Example Systems

Small Stand-Alone Systems

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This Code Corner will continue the series of examples on the selection of the wiring, overcurrent devices, and disconnects for various types of PV systems. These designs will meet the requirements of the National Electrical Code (NEC).

These are examples only and should not be used to define the requirements for any particular system. No information will be presented on sizing the PV array. The array sizes and the loads are used only for illustration. Calculations for a specific system should be accomplished using the methods presented in previous issues of Home Power. The examples in this Code Corner will cover small DC-only systems. The last example in the series will cover a complex residential hybrid PV system with a backup generator.

The systems described below and the calculations shown are presented as examples only. The calculations for conductor sizes and the ratings of overcurrent devices are based on the requirements of the 1993 National Electrical Code (NEC) and on UL Standard 1703 which governs the installation of UL-Listed PV modules. Local codes and site-specific variations in irradiance, temperature, and module mounting as well as other installation particularities dictate that these examples should not be used without further refinement. Tables 310-16 and 310-17 from the NEC provide the ampacity data and temperature derating factors.

EXAMPLE 1 Stand-Alone Lighting System

Array Size: 4, 12-volt, 64-watt modules, Isc = 4.0 amps, Voc = 21.3 volts

Batteries: 200-amp-hours at 24 volts

Load: 60 watts at 24 volts

Description

The modules are mounted at the top of a 20-foot pole with the metal-halide lamp. The modules are connected in series and parallel to achieve the 24-volt system rating. The lamp with an electronic ballast and timer/controller draws 60 watts at 24 volts. The batteries, disconnect switches, charge controller, and overcurrent devices are mounted in a box at the bottom of the pole. The system is grounded as shown in Figure 1.

Calculations:

The array short-circuit current is 8 amps (2 x 4).

NEC 125%: 1.25 x 8 = 10 amps

UL 125%: 1.25 x 10 = 12.5 amps

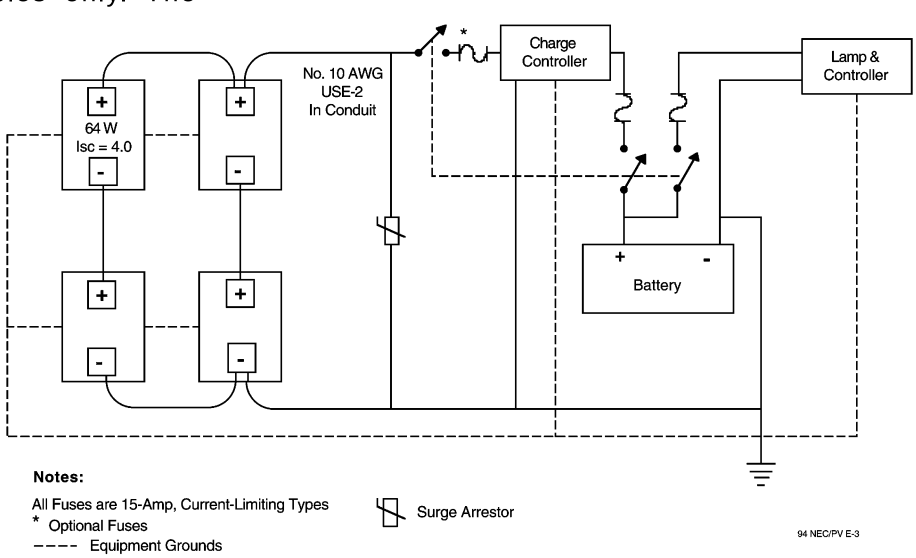
Load Current: 60/24 = 2.5 amps

NEC 125%: 1.25 x 2.5 = 3.1 amps

Number 10 AWG USE-2 is selected for module interconnections and is placed in conduit at the modules and then run down the inside of the pole.

The modules operate at 61-70°C which requires that the module cables be temperature derated. Number 10 AWG USE-2 (90°C insulation) cable has an ampacity of 40 amps at 30°C in conduit. The derating factor is 0.58. The temperature derated ampacity is 23.2 amps (40 x 0.58) which exceeds the 12.5 amp requirement. Checking the same #10 AWG cable with a 75°C insulation, the ampacity at the fuse end at 40°C ambient temperature is 30.8 amps (35 x 0.88) which

FIGURE 1 Stand-Alone Lighting System



exceeds the 10-amp requirement. This cable can be protected by a 15-amp fuse or circuit breaker.

The same USE-2, number 10 AWG cable is selected for all other system wiring as it has the necessary ampacity for each circuit.

A three-pole fused disconnect is selected to provide the PV and load disconnect functions and the necessary overcurrent protection. The fuse selected is an RK-5 type providing current-limiting from the high battery currents. A pull-out fuse holder with either Class RK-5 or Class T fuses could also be used for a more compact installation. The 15-amp fuse at the input to the charge controller is not absolutely necessary since this circuit is protected from overcurrents by the 15-amp fuse between the charge controller and the battery. The disconnect at the input of the charge controller is necessary.

The equipment grounding conductors and the system grounding conductor to the ground rod should be number 10 AWG conductors.

The DC voltage ratings for all components used in this system should be at least 53 volts (2 x 21.3 x 1.25).

EXAMPLE 2 Remote Cabin DC-Only System

Array Size: 6, 12-volt, 75-watt modules, Isc = 4.8 amps, Voc = 22 volts

Batteries: 700 amp-hours at 12 volts

Load: 75 watts peak at 12-volts DC

Description

The modules are mounted on a rack on a hill behind the house. Non-metallic conduit is used to run the cables from the module rack to the control panel. A disconnect and control panel are mounted on the back porch and the batteries are in an insulated box under the porch. All the loads are DC with a peak combined power of 75 watts at 12 volts due primarily to a pressure pump on the gravity-fed water supply. The battery bank consists of 4 350-amp-hr, 6-volt deep-cycle batteries wired in series and parallel. Figure 2 shows the system schematic.

Calculations

The array short-circuit current is 28.8 amps (6 x 4.8).

UL 125%: 1.25 x 28.8 = 36 amps

NEC 125%: 1.25 x 36 = 45 amps

The module interconnect wiring and the wiring to a rack-mounted junction box will operate at 65°C. If USE-2 cable with 90°C insulation is chosen, then the temperature derating factor will be 0.58. The required ampacity of the cable at 30°C is 77.6 amps (45/0.58) which can be handled by number 8 AWG cable with an ampacity of 80 amps in free air at 30°C. Conversely, the ampacity of the number 8 AWG cable is 46.4 amps (80 x 0.58) at 65°C which exceeds the 45 amp requirement. Checking a number 8 AWG cable with 75°C insulation operating at 45°C (assumed junction box temperature) yields an ampacity of 57.4 amps (70 x 0.82) which is in excess of the 36 amp requirement.

From the rack-mounted junction box to the control panel, the conductors will be in conduit and exposed to 40°C temperatures. If XHHW-2 cable with a 90°C insulation is selected, the temperature derating factor is 0.91. The required ampacity of the cable at 30°C would be 45/0.91 = 49.5 amps in conduit. Number 8 AWG cable has an ampacity of 55 amps at 30°C in conduit which exceeds the 49.5 amp requirement. Conversely, the number 8 AWG conductor has an ampacity of 50 amps (55 x 0.91) at 40°C in conduit which exceeds the 45 amp requirement.

The number 8 AWG cable, evaluated with a 75°C insulation, has an ampacity at 40°C of 44 amps (50 x 0.88) which is greater than the 36 amps that might flow through it under noon-time irradiance conditions.

The array is mounted 200 feet from the house and the round trip cable length is 400 feet. A calculation of the voltage drop in 400 feet of Number 8 AWG cable

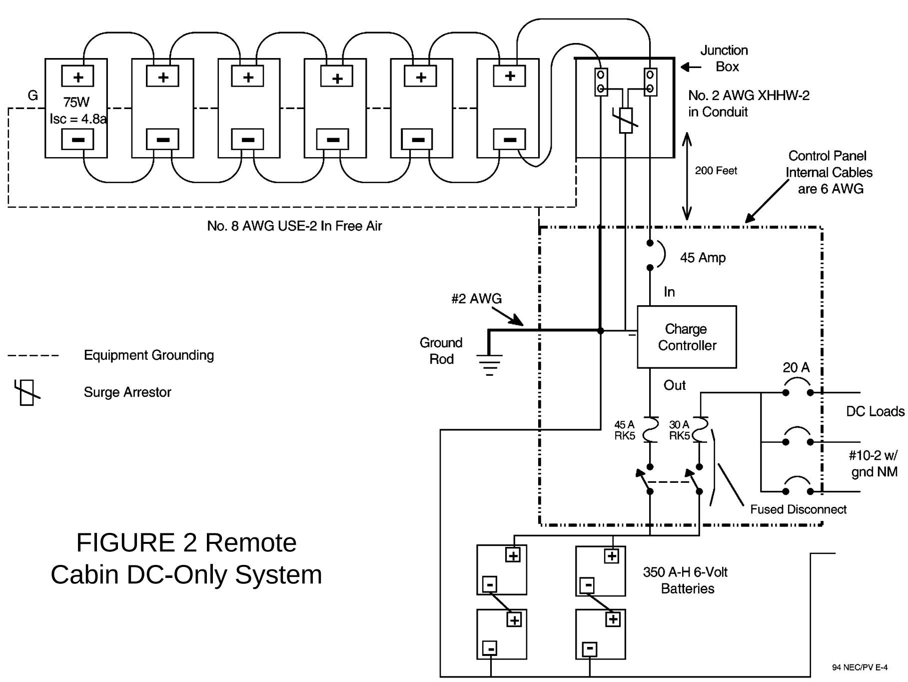


FIGURE 2 Remote Cabin DC-Only System

operating at 36 amps (125% Isc) is 0.778 ohms per 1000 feet x 400 / 1000 x 36 = 11.2 volts. This represents an excessive voltage drop on a 12-volt system and the batteries cannot be effectively charged. Number 2 AWG cable was substituted which has a voltage drop of 2.8 volts which is acceptable for this installation.

The PV conductors are protected with a 45-amp single-pole circuit breaker on this grounded system.

Number 6 AWG THHN cable is used in the control center and has an ampacity of 95 amps at 30°C when evaluated with 75°C insulation. Number 2 AWG cable is used from the negative DC input to the point where the grounding electrode conductor is attached instead of the number 6 AWG conductor used elsewhere to comply with grounding requirements.

The 75-watt peak load draws about 6.25 amps and number 10-2 with ground (w/gnd) nonmetallic sheathed cable was used to wire the cabin for the pump and a few lights. DC-rated circuit breakers rated at 20 amps were used to protect the load wiring which is in excess of the peak load current of 7.8 amps (1.25 x 6.25) and less than the cable ampacity of 30 amps.

Current-limiting fuses in a fused disconnect are used to protect the DC-rated circuit breakers which do not have an interrupt rating sufficient to withstand the short-circuit currents from the battery under fault conditions. RK-5 fuses were chosen with a 45-amp rating in the charge circuit and a 30-amp rating in the load circuit. The fused disconnect also provides a disconnect for the battery from the charge controller and the DC load center.

The equipment grounding conductors should be number 10 AWG and the grounding electrode conductor should be number 2 AWG.

All components should have a voltage rating of at least 1.25 x 22 = 27.5 volts.

Summary

The calculations used in these examples are based on UL and NEC requirements. While there is some leeway in the selection of cable types, overcurrent devices, and disconnects, all DC-rated devices should be used. Oversizing the cables will lower voltage drop and increase performance, particularly where long cable runs are involved.

Access

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