Calculation Example of Small Photovoltaic (PV) Residential Stand-Alone System

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2kW Solar PV Array on Campus Crossings at Briarcliff (photo by Soenso Energy)

Example

- *Array Size*: 10, 12-volt, 51-watt modules; Isc= 3.25 amps, Voc= 20.7 volts
- *Batteries:* 800 amp-hours at 12 volts
- *Loads:* 5 amps DC and 500-watt inverterwith 90% efficiency.

Description

The PV modules are mounted on the roof. Single-conductor cables are used to connect the modules to a roof-mounted junction box. Potential reverse fault currents indicate that a PV combiner be used with a series fuse for each PV module.

UF two-conductor sheathed cable is used from the roof to the control center.

Physical protection (*wood barriers or conduit*) for the UF cable is used where required. The control center, diagrammed in ***Figure 1***, contains disconnect and overcurrent devices for the PV array, the batteries, the inverter, and the charge-controller.

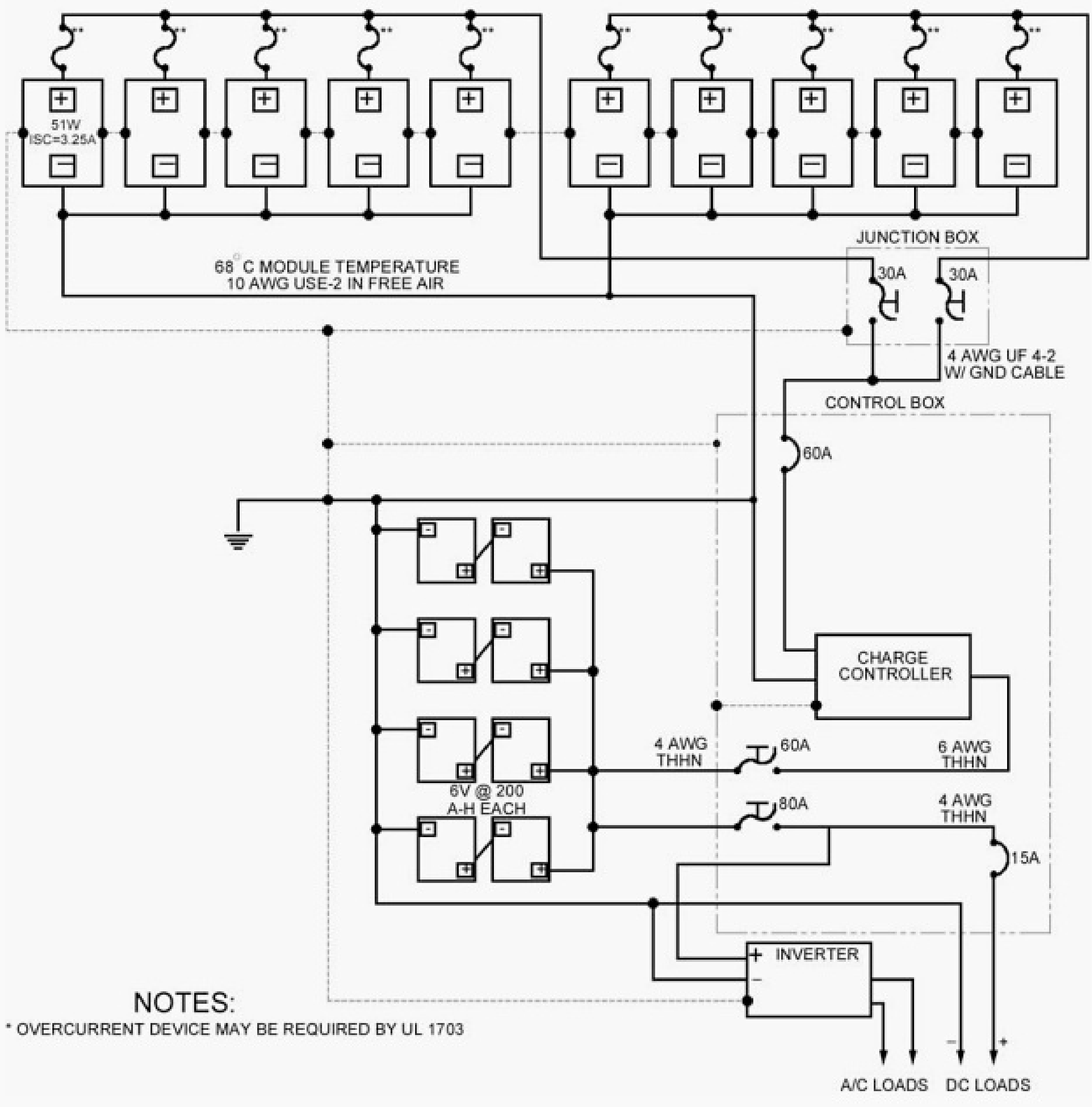

Figure 1 - Small Residential Stand-Alone System

Calculations

- The moduleshort-circuit current is 3.25 amps.
- CONTINUOUS CURRENT: 1.25 x 3.25 = 4.06 amps
- 80% OPERATION: 1.25 x 4.06 = 5.08 amps per module

The maximum estimated moduleoperating temperature is ***68°C***.

From NECTable 310.17:

- The derating factor for USE-2 cable is 0.58 at 61-70°C.
- Cable 14 AWG has an ampacity at 68°C of 20.3 amps (0.58 x 35) (*max fuse is 15 amps*).
- Cable 12 AWG has an ampacity at 68°C of 23.2 amps (0.58 x 40) (*max fuse is 20 amps*).
- Cable 10 AWG has an ampacity at 68°C of 31.9 amps (0.58 x 55) (*max fuse is 30 amps*).

- Cable 8 AWG has an ampacityat 68°C of 46.4 amps (0.58 x 80).

The array is divided into two five-module sub-arrays.

The modules in each sub-array are wired from module junction box to the PV combiner for that sub-array and then to the array junction box. Cable size 10 AWG USE-2 is selected for this wiring, because it has an ampacityof 31.9 amps under these conditions, and the requirement for each sub-array is ***5 x 4.06 = 20.3 amps***.

Evaluated with 75°C insulation, a 10 AWG cable has an ampacity of 35 amps at 30°C, which is greater than the actual requirement of 20.3 amps (5 x 4.06).

In the array junction box on the roof, two 30-amp fuse sin pullout holders are used to provide overcurrent protection for the 10 AWG conductors. These fuses meet the requirement of 25.4 amps (*125% of 20.3*) and have a rating less than the derated cable ampacity.

In this junction box, the two sub-arrays are combined into an array output. ***The ampacity requirement is 40.6 amps (10 x 4.06).*** A 4 AWG UF cable (*4-2 w/gnd*) is selected for the run to the control box. It operates in an ambient temperature of ***40°C*** and has a temperature-corrected ampacity of ***86 amps (95 x 0.91)***. This is a ***60°C*** cable with 90°C conductors and the final ampacity must be restricted to the 60°C value of 70 amps, which is suitable in this example.

Appropriately derated cables must be used when connecting to fusesthat are rated for use only with 75°C conductors. A 60-amp circuit breaker in the control box serves as the PV disconnect switch and overcurrent protectionfor the UF cable.

The minimum rating would be 10 x 3.25 x 1.56 = 51 amps.

The NEC allows the next larger size; ***in this case, 60 amps***, which will protect the 70 amp rated cable. Two single-pole, pullout fuse holders are used for the battery disconnect. ***The charge circuit fuse is a 60-amp RK-5 type.***

The inverter has a continuous rating of 500 watts at the lowest operating voltage of ***10.75 volts*** and an efficiency of ***90%*** at this power level. The continuous current calculation for the input circuit is ***64.6 amps ((500 / 10.75 / 0.90) x 1.25)***.

The cables from the battery to the control center must meet the inverter requirements of 64.6 amps plus the DC load requirements of 6.25 amps (1.25 x 5).

A 4 AWG THHN has an ampacityof 85 amps when placed in conduit and evaluated with 75°C insulation. This exceeds the requirements of 71 amps (64.6 + 6.25). ***This cable can be used in the custom power center and be run from the batteries to the inverter.***

The ***discharge-circuit fuse*** must be rated at least ***71 amps***. An ***80-amp fuse*** should be used, which is less than the cable ampacity.

The DC load circuit is wired with 10 AWG NM cable (*ampacityof 30 amps*) and protected with a ***15-amp circuit breaker***.

The grounding electrode conductor is 4 AWG and is sized to match the largest conductor in the system, which is the array-to-controlcenter wiring. This size would be appropriate for a concrete-encased grounding electrode. Equipment-grounding conductors for the array and the charge circuit can be 10 AWG based on the 60-amp overcurrent devices.

The equipment ground for the inverter mustbe an ***8 AWG conductor*** based on the ***80-amp overcurrent device***. All components should have at least a DC voltage rating of ***1.25 x 20.7 = 26 volts***.

Reference: *Photovoltaic Power Systems And the 2005 National Electrical Code – John Wiles Southwest Technology Development Institute New Mexico State University*

Source:
http://electrical-engineering-portal.com/calculation-example-of-small-photovoltaic-pv-residential-stand-alone-system