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

Example

- **Array Size**: 10, 12-volt, 51-watt modules; $I_{sc} = 3.25$ amps, $V_{oc} = 20.7$ volts
- **Batteries**: 800 amp-hours at 12 volts
- **Loads**: 5 amps DC and 500-watt inverter with 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.

**Calculations**

- The **module short-circuit current** is 3.25 amps.
- **CONTINUOUS CURRENT**: $1.25 \times 3.25 = 4.06$ amps
- **80% OPERATION**: $1.25 \times 4.06 = 5.08$ amps per module

The maximum estimated module operating 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 $(0.58 \times 35)$ (max fuse is 15 amps).
- Cable 12 AWG has an ampacity at 68°C of 23.2 amps $(0.58 \times 40)$ (max fuse is 20 amps).
- Cable 10 AWG has an ampacity at 68°C of 31.9 amps $(0.58 \times 55)$ (max fuse is 30 amps).
Cable 8 AWG has an ampacity at 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 ampacity of 31.9 amps under these conditions, and the requirement for each sub-array is \(5 \times 4.06 = 20.3\) 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 fuses that 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 protection for 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 ampacity of 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 ( ampacity of 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-control center 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 must be 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