Article 1.3

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Overcurrent Clearing Times

Abstract

The total clearing time or operating time of an over-current circuit protector is defined as the time duration from overcurrent initiation to complete cessation of current flow. This total operating time is divided into two principal sub-periods: the detection time period and the interruption time period. The detection time period is engineered to be commensurately shorter as levels of overcurrent are higher. It is this period that determines the ability of circuit protectors to coordinate with, or back up, one another. The interruption time period is the "action" period in which the device forcibly opens the path of overcurrent flow.

Overload Detection

Our discussion of the physics of current interruption in the previous article (1.2 The Physics of Circuit Interruption) did not address the question of detection of an over-current state. Before the interruption process is initiated—that is, when the contacts start to open or the injection of mobile carriers into a semiconductor switch is restricted—the circuit protector must first make a trip/no-trip decision. The period of time between the initiation of an overcurrent condition within a circuit and the initiation of interruptive action by the circuit protector is termed the detection period. The different types of circuit protectors detect overcurrents in different ways. Thus, they can have different detection periods for the same overcurrent conditions.

The detection mechanism in a fuse is the melting and the vaporization of a fusible link. In a thermal circuit breaker, dissimilar metals, bonded together along a single surface, expand differently under the direct or indirect resistive heating of the overcurrent. This forces a lateral mechanical movement, perpendicular to the bonded surface, which releases a latched contact separation mechanism. In some types of thermal circuit breakers, the contact mechanism can be formed using the bi-metal material itself. In these devices, the bi-metal arms/ contacts snap open when they absorb sufficient energy from the circuit overcurrent. Another form of thermal circuit breaker utilizes the longitudinal expansion of a hot wire, which carries the overcurrent, to release a contact latch.

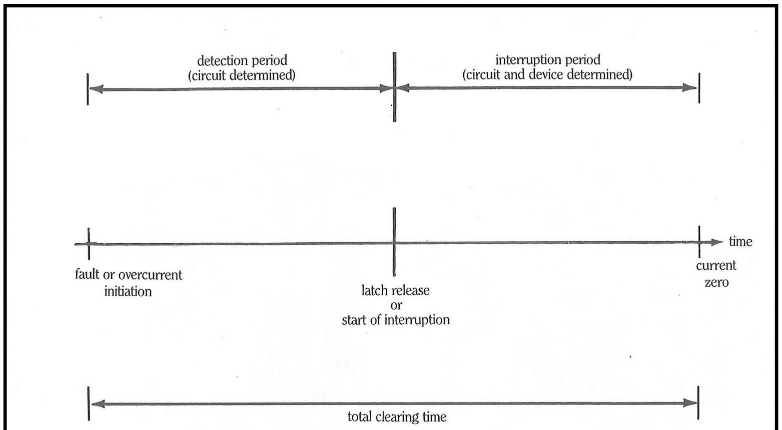
The detection portion of a magnetic circuit breaker is comprised of an electromagnet driven by the circuit current. An overcurrent will develop, within the electromagnet, enough magnetic pull to trip a spring restrained latch that, as in the thermal circuit breaker, allows the spring-loaded contacts to separate. A solid-state switch detects overcurrents electronically, in many cases by simply monitoring the voltage drop across a low-value resistance that carries the circuit current. Obviously, the faster a circuit protector can detect an overcurrent the shorter the detection period. But, in the majority of cases, the fastest possible detection speed is not desirable. The speed of detection must be controllable and inversely matched to the severity of the overcurrent.

Trip Time

As noted in Article 1.1 (Overcurrent Protection and Overcurrent Protectors), series-connected circuit protectors must be coordinated. For a given level of overcurrent, the device nearest to, and upstream from, the cause of the overcurrent must have the fastest response. Devices that are further upstream must have a delayed response, such that the minimum circuit removal principle is adhered to.

When we speak of response, we are referring to the total response time, or total clearing time, of the circuit protector, from the time of the overcurrent initiation to the final current-zero at which interruption is completed. Since it is far easier to engineer the extent of the detection period for a given level of overcurrent than it is to control the extent of the actual current interruption process, the total response time of any circuit protector is, by design, determined principally by the size of, and the time required to detect the overcurrent state.

The interruption period is defined as the length of time between the start of interruptive action— for example, when the contacts start to part— and the final current-zero. The sum of the detection period and the interruption period is then the total clearing time, or total trip time, of the circuit protector. These different time periods are shown in Figure 1.4.



The Time Periods in the Clearing Cycle
of an Overcurrent Protection Device

Figure 1.4

<u>Time Periods in the Clearing Cycle of an Overcurrent Protection Device</u>

In contrast to the detection period, the interruption period cannot be engineered to decrease as the intensity of an overcurrent increases. The interruption period is, however, almost always designed to be as short as possible, since during this period the circuit protector is absorbing energy, due to the overcurrent flowing through the voltage drop across the contacts (or terminals in the case of a solid-state device). If circuit protectors, other than fuses, do not clear the overcurrents fast enough during this period, they can be destroyed due to their own power dissipation. Of course, fuses by design are always destroyed when they interrupt a circuit

In AC circuits, the interruption period will last to either the first forced current-zero or the first natural current-zero at which the switching medium (arc or solid-state material) can reach its non-conducting blocking state. In DC circuits, the current-zero state is always a result of a forcing action by the circuit protector.

There are additional time periods of interest during the current interruption process, such as contact travel time, arc restrike voltage transient time, thermal recovery time, and charge storage time (for solid-state devices). These times are discussed in other articles detailing the actions of particular interruption devices.

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