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PDHengineer.com
5870 Highway 6 North, Suite 310
Houston, TX 77084
Toll Free: 877 500-7145
administrator@PDHengineer.com

Overcurrent Protection

Written by: Rebecca Johnson, PE

What is an overcurrent and why do you need protection?

An overcurrent is a current that exceeds the ampere rating of the conductors (cable), equipment (motors, instruments) or other devices. Overcurrents include short circuits and overloads. They can occur as a result of normal conditions such as motor starting, or abnormal conditions such as a fault.

Overload

An overload is an overcurrent that is confined to normal current paths. One type of overload is when there are too many devices on a circuit. You might notice that the lights dim when your air conditioner comes on, or that a cable or equipment is hotter than normal. An overload may also occur when a single high amperage device is added to a circuit that is already marginally sized for the demand. For example on a single phase circuit, adding an electric space heater rated at 1750 Watts to an already heavily loaded circuit can cause an overload. By comparison, a small appliance, television or 100W light bulb would be much less likely to overload a circuit. Most residential circuits are sized for 20 amps. Using the power formula for single phase loads, Watts = (Volts x Amps), you can approximate the load on a circuit before you plug in a new device.

Short Circuits

Short circuits usually occur when abnormally high currents flow due to the failure of the insulation of the conductors. When the insulation between phases or between phases and ground breaks down, short circuit currents can be expected to flow into the fault. A short circuit is limited only by the capabilities of the distribution system.

Large currents are associated with short circuits which can cause heating, magnetic stress and arcing. The amount of current that is available in a short-circuit is determined by the capacity of the system voltage sources and the impedances of the system, including the fault.

The energy of a fault can be measured by the formula Energy = I^2t. For example, if a short circuit is 10,000 amps (I) for .01 second, I^2t = 1,000,000. A short circuit of 7,500 amps can melt a #8 copper wire in .1 second. Also, arcs at the point of a fault or from mechanical switching, such as a circuit breaker may ignite vapors causing violent explosions.

There are several types of short circuits: a bolted fault, arcing faults and ground faults:

Bolted Fault

A bolted fault is a short circuit of very high magnitude. The magnitude of a bolted fault is greater than that of an arcing fault and is the value used for most fault calculations. The principle effects of a high value short circuit are heating and magnetic stresses that vary as the square of the current.

Magnetic Stress

Magnetic stress is a function of peak current squared (I_p^2). Excessive values of magnetic stress can result in damage to insulation, conductors and components involved in the fault. It can also be extreme enough to burn through raceways and equipment enclosures.

Insulation damage in electrical conductors is usually the result of overload conditions. When an overload condition exists, the temperature builds up between the conductor and the insulation, which can reduce the life of the conductor and result in a short circuit as the insulation fails.

Arcing Fault

An arcing fault results from a gap between two electrodes (such as a loose wire on a terminal block).

Ground Fault

Ground faults normally occur either by accidental contact of an energized conductor with normally grounded metal, or as a result of an insulation failure of an energized conductor. Normal phase overcurrent protective devices provide no protection against low level ground faults.

Overcurrent Protection

The purpose of protective devices is to detect the overcurrents and with proper coordination, to selectively protect equipment and personnel, while minimizing the loss of power on the rest of the system. A power outage can create unsafe conditions and cause economic loss due to lost production (both from equipment and people). Coordination of a system involves selecting the proper protective device so that the device closest to the fault trips first to isolate the fault. Each protective device up stream of the one closest to the fault serves as a backup to help isolate the fault should the fault condition persist. Ideally, every protective device would be coordinated with the device upstream, but if that is not possible, then the lack of coordination should be limited to the smallest part of the system possible. Coordinated systems are systems whose overcurrent protective devices have been carefully chosen and their time current characteristics coordinated. If possible, only the overcurrent device immediately on the line side of an overcurrent will open for any overload or short circuit condition. The primary purpose of fault current calculations is to determine the fault current at the location of a circuit breaker, fuse or other fault interrupting device in order to select a device adequate for the calculated fault current.

NEC Requirements for Overcurrent Protection

Article 240 of the National Electric code provides the general requirements for overcurrent protection. Parts I through VII are for protective devices not more than 600 volts nominal. Part VIII is for supervised industrial applications operating at less than 600 volts and part IX is for overcurrent protection greater than 600 volts, nominal.

According to the NEC definitions in Article 240.2, coordination is “the proper localization of a fault condition to restrict outages to the equipment affected, accomplished by the choice of selective fault-protective devices.”

According to the NEC definitions in Article 240.2, a current-limiting overcurrent protective device is “a device with a current limiting range. When the device operates within that range, it reduces the current flowing in the faulted circuit to a magnitude substantially less than the current that can be obtained if the device is not installed.”

Types of Overcurrent Protection Devices

There are several types of devices that can be used to protect equipment and people from overcurrents such as fuses and circuit breakers.

Some standard fuse and fixed trip circuit breaker ratings are 15, 20, 25, 50, 100, 150, 200, 225, 250, 300, 400, 600, 800, 1000, 1200, 1600, and 2000 amperes to name a few.

Fuses

Cartridge fuses are one type of fuse. The fuse holders are designed so that it is difficult to put a fuse of any given class into a fuse holder designed for a lower current or higher voltage than the class that the fuse belongs in. Fuse holders for current-limiting fuses shall not permit the insertion of fuses that are not current-limiting. The fuses shall be clearly marked with a label containing the following information:

ampere rating,
voltage rating,
interrupting rating where other than 10,000 amps,
current-limiting, where applicable,
the manufacturer's name or trademark

Cartridge fuses and fuse holders shall be classified according to voltage and amperage ranges. Fuses rated 600 volts, nominal, or less shall be permitted to be used for voltages at or below their ratings.

Circuit Breakers

Circuit breakers shall be capable of being opened and closed manually. They can be operated electrically or pneumatically only if means for manual operation are also provided. They must clearly indicate whether they are open (off) or closed (on). Where circuit breaker handles are operated vertically, the "up" position of the handle shall be the "on" position.

Circuit breakers shall be marked such that their ampere rating is visible after installation, and shall be permitted to be made visible by the removal of a trim or cover. Every circuit breaker having an interrupting rating other than 5000 amperes shall have its interrupting rating shown on the circuit breaker. They shall be marked with a voltage rating not less than the nominal system voltage that is indicative of their capability to interrupt fault currents between phases or phase to ground.

An adjustable trip circuit breaker is a circuit breaker that has an external means for adjusting the current setting (long time pickup setting). The rating of the circuit breaker is the maximum setting possible.

There are 2 classifications and 3 types of circuit breakers used for low voltage circuit protection. The classes are Low Voltage Power Circuit Breaker Class and the Molded Case Circuit Breaker Class. The 3 types of circuit breakers are:

1. Low voltage power circuit breakers – used primarily in draw-out switchgear. They have replaceable contacts and are designed to be maintained in the field.

2. Molded case circuit breakers are primarily used in panelboards and switchboards where they are fix-mounted. Molded case circuit breakers are rated in amperes at a specific ambient temperature. This ampere rating is the continuous current the breaker will carry in the ambient temperature for which it is calibrated in open air. According to the National Electric Code, all overcurrent devices may be loaded to a maximum of 80% of their continuous ampere rating, unless they are specifically listed for 100%.

3. Insulated case circuit breakers. These utilize the characteristics of design from both classes. They are primarily used in fix mounted switchboards.

Location of Overcurrent Protection Devices

In general, overcurrent devices should be readily accessible, not located where they would be exposed to physical damage, not located in the vicinity of easily ignitable material, such as a clothes closet and not located in bathrooms.

To protect them from physical damage, overcurrent devices can be installed in enclosures, cabinets, cutout boxes or equipment assemblies. They can also be installed in panelboards or control boards that are in rooms or enclosures free from dampness, easily ignitable material and accessible only to qualified personnel. Also, the operating handle shall be accessible without opening the door or cover.

Fuses and circuit breakers should be located or shielded so that people will not be burned or otherwise injured by their operation. Handles or levers of circuit breakers and similar parts that may move suddenly in such a way that persons in the vicinity are likely to be injured by being struck by them shall be guarded or isolated.

Data is available for all protective devices to allow for a system to be designed with proper overcurrent protection and coordination. For circuit breakers, time-current curves are available. Different types of circuit breakers have different settings that are available for long and short time delays, as well as ground fault tripping and instantaneous and inverse-time trips. Selection of these settings changes how fast the circuit breaker reacts to a particular overcurrent. Fuses also have time-current curves, but these are not adjustable. There are programs available to assist with proper coordination.

Per section 240.21 of the NEC, location in a circuit for overcurrent protection, a fuse or an overcurrent trip unit of a circuit breaker shall be connected in series with each ungrounded conductor, and shall be located at the point where the conductors receive their supply with exceptions (some are listed below as an example).

A. Branch circuit conductors that meet the requirements of Article 220.19 shall have overcurrent protection sized as required in section 210.20. This means that where a branch circuit supplies continuous (runs all the time) loads, or a combination of continuous and non-continuous (intermittent) loads, the rating of the overcurrent device shall not be less than the non-continuous load plus 125% of the continuous load. Branch circuit conductors shall be protected in accordance with Article 240.4. Flexible cords and fixture wires shall be protected in accordance with Article 240.5. For example, to size overcurrent protection on a branch circuit with 10 Amps of continuous load and 15 amps of non-continuous load, the circuit breaker or fuse should be at least 27.5 amps. (10 x 1.25 + 15 = 27.5). This is not a standard size. The next larger size is 30 amps. The circuit breaker or fuse should be rated 30 amps. The conductors feeding the loads should also be rated for 30 amps.

B. Service Entrance Conductors shall be permitted to be protected by overcurrent devices in accordance with Article 230.91. The overcurrent device shall be an integral part of the service disconnecting means or shall be located immediately adjacent to it. Each ungrounded service conductor shall have overload protection.

C. Motor Feeder and branch circuit conductors shall be permitted to be protected against overloads in accordance with Articles 430.28 and 430.53, respectively. This part specifies overload devices intended to protect motors, motor control apparatus and motor branch circuit conductors against over heating due to overloads and failure to start.

The NEC covers continuous duty motors, greater and less than 1 HP, intermittent duty motors, and motors on general purpose branch circuits.

One of the ways to protect a continuous duty motor greater than 1 HP from an overload is by means of a separate overload device that is responsive to the motor current. This device shall be selected to trip or be rated at no more than the following percent of the motor nameplate full-load current rating: if the motor has a service factor of 1.15 or greater, the device should be sized no more than 125% of the motor nameplate full-load current rating. For a motor rated with a temperature rise 40-degree C or less, the device should be sized no more than 125% of the motor nameplate full-load current rating. For all other motors, the device should be sized no more than 115% of the motor nameplate full-load current rating.

Continuous duty motors that are larger than 1500 HP shall have a protective device having embedded temperature detectors that cause current to the motor to be interrupted when the motor attains a temperature rise greater than marked on the nameplate in an ambient temperature of 40-degrees C

D. Conductors from generator terminals that meet the size requirement in Article 445.13 shall be permitted to be protected against overloads by the generator overload protective device required by 445.12. Part of Article 445.13 states that the ampacity of the conductors from the generator terminals to the first distribution device containing overcurrent protection shall not be less than 115% of the nameplate current rating of the generator. If the generator is rated 800 amps, then the conductors should be sized not less than 920 amps.

Further information is available in the National Electric Code. Other resources include manufacturer's guides for selecting protective devices for the appropriate application.