

TechTopics No. 93

Capacitor switching performance classes

The requirements for capacitance current switching for circuit breakers have been expanded significantly in the IEEE Standards. Amendments to the basic circuit breaker standard, IEEE C37.04-1999 and the test standard, IEEE C37.09-1999 were approved to modernize the capacitor switching requirements and tests. These amendments are C37.04a-2003 and C37.09a-2005. These amendments harmonize the requirements for capacitance current switching with those of IEC. They also provide more rigorous requirements for demonstrating capacitance current switching capabilities.

The amendments to C37.04 and C37.09 introduce new classifications of circuit breakers, and also a bit of confusion between the two standards. The classifications for capacitance current switching circuit breakers shown in the standards are:

- Class C1: A circuit breaker with low probability of restrike.
- Class C2: A circuit breaker with very low probability of restrike.
- Class C0: A circuit breaker with an unspecified probability of restrike.

C37.04a does not discuss a Class C0 (nor does the application guide, C37.012-2005), whereas C37.09a does. This reflects evolution of thinking on the subject within the standards working groups. As discussed later in this issue, Class C0 is somewhat meaningless, and it is likely that it will be eliminated in the present revision efforts on C37.04 and C37.09. The Class C0 designation was intended to represent the historic “general purpose” circuit breaker that was discussed in earlier standards, for which no capacitance current switching tests were necessary.

With respect to capacitance current switching, restrike performance is the expected probability of restrike during interruption of capacitance current. The concept of the probability of restrike was introduced to recognize that a “restrike-free” circuit breaker is practically impossible, as it would require an infinite number of capacitor switching interruptions to demonstrate that a restrike will never happen.

Restrike performance for classes C2, C1, and C0:

- Class C2: No restrikes occur during the test series. If a single restrike occurs, the entire test series must be repeated with no restrikes on the second set of tests.
- Class C1: Up to one restrike may occur during the test series. If more than one restrike occurs, then the entire test series must be repeated with no more than one restrike on the second set of tests.
- Class C0: If tested for capacitance current switching capability, one restrike per interruption is allowed.

The design of the tests for Class C2 results in a circuit breaker with a likelihood of restrike that is about 10 percent of the likelihood with a Class C1 circuit breaker. A Class C0 circuit breaker, on the other hand, could have a 100 percent likelihood of restrike on each interruption, so this is not a class of circuit breaker that the user would want to apply for capacitor bank switching.

In this issue of TechTopics, the most severe capacitance current switching tests will be focused on - those for isolated bank and/or back-to-back bank switching (BC). Other tests, for line-charging (LC) and cable-charging (CC) applications, are less severe, but have somewhat similar test considerations as for the BC tests. Tests conducted in three-phase laboratory test arrangements, rather than those for single-phase testing, will also be focused on.

The BC1 test series is performed with a current in the range of 10-40 percent of the capacitance current switching rating of the circuit breaker, and requires 24 opening operations (or close-open operations at manufacturer's option). The test series including the following required operations:

- Four opening operations, at various contact part times, distributed approximately at 15 degree intervals, on each polarity.
- Six opening operations, at minimum arcing time, on each polarity.
- Additional opening operations, with contact part time distributed at various times, so as to bring the total number of opening operations to at least 24.

The BC2 test series is performed with a current of at least 100 percent of the capacitance current switching rating of the circuit breaker, and requires 80 close-open operations, with the test series including the following required operations:

- Four close-open operations, at various contact part times, distributed approximately at 15 degree intervals, on each polarity.
- 32 close-open operations, at minimum arcing time, on each polarity.
- Additional close-open operations, with contact part time distributed at various times, so as to bring the total number of opening operations to at least 80.

Thus, for the combined BC1 and BC2 tests, a total of at least 104 tests (three-phase) are required to demonstrate the Class C2 capability. If more tests are required in order to obtain the required number of minimum arcing time tests (12 in BC1, and 64 in BC2), then the total number of tests would exceed 104.

In both the BC1 and BC2 test series, the minimum arcing times shall all occur on the same phase. The minimum arcing time is determined by changing the instant of contact part in increments of 0.3 ms until the minimum arcing time is obtained. The minimum arcing time is that time, for which changing the contact part time by one more increment of 0.3 ms changes the interruption from minimum arcing time to maximum arcing time.

Note in the required tests indicated above, 80 percent of the BC2 tests (50 percent of the BC1 tests) must be tests with minimum arcing time. The standards focus on minimum arcing time as this is the most severe case for the circuit breaker. Minimum arcing time is obtained when the contacts part immediately prior to a current zero. When this happens, the contact gap is very small, but the system voltage is at a maximum, so that the stress on the very small contact gap is most severe, and hence, the likelihood of a restrike following the interruption of the current is much greater. This focus in essence multiplies the "value" of the tests. If random switching were used, only a few tests would take place with the most severe minimum arcing time. By focusing on minimum arcing time, the test series simulates the severity that a much greater number of operations with random contact part times would impose on the circuit breaker.

For Class C2 and Class C1, the description above is greatly simplified. The standard allows additional restrikes during a test series, provided that certain sequences of tests are repeated under conditions established in the standard. Since these situations are confusing, we have chosen to use the simplified requirements shown above. The reader is referred to the text of IEEE C37.09a-2005 if further detail is desired.

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