Arc-fault circuit interrupter

An **Arc Fault Circuit Interrupter** (**AFCI**) is a circuit breaker designed to prevent fires by detecting a non-working (i.e., non-intended/non-useful) electrical arc and disconnecting the power before the arc starts a fire. An AFCI should, but may not always, distinguish between a working arc that may occur in the brushes of a vacuum cleaner, on operation of a light switch, on insertion / removal of a plug into an electrical receptacle, or during the operation of other household devices and a non-working arc that can occur — for example a lamp cord that has a broken conductor in the cord from overuse. Arc faults in a home are one of the leading causes for household fires.[1]

Annually, over 40,000 fires are attributed to home electrical wiring. These fires result in over 350 deaths and over 1,400 injuries each year.[2]

Conventional circuit breakers only respond to overloads and short circuits; so they do not protect against arcing conditions that produce erratic current. An AFCI is selective so that normal arcs do not cause it to trip. The AFCI circuitry continuously monitors the current through the AFCI. AFCIs use unique current sensing circuitry to discriminate between normal and unwanted arcing conditions. Once an unwanted arcing condition is detected, the control circuitry in the AFCI trips the internal contacts, thus de-energizing the circuit and reducing the potential for a fire to occur. An AFCI should not trip during normal arcing conditions, which can occur when a switch is opened or a plug is pulled from a receptacle.[3]

AFCIs resemble a GFCI/RCD (Ground-Fault Circuit Interrupt/Residual-Current Device) in that they both have a test button although it is important to distinguish between the two. GFCIs and RCDs are designed to protect against electrical shock while AFCIs are primarily designed to protect against arcing and/or fire.

Electrical code requirements

Starting with the 1999 version of the National Electrical Code (NEC 70), also called NFPA, in the United States (US) and the 2002 version of the Canadian Electrical Code in Canada (CSA Standard C22.1) the national codes require AFCIs in all circuits that feed outlets in bedrooms of dwelling units. This requirement is typically accomplished by using a kind of circuit-breaker (defined by UL 1699) in the breaker panel that provides combined arc-fault and overcurrent protection. Not all US. jurisdictions have adopted the AFCI requirements of the NEC as written.

The AFCI is intended to prevent fire from arcs. AFCI circuit breakers are designed to meet one of two standards as specified by UL 1699: "branch" type or "combination" type (note: the Canadian Electrical Code uses different terminology but similar technical requirements). A branch type AFCI trips on 75 amperes of arcing current from the line wire to either the neutral or ground wire. A combination type adds series arcing detection to branch type performance. Combination type AFCIs trip on 5 amperes of series arcing.

The advanced electronics inside an AFCI breaker detect sudden bursts of electric current in milliseconds; long before a standard circuit breaker or fuse would trip. A "combination AFCI breaker" will provide protection against Parallel arcing (line to neutral), Series arcing (a loose, broken, or otherwise high resistance segment in a single line), Ground arcing (from line, or neutral, to ground), Overload protection (for resistance loads such as heaters; inductive loads such as motors may require additional overload protection) and from Short circuit protection.

In 2002 the NEC removed the word "receptacle" leaving "outlets"; in effect adding lights within dwelling bedrooms to the requirement [debated interpretation]. The 2005 code made it more clear that all outlets must be protected despite discussion in the code-making panel about excluding bedroom smoke detectors from the requirement. "Outlets" is defined in "Article 100 Definitions" of the NEC as "A point on the wiring system where current is taken to supply utilization equipment" and this includes receptacles, light fixtures and smoke alarms, amongst other things.

As of January 2008 only "combination type" AFCIs will meet the NEC requirement. The 2008 NEC requires the installation of combination-type AFCIs in all 15 and 20 ampere residential circuits with the exception of laundries,

kitchens, bathrooms, garages and unfinished basements.

Limitations

AFCIs are designed to protect against fires caused by electrical arcing faults. However they provide no specific protection against "glowing" connections, excess current, high line voltages or low line voltages.

Glowing connections occur when relatively high electric current exists in a relatively large resistance object. Heat comes from power dissipation. Power (in watts, W) equals the current (in amperes, A) squared, multiplied by the resistance (in ohms, symbol Ω). For example a 60 watt lamp operating on a 120 V circuit draws 1/2 ampere of current. A 1,800 watt space heater on a 120 V circuit draws up to 15 amperes. If a bad wiring junction in a circuit has a resistance of 1 ohm, then a 60 W lamp will cause it to dissipate 0.25 watt of power (0.5 A * 0.5 A * 1 Ω). In contrast a 1,800 W heater could theoretically cause the bad wiring junction to dissipate 169 watts (13 A * 13 A * 1 Ω). Note that the current is less than 15 A because of the combined resistance of the heater plus the bad wiring junction. This energy, when dissipated in a small junction area, can generate temperatures above 1000 degrees Celsius and can ignite most flammable materials.

Bad wiring junctions can occur in utilization equipment, cords or in-situ wiring and especially in a defective switch, socket, plug, wiring connection and even at the circuit breaker or fuse panels. Terminal screws loosened by vibration, improper tightening or other causes offer increased resistance to the current, with consequent heating and potential thermal creep, see "Coefficient of expansion" in aluminium wire, which will cause the termination to loosen further and exacerbate the heating effect. In North America, high resistance junctions are sometimes observed at the terminations of aluminum wire circuits, where oxidation has caused increased resistance, resulting in thermal creep. No technology located in a circuit breaker or fuse panel could detect a high-resistance wiring fault as no measurable characteristic exists that differentiates a glow fault from normal branch circuit operation. Power Fault Circuit Interrupters (PFCI) located in receptacles are designed to prevent fires caused by glowing connections in premise wiring or panels. From the receptacle a PFCI can detect the voltage drop when high current exists in a high resistance junction. In a properly designed and maintained circuit substantial voltage drops should never occur. Proper wire terminations inside utilization equipment, such as appliances, and cords prevent high-resistance connections that could lead to fires.

Excess current can heat entire lengths of wire. Thermal circuit breakers are designed to protect against excess current through the permanent circuit wiring. However excess current through the smaller wires in equipment can exist at levels below the trip thresholds of a circuit breaker. Overload fault circuit interrupters (OFCI) are designed to protect against excess current drawn by utilization equipment. OFCIs must be located within receptacles. Both thermal circuit breakers and OFCIs are required to prevent fire ignition from excess current.

High line-voltage creates excess power and heat in utilization devices such as heaters, light bulbs, appliances, motors and other electronics. In extreme cases, this heat can ignite fires. One common source of high line voltage occurs from a 'neutral' path opening within a multi-wire branch circuit. A three-conductor cable supplying two 120V circuits using two ungrounded conductors ('hot legs') at 240V to each other, and one grounded conductor ('neutral') at 120V to each 'hot', may deliver 240V to connected 120V-rated loads if the ungrounded conductor is opened because of a failed connection or worker error. When the grounded conductor breaks or opens, the utilization equipment voltage can almost double to over 200 V with large leg-to-leg load imbalances. This extreme situation can result in almost four times the normal power and heat under load. During such overheating, some utilization equipment can reach self-ignition temperature in less than 10 minutes. Power fault circuit interrupters (PFCIs) are designed to prevent fires caused by excess voltage across loads. Voltage-trip circuit breakers detect excess line voltages but are unable to detect sub-circuit open neutral conditions.

Low line voltage can cause electro-mechanical relays to repeatedly turn off (relay opens) and on (relay closes again). If current is flowing through the load contacts it will cause arcing across the contacts when they open. The arcing can oxidize, pit and melt the contacts. This process can increase the contact resistance, superheat the relay and lead to

fires. Power fault circuit interrupters are designed to prevent fires from low voltage across loads.

Interference with power line networking

AFCIs may interfere with the operation of some power line communication technologies.[4]

External links

- Underwriters Labs summary on UL 1699 standard on AFCIs [5]
- www.AFCIsafety.org – AFCI Educational Web site [6]
- CPSC AFCI Fact Sheet [7]
- AFCIs: Emerging Technology Solutions for Fires Resulting from Electrical Arcing [8] from *IAEI News: The Magazine*
- EFCI / OFCI on Popular Science [9]
- http://www.ul.com/regulators/afci/categories.cfm 6 types of AFCIs are listed by Underwriters Laboratory

References

[1] Witt, Roger, Comment on Proposal Number 2-129, "National Electrical Code Committee Report on Comments", NFPA 70 – A98 ROC, State Farm Insurance Co., p. 106. available at http://ohio.iaei.org/Ohio%20Electrical%20Committee%20Report.pdf

[2] Ault, Singh, and Smith, "1996 Residential Fire Loss Estimates", October 1998, U.S. Consumer Product Safety Commission, Directorate for Epidemiology and Health Sciences.

[3] Source:"Arc Fault Circuit Interrupter (AFCI)FACT SHEET" accessed from http://www.cpsc.gov/CPSCPUB/PUBS/afcifac8.PDF, July 22, 2010

[4] A Work in Progress: Belkin Gigabit Powerline HD available at http://www.smallnetbuilder.com/lanwan/lanwan-reviews/30888-a-work-in-progress-belkin-gigabit-powerline-hd-starter-kit-reviewed?start=4

[5] http://ulstandardsinfonet.ul.com/scopes/1699.html

[6] http://www.AFCIsafety.org

[7] http://www.cpsc.gov/cpscpub/pubs/afcifac8.pdf

[8] http://www.iaei.org/magazine/?p=3915

[9] http://www.popsci.com/scitech/article/2009-06/plugged-smartplugs-are-simple-way-save-energy

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