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QUESTION N° : Q10

420 kV C4-FN circuit breaker – successful series connection of interrupters

In our experience, post-arc (PA) currents do not present a challenge to using C4-FN interrupters in series and they do not complicate their design. This has been demonstrated by developing a double-interrupter circuit breaker based on a 3.5 mol% C4-FN, 10 mol% O_2, and 86.5 mol% CO_2[1] gas mixture that can successfully pass all short-circuit current test duties (at 50 and 60 Hz, including L75 and L90) in accordance with the IEC/IEEE standard, with margin and without line-to-ground capacitance. The double-chamber circuit breaker (CB) is rated 420 kV and 63 kA and is shown in Figure 1. An illustration of a successful short-line fault current interruption test of this C4-FN double chamber circuit breaker is presented in Figure 2.

Figure 1. Double chamber 420 kV and 63 kA C4-FN-mixture-based circuit breaker.

[1] developed at Hitachi Energy

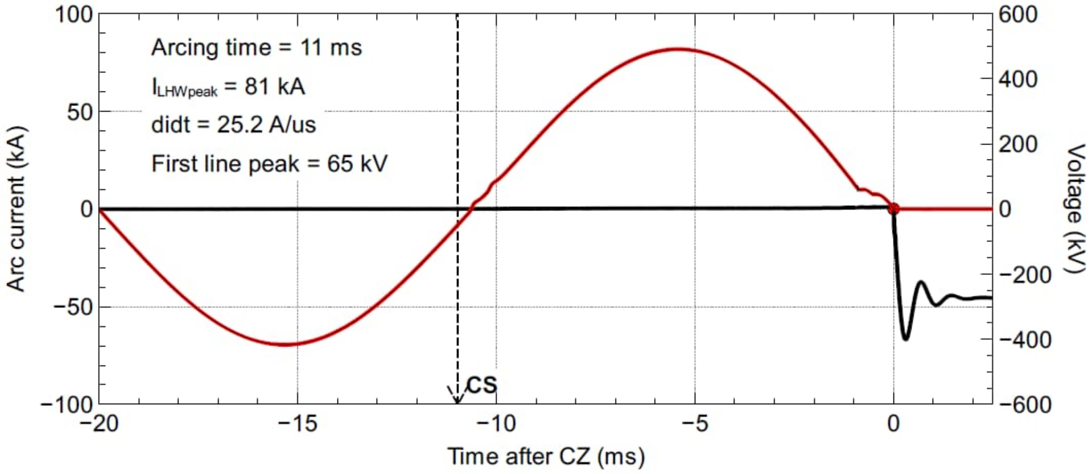


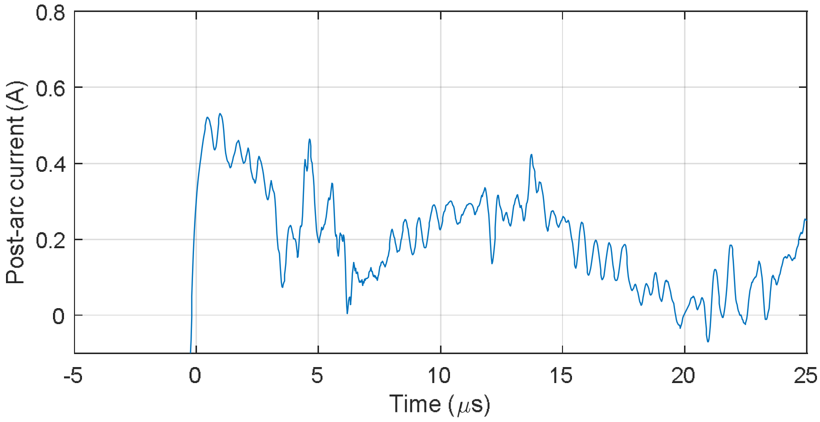
Figure 2. Current and voltage during a short-line fault current interruption test of the C4-FN double chamber circuit breaker shown in Figure 1.

The circuit breaker adopts standard grading capacitors to evenly distribute the voltage between the two interrupters. The reasons why post-arc currents do not pose an issue for this particular circuit breaker, and for well-designed C4-FN-based circuit breakers in general, are explained here.

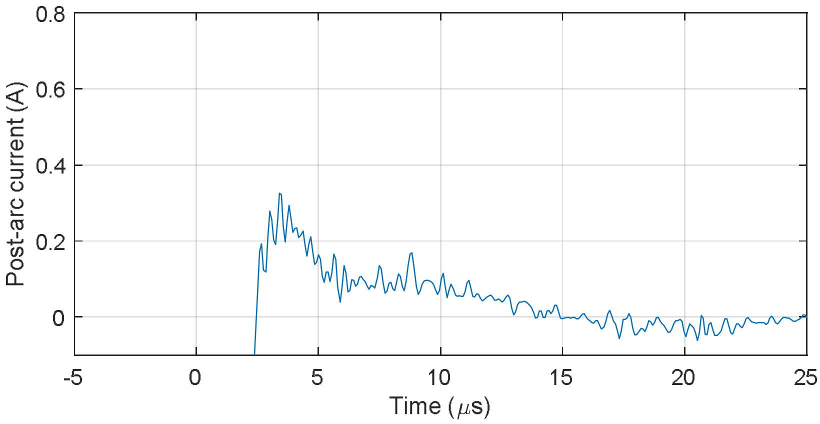
First, vacuum circuit breakers **inherently** have high post-arc currents (around 10 A and with a duration of order 10 µs). Examples are given in [A3_PS2_11068_2022]. Gas circuit breakers generally have lower post-arc currents than vacuum circuit breakers. Second, in gas circuit breakers, the magnitude of the post-arc current depends significantly on the design of the interrupter(s), on the technology used, and, in the end, on the cooling power at current zero.

A good arc zone design has low post-arc currents, and this is true also for CO_2 based circuit breakers. The design and technology implemented in the 420 kV / 63 kA circuit breaker result in very low post-arc currents (< 1 A, duration of about 10-20 µs). Such low post-arc currents can be more accurately measured with a high sensitivity post-arc current system, such as the one developed and tested at Hitachi Energy Research. Figure 3 shows a post-arc current (measured with a commercial system) of the 420 kV C4-FN circuit breaker described here, as well as an example of the more accurate measurements obtained with the internally developed system (used on a 145 kV test circuit breaker). The peak currents are of similar magnitude (the maximum observed post-arc current peaks never exceed 500-600 mA). The internally developed system is less affected by stray coupling and shows less noise and fewer oscillations at the sub-ampere level.

For such low-level post-arc currents (< 1 A and duration of order 10-20 µs), the estimated maximum voltage imbalance, which is evaluated in a similar way to that shown in paper 11068, will not exceed 5 kV. At the same time, the first line peak in a short-line fault test for a rating of 420 kV may be up to 65 kV (in some of the tests performed such values were reached), and the tolerance (+20%) allowed by the standard on the first line peak voltage (nominally 54.9 kV) is, therefore, higher than any voltage imbalance that might result from a post-arc current. Moreover, this imbalance is within the tolerance for the voltage distribution factor for the grading capacitors mounted parallel to the two interrupters.



(a)



(b)

Figure 3. Post-arc current measurements (with a commercial system) of the tested 420 kV C4-FN double chamber circuit breaker (a) and post-arc current measurement of a single chamber 145 kV C4-FN circuit breaker obtained with the high-sensitivity measurement system internally developed at Hitachi Energy Research (b).

In conclusion, for multi-chamber gas circuit breakers based on C4-FN mixtures, a carefully designed arc region enables good current interruption performance. The post-arc currents are kept to a level at which any resulting voltage imbalance between the chambers is small compared to the tolerances allowed by the IEC standard.