Fruit Heights City Residential Solar Photovoltaic (PV) System Plan Review
For systems utilizing a STRING INVERTER with or without battery backup

BUILDING ADDRESS_____
SUBDIVISION_____LOT_____
OWNER'S NAME_____
CONTRACTOR_____

This checklist is compiled for plan checking purposes for residential solar photovoltaic (PV) systems utilizing a **STRING INVERTER** (non-micro inverter systems) with or without battery backup. The information contained herein is compiled from the *2011 National Electrical Code (NEC), 2012 International Residential Code*, manufacture and PV industry standards, and Fruit Heights City requirements. This checklist is not intended to indicate any change of any code or ordinance by inference or omission.

This review is not all inclusive and all system components and equipment must be installed per adopted code, city ordinances, and manufacture requirements regardless of whether or not such items or issues have been addressed using this checklist.

ITEMS REQUIRING CORRECTION (items marked with an X):

General

1. ___ Provide two complete sets of construction drawings, line diagram(s), and site plan.
2. ___ Provide two complete sets of manufacture specs and system component information. Manufacture specifications are required (where applicable per the system design) for the following items: inverter(s), modules (panels), any DC combiner panels, any DC to DC converters/power optimizers, disconnect switches, any new AC panelboards, batteries, charge controllers, and the supporting racking system.

Site Plan

3. ___ Site plan must show the location of the home's service panelboard, any sub-panelboard (that is to be backfed by the solar PV system), location(s) of the inverter(s), locations of any disconnects, and layout of the solar PV modules (panels).
4. ___ Show any detached structure on the property if solar modules (panels) are to be installed thereon and show dimensions from such structure to property lines.

Solar PV Mounting System

5. ___ Specify the type of roof covering and note how many layers of such covering.
6. ___ Indicate what type of rafters the roof is composed of (engineered trusses, dimensional lumber, TJI etc…), and note the size, spans, and spacing of the rafters.
7. ___ Show that the existing roof rafters can safely handle the new loads of the system. Note: Engineering to meet this requirement *may* not be required if the existing rafters are engineered trusses, the roof only has one layer of asphalt shingles, and the total weight of all racking system with PV modules (panels) installed does not exceed 5 lbs per square foot and there is not more than 60 lbs per solar racking support (subject to City approval).
8. ___ Provide manufacture info that shows the mounting system is listed for the mounting of PV modules on the roof (for roof mounted systems).
9. ___ Specify on the plans the spacing of supports per the manufacture specs and show that such system can handle the local wind and snow loads and is designed for such. **Maximum wind load is to be based on 150 mph, ground snow load is to be based on 43 psf, and roof snow load is to be based on 40psf. (this information differs from city to city)**

10. ___ Provide information on how all roof penetrations (supports, J-boxes, conduit etc…) are going to be properly flashed. *IRC* M2302.2.2.
11. ___ Specify on the plans that solar PV modules (panels) cannot be installed over or block any attic vents, plumbing vents, furnace or water heater vents etc.
12. ___ For a ground-mount racking system, please provide complete plans of the structure indicating that all associated requirements of the code are met (setbacks, square footage of the racking footprint, size/spacing of footings, connectors, snow loads, wind loads etc).

Line Diagram

13. ___ Specify exactly how many solar PV modules (panels) per string (DC source circuit) will be installed.
14. ___ Specify how many strings (DC source circuits) are to be installed.
15. ___ Show all PV system components, such as: J-boxes, combiner box (if used), inverter(s), panelboards, disconnects, and other equipment like charge controllers and batteries (if used). Indicate where all the components will be located in or on the home.
16. ___ Indicate the electrical panelboard that the PV system will tie into: A sub-panelboard or to the home's electrical service panelboard.
17. ___ Specify on the diagram the ratings of all breakers or fuses (DC and AC overcurrent protection devices), including existing breakers feeding any panels that are to be backfed by the PV system.
18. ___ Show all wire sizes, and wire types (including any existing feeder wires that are to be backfed by the PV system).
19. ___ If 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: RHW-2, THWN-2, and XHHW-2) due to deration issues.
20. ___ For transformerless inverters, all DC wiring at the array must be the "PV wire" type and be listed as such. Please specify this on the plans.
21. ___ Specify the size and type of all equipment grounding conductors and grounding electrode conductors. (note: transformerless inverters often do not require a grounding electrode conductor, but <u>all</u> types of solar PV systems will require DC and AC equipment grounding conductors). *NEC* 690.43 through 690.47.
22. ___ String (DC source circuit) conductors (wires) must be at least #12 AWG copper (#10 AWG is recommended). Note: wires may need to be increased in sized due to conduit fill or ampacity derations per *NEC* Tables 310.15(B)(3)(a), 310.15(B)(3)(c), and table 310.15(B)(2)(a) where applicable.
23. ___ Show conduit types, sizes, and how many conductors will be in each conduit.
24. ___ Specify locations where conduit and/or cables are to be installed.
25. ___ If more than two strings (DC source circuits) are to be combined together, please specify 15 amp DC fuses for each ungrounded wire (usually the positive DC wires) at the DC combiner (*NEC* 690.9). For transformerless inverters, specify a fuse for <u>both</u> the positive and negative conductors for each string when combining 3 or more strings (*NEC* 690.35(B)).
26. ___ If a detached DC combiner panel is to be installed, please specify the size of wires between the DC combiner and the inverter (this is called the "PV output circuit" per the *NEC*). These wires are sized by multiplying the solar PV module (panel) short circuit current (Isc) rating by 1.56 and then multiplying by the number of DC strings being combined (example: solar module Isc of 9 amps, 9 × 1.56= 14.04 amps, and if there are 3 strings being combined together then the PV output circuit wires must be sized per 42.12 amps). *NEC* 690.8(A)(1&2) and 690.8(B)(2).
27. ___ Note that any DC circuits that penetrate and enter the home will be ran in metal conduit or be MC cable. *NEC* 690.31(E)
28. ___ The wires and breaker for the inverter's AC output circuit must be sized by taking the inverter's AC output current (amps - from inverter spec sheet) and increased by 1.25 (125%).

Example: if inverter AC output amps is 22A, 22 × 1.25= 27.5A. Thus the wires in this example are sized per 27.5A and connect to a 30 amp AC breaker. *NEC* 690.8(A)(3) and 690.8(B)(1&2).

Grounding and Bonding

29. ___ Provide detailed info on the types of connectors and/or devices that will be used for bonding modules, supports, and other metal equipment 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
30. ___ Provide info showing that if the metallic mounting structures (rails, supports etc.) for the PV modules 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).
31. ___ 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.
32. ___ Indicate on the plans how the equipment grounding conductor(s) will be installed 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)
33. ___ Please note on the plans that equipment grounding conductors shall be ran with the associated circuit conductors when those conductors leave the vicinity of the PV array, as required per *NEC* 690.43(F).
34. ___ Please specify on the plans the type of grounding electrode(s) used for grounding the existing electrical service for the home and specify the size of the existing grounding electrode conductor (wire) that connects to it. If the existing grounding electrode system is not adequate, please specify that a new system will be installed and specify the type of electrode to be used (concrete encased, ground rods, metal water pipe and ground rod, etc). See *NEC* 250.50 through 250.66.

PV Modules (Panels)

35. ___ Provide manufacture specifications for the solar PV modules (panels).
36. ___ Manufacture specs must show the PV modules are UL 1703 listed. *NEC* 690.4(D)
37. ___ Solar PV Module spec sheets must show the **STC** rated open circuit voltage (Voc) and short circuit current (Isc) of the modules (panels).
38. ___ The maximum DC voltage (Voc) at the coldest outside temperature cannot exceed 600V DC (for residential). To find the max DC voltage, add the Voc from each module on a single string and increase such voltage by 16% to 20% (depending on the module spec sheets). Note: 20% increase is considered very conservative (for areas where temperature can be as low as -13˚F) but module spec sheets can be used to obtain a more accurate calculation when needed. See *NEC* 690.7.

Inverter(s)

39. ___ Provide manufacture specifications for the inverter(s).
40. ___ Manufacture specs must show that inverter(s) is/are UL 1741 listed. *NEC* 690.4(D)
41. ___ For utility interactive inverters, specs must show that the inverter is listed as such. *NEC* 690.4(D) and 690.60- 690.61
42. ___ Specs must show that the inverter has DC ground fault protection. *NEC* 690.5
43. ___ Systems operating at over 80 volts DC require DC arc-fault protection (this is <u>not</u> required for micro inverter systems currently on the market). *NEC* 690.11
44. ___ Specs must show whether the inverter has a transformer or is transformerless.
45. ___ Specs must show the maximum continuous AC output current (amps) and the rated output AC voltage of the inverter(s).
46. ___ Specs must note how many strings can be connected to the inverter, and note the ratings of any DC fuses (if applicable).

Point of Interconnection Requirements (rules for backfed panelboards)

47. ___ Provide photos of the service panelboard and any backfed sub-panelboards, and provide photos of all panelboard's interior labels. Photos must be with the panelboard's front covers open and show the ratings of all breakers therein. The photos of labels must also clearly show the rating of the panelboard. These photos are essential to determining if the requirements of *NEC* 705.12(A) or 705.12(D) are going to be met.
48. ___ If a service panelboard upgrade is to be performed, please specify the rating, manufacture, and model number of the panelboard. Please also provide manufacture spec sheets on such panel.
49. ___ If the solar PV system is to backfeed an AC breaker on the supply side (service side) of the home's main service breaker(s), then the rating of the backfed AC breaker cannot exceed what is allowed to be plugged into the breaker slot (noted on the panelboard label), and also cannot exceed the rating of the service conductors (wires) for the home. *NEC* 705.12(A).
50. ___ If the solar PV system is to backfeed an AC breaker on the load side (the home's side of the main service breaker(s)), then the sum of the ratings of the main breaker protecting the panelboard and the rating of the solar PV breaker cannot exceed 120% of the rating of the panelboard. To meet this requirement, the PV breaker must also be located at the very end of the panelboard's busbars (opposite of where the panelboard is fed from the utility source of power). This must be specified on the plans. *NEC* 705.12(D)(2) and (D)(7). Note: This calculation applies to every panelboard that is to be backfed by the PV system.
51. ___ If feeder taps are to be performed in order to connect the PV system to the electrical system of the home, then the tap rules of *NEC* 240.21(B) must be followed. In addition, the sum of the rating of the main breaker (protecting the existing feeder conductors) and the rating of the PV breaker (or fuses) cannot exceed 120% of the ampacity rating of the feeder conductors being tapped, *NEC* 705.12(D)(2).
52. ___ Factory installed conductors (wires) within a service panelboard cannot be tapped unless such taps are to be field evaluated and approved by a listed testing agency (such as UL, Intertek, etc…). This is in accordance with the listing of the panelboard. *NEC* 110.3(B)

General Equipment Requirements

53. ___ Show that the inverter(s) have both a DC disconnect and an AC disconnect. If a DC or AC disconnect is not provided as part of the inverter, please specify one is to be installed adjacent to the inverter. See *NEC* 690.15. Note: Most string inverters contain at least a DC disconnect. Also, if the inverter is installed next to the AC breaker it is to backfeed, then the AC breaker can count as the AC disconnect for the inverter.
54. ___ Provide a note on the plans stating that all wiring must be properly supported by devices or mechanical means designed and listed for such use, and for roof-mounted systems, wiring must be permanently and completely held off of the roof surface. See *NEC* 110.2, 110.3(A), 110.3(B), and 300.4.
55. ___ For a ground-mount system, please specify on the plans exactly how the wiring at the array is going to be protected so the wiring is not readily accessible. Typically, this is accomplished by providing a lockable fence immediately around the array, or to enclose the back sides of the solar modules (panels) so there is not any readily accessible wiring. See *NEC* 690.31(A) (see also the same section in the 2014 *NEC* for additional information).
56. ___ Provide info showing that all equipment is listed and rated for wet locations and is listed as "rain tight" if installed outdoors. See *NEC* table 110.28.
57. ___ Breakers or fuses used for protecting DC circuits must be designed for the maximum DC voltage (see item #38). See *NEC* 690.9(D).

Signage (specify the following signage requirements on the plans)

58. ___ A sign is required at the service panel stating that the home has a solar PV system as an additional power source. *NEC* 705.10.

59. ___ A sign is required at the home's service box giving the location of the main PV system disconnect (this is typically the inverter's DC disconnect) if the disconnect is not located next to the utility service panel. *NEC* 690.4(H) and *NEC* 705.10.
60. ___ A sign is required at the main PV system disconnect labeling it as such. *NEC* 690.14(C)(2).
61. ___ 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 battery charge controller is installed). *NEC* 690.53.
62. ___ A sign is required at any breaker or AC panelboard which is backfed by the PV system. Such sign must note the rated AC output current (amps) and AC voltage of the inverter(s). *NEC* 690.54.
63. ___ If the 120% rules of *NEC* 705.12 (D)(2) and (D)(7) are utilized, then please specify that a sign is required at the PV backfed breaker location noting the following: "Warning, Inverter Output Connection, Do Not Relocate This Overcurrent Device." Note: See also item #50 in this review for more info.
64. ___ Specify that any conduits, enclosures, or MC cable that contain <u>DC</u> circuits shall be marked on their exterior with the wording "Photovoltaic Power Source." The markings shall be provided at every enclosure, every 10' along conduit or MC cable, and at each side of where the conduit or cable passes through a wall, floor, or any other partition. The markings shall be permanently affixed and visible after installation. *NEC* 690.31(E)(3-4).

<u>Battery Backup Systems (these requirements are in addition to those already mentioned in this review – if applicable)</u>

65. ___ Detailed manufacture's 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.
66. ___ Provide manufacture's info indicating that the battery inverter is listed as being utility interactive meeting UL 1741 if grid-tied. *NEC* 690.4(D), 690.60, 690.61 and 705.40.
67. ___ If the same inverter is to be used for the solar PV system <u>and</u> the battery system, please show that the inverter contains DC ground fault protection, as required per *NEC* 690.5.
68. ___ If the same inverter is to be used for the solar PV system <u>and</u> the battery system and there are DC voltages over 80 volts for the solar PV portion of the system, please show that the inverter contains DC arc-fault protection, as required per *NEC* 690.11.
69. ___ Inverter manufacture spec sheets must note the maximum allowable DC voltage and amperage from the PV array and/or the batteries that the inverter can safely handle.
70. ___ Specify the rating and type of DC overcurrent protection (fuses or breaker) that is/are to be provided for protecting the battery conductors (wires). The inverter specs must note the rating of the battery system overcurrent protection device(s).
71. ___ Show that the batteries' overcurrent protection device(s) will protect all other equipment or conductors 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.
72. ___ The battery system overcurrent protection (DC fuses or breaker) must be located as close as possible to the batteries (no more than 4 or 5 feet is usually required by manufacture instructions, but closer is better) and cannot be located in a different room than the batteries. However, such overcurrent protection cannot be located within the same enclosure as flooded or vented batteries. See *NEC* 690.71(C), 240.21(H), and 480.5. See also 690.71(H) in the 2014 *NEC* for additional information.
73. ___ Specify the size and type of conductors (wires) that interconnect batteries and extend to the inverter. Such wires must be sized in accordance with the rating of the battery system DC fuses or DC breaker as specified by per the inverter manufacture (inverter specs must note the rating of the battery overcurrent protection device). See *NEC* 690.8(A)(4) and 690.8(B)(1) and (B)(2).

74. ___ 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. The conductors must also be listed for "hard-service" and be identified as moisture resistant. *NEC* 690.74.
75. ___ If fine-stranded cables are going to be installed, specify on the plans that only terminals, lugs, devices, and connectors that are listed and marked for such use can be installed for such wires. *NEC* 690.31(F) and 110.14. All fittings for fine stranded cables must also meet UL 486 A&B. Note: All fittings for fine stranded cables must also meet UL 486 A&B.
76. ___ Specify that the size and type of equipment grounding conductor that is to be installed with the battery conductors (wires) and is to bond all metal parts of battery racking, metal conduit, metal enclosures, etc. to the inverter. Such equipment grounding conductor is to be sized in accordance with *NEC* 250.122 based on the rating of the battery system overcurrent protection device (DC fuses or breaker).
77. ___ Specify the rating of the AC output overcurrent protection device(s) for the inverter. Note: see item #28 in this review for sizing the inverter's AC output circuit conductors (wires) and overcurrent protection devices (fuses or breakers).
78. ___ For the inverter AC output breaker that feeds a stand-alone panelboard (often called a "critical load panelboard"), please specify on the plans that the AC output circuit overcurrent protection device shall be located at the output of the stand alone or battery backup inverter, per *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 panelboard busbars), per *NEC* 690.10(E).
79. ___ Indicate what types of batteries are going to be installed and if they are the flooded/vented type or sealed type.
80. ___ Specify that the inverter or charge controller will <u>not</u> "equalize" or overcharge sealed batteries.
81. ___ 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. Total battery system voltage in a residential home is typically limited to 48 volts unless the live parts of the batteries are not accessible during routine battery maintenance (NEC 690.71 (B)(1)). An example of a 48 volt battery system would be four-12 volt batteries connected in series per string (more than one string can be parallel connected together if the total battery system amp-hours is within the limits of the inverter).
82. ___ Please specify on the plans the location of the batteries on the premise. Specify that all batteries must be located inside a lockable enclosure or room (guarded against accidental contact by persons) and cannot be installed in the inverter's working space area. *NEC* 690.71(B)(2).
83. ___ Specify that working space must be provided per *NEC* 110.26 in the vicinity of any battery enclosure or electrical equipment, and note the dimensions of such working space. *NEC* 480.9(C).
84. ___ 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." Note: The 2011 *NEC* and the 2012 *International Residential Code (IRC)* do not specifically require mechanical ventilation to be provided for batteries, but may be required if no other ventilation options exist. Also, the battery manufacture may not require ventilation for certain types of batteries. See manufacture recommendations.
85. ___ If a battery system over 48 volts is going to be installed, the batteries cannot be installed on or within conductive cases or racks. This requirement does not apply to VRLA or other types of sealed batteries. *NEC* 690.71(D).
86. ___ If any charge controllers are to be installed for the battery system, please provide manufacture spec sheets for such and also show that the charge controller(s) is/are listed in accordance with UL 1741. *NEC* 690.4(D).

87. ___ 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, solar PV, wind turbine ect.) that is/are connected to the batteries in order to control the charge of the batteries (this may sometimes require multiple charge controllers). See *NEC* 690.72. Note: in some systems such as a SMA Sunny Island system, the inverter acts as the charge controller and an external charge controller is not required (if installed per manufactures requirements).
88. ___ Detailed information from the inverter manufacture on the requirements for grounding the battery system must be provided. Note: Some battery inverter manufactures require a grounding electrode conductor to be connected to the negative conductor at a single point external of the inverter, others may require a grounding electrode conductor to connect within the inverter, and some may not require a grounding electrode conductor at all (always follow manufacture's requirements).
89. ___ 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). Please specify this on the plans. *NEC* 690.55.

Additional items to be corrected on the plans: