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Three-cycle vs. five-cycle interrupting time - type 3AK1 circuit breakers

This issue of TechTopics discusses the rated interrupting time for circuit breakers used in metal-clad switchgear. Historically, ANSI/IEEE C37.04 characterized circuit breakers with interrupting time classes, such as three cycle, five cycle and eight cycle. These classes always were rather gross approximations, because they made no allowance for production variations, and also because the rated interrupting time could be exceeded by up to 50 percent under certain conditions. Further, a circuit breaker that was just slightly in excess of one rating class would fall into the next higher (longer) class, giving the impression of a radical change in performance that does not reflect reality. Thus, there is a need to establish some facts pertinent to discussion of three-cycle versus five-cycle circuit breakers.

ANSI standards no longer establish three-cycle and five-cycle classes, nor do they give assumed values for "contact-part time" associated with a particular interrupting time. Instead, rated interrupting time is now stated in terms of absolute time in milliseconds.

ANSI/IEEE C37.04-1999, clause 5.6, defines "rated interrupting time" as "the maximum permissible interval between the energizing of the trip circuit at rated control voltage and rated operating pressure for mechanical operation, and the interruption of the current in the main circuit in all poles."

This definition makes it clear that the rating must consider the "worst-case" conditions for all variables. Thus, it must consider the longest arc duration under the most onerous conditions. Of equal importance, it must consider the longest opening time (including worst-case production variations).

For Siemens type 3AK1 circuit breakers, the average arcing time is approximately 9 ms, which is representative of a very large number of interrupting tests in the short-circuit test laboratory. The longest arcing time is 17 ms during 60 Hz testing. The longest arcing time occurs on tests with maximum offset, asymmetrical current interruptions, during tests designed to explore the outer limits of interrupting performance. In accordance with ANSI/IEEE C37.09-1999, tests must explore both the shortest possible arcing time and the longest possible arcing time. The longest possible arcing time occurs when contact part occurs just prior to a current zero that precedes a minor loop of current. Because the first current zero occurs in a fraction of a millisecond, and the second current zero occurs only a short time later (perhaps 1-2 ms), the interruption does not take place until the current zero that ends the major loop of current.

As stated, the purpose of these tests is to expose the circuit breaker to the worst-conceivable set of circumstances, to establish that under this most extreme condition, the circuit breaker successfully interrupts. In the real world, such interruptions probably never occur. Certainly, they would comprise a very tiny fraction of one percent of short-circuit interruptions.

Answers for infrastructure.

For Siemens type 3AK1 circuit breakers, the relevant data is as follows:

Description	Average time	Range of values
Opening time		
■ First shunt trip coil position	58 ms	50 – 65 ms
■ Second (optional) trip coil position	38 ms	31 – 45 ms
Arcing duration	9 ms	2 – 17 ms
Interrupting time		
■ First shunt trip coil position	67 ms	52 – 82 ms
■ Second (optional) trip coil position	47 ms	33 – 62 ms

The type 3AK1 circuit breaker is available with multiple shunt trip coils. The normal trip coil is referred to as the first shunt trip coil, so-named because it mounts in the first physical position for a trip coil on the circuit breaker. This coil is designed to have relatively low operating currents, and is used for over 95 percent of all applications. For circuit breakers employing this trip coil, if ANSI/IEEE C37.04 based rated interrupting time on average opening time and average arcing duration, Siemens type 3AK1 circuit breakers would have an interrupting time of 67 ms (4.0 cycles). However, ANSI/IEEE C37.04 says the rating has to be based on the worst-case conditions, which means that the type 3AK1 circuit breakers have a real interrupting time of 82 ms (4.9 cycles) with the first shunt trip coil. Actual interrupting times on production circuit breakers could range from 67 ms (4.0 cycles) (50 ms opening time + 17 ms arcing duration) to 82 ms (4.9 cycles) (65 ms opening time + 17 ms arcing duration), using the worst-case arcing duration. Since ANSI/IEEE C37.06 lists the preferred interrupting time as 83 ms (five cycles), the type 3AK1 circuit breaker rating label indicates that the rated interrupting time is 83 ms.

Optionally, the type 3AK1 circuit breaker can be equipped with a second shunt trip coil, where the name indicates that the coil mounts in the second physical trip coil position on the circuit breaker. This trip coil is typically used only when the user wishes to have redundant trip coils. Accordingly, use of the second shunt trip coil is rare. This coil uses sophisticated mechanical energy storage to reduce operating time while maintaining low operating current values. For circuit breakers employing this trip coil, if ANSI/IEEE C37.04 based rated interrupting time on average opening time and average arcing duration, Siemens type 3AK1 circuit breakers would have an interrupting time of 47 ms (2.8 cycles). However, ANSI/IEEE C37.04 says the rating has to be based on the worst-case conditions, which means that the type 3AK1 circuit breakers have a real interrupting time of 62 ms (3.7 cycles) with the second shunt trip coil. Actual interrupting times on production circuit breakers could range from 48 ms (2.9 cycles) (31 ms opening time + 17 ms arcing duration) to 62 ms (3.7 cycles) (45 ms opening time + 17 ms arcing duration), using the worst-case arcing duration.

As indicated earlier, ANSI/IEEE C37.06 shows a preferred interrupting time of 83 ms, and this is the rating shown on the circuit breaker rating label.

What does this mean to a user with respect to application of the circuit breakers? Basically, nothing. The reason for this relates to the way that circuit breakers are tested in the short-circuit test laboratory. When circuit breakers are tested for short-circuit performance, they are tested to a philosophy that is completely REVERSED from the manner in which they are rated. For ratings, the circuit breakers are rated in accordance with the worst-case (longest) times. For testing, actual test parameters are set up based on the worst-case short-circuit conditions, which means the shortest possible times.

What does this mean for the type 3AK1 circuit breaker? Using the data above, the circuit breaker is tested as though it is the fastest circuit breaker (with the shortest opening time). The short-circuit conditions are set up in the short-circuit laboratory to expose the circuit breaker to the conditions that would occur if (for the type 3AK1 circuit breaker) it had an opening time of 31 ms. Therefore, the circuit breaker is tested as though it has a historic interrupting time of 2.9 cycles.

The result is that the type 3AK1 circuit breaker has the interrupting capability of a three-cycle circuit breaker, even though we must rate it as a five-cycle (83 ms) circuit breaker.