Power to the People- Load Circuits

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Load circuits in any power system are among the most critical in terms of safety because the casual, sometimes uninformed user has unrestricted access to them. "Power too cheap to meter" and the ubiquitous ac outlet have lulled many into a false sense of security which may not be warranted in our alternate energy systems. Alternating-current systems are installed with standardized wiring methods, standardized junction boxes and outlets, and appliances with standardized cords and plugs -- all tested and listed by Underwriters Laboratories (UL). Can we say the same about our PV systems?

To minimize safety hazards in PV and other alternate-energy load circuits, particular attention should be paid to the National Electric Code (NEC) which applies to both ac and dc power systems. Load circuits start at the battery and run to the outlet receptacle or to the appliance if directly wired. In Code Corner in Home Power #21 and previous issues, the dc load center with circuit breakers was discussed. Because of the importance of protecting the load circuits from short circuits, current-limiting fuses must again be addressed and stressed.

First -- Limit That Short-Circuit Current

Battery banks have the potential of delivering far higher currents into a short circuit than does the typical ac residential power system. Normal hardware store variety fuses and circuit breakers (even Square D QO breakers) do not have the ability to withstand or interrupt these high short-circuit currents. Special, high-interrupt circuit breakers are available which can be used, but price, availability, and ease of use probably makes them only practical for the battery-to-inverter circuit (See Code Corner - HP #21). In all other circuits some method must be used to limit the available short-circuit currents from the battery since either low-cost fuses or circuit breakers will be used for the overcurrent protection.

Standard fuses, either slow-blow, time-delay fuses or the fast-acting fuses, do not open fast enough under short-circuit conditions to significantly reduce or limit the high currents before they can do damage to other down-stream fuses, circuit breakers, and switches. A special current-limiting fuse must be used that does open fast enough under short-circuit conditions to significantly reduce or limit the very high peak currents. These fuses have industry generic designations of RK-1 or RK-5 among others. Most manufacturers make these in fast-blow and slow-blow configurations which refer to the overcurrent function, not the short-circuit function. Manufacturers who have dc ratings on these fuses, like Littelfuse Inc., have had them tested by UL. The dc rating is usually half the ac voltage rating and one tenth (10%) the ac interrupt current rating. Some manufacturers don't have dc ratings or UL dc listing on these fuses and if it doesn't say current limiting and dc, it may not provide full system protection. Let the buyer beware!

Next -- Use the Proper Wiring Method

With the circuit protected from overloads (fuses or circuit breakers) and short circuits (special circuit breakers or current-limiting fuses), care must be taken to use wiring methods that will minimize the use of these safety devices. These methods are specified in the NEC and are used daily by electricians on ac systems. In many cases, alternate energy systems will be wired using non-metallic cable concealed in walls or otherwise protected. PVC electrical conduit containing individual wires is also a possibility. Other methods are available and the local electrical codes may require electrical metallic conduit.

Separate conductors, either exposed or concealed in walls, are not allowed by the NEC and pose a very real hazard. Separate conductors do not have the necessary mechanical protection (from rats, nails, feet, etc) nor the electrical insulation (from heat, other conductors, or grounded surfaces) that is required of NEC approved wiring methods. These constraints apply to battery cables as well as load circuits.

Number 10 AWG is a wire size commonly used for low-voltage branch and load circuits. In the form of 12-2 with ground, nonmetallic cable (type NM), it is reasonably priced at building supply stores and minimizes voltage drop when compared to smaller sizes. Unfortunately it is a little more difficult to work with and it is hard to attach to some receptacles and switches. These devices are frequently sized for number 12 AWG or smaller wire. If voltage drop calculations allow, number 12 AWG conductors might be used for general lighting circuits with up to 4-5 amps load (40+ watts -- pretty bright). Appliances using more current could be direct wired using a wall mounted junction box, the appropriate flexible cable, and an appliance mounted junction box.

Also large conductor cables could be used as feeders and then spliced to smaller conductor cables near the end use appliances. All splices must be made using an approved method and placed in an approved junction box. In this case, the overcurrent protection must be sized to protect the smallest conductor in the circuit. For example a number 8 AWG feeder connected to a number 12 AWG lighting circuit must have no larger than a 20 amp overcurrent protective device to protect the number 12 AWG wire.

An exception to this is that a short (less than 18 inches) "pigtail" of number 12 AWG could be attached (with an approved splicing device or method) to a number 10 AWG cable and the combination protected for the 30 amp rating of the number 10 conductor. The splice would have to be made in an approved outlet or junction box, but this technique will allow easier connection to the receptacles. Incidentally, Article 720 of the NEC says that number 12 AWG conductors are the smallest that can be used on ac or dc systems operating at less than 50 volts.

The NEC requires that each service (ac, dc, high-voltage, low-voltage) in a building or residence have non-interchangeable receptacles and plugs for portable loads.

Last -- Power To The Load

The demand in the PV industry is insufficient to have a separate, UL listed plug and receptacle developed and marketed. It is up to the dealer/installer or homeowner to choose an appropriate device. Since the NEC requires a grounding conductor on each receptacle for use with appliances that might have metal exterior surfaces, three bladed plug/receptacle devices will be needed whether the system is grounded or not. There is a standard 28-volt, 30-amp, dc UL listed specification-grade, twist-lock plug and receptacle which could be used. It has a NEMA (National Electrical Manufacturers Association) designation of FSL1, is large like an electric range plug, costs about $15 per piece (i.e. $15 for the plug and $15 for the receptacle), and is manufactured in limited quantities.

Another choice might be a 125-volt 15 or 20-amp, 3 blade twist-lock device that is sold in many hardware stores at a reasonable cost ($3-6 each). Do not use a standard 125-volt receptacle because someone might plug a 125-volt appliance into the 12-volt circuit. If a 240-volt power system is not used in the residence, 240-volt devices could be used for the 12 or 24-volt dc requirement. Incidentally, if both 12 and 24-volt circuits are used, the use of the grounding blade or the grounding conductor for a common negative conductor is not approved. In each case, it appears that better performance (lower voltage drop and longer life) will be realized if specification grade (SPEC stamped on the device) devices are used rather than the lower quality standard grade of devices. All of these devices, if not available locally, may be special ordered from electrical supply houses.

Access

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FSL1 Receptacles and Plugs: Bryant Electric, Milford Place Corp. Center, Milford CT 06460 • 203-876-3600

National Electric Code, National Fire Protection Assoc., Batterymarch Park, Quincy, MA 02269 • 800-344-3555

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