High-Power Testing of Circuit Breakers

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KEMA

categories of tests

- development tests
- type-tests (for certification)
- acceptance tests

1 development tests

product development

testing of prototypes

ordered by:	manufacturer
standard:	according clients instructions
laboratory:	mostly at manufacturer's site

2 type tests

provide confidence that a duly indentified product conforms with requirements of a specific standard

ordered by:	manufacturer
standard:	(Inter)national standard
aim:	certification
laboratory:	independent testing institute
	recognised group of manuf. labs

3 acceptance tests

verify that a certain product complies with a specific application specified by the user

ordered by:	user of the equipment
standard:	agreement manufacturer - user
laboratory:	independent testing institute
	recognised group of manuf. labs

test methods

direct testing
- on the grid
- generator fed
- capacitor bank fed

synthetic testing

direct testing

laboratory supplied by power grid

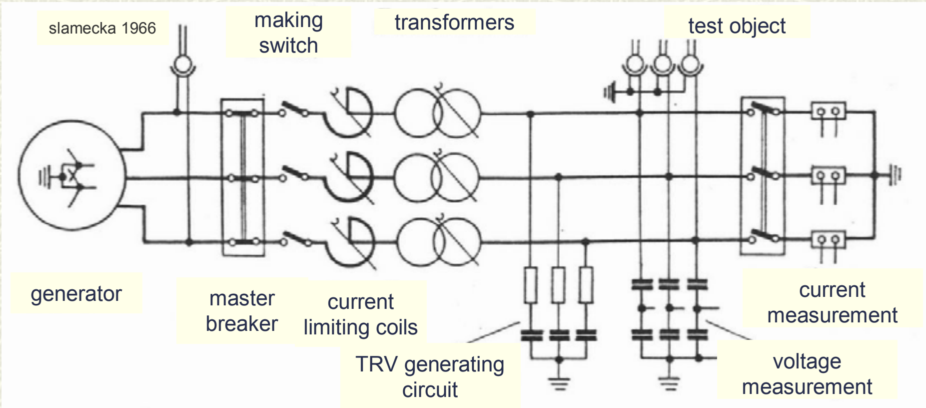
- pros
  - simple
  - cheap
  - representative
  - high-power available
- cons
  - poor flexibility
  - difficult to adjust

direct testing

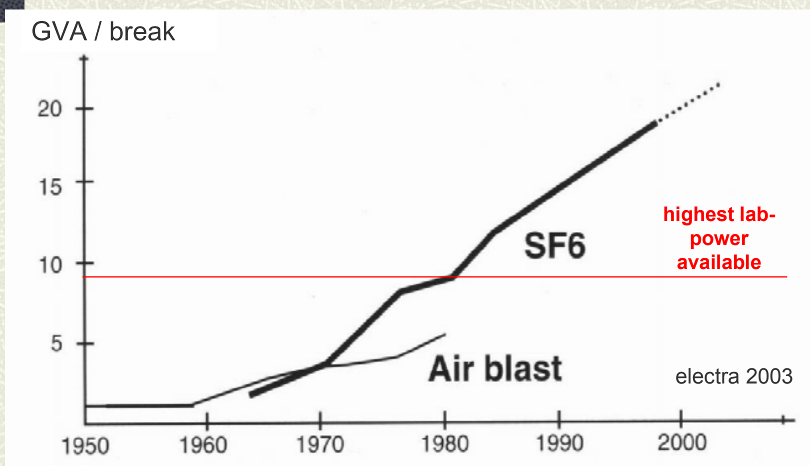
generator supplied laboratory

- pros
  - adjustable
  - flexible
  - no influence on local grid
- con
  - huge investment

direct test lay-out



increase of capacity per break



synthetic testing

example: short-circuit test of a CB (three-phase)
420 kV - 63 kA - 50 Hz
⇒ necessary power: 420 x 63 x √3 = 45830 MVA

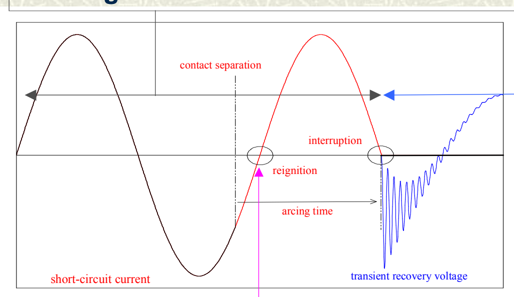
this exceeds any laboratory's direct power
(Max: 8400 MVA)
other methods must be sought:

- single phase test: necessary power 45830/3 = 15277 MVA
- half-pole testing (if possible): 15277/2 = 7638 MVA

this still does not match the power-voltage characteristics of the most powerful labs.

solution

before interruption a sufficiently large power must be available to maintain the full (arc) current at moderate voltage (< 60 kV)
- from generators

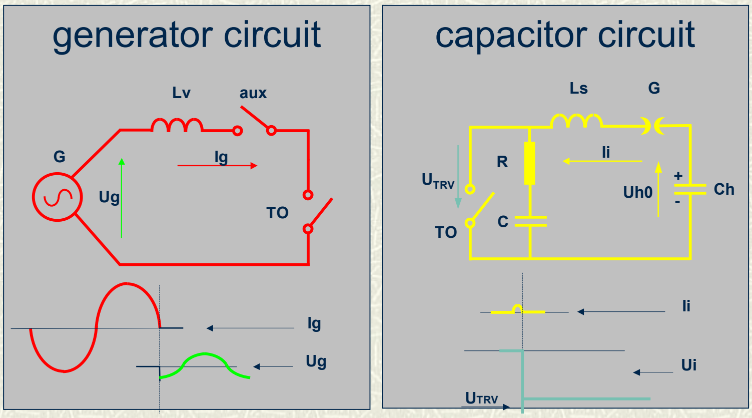


after interruption there is only the need for a sufficiently high voltage
- from precharged capacitor

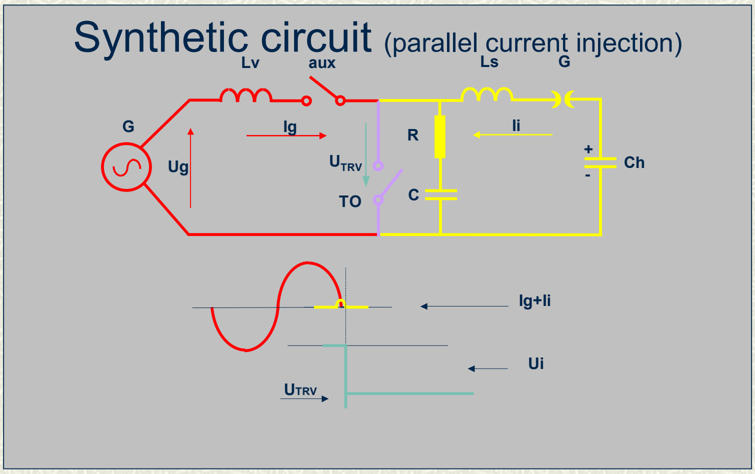
special circuit needed to reignite the arc

⇒ synthetic test

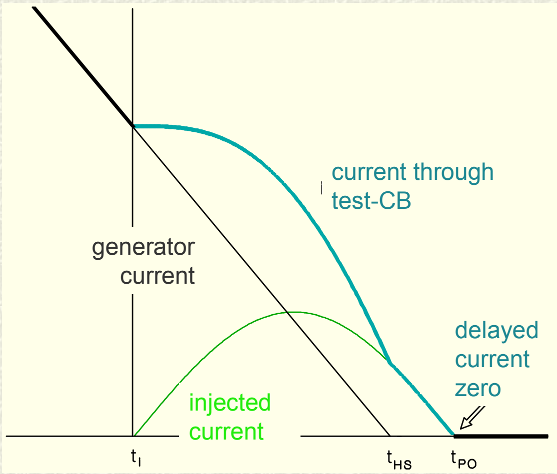
synthetic tests



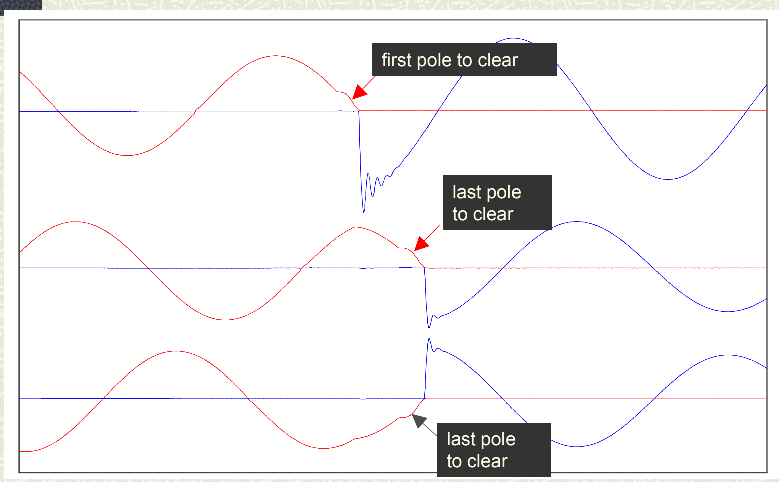
synthetic testing



synthetic testing

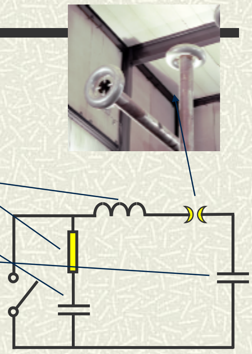


three-phase synthetic testing



synthetic testing in practice

test methods:
current injection
voltage injection

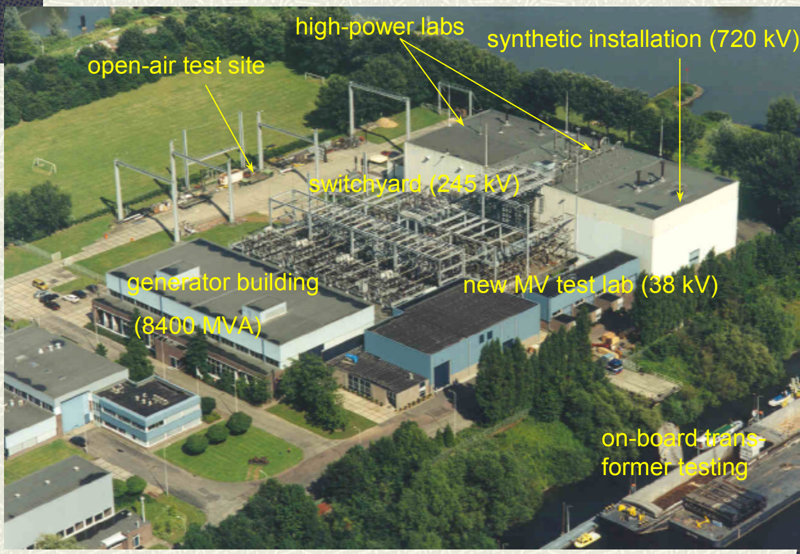


2 x cap. bank
720 kV - 1.7 MJ

ratings to be tested synthetically:
1100 kV - 63 kA - 60 Hz - 1ø (experimentally)
550 kV - 63 kA - 60 Hz - 1ø (routine)
245 kV - 63 kA - 60 Hz - 3ø

high-power test of 1100 kV CB

test station lay-out



grey zones in testing

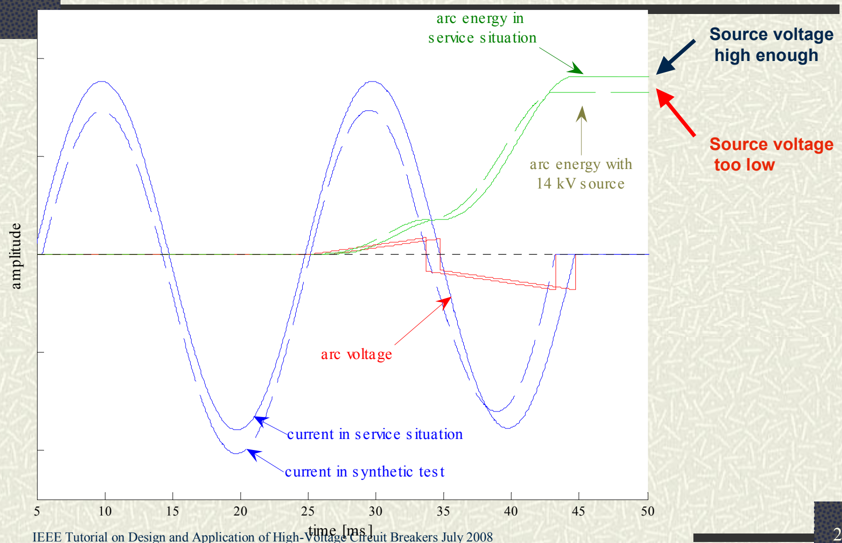
- Test-circuit should represent the service conditions of equipment as much as possible
- Standards prescribe inherent behaviour of test-circuits. Inherent means 'naked' circuit only, without test-object.
- This can be different when a real test-objects interacts with the test-circuit
- Then, the representation must still be realistic.

But: test are possible with test-circuits that show inherently adequate behaviour in accordance with standards, but do not reflect realistic service conditions

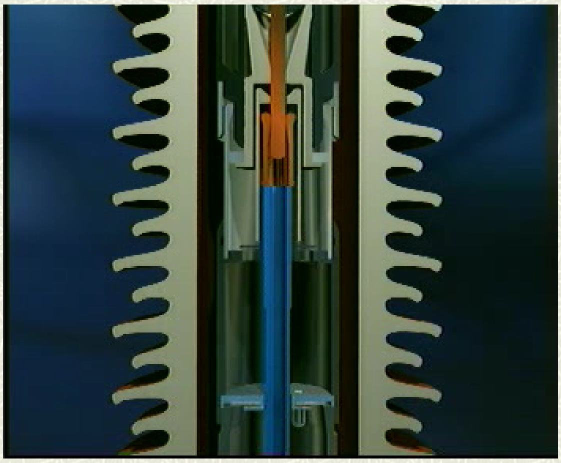
circuit breaker testing

- Many arcs in series: high total arc voltage counteracts source voltage (in 800 kV testing: 8 arcs in series)
- Especially with
  - synthetic testing (auxiliary breakers)
  - when testing breakers with multiple arcing chambers
- Current supply sources must have terminal voltage as high as possible to guarantee sufficient arcing stresses
- Risk is to apply too little energy into the fault current arc.
- Testing is too light in that case

influence of many series arcs on current



Immediately after interruption

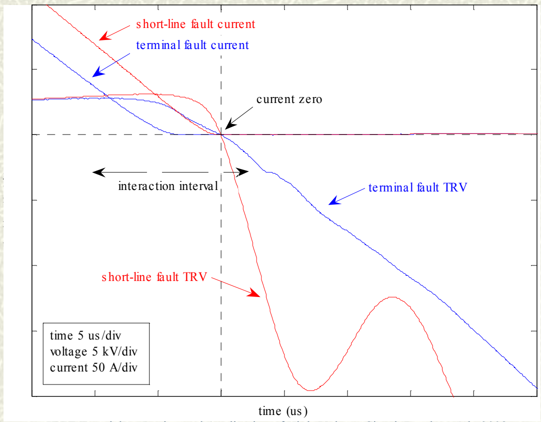


Immediately after interruption hot gases are still in the gap and feel fast rising voltage: thermal stresses

A little later very high voltage is reached across the open gap: dielectric stresses

transient recovery voltage (TRV)

Voltage immediately after current interruption (TRV) is of crucial importance for success or failure



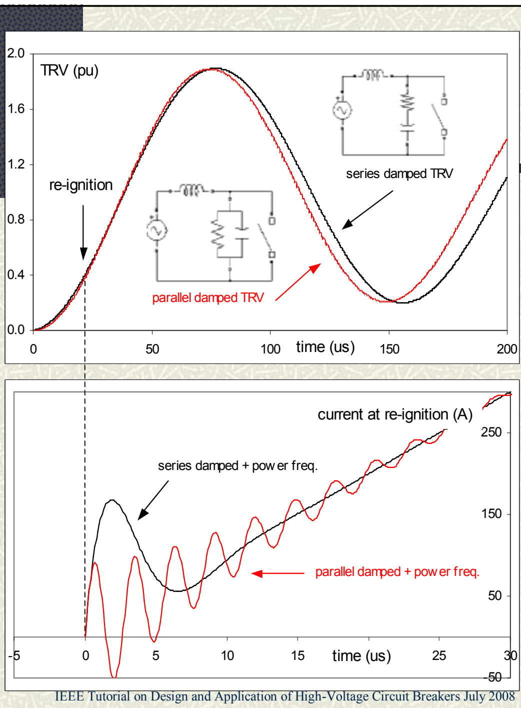
- circuit breaker arc strongly interacts with TRV circuit
- test-circuit topology very important
- microsecond scale

high-frequency effects of circuits

- Seldomly specified in standards
- Will affect result of tests in which high-frequency behaviour is important

- Example: interruption tests with vacuum circuit breaker
- Such a breaker is very good in interruption of current of high-frequency

effect of TRV circuit



Research:
cable systems have oscillatory TRV, so test should be performed with oscillatory TRV

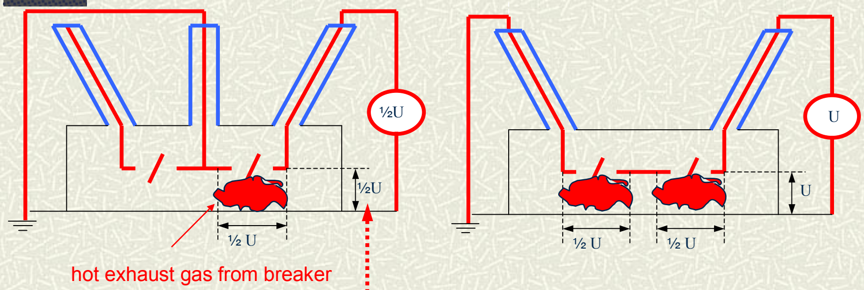
half-pole tests for (U)HV

test voltage application across full-pole
half-pole testing
quarter-pole testing

800 kV breaker

non-full pole ("unit"-) testing should consider uneven voltage distribution across circuit breaker,
<u>especially when there are no grading capacitors</u>
full-pole testing eliminates doubts

half-pole testing of GIS



Half-pole test:
interrupter stress OK
internal stress NOK

Full-pole test:
interrupter stress OK
internal stress OK

ultra high voltage testing

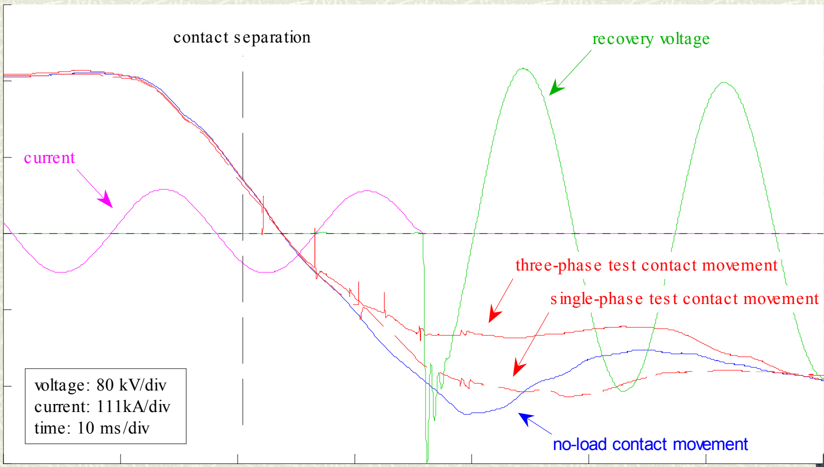
For metal enclosed breakers, half-pole testing does not represent the conditions in service:

- dielectric stresses of half-pole tests equivalent to full-pole conditions
  - between phases
  - between phases and enclosure
- effects of exhaust gases equivalent
- mechanical stresses equivalent
- forces (electrodynamical stresses) equivalent

single phase testing of three-phase circuit breaker

- Often practiced when power of test laboratory is insufficient
- In principle possible, but with care
- Not realistic when common mechanism is controlling contact movement (circuit breaker, earthing switch)
- Beware of three-phase interactions, that single phase circuits fail to represent

three-phase testing of three-phase devices



conclusions

- Standards do not cover everything
- Grey zone exists between allowable but different stresses that make life easier/worse for a breaker
- Test-engineers knowledge and test-lab policies must ensure that realistic testing will prevail:
  - supply sufficient arc energy even for highest voltages
  - have knowledge of arc-circuit interactions
  - being aware of high-frequency pitfalls
  - test three-phase when necessary