ampacity of the output conductors shall be based on the maximum rated continuous output current (max output current multiplied by 125%) of the controller or converter, and the output circuit conductors must be rated for the maximum output voltage of the controller or converter. *NEC* 690.72(C)

13.4 Grounding:

13.4.1 Detailed information from the inverter manufacture on the requirements for grounding the battery system must be provided.

Some manufactures require a grounding electrode conductor to be connected to the negative conductor at a single point external of the inverter, and some may require a grounding electrode conductor to connect within the inverter (<u>always</u> follow manufacture's requirements). See also section 11 in this plan check for additional requirements.

13.5 Additional comments:____

____
____
____
____
____
____
____
____
____
____

14. <u>Ungrounded Systems</u> (These requirements, where applicable, shall be in addition to those already covered in this plan review.)

14.1 System equipment:

14.1.1 Provide manufacture's info showing that the inverter(s) and charge controllers (if used) in an ungrounded PV system are listed for the purpose. *NEC* 690.35(G)

14.1.2 If the inverter(s) are going to be grid tied, provide information showing that it/they are listed as "utility interactive" having anti-islanding protection and meet UL 1741. *NEC* 690.61 and 690.62

14.1.3 Provide info showing that the PV inverter(s) have ground fault protection (GFPD) for the DC portion of the PV system, or show that a listed detached GFPD will be provided, *NEC* 690.35(C).

14.1.4 Provide info showing that the DC portion of the PV system will be protected by an arc-fault device (AFCI). *NEC* 690.11

14.2 Batteries:

14.2.1 If an ungrounded battery system is going to be used with a PV system (whether the PV system is grounded or ungrounded), all requirements of *NEC* 690.71(G) must be followed. See also section 13 requirements.

14.3 Conductors and overcurrent protection:

14.3.1 In an ungrounded system all current carrying conductors are considered ungrounded and each conductor is required to be able to be disconnected at all required disconnects (NEC 690.35(A)) and each conductor (both the positive *and* negative) is required to be protected by a breaker or fuse where overcurrent protection is required, *NEC* 690.35(B).

14.3.2 Since there are not any grounded circuit conductors in an ungrounded system, the color white <u>cannot</u> be used to identify any DC circuit conductors. *NEC* 310.12(C)

14.4 Grounding. Equipment grounding conductors must still be required to bond all metal parts and equipment of the PV system and be installed with the circuit conductors they are associated with, even though neither the positive conductor nor the negative conductor is connected to ground (no ground<u>ed</u> **DC** conductor). Also, a grounding electrode conductor <u>may</u> be required by the inverter manufacture and if so must be installed as per manufacture's requirements. The equipment grounding conductors and grounding electrode conductor must be installed as per article 250 in the *NEC* (see also *NEC* 250.169).

14.5 Required signs:

14.5.1 A sign is required at each junction box, combiner box, disconnects, and devices where energized ungrounded conductors may be exposed while being serviced and must state: "WARNING, ELECTRIC SHOCK HAZARD. THE DC CONDUCTORS OF THIS SYSTEM ARE UNGROUNDED AND MAY BE ENERGIZED." *NEC* 690.35(F)

14.6 Additional comments:____

____

15. <u>Any Additional Comments Concerning This Proposed PV System</u>:____________

____

16. <u>Validity of Permit</u>

16.1 The issuance or granting of a permit or approval of plans, specifications, and computations shall not be construed to be a permit for, or an approval of, any violation of any of the provisions of any state adopted code or of any other ordinance of the jurisdiction. Permits presuming to give authority to violate or cancel the provisions of this code, national codes, or other ordinances of the jurisdiction shall not be valid.

16.2 The issuance of a permit based upon plans, specifications and other data shall not prevent the building official from thereafter requiring the correction of errors in said plans, specifications and other data, or from preventing building or installing operations being carried on thereunder when in violation of this code, national codes, or of any other ordinances of this jurisdiction.

____ ____________________

Contractor or Owner Signature Date