Surfing through Breakers

John Wiles

Sponsored by The Photovoltaic Systems Assistance Center
Sandia National Laboratories

Breakers, the electrical kind—not those used for surfing—are used in electrical circuits as both overcurrent protective devices and as disconnect devices. This Code Corner will present some general information on circuit breakers and where they may be properly used.

Circuit breakers offer several advantages over the combination of fuses and disconnects and in many cases provide equivalent functions. They can be reset after they are tripped by overcurrents and do not have to be replaced, and they are usually more compact than fuses and switches with the same ratings.

Circuit breakers are found in nearly all modern residential load centers. While these breakers are rated for alternating current (AC) there are also circuit breakers rated for direct current (DC). The AC and DC breakers are not interchangeable (AC breakers should be used for AC circuits and DC breakers for DC circuits), although a few circuit breakers are rated for both AC and DC.

Branch Circuit vs. Supplementary

Like fuses, circuit breakers are used in branch circuit and supplementary applications. The branch circuit-rated breakers, like those found in the typical AC residential load center, are generally larger and more robust than the supplementary breakers that are used inside electronic equipment like radios, televisions, microwave ovens, and the like. It is generally required that both AC and DC supplementary circuit breakers be protected by a circuit breaker rated for branch circuit use nearer the power source.

In PV applications, the less expensive supplementary breakers may be used in PV source circuits. In these circuits they are used to provide overcurrent protection for the conductors to the modules while serving as a disconnect for these same source circuits. They can be used in source circuits because the fault currents from PV modules are limited. These breakers may also be used in these circuits because they are sufficiently far from the battery that the potential fault currents can be handled by these low-interrupt rating devices. Usually there is also a required current-limiting fuse located near the battery that may serve to further limit fault currents.

Some circuit breakers are also equipped with auxiliary switches that can be used in alarm circuits to signal when they are open. This allows breakers to be mounted in remote locations, e.g., on the roof (out of sight, out of mind), and have an alarm inside the house to indicate when they have tripped due to a fault or surge.

DC Rated Circuit Breakers

Listed, DC-rated circuit breakers installed in listed enclosures are generally not available to the individual but are manufactured by original equipment manufacturers (OEM) like Trace Engineering, Pulse Energy Systems, Heliotrope General, and others. These manufacturers are now producing assemblies of DC-rated circuit breakers in enclosures that can be used in renewable energy systems. Examples of these are the Trace Engineering "DC 250 Disconnect" which includes a 250 Amp circuit breaker to provide the disconnect and overcurrent protection for the circuit between the inverter and the battery bank. Up to four additional circuit breakers for either source or load circuits can be installed in the enclosure. Another example is the Trace ground-fault protection device which includes a dual circuit breaker and associated equipment to provide the PV array ground-fault protection required by section 690-5 of the National Electrical Code® (NEC).

When an OEM uses DC-rated circuit breakers in a piece of equipment, the ratings that apply to the individual circuit breakers may differ from the ratings that apply to the overall equipment. The equipment was fully tested for the application by an organization like Underwriters Laboratories (UL), and with laboratory testing of the entire product, ratings for the equipment may be in excess of the circuit-breaker ratings alone.

AC-Rated Circuit Breakers

Circuit breakers for AC use are usually installed in load centers made by the manufacturer that makes the breakers. These load centers hold a number of individual breakers and the necessary bus bars to connect them together. They are readily available in building supply stores and at electrical equipment supply houses. These AC circuit breakers and AC load

centers should only be used in AC circuits and never in DC circuits.

Dual-Rated Circuit Breakers

The Square D line of QO breakers and QO load centers are rated for 120/240 Volts AC, and they also have a lower voltage DC rating. When used in DC branch circuits (circuits from the battery to the load) they can be used on 12 and 24 Volt battery systems. Although rated for 48 Volts DC, the higher battery voltages (above 48 Volts) in normal charging and during equalizing pose stresses on these breakers and they should not be used in 48 Volt battery systems.

In PV source circuits there is the potential for higher than nominal voltages. A 24 Volt system with crystalline silicon modules may have an open-circuit voltage above 48 Volts. Because of this consideration, Square D QO breakers and load centers should be used only on 12 Volt PV systems. Some thin-film modules may not have open-circuit voltages this high and it may be possible to use these breakers in PV source circuits in 24 Volt systems. In both uses (source circuits and load branch circuits), the interrupt-current rating is only 5000 Amps and if they are placed in systems with large batteries and are located in the circuits near the batteries, they should have a current-limiting fuse between the battery and the circuit breaker. An analysis (beyond the scope of this column) of potential fault currents may be used to determine the need for a current-limiting fuse.

Disconnects

When circuit breakers are used as disconnects, their overcurrent rating must also be sufficient to handle the normal and expected operating currents. The OEM can obtain devices that look like circuit breakers, but have no overcurrent function, and are used only as switches or disconnects. These molded case switches, when they are used, must be accompanied by some form of overcurrent protection for the circuit.

In many cases, circuit breakers are more compact than equivalent fused safety switches. Like other devices used as disconnects, circuit breakers must be mounted so that the handles in the up position are no higher than six and one-half feet above the floor.

Current Limiting

There are no listed, DC-rated circuit breakers that are considered to be current limiting by US standards. There are some breakers on the market that are marketed as current limiting but they have been tested only to European standards and should not be used for current limiting in DC circuits that must meet NEC requirements. Wherever circuit breakers are used, the interrupt rating must be greater than the short-circuit current at that point. If the circuit breaker interrupt rating is less than the short-circuit current at the point where it is used, a current-limiting fuse should be used to limit the available short-circuit current.

1999 National Electrical Code®

The 1999 NEC® has been published and is available from most electrical equipment distributors in jurisdictions where the 1999 Code will be adopted at the first of the year. The National Fire Protection Association (see Access) also sells the NEC and will have the 1999 NEC Handbook® available by the end of the year. The next Code Corner will summarize the changes that appear in Article 690 in the 1999 NEC.

Questions or Comments?

If you have questions about the NEC or the implementation of PV systems following the requirements of the NEC, feel free to call, fax, email, or write me at the location below. Sandia National Laboratories sponsors my activities in this area as a support function to the PV Industry. This work was supported by the United States Department of Energy under Contract DE-AC04-94AL8500. Sandia is a multi-program laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy.

Access

Author: John C. Wiles, Southwest Technology Development Institute, New Mexico State University, Box 30,001/ MSC 3 SOLAR, Las Cruces, NM 88003
505-646-6105 • Fax: 505-646-3841 • jwiles@nmsu.edu

Sandia National Laboratories Sponsor: Ward Bower, Sandia National Laboratories, Division 6218, MS 0753, Albuquerque, NM 87185 • 505-844-5206
wibower@sandia.gov

National Electrical Code® and NEC® are registered trademarks of the National Fire Protection Association. The 1999 NEC and the NEC Handbook are available from the NFPA, 1 Batterymarch Park, Quincy, MA 02269-9101 • 800-344-3555 • 617-770-3000