



CIGRE-IEC 2016 Colloquium on EHV and UHV  
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# MAKING TEST OF A FAST ACTING EARTHING SWITCH FOR AN EHV GIS

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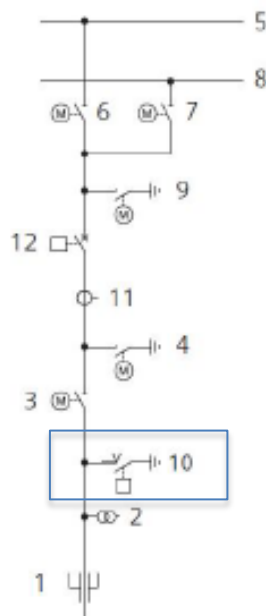
- Introduction
- Determination of the pre-arcing time
- Making test with reduced voltage
  - Test with both reduced voltage and reduced gas pressure
  - Test with ignition wire
  - Influence of electromagnetic force
- Standard requirement discussion
- Conclusion





## Introduction - FAES

- FAES, a common part of GIS
  - Ground sections of the switchgear
  - Interrupt induced currents (electrostatically, electromagnetically)
  - **Make-proof:** close on an energized section of GIS without significant damage to the switch



1. Bushing
2. Voltage transformer
3. Outgoing feeder disconnecter
4. Maintenance earthing switch
5. Busbar 1
6. Busbar disconnector 1
7. Busbar disconnector 2
8. Busbar 2
9. Maintenance earthing switch
10. Fast-acting earthing switch
11. Current transformer
12. Circuit breaker

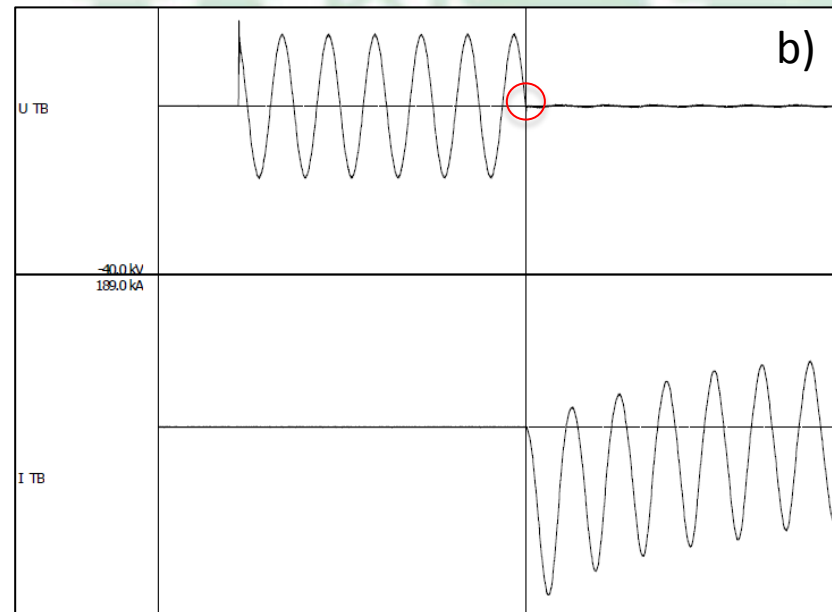
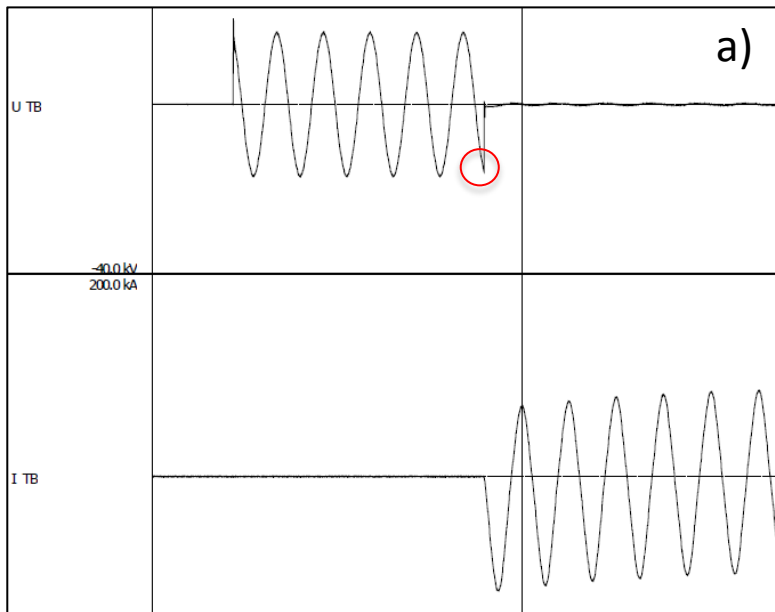
Single line diagram of typical GIS overhead line bay



## Introduction - making test

- Class E1 FAES: make in two extreme cases without any maintenance

	Making point	Pre-arcing	Short-circuit current
1	Peak of voltage wave	Longest	Symmetrical
2	Zero of voltage wave	No	Fully asymmetrical





## Introduction - making test

- Synthetic test circuit with **rated** voltage and rated short circuit current - low voltage level
- Alternative test method with **reduced** voltage - EHV/UHV level
  - 800 kV FAES: 653 kV peak/63 kA rms

	Test procedure	Voltage	Current
1	Determination of the pre-arcing time	Rated	Reduced
2	Making test, with the required pre-arcing time	Reduced	Rated short-circuit making current

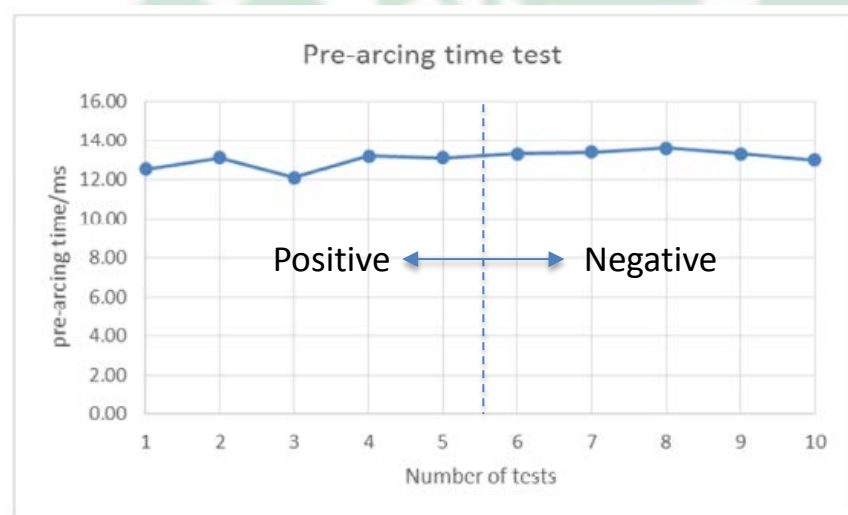
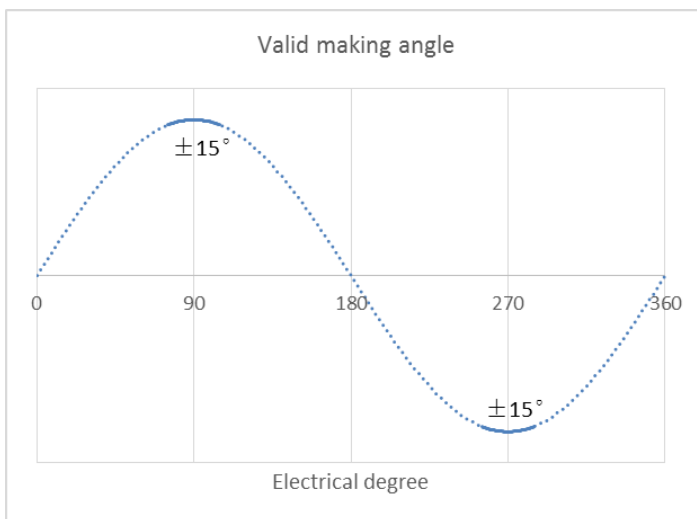


800 kV FAES assembled for making test



## Determination of the pre-arcing time

- Low current → slight ablation on contacts
- Valid making angle for AC voltage:  $\pm 15^\circ$  around voltage peak
- Required pre-arcing time in making test:
  - Ave. of 10 valid pre-arcing time *plus*  $2\sigma$  (standard deviation)
- Conditioning shots needed to obtain stable pre-arcing time



800 kV FAES Pre-arcing time measurement





## Making test with reduced voltage – reduced gas pressure

- Reduced SF<sub>6</sub> pressure or using gas with lower insulation strength
- Different **arc properties** at low SF<sub>6</sub> pressure



(a) Test at reduced SF<sub>6</sub> pressure



(b) Test at rated SF<sub>6</sub> pressure (ignition wire)

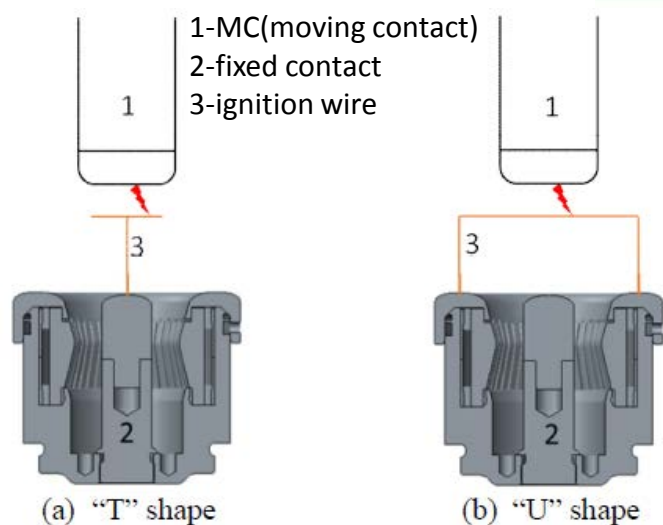
Amount of powder on conductor after making test at different SF<sub>6</sub> pressures

- Unreliable test results, e.g. more severe contact ablation
  - Unstable test results, e.g. unstable making instant  
→ test failure (making angle fall out of the valid range)
- Advantage: no need to be equipped with an ignition wire



## Making test with reduced voltage – ignition wire

- **Reliable setting** of the making angle and the pre-arcing time
  - Pre-arcing distance between MC and the ignition wire, very small
  - Adjust length of ignition wire



- Disadvantage: residue of the ignition wire → deposit on insulator → subsequent condition check could fail





## Making test with reduced voltage – comparison of test method

	Aspect	Reduced gas pressure	Ignition wire
1	Setting of making angle and pre-arcing time	- Unstable	+ Reliable
2	Arc properties related to SF <sub>6</sub> pressure	- Low SF <sub>6</sub> pressure, uncertainty	+ Rated SF <sub>6</sub> pressure
3	Ignition wire	+ No need	- Risk of residue deposit on insulator
4	Test circuit	- Synthetic test circuit, two sources	+ Simpler, only one source

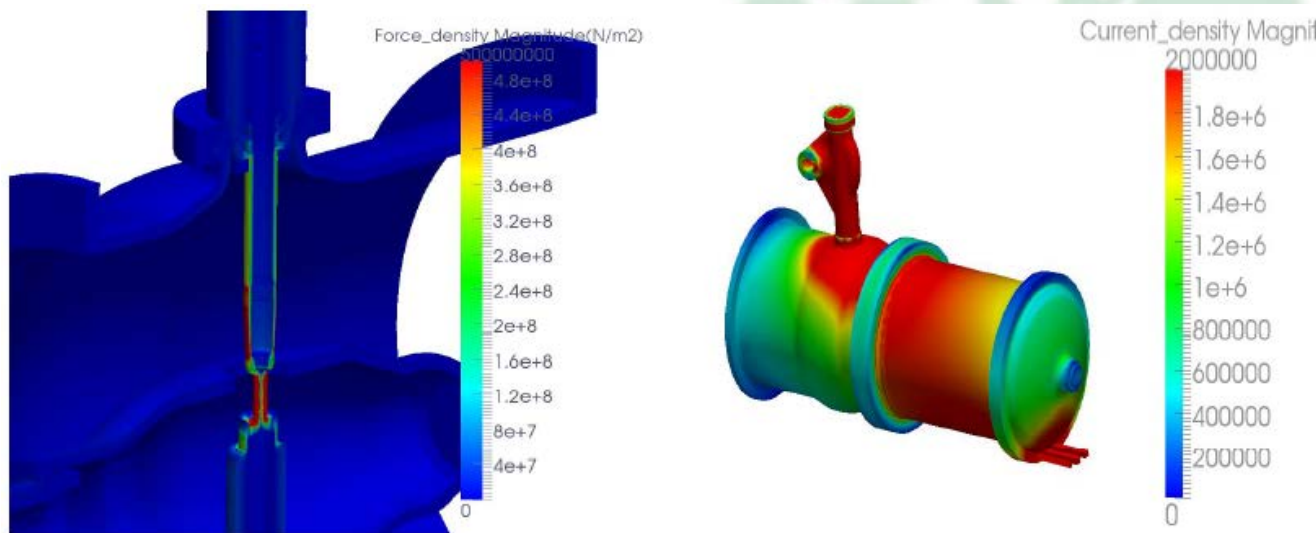
+: advantage.  
-: disadvantage.

- 800 kV FAES passed the type test with ignition wire method



## Making test with reduced voltage – electromagnetic force

- Influence of electromagnetic force
  - Risk that the arc leaves the arcing contacts
  - Reduce closing speed, extend the arcing time
- Numerical simulations for set-up → obtain low electromagnetic force



800 kV FAES electromagnetic force simulation



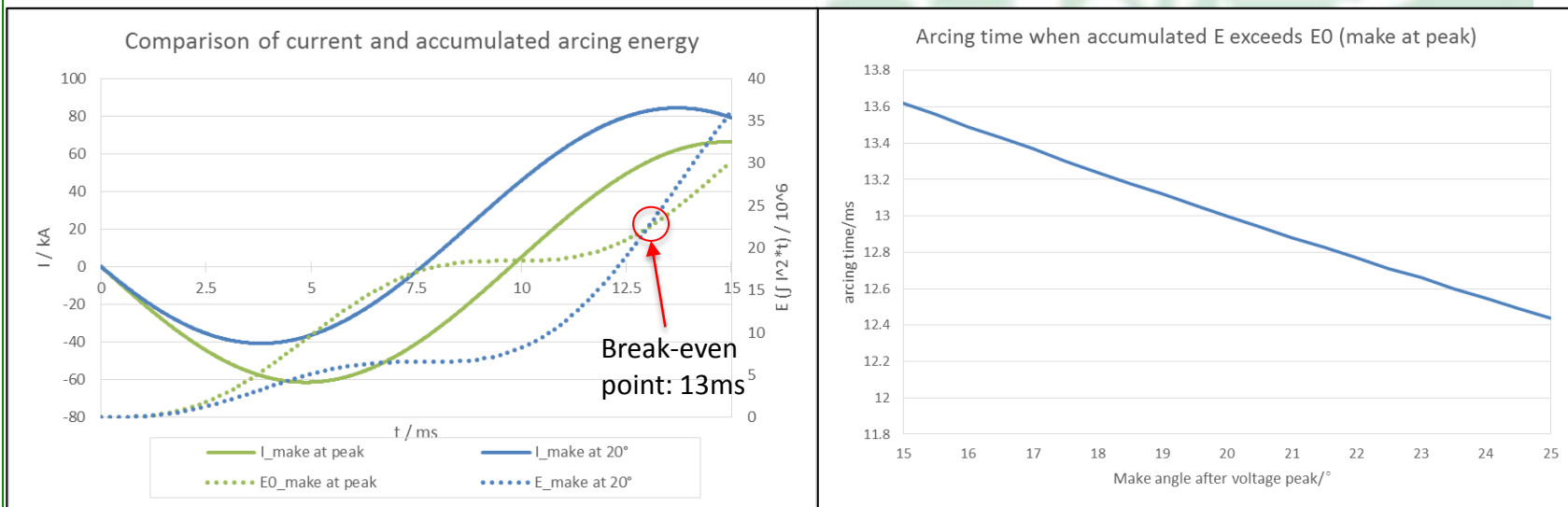
## Standard requirement discussion (IEC 62271-102 Annex G)

- Pre-arcing time (std. criteria) v.s. pre-arcing distance
  - Electromagnetic forces → lower contact speed → longer pre-arcing time → pre-arcing distance may shorter than prospective → test less severe than the worst case service conditions
- Pre-arcing distance: largely unchanged, more accurate
- Pre-arcing time: may be changed by variations in closing speed and electromagnetic forces



## Standard requirement discussion (IEC 62271-102 Annex G)

- Making angle: ( $-40^\circ \dots +15^\circ$ ) around voltage peak: ensure the pre-arcing energy
- The pre-arcing time for EHV /UHV FAES is long enough that the making angle is less important
  - If the required pre-arcing time is longer than 13.6 ms, the accumulated arcing energy is always larger than the prospective energy  $E_0$ .



Energy calculation in terms of  $\int I^2 t$



## Conclusion

- Test laboratories use one of the following methods for EHV/UHV FAES making test with reduced voltage: (a) reduce the SF<sub>6</sub> gas pressure or use a gas with lower insulation strength, e.g. N<sub>2</sub>; (b) test with an ignition wire. After comparison, method (b) is preferred as making angle and pre-arcing time can be set more reliably.
- Numerical simulations could be performed to optimize the test set-up in order to obtain a lower electromagnetic force, thus causing less influence on closing speed and pre-arcing time.
- Practical implications of two critical requirements in IEC standard were reviewed and discussed. (a) Pre-arcing distance is more accurate than pre-arcing time as it is largely unchanged. (b) The making angle requirement (i.e. -40° ...+15° ) is less important for EHV / UHV FAES, since the arcing energy is largely independent of the making instant.





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# Thank you

