**Objective:** To support the inspection community and rapidly growing energy storage industry in California, SEAC has developed the following correction list.

**Correction List for Electrical Plan Check for Storage Battery Systems in One- and Two-Family Dwelling with Solar Photovoltaic System (2016 CEC, based on 2014 NEC)**

This Correction List contains typical corrections to be used in the electrical plan review of new interactive battery storage systems for one- and two-family dwellings with a solar photovoltaic system. The system must interconnect to a single-phase ac service panel of nominal 120/240Vac with a bus bar rating of 225A or less. This corrections list is not intended for systems integrated with bipolar or hybrid PV systems. Other than the below corrections, systems must be in compliance with current California Building Standards Codes and local amendments of the authority having jurisdiction (AHJ).

**General**

- Provide clear scope of work statement on the plans. (Local code section)
- Denote whether system is ac-coupled or dc-coupled.
- Show location of electrical equipment on site plan and floor plan. (Local code section)
- Include a legend or key for site/floor plan equipment symbols.
- Show required (indoor/outdoor) working clearances for new electrical equipment on floor plan. (CEC 110.26, 480.9(C), 480.9(D))
- Show whether equipment is to be installed indoors or outdoors. (Local code section)
- Show method and location of required ventilation equipment (if required) for indoor installations. (CEC 480.9(A))
- Show method of protection from physical damage for storage batteries. (CEC 110.27(B))
- Show means of access to the working space about storage batteries. (CEC 110.26(C))
- Show conduit/cable routing of storage batteries, PV, and related circuits. (Local code section)
- Denote whether conductors are routed indoors, outdoors, or on the roof. (Local code section)
• Show that the rapid shutdown functionality for controlled conductors of a roof-mounted PV system remains unaffected by ac or dc-coupled storage battery circuit(s). (CEC 690.12)
• Provide manufacturer’s documentation if PV strings are prevented from receiving or providing dc current (backfeed) to or from storage battery system. If not, indicate how much current can be backfed. (Local code section and 690.9(A))

Storage Batteries

• Indicate the type of batteries used in the installation. (Local code section)
• Clarify if individual batteries are wired in a bank or installed as pre-packaged equipment. (Local code section)
• Indicate if the batteries are of rechargeable (secondary) storage type. (Local code section, CEC 480.2)
• Storage battery cells shall be connected such that they operate at less than 50 volts nominal, unless battery live parts are not accessible during routine maintenance and the battery system voltage does not exceed the maximum permitted system voltage as prescribed in section 690.7. (690.71(B)(1))
• All live parts of batteries must be guarded regardless of voltage or battery type. (690.71(B)(2))
• Provide adequate ventilation for batteries. (480.9(A))
• Batteries’ live parts shall be guarded in accordance with 110.27. (480.9(B))
• Provide sufficient working spaces and clearances for batteries. Working space shall be measured from the edge of the battery cabinet, racks, or trays. (480.9(C) and 110.26)
• A minimum clearance of 1in shall be provided between a cell contained and any wall or structure on the side not requiring access for maintenance. (480.9(C))
• Metal battery racks must be painted or otherwise treated to resist degradation from electrolytes and to provide insulation between conducting members and the battery cells. (480.8(A)(1))
• Nonmetal battery racks must be of fiberglass or other approved non-conductive materials. (480.8(A)(2))
• Conductive battery cases are not permitted to be used for flooded, vented, lead-acid batteries with more than twenty-four 2-volt cells connected in series. (690.71(D))
• Where flooded, vented, lead-acid batteries with more than twenty-four 2-volt cells are connected in series, the top of nonconductive battery cases must be at least 6 inches away from any conductive racks. (690.71(D))

Charge Controllers

• Indicate whether or not charge controllers are present. (Local code section)
• Indicate what functions are performed by charge controllers. (Local code section)
• Clarify if the charge controller is a diversion charge controller. (Local code section)
- Provide a charge controller for the battery system, unless the design of the PV source circuit matches the voltage rating and charge current requirements of the interconnected battery cells and maximum charging current multiplied by 1 hour is less than 3 percent of the rated battery capacity. (690.72(A))

- PV systems with diversion charge controllers used for regulating the charging of a battery shall have a second independent means to prevent battery overcharge. (690.72(B)(1))

- For systems with charge controllers that are not inverter-integrated, indicate if the charge controllers with direct photovoltaic source or output circuit inputs from the grounded photovoltaic array or arrays are provided with a dc ground-fault detector/interrupter (GFDI) protection? (690.5)

- Indicate if the charge controller GFDI is capable of detecting a ground fault, provide an indication of the fault, interrupt the flow of fault current, and either isolate the faulted array section or disable the charge controller to cease the export of power. (690.5(A) and (B))

- Clarify if all charge controllers are of the same ratings and same settings for each series-connected battery circuit. If not, clarify their difference and how it affects the system. (Local code section)

- Indicate if the charge controllers switch the PV array either as a shunt or series controller. If so, indicate which of the following regulation algorithms (control strategies) are used for charging batteries (Local code section):
  - On-off (interrupting),
  - Single – or multi-stage (i.e., three-stage),
  - Linear or constant voltage,
  - Pulse-width-modulated (PWM),
  - Maximum power point tracking (MPPT), or
  - Diversionary controls.

- Diversionary charge controllers with utility-interactive and multimode inverters shall have a second independent controller to prevent battery overcharge in the event the diversion loads are unavailable or the diversion charge controller fails. (690.72(B)(3)(2))

- Charge controllers with utility-interactive inverters must use appropriate charge regulation settings for the type of battery used. (690.72(B)(3)(1))

- Buck/Boost charge controllers and converter output circuits shall comply with the following:
  - The circuit conductor ampacity shall be based on the maximum rated continuous output current of the controller for the selected output voltage range. (690.72(C)(1))
  - The circuit voltage rating shall be based on the maximum output voltage of the controller for the selected output voltage range. (690.72(C)(2))
Overcurrent Protective Devices

- Battery circuit and equipment shall be protected by overcurrent protective devices as close as practicable to the storage battery terminals in accordance with the requirements of Article 240. (240.21(H), 705.65(A), 690.9(A), 690.71(H)(1))
- When a battery circuit is connected to another source of power, the overcurrent protective devices shall be located so as to provide protection from all sources except as provided in 690.9(A) Exception (b). (690.9(A) Exception (a))
- Unless the short-circuit currents from all sources do not exceed the ampacity of the conductors, storage battery inverters shall be protected by overcurrent protective devices from all other sources. (705.65(A))
- If dc-coupled storage battery system is capable of backfeeding PV strings, provide overcurrent protection for PV strings if 690.9(A) Exception (b) does not apply. (690.9(A))
- Provide battery circuits with current-limiting overcurrent protection when the available short-circuit current of a battery exceeds the interrupting or withstand ratings of equipment (normal overcurrent devices, disconnect means, etc.) in the circuit. (690.71(C))
- For a dc-coupled system, fuses shall comply with 690.16(B). (690.16(B))
- For an ac-coupled system, fuses shall comply with 240.40 and 690.16(A). (705.30)
- In an ac-coupled system, the plug-in type circuit breaker connected to the output of the storage battery or multimode inverter is required to be secured in accordance with 408.36(D). (408.36(D) and 690.10(E))
- Storage battery, multimode, and utility-interactive inverter output circuit breakers that are marked “Line” and “Load” are not permitted to be back-fed. (690.10(E), 110.3(B), and 705.12(D)(4))

Disconnecting Means

- Provide a disconnecting means from all ungrounded conductors of all sources for the following PV system components (690.15):
  - The multimode inverter,
  - Batteries,
  - Charge controllers, and
  - Other: ____________________________
- Disconnecting means for inverters, batteries, and/or charge controllers energized from more than one source shall be grouped and identified. (690.15)
- A PV dc disconnecting means located between the PV array and the charge controller shall comply with 690.17. (690.15)
- Battery circuits subject to field servicing, where more than twenty-four 2-volt cells are connected in series, shall have provisions to disconnect the series-connected strings of batteries into segments of 24 cells or less for maintenance purposes by qualified persons. This disconnect may be a non-load-break bolted or plug-in disconnect. (690.71(E))
• Provide a disconnecting means for the grounded circuit conductors of all battery strings greater than 48 V nominal under maintenance without disconnecting the grounded conductors of the remaining operating strings. This disconnect must only be accessible by qualified person. This disconnect is permitted to be a non-load-break switch. (690.71(F))

• For a dc-coupled system, the disconnecting means for a fuse on the dc storage battery circuit shall comply with 690.16(B) and 690.17. (690.16)

• Provide a disconnecting means at the energy storage device end of the circuit. Energy storage device input and output terminals are more than 5ft from connected equipment, or the circuits from these terminals pass through a wall or partition. (690.71(H)(1))

• The disconnecting means required by 690.71(H)(1) is not in line of sight of the connected equipment. Provide a second disconnecting means at the connected equipment. (690.71(H)(4))

• Where controls to activate the disconnecting means of a battery are not located within sight of a stationary battery system, the disconnecting means shall be capable of being locked in the open position. (480.6(B))

Interconnecting Circuit Cables

• Interconnecting flexible circuit cables between battery terminals, battery terminals and cells, and a battery terminal to a nearby junction box for transition to the building wiring must not be less than 2/0 AWG in size. (690.74(A))

• The interconnecting circuit cables shall be identified as moisture resistant and listed for hard-service (hard usage) use as specified in Article 400. (690.74(A))

• Flexible, fine-stranded cables shall be terminated to terminals, lugs, devices or connectors in accordance with provisions of CEC section 110.14(A). (690.74(A))

Interconnection

• The output of an interconnected electric power source shall be connected as specified in 705.12(A) or 705.12(D)

• A storage battery system not integrated with a PV system or other power production source shall not be connected to the supply side of the service disconnecting means. (705.12(A) and 230.82(6))

Grounding

• The interconnected battery cells shall be grounded unless permitted by 690.71(G). (690.71(A) and 690.35(E))

• Battery banks of more than 48 V nominal are permitted to operate with ungrounded conductors only, if they comply with all the following conditions: (690.71(G))
The PV array source and output circuit comply with Section 690.41, or meet the requirements of Section 690.35.
- The dc and ac load circuits are solidly grounded.
- All main ungrounded battery input/output circuit conductors are provided with switch disconnects and overcurrent protection.
- A ground-fault detector and indicator are installed to monitor for ground faults in the battery bank.

- Any conductive battery racks, cases or trays must be connected to an equipment grounding conductor. (250.110)
- Provide an equipment grounding conductor (EGC) for the dc side of the PV system, sized according to Table 250.122 of the CEC with a minimum size of 14 AWG. (690.45)

**AC Branch Circuit**

- Single 120-volt inverter in ac coupled systems should not supply back-up loads containing multiwire branch circuit or any 240 volt outlets. Such action can overload the common neutral in such a wiring method. (690.10(C))

**Calculations**

- **Battery-Inverter Circuit**
  - The maximum dc inverter input current for a multimode inverter operating in stand-alone mode must be sized based on the continuous inverter input current rating when the inverter is producing rated power at the lowest input voltage. The input current may be calculated as shown below: (690.8(A)(4))

  \[
  I_{dc} = \frac{\text{inverter power}}{\text{inverter efficiency} \times \text{dc voltage at min. operating voltage}}
  \]

  **Step 1:**
  \[
  I_{dc} = \frac{\text{inverter power}}{\text{inverter efficiency} \times \text{dc voltage at min. operating voltage}}
  \]

  **Step 2:**
  \[
  I_{\text{total}} = (I_{dc} + I_{ac \text{ripple}}) \times 1.25
  \]

- **Charge Controllers**
  - The charge regulation circuits of utility interactive inverters that are used to control battery state of charge by diverting excess power to the utility system shall comply with the requirements of 690.8 and 400.5 (as applicable). (690.72(3)(1))

- **PV Array-Charge Controller Circuit**
  - In a dc-coupled system with charge controllers, the circuit conductors between the charge controller and the battery are to be sized based on the rated output of the charge controller. These conductors shall be sized at 125% of the rated output current of the charge controller. (690.72(C)(1))

- **Circuits containing a dc diversion charge controller and a dc diversion load (i.e., dc water pumps, resistive water heating elements or other loads that can utilize or store the energy in some other form) must comply with the following (690.72(B)(2)):**
The dc diversion load current rating must be less than or equal to the controller maximum current rating. (690.72(B)(2)(1))

The dc diversion load must have a voltage rating greater than the maximum battery bank voltage. (690.72(B)(2)(1))

The dc diversion load power rating must be at least 150% of the PV array power rating. (690.72(B)(2)(1))

The dc diversion load circuit conductor ampacity and their overcurrent protective device rating must be sized for at least 150% of controller maximum current rating. (690.72(B)(2)(2))

- **Overcurrent Protective Device Rating**
  - An overcurrent protective device installed at the battery circuit must be rated at 125% of the multimode and battery inverter rated (dc/ac) current when operating in the inverting mode. (215.3, 210.20(A), 240, and 705.60(B))

- **DC Short Circuits**
  - Provide and indicate the maximum available short circuit at the output of the combined series/parallel battery circuits at 25 °C. The battery nominal voltage should be used when calculating the maximum short circuit current. (110.9, 110.10)
  - Note: Any overcurrent device must have ratings that can handle battery short circuit currents. Current-limiting dc fuses and circuit breakers are generally available with sufficient ratings and should be used in order to reduce the battery short circuit current to the maximum permitted inverter and charge controller short circuit current ratings as applicable.

- **Power Ratings and Phase Configuration**
  - Unless as permitted otherwise, in a multimode and PV inverter ac-coupled system, the rated power of PV inverter should not exceed the rated power of the multimode inverter. The PV inverter’s phase configuration must match that of the multimode inverter. (110.2, 110.3)

- **AC Panelboard/Load Center Busbar Loading - One option must be used**
  - For an inverter circuit connected to the load side of a panelboard/load center, the busbar ampacity rating shall not be less than 125% of the inverter output circuit current rating and the rating of the overcurrent device protecting the busbar. (705.12(D)(2)(3)(a))
  - For an inverter circuit connected to the opposite end of a busbar of a utility-fed panelboard/load center that contains loads, the sum of 125% of the inverter output circuit current rating and the rating of the overcurrent device protecting the busbar shall not exceed 120% of the busbar rating. The busbar shall be sized for the loads connected in accordance with Article 220. (705.12(D)(2)(3)(b))
  - The sum of the ampere ratings of all overcurrent devices on panelboards, both load and supply devices, excluding the rating of the overcurrent device protecting the busbar, shall not exceed the ampacity of the busbar. The rating of the overcurrent device protecting the busbar shall not exceed the rating of the busbar. (705.12(D)(2)(3)(c))
Connections on center-fed panelboards shall be designed under engineering supervision that includes fault studies and busbar load calculations. (705.12(D)(2)(3)(d))

**Standalone Operation**
- At night or at their initial startup, multimode inverters may allow the premises wiring system to charge the batteries as needed (if permitted by the serving utility). At night, if the battery is discharged, the premises wiring system can charge the battery on a continuous basis as a load. A panel or premises wiring system supplying power to loads under multimode stand-alone operation mode shall be adequately sized to meet the requirements of the code for a similar installation connected to a service as specified in Article 220. (690.10)

**Battery Intercell and Intertier Conductors and Connections**
- Show that the ampacity of field-assembled intercell and intertier connectors and conductors are of such cross-sectional area that the temperature rise under maximum load conditions and at maximum ambient temperature shall not exceed the safe operating temperature of the conductor insulation or of the material of the conductor supports. (480.3(B))

**Labels and Markings**
- Install this warning label in a visible location at the batteries and at the utility-interactive inverter or near the ground-fault indicator. (690.5(C))
  
  WARNING
  ELECTRIC SHOCK HAZARD
  IF A GROUND FAULT IS INDICATED, NORMALLY GROUNDED CONDUCTORS MAY BE UNGROUNDED AND ENERGIZED

- Equipment containing overcurrent devices in circuits supplying power to a busbar or conductors supplied from multiple sources shall be marked to indicate the presence of all sources. (705.12(D)(3))

- Photovoltaic power systems and utility-interactive power systems employing energy storage shall also be marked with the maximum operating voltage, including any equalization voltage, and the polarity of the grounded circuit conductor. (690.55, 705.80)

- DC system conductors of 6 AWG or smaller shall be identified for negative or positive polarity per 210.5(C)(2)(a) and (b). (210.5(C)(2))

- If a battery dc disconnecting means is not provided at the batteries, the disconnecting means shall be legibly marked in the field. The marking shall be of sufficient durability to withstand the environment involved and shall include the following (480.6(D)):
  - Nominal battery voltage
  - Maximum available short-circuit current derived from the stationary battery system
  - Date the calculation was performed for the value above
• Where controls to activate the disconnecting means of a battery are not located within sight of a stationary battery system, the location of the controls shall be field marked on the disconnecting means. (480.6(B))

• A permanent plaque or directory denoting all electric power sources on or in the premises shall be installed at each service equipment location and at locations of all electric power production sources capable of being interconnected. (705.10)

• Where the energy storage device disconnecting means is not within sight of the PV system ac and dc disconnecting means, placards or directories shall be installed at the locations of all disconnecting means indicating the location of all disconnecting means. (690.71(H)(5))

• Where the sum of inverter overcurrent device rating(s) and the rating of the overcurrent device protecting the busbar exceeds the ampacity of the busbar, and the sum of ratings for all overcurrent device ratings in the panelboard (both load and supply, but excluding the device protecting the busbar) does not exceed the busbar ampacity, the following label shall be applied to the distribution equipment:

  WARNING:
  THIS EQUIPMENT FED BY MULTIPLE SOURCES.
  TOTAL RATING OF ALL OVERCURRENT DEVICES,
  EXCLUDING MAIN SUPPLY OVERCURRENT DEVICE,
  SHALL NOT EXCEED AMPACITY OF BUSBAR.

• Where a busbar is the point of connection for the inverter(s) and is rated to 120% in accordance with 705.12(D)(2)(3)(b), a warning label with the following language shall be applied to the distribution equipment adjacent to the backfed breaker from the inverter:

  WARNING:
  INVERTER OUTPUT CONNECTION;
  DO NOT RELOCATE THIS OVERCURRENT DEVICE.

• Markings and labels shall comply with 110.21(B). (110.21(B))

Applicable to whom:

The recommendations would apply to all solar PV and energy storage stakeholders.

Disclaimer: The Recommended Practices of SEAC are tools and information to assist those enforcing the electrical and building codes as they relate to storage batteries and energy storage systems. Recommended Practices published by SEAC that are not directly quoting code requirements are non-binding and/or regulatory.

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