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GROUP REF. : A3
PREF. SUBJECT : A3_PS2
QUESTION N° : Q10

QUESTION :

Q10: 11068 reports high post-arc current impacts the series application of vacuum interrupters. Report 10317 observes also in C4-FN gas breakers post-arc current much higher than in SF_6. Can high/variable post-arc current potentially complicate series combination of C4-FN interrupters?

ANSWER:

Post arc current determines the ability to interrupt current. It is occurring in the nanoseconds / microseconds following current zero crossing. Its duration and amplitude highly depend on the interrupting technology used and on the design. It reflects the arc time constant of the interrupting media and the corresponding arc conductance.
Whereas SF_6 post arc current would generally last not more than a couple of microseconds, 11068 and 10317 report larger post arc duration and amplitude for alternatives to SF6.

In the case of C4FN / CO2 mixtures, it is reported post arc current lasting ~10µs and reaching 20-30A on a 245kV 63kA application.
Post arc current measurement are reported lasting ~9µs and 15-25A on series connected vacuum interrupter each being rated 145kV application.
In this last publication, the effect of post arc current variability in vacuum interrupter is studied to check its impact on the possibility to realise series interrupter for multiple break high voltage ratings.
With similar post arc current in each chamber, a voltage distribution between chamber of 55% / 45% is obtained during short circuit current interruption thanks to the addition of grading capacitors. However, a 3ms deviation on the arcing time can result in a drastic modification of the post arc behaviour and result in an unbalanced 70/30% voltage repartition.

Our contribution aims at answering the question by providing data on post arc current measurement for the C4FN / O_2 / CO_2 (technology called g^3 as developed by GE Grid Solutions).

- Comparison between C4FN / O_2 / CO_2 and SF_6

Firstly, it is important to confirm the observation made on post arc current measurement. CO_2 as the background gas mainly drives the breaking (thermal phase) capability of the mixture. Its longer arc time constant (time to recombine from plasma to gas) leads to a weaker arc quenching capability compared to SF6. C4FN and mainly O_2 allow to enhance the interrupting ability of CO_2 which still remains lower compared to SF_6. Design optimization of the arc chamber allows to compensate this relative reduction and recover a similar Short Line Fault performance. However, this longer arc time constant of the gas mixture is still measurable through post arc current measurement. Figure 1 and 2 highlight this difference on a L75 63kA test measurement.
The SF6 example proposed is post-arc current measurement on a 245 kV 63 kA 60 Hz circuit breaker without capacitor (figure 2). The C4FN / O_2 / CO_2 measurements (figure 1) were made on a 420kV 63kA 60hz double break (LIFE GRID project).

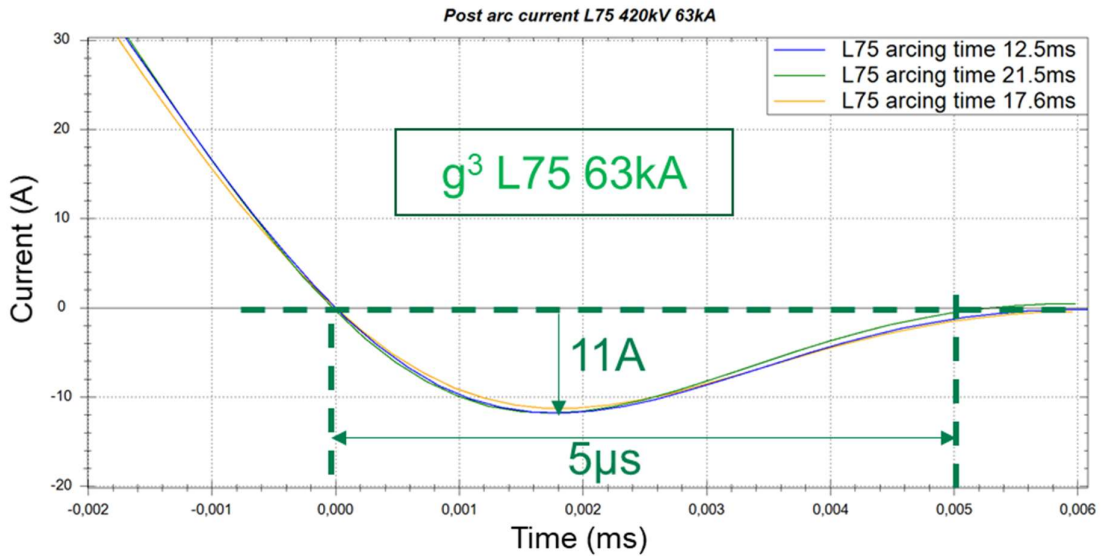

Figure 1:g3 post arc current measurements in L75 63 kA

It is observed in C4FN / O_2 / CO_2 post arc currents lasting 5 µs and reaching 11 A.

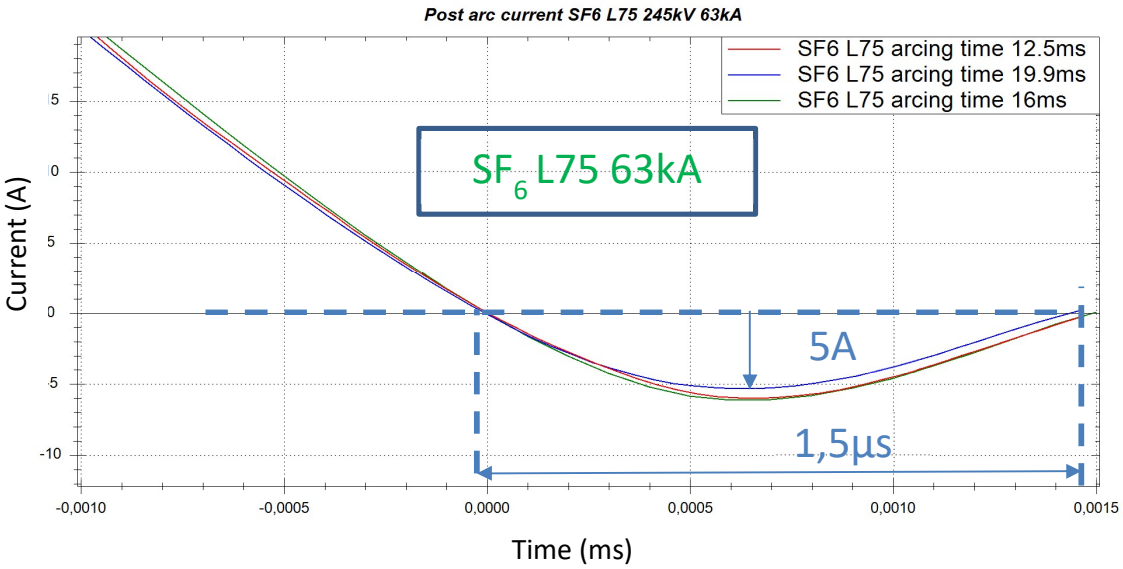

Figure 2:SF_6 post arc current measurements in L75 63 kA

It is observed in SF_6 post arc currents lasting 1.5 µs and reaching 5 A. Minor differences can be observed between the different arcing times.

It is therefore confirmed that larger post arc currents are observed in C4FN / O_2 / CO_2 than in SF_6.

- Post arc current variability in C4FN / O_2 / CO_2

To evaluate the impact of the post arc current on the voltage distribution it is necessary to check its variability across the arcing window (demonstrated arcing time range). To do so, post arc current measurements overlay is proposed for short line fault 75% (figure 3) and 90% (figure 4) test duties. These measurements were performed on the GIS circuit breaker 420 kV 63 kA 50 Hz developed through the LIFE GRID project (cofounded with the European Union).

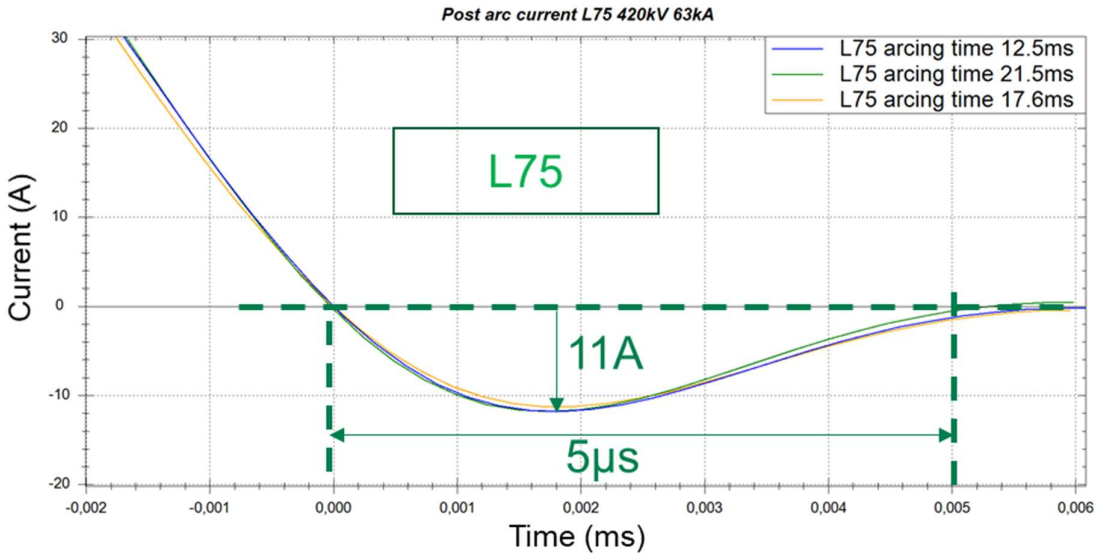

Figure 3: g³post arc current measurements in L75 420 kV 63 kA

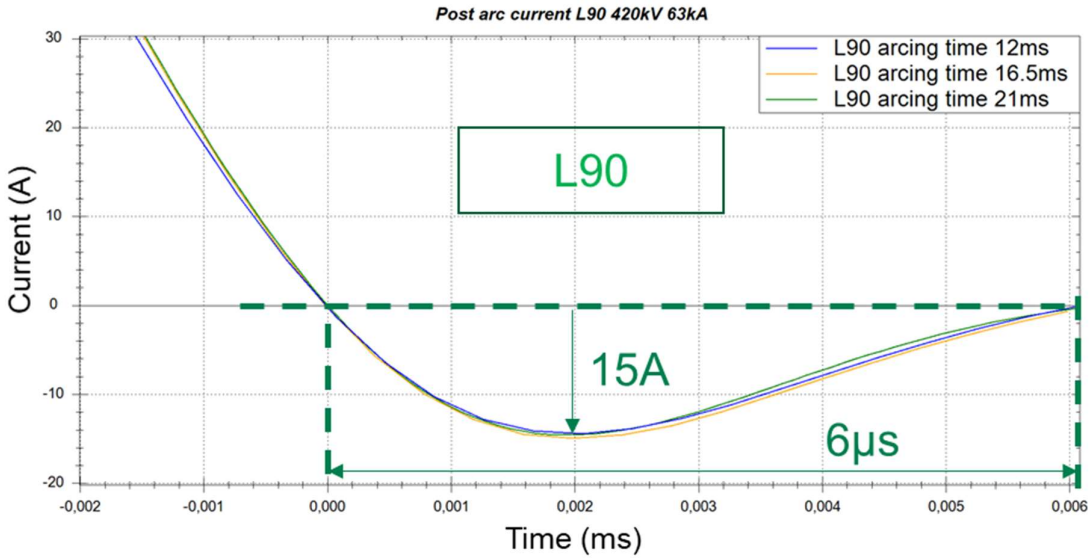

Figure 4: g³post arc current measurements in L90 420 kV 63 kA

Standard arcing times (short, maximum and medium arcing times) are presented ranging from 12 to 21.5ms. These measurements were performed taking into account IEC standard requirements for testing including O, CO and OCO test sequences. Negligible differences can be observed across the arcing window at a given fault current between the 3 arcing times post arcs. Negligible differences are observable for both L75 and L90. As a result, a small offset in the opening times of both interrupting units will not impact the post arc current. Therefore, the voltage distribution benefit offered using grading capacitors will be preserved in C4FN / O_2 / CO_2.

- Conclusion and confirmation with test results on LIFE GRID project 420 kV 63 kA 50 Hz double-break

Despite larger post arc currents, it is possible to reach the highest ratings with C4FN / O_2 / CO_2 as it was the case in SF6. The scalability of this gas mixture towards the highest ratings is demonstrated through the development of a 420 kV 63 kA 50 Hz circuit breaker.

As in SF6, the use of grading capacitors allows an advantageous voltage distribution across series interrupters in C4FN / O_2 / CO_2 double break architectures. This means that half pole testing of C4FN / O_2 / CO_2 Circuit breakers can be performed as allowed in unit testing clause of international standards with a predetermined voltage distribution factor.

These assumptions were confirmed through high power synthetic tests in CERDA laboratories when testing full pole of double break circuit breaker. See picture on figure 5.

Figure 5: Full pole g³ GIS 420 kV 63 kA synthetic testing in high power laboratories in CERDA, France

L90 and T100 were successfully demonstrated as per IEC on the full pole GIS double break rated 420 kV 63 kA 50 Hz k_{pp}=1.5 /1.3.
These positive results confirm that the use of grading capacitors allow the expected advantageous voltage distribution in C4FN / O_2 / CO_2.