IEEE SWITCHGEAR COMMITTEE

THREE-PHASE SHORT-CIRCUIT TESTING OF HIGH-VOLTAGE CIRCUIT-BREAKERS USING SYNTHETIC CIRCUITS

Denis DUFOURNET

Head of CERDA High Power and High Voltage Laboratories in Villeurbanne, France.

Georges MONTILLET

Dead Tank Circuit Breakers Product Manager Development, Charleroi, PA USA.

THREE-PHASE SHORT-CIRCUIT TESTING OF HIGH-VOLTAGE CIRCUIT-BREAKERS USING SYNTHETIC CIRCUITS

WHY THREE-PHASE SHORT-CIRCUIT TESTING OF HIGH-VOLTAGE CIRCUIT-BREAKERS ?

– *Both IEC and ANSI/IEEE define 3-phase faults as the basis for rated short-circuit current.*

– *Reason : 3-phase faults produce the highest stress on circuit-breakers during interruption*

- *higher short-circuit current*
- *higher peak of Transient Recovery Voltage*

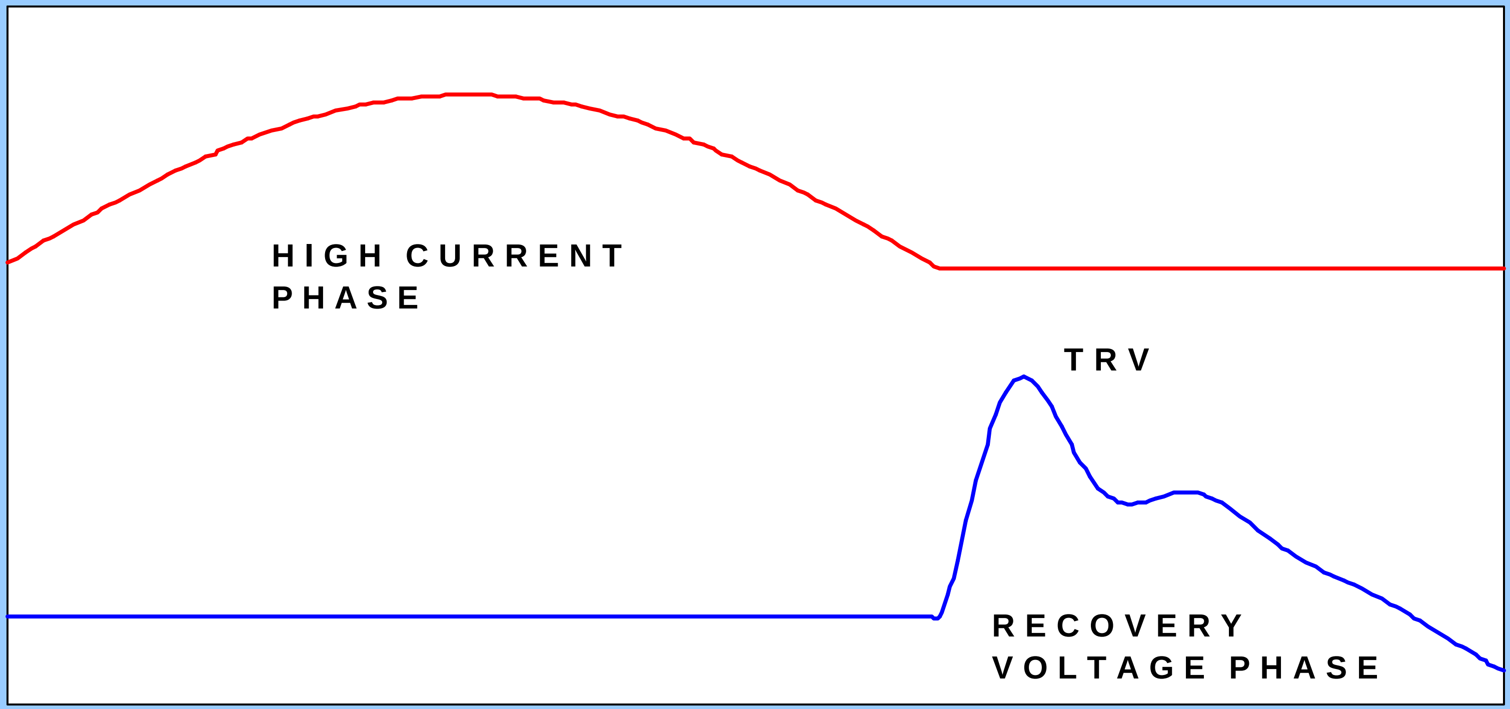
THREE-PHASE SHORT-CIRCUIT TESTING OF HIGH-VOLTAGE CIRCUIT-BREAKERS USING SYNTHETIC CIRCUITS

WHY SYNTHETIC TESTING ?

- HV circuit-breakers have very high short-circuit interrupting capabilities :
  - 245 kV 50/63kA 1 break (21200 / 26700 MVA 3-phase or 10600 / 13350 MVA 1-phase)
  - They cannot be tested with one source of current and voltage (max. short-circuit power = 8000 MVA)
- Solution : synthetic tests with separate sources of current and voltage

THREE-PHASE SHORT-CIRCUIT TESTING OF HIGH-VOLTAGE CIRCUIT-BREAKERS USING SYNTHETIC CIRCUITS

PHASES DURING SHORT-CIRCUIT INTERRUPTION



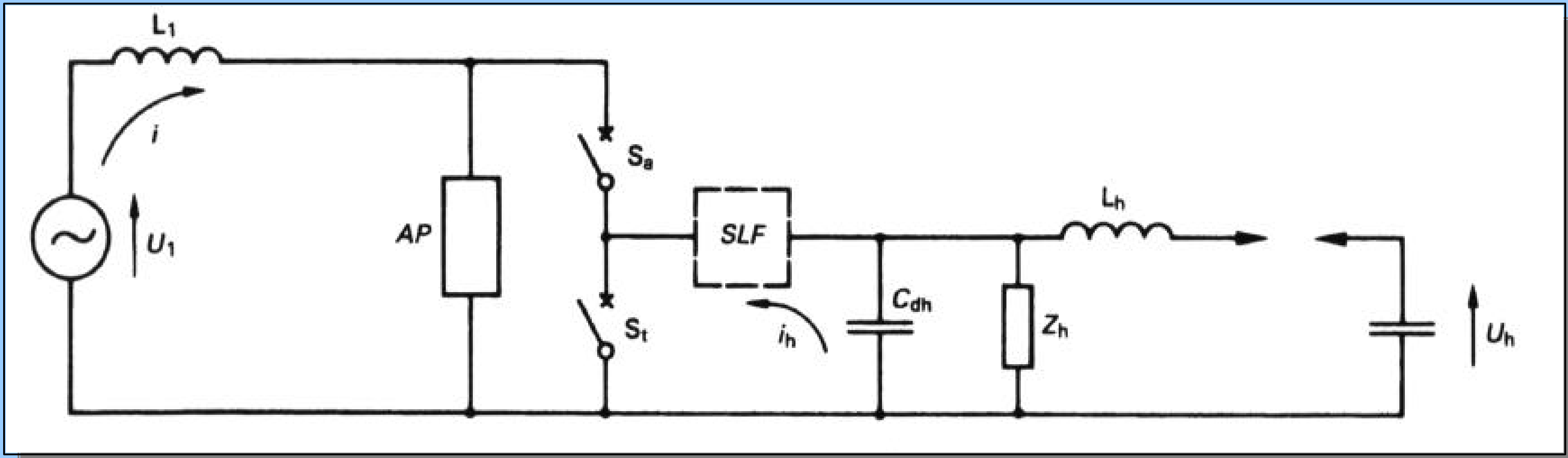
THREE-PHASE SHORT-CIRCUIT TESTING OF HIGH-VOLTAGE CIRCUIT-BREAKERS USING SYNTHETIC CIRCUITS

SYNTHETIC TESTING PRINCIPLE

- High current period : current delivered by generator(s) or power network,
- TRV and Recovery voltage period : voltage delivered by a high-voltage source (capacitor bank),
- 2 schemes used :
  - current injection,
  - voltage injection.

THREE-PHASE SHORT-CIRCUIT TESTING OF HIGH-VOLTAGE CIRCUIT-BREAKERS USING SYNTHETIC CIRCUITS

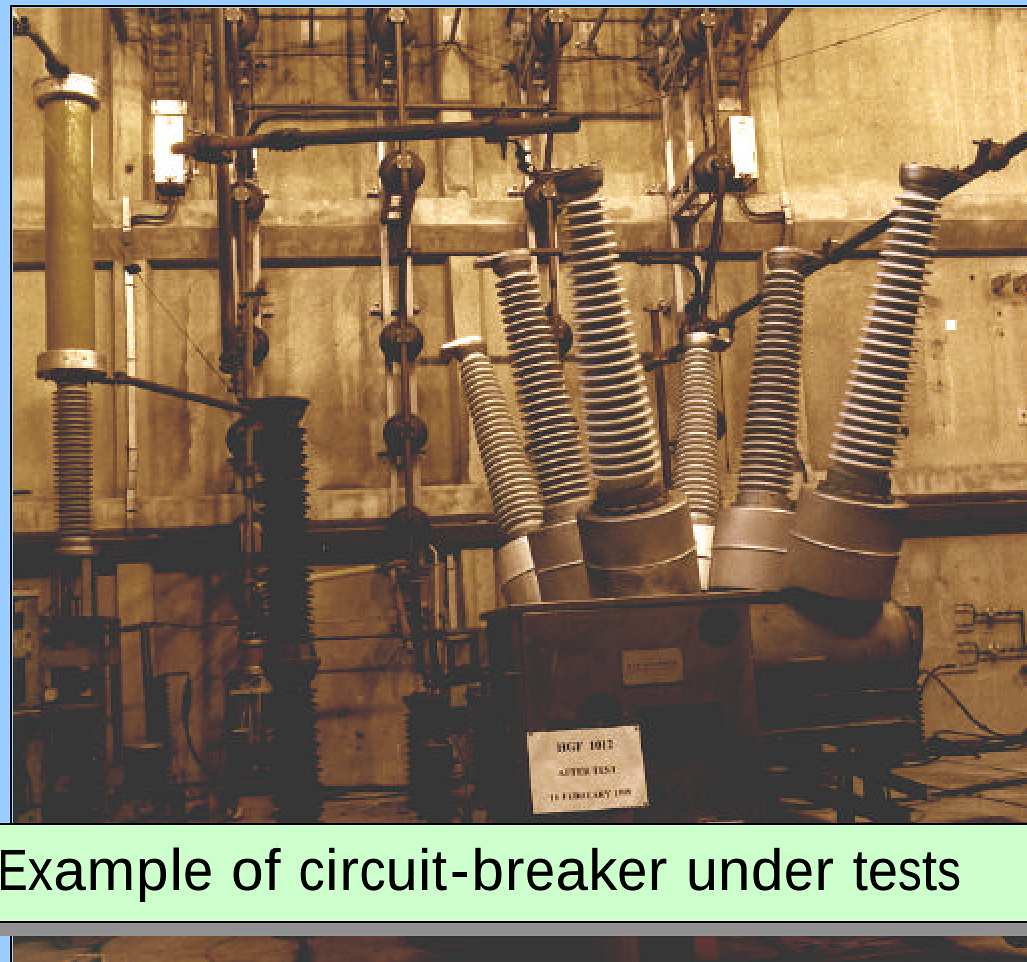
SYNTHETIC TESTS WITH CURRENT INJECTION



IEEE SWITCHGEAR COMMITTEE

Example of synthetic test laboratories to illustrate the testing discussed in this paper.

THREE-PHASE SHORT-CIRCUIT TESTING OF HIGH-VOLTAGE CIRCUIT-BREAKERS USING SYNTHETIC CIRCUITS



SYNTHETIC TESTS : Example of circuit-breaker under tests

THREE-PHASE SHORT-CIRCUIT TESTING OF HIGH-VOLTAGE CIRCUIT-BREAKERS USING SYNTHETIC CIRCUITS

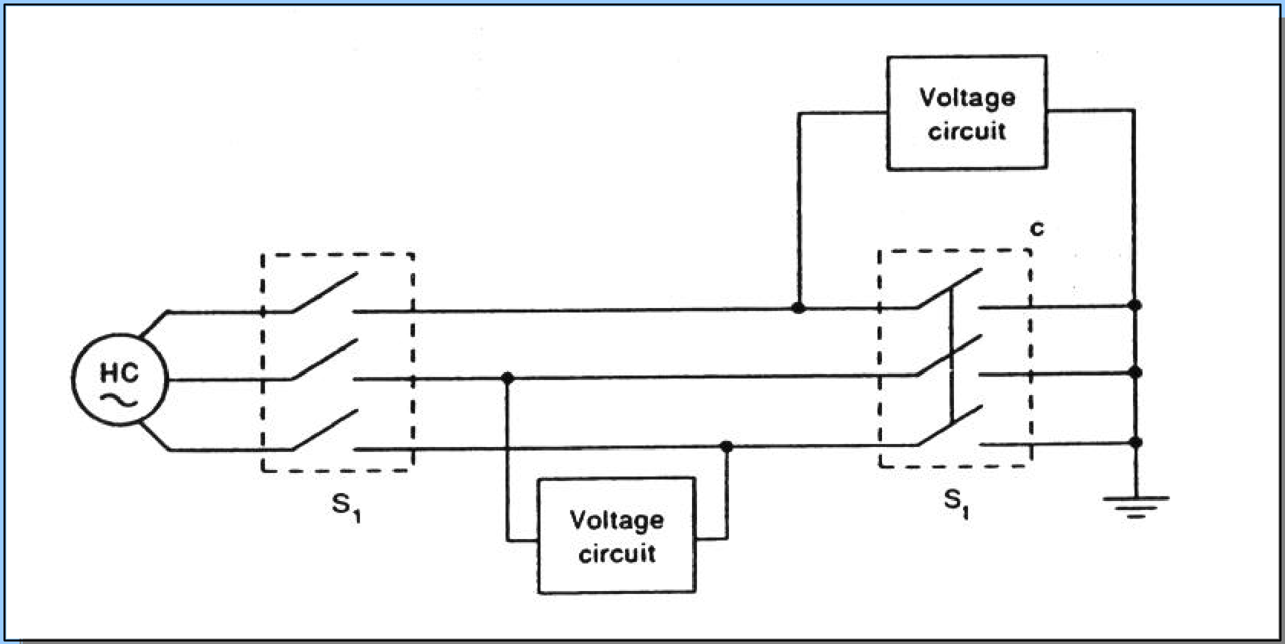
THREE-PHASE SYNTHETIC TESTS PRINCIPLE

2 voltage circuits :

- one to apply the TRV on the first pole to clear.
- one to apply the TRV on second and third pole to clear.

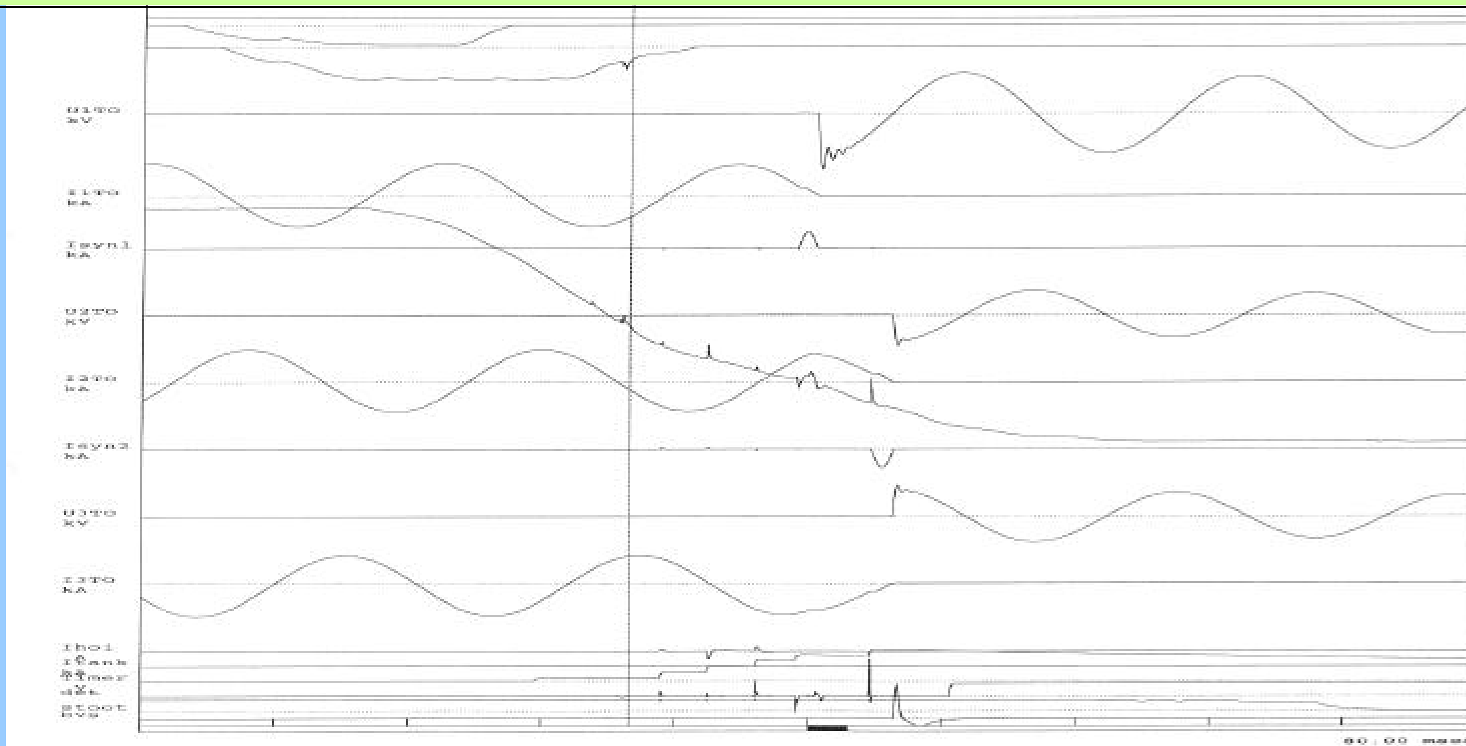
THREE-PHASE SHORT-CIRCUIT TESTING OF HIGH-VOLTAGE CIRCUIT-BREAKERS USING SYNTHETIC CIRCUITS

THREE-PHASE SYNTHETIC TESTS : SCHEME USED



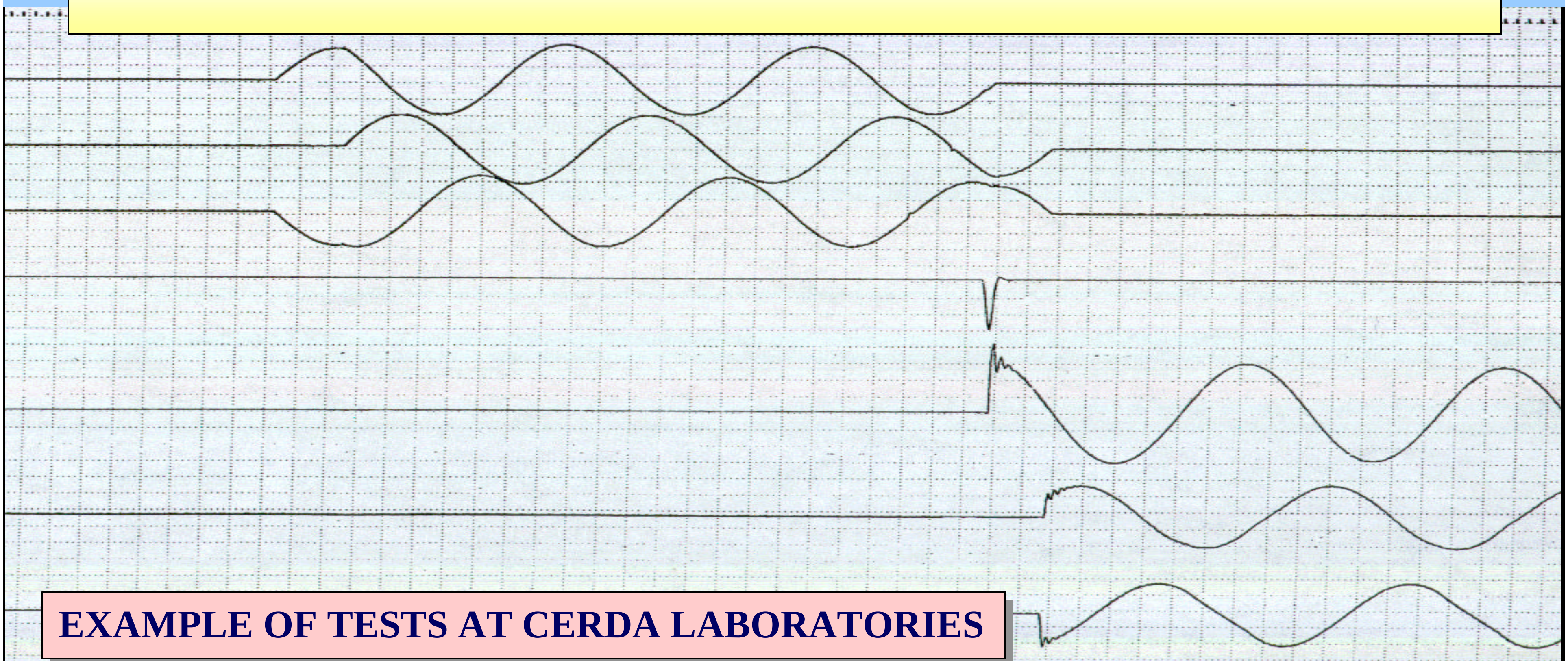
THREE-PHASE SHORT-CIRCUIT TESTING OF HIGH-VOLTAGE CIRCUIT-BREAKERS USING SYNTHETIC CIRCUITS

SYNTHETIC TESTS : example of oscillograph from KEMA



IEEE SWITCHGEAR COMMITTEE

THREE-PHASE SHORT-CIRCUIT TESTING OF HIGH-VOLTAGE CIRCUIT-BREAKERS USING SYNTHETIC CIRCUITS



EXAMPLE OF TESTS AT CERDA LABORATORIES

THREE-PHASE SHORT-CIRCUIT TESTING OF HIGH-VOLTAGE CIRCUIT-BREAKERS USING SYNTHETIC CIRCUITS

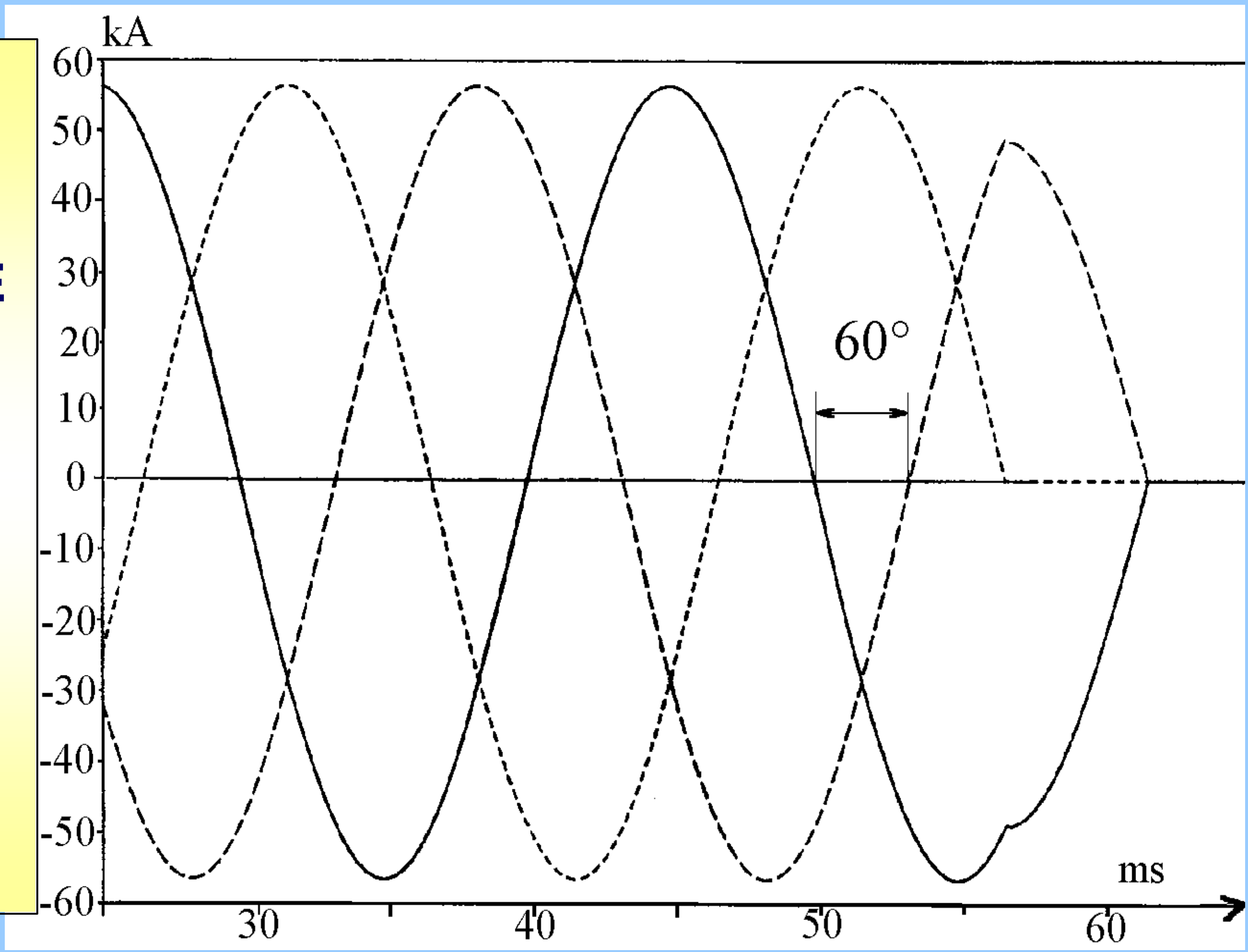
3-PHASE SYNTHETIC TESTS WITH SYMMETRICAL CURRENTS

- current zeros occur in any phase every 60° el.
- range of arcing times for the 1st pole to clear = 60° - E = 42° el.
- 3 interruptions are required with arcing times (1st pole) :

To	(minimum arcing time)
To + 42° el.	(maximum arcing time)
To + 21° el.	(medium arcing time)

THREE-PHASE SHORT-CIRCUIT TESTING OF HIGH-VOLTAGE CIRCUIT-BREAKERS USING SYNTHETIC CIRCUITS

Three-phase symmetrical current interruption



THREE-PHASE SHORT-CIRCUIT TESTING OF HIGH-VOLTAGE CIRCUIT-BREAKERS USING SYNTHETIC CIRCUITS

3-PHASE SYNTHETIC TESTS WITH SYMMETRICAL CURRENTS

Arcing times for the 2nd and 3rd pole to clear will be

- 90° el. longer (ungrounded system)
- 77° el. and 120°el. longer (grounded system)

THREE-PHASE SHORT-CIRCUIT TESTING OF HIGH-VOLTAGE CIRCUIT-BREAKERS USING SYNTHETIC CIRCUITS

3-PHASE SYNTHETIC TESTS WITH ASYMMETRICAL CURRENTS

- No standardized method today in IEC and ANSI/IEEE.

- Our proposal in IEEE Paper accepted for publication in Transactions on Power Delivery.

To define a procedure which:

- test the 2 most severe cases required in standards, and
- require a maximum of 3 tests with asymmetrical currents.

THREE-PHASE SHORT-CIRCUIT TESTING OF HIGH-VOLTAGE CIRCUIT-BREAKERS USING SYNTHETIC CIRCUITS

WHAT ARE THE 2 MOST SEVERE CASES ?

as defined in future ANSI C37-09 & IEC 60056 :

- Case 1 : interruption by the 1st pole to clear after a major loop of current with the required asymmetry,
- Case 2 : interruption by one of the last pole after a major extended loop of current with the required asymmetry.

THREE-PHASE SHORT-CIRCUIT TESTING OF HIGH-VOLTAGE CIRCUIT-BREAKERS USING SYNTHETIC CIRCUITS

PROPOSED METHOD

- defined for grounded neutral networks and ungrounded neutral networks
- covers the most general possible cases
- special cases should be treated separately : a standard is not a catalogue of all possible cases

ALSTOM

THREE-PHASE SHORT-CIRCUIT TESTING OF HIGH-VOLTAGE CIRCUIT-BREAKERS USING SYNTHETIC CIRCUITS

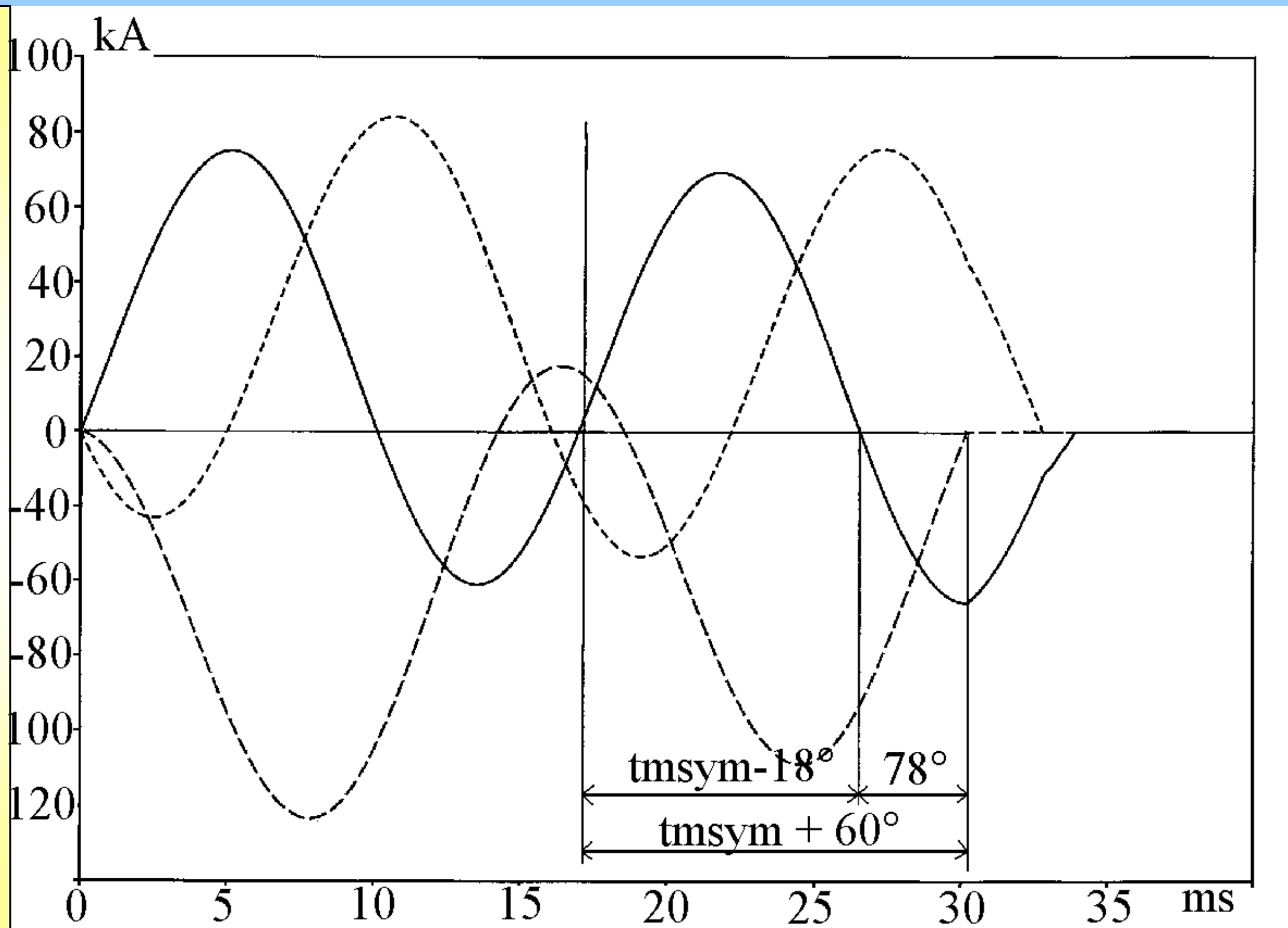
NETWORKS WITH GROUNDED NEUTRAL

Case 1: interruption by the 1st pole to clear after a major loop of current with the required asymmetry
- maximum arcing time for 1st pole to clear :

t1 = t0 (minimum symmetrical) + 60° el. (2 cycle c.b.)

t1 = t0 (minimum symmetrical) + 54° el. (3 cycle c.b.)

Asymmetrical currents during 3-phase short circuit interruption of 40 kA-60 Hz by 2-cycle circuit breaker with kpp=1.3. Interruption of the first pole to clear after a major loop.



THREE-PHASE SHORT-CIRCUIT TESTING OF HIGH-VOLTAGE CIRCUIT-BREAKERS USING SYNTHETIC CIRCUITS

NETWORKS WITH GROUNDED NEUTRAL

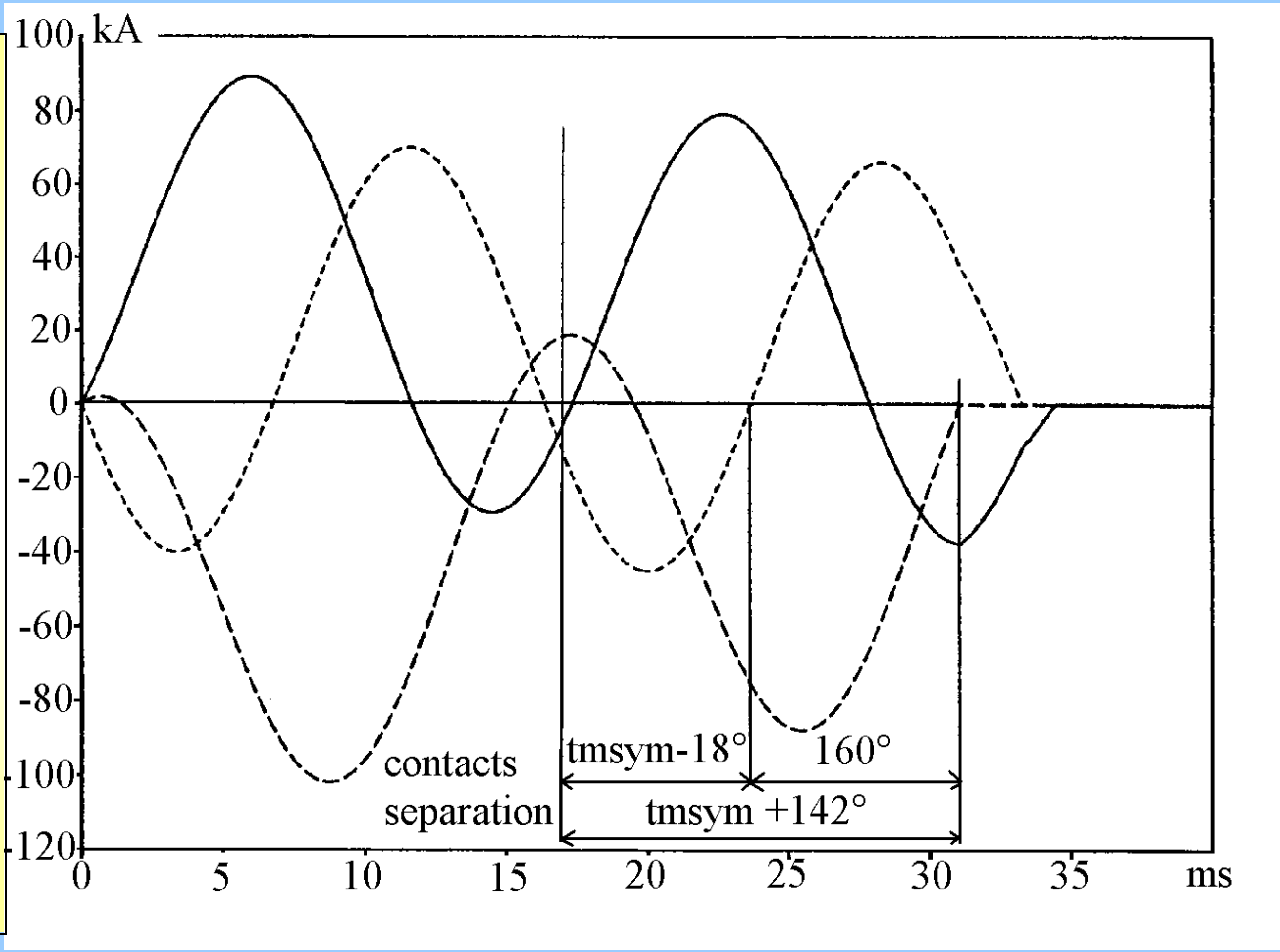
Case 1: interruption by the 1st pole to clear after a major loop of current with the required asymmetry

if the 1st pole cannot interrupt with arcing time t1, another phase must be interrupted with the same conditions (I, TRV) and a longer arcing time :

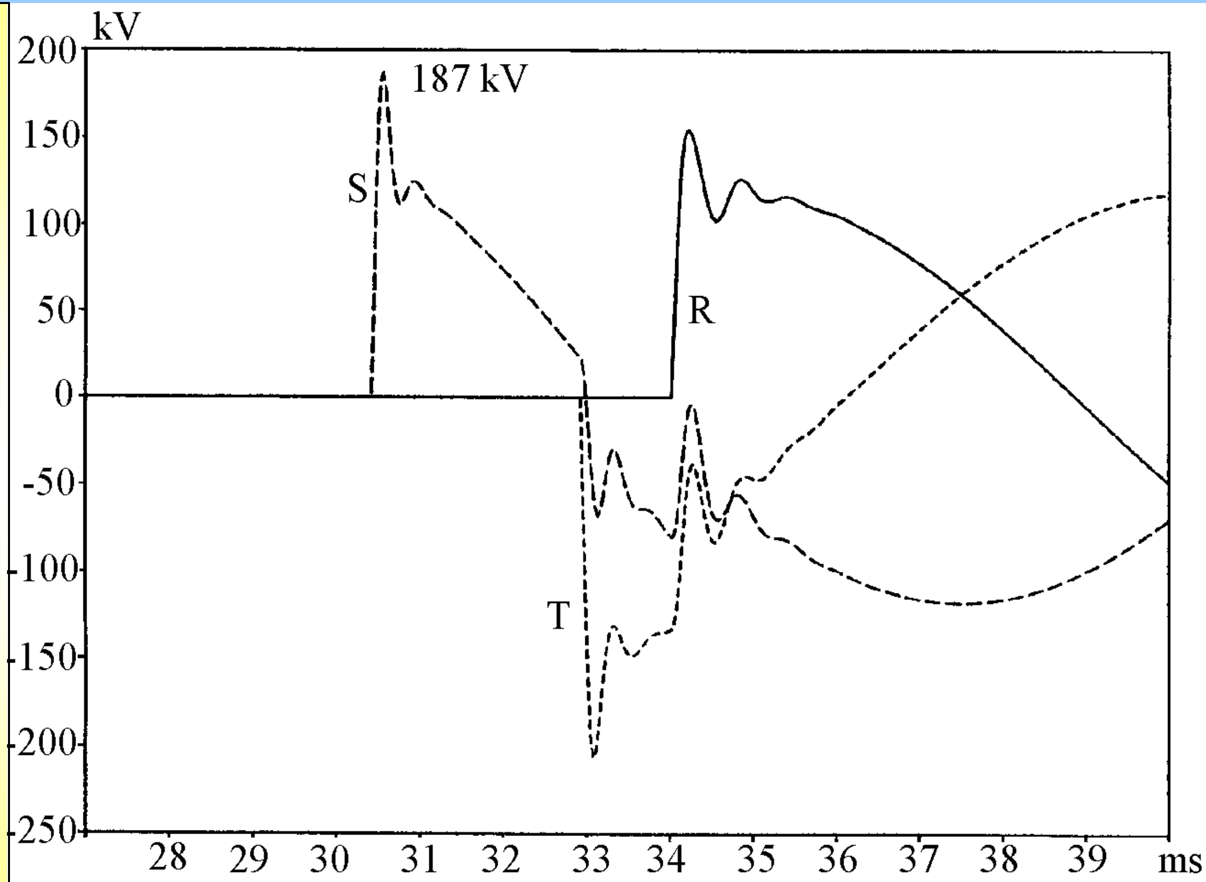
t1 = t0 (minimum symmetrical) + 142° el. (2 cycle c.b.)

t1 = t0 (minimum symmetrical) + 129° el. (3 cycle c.b.)

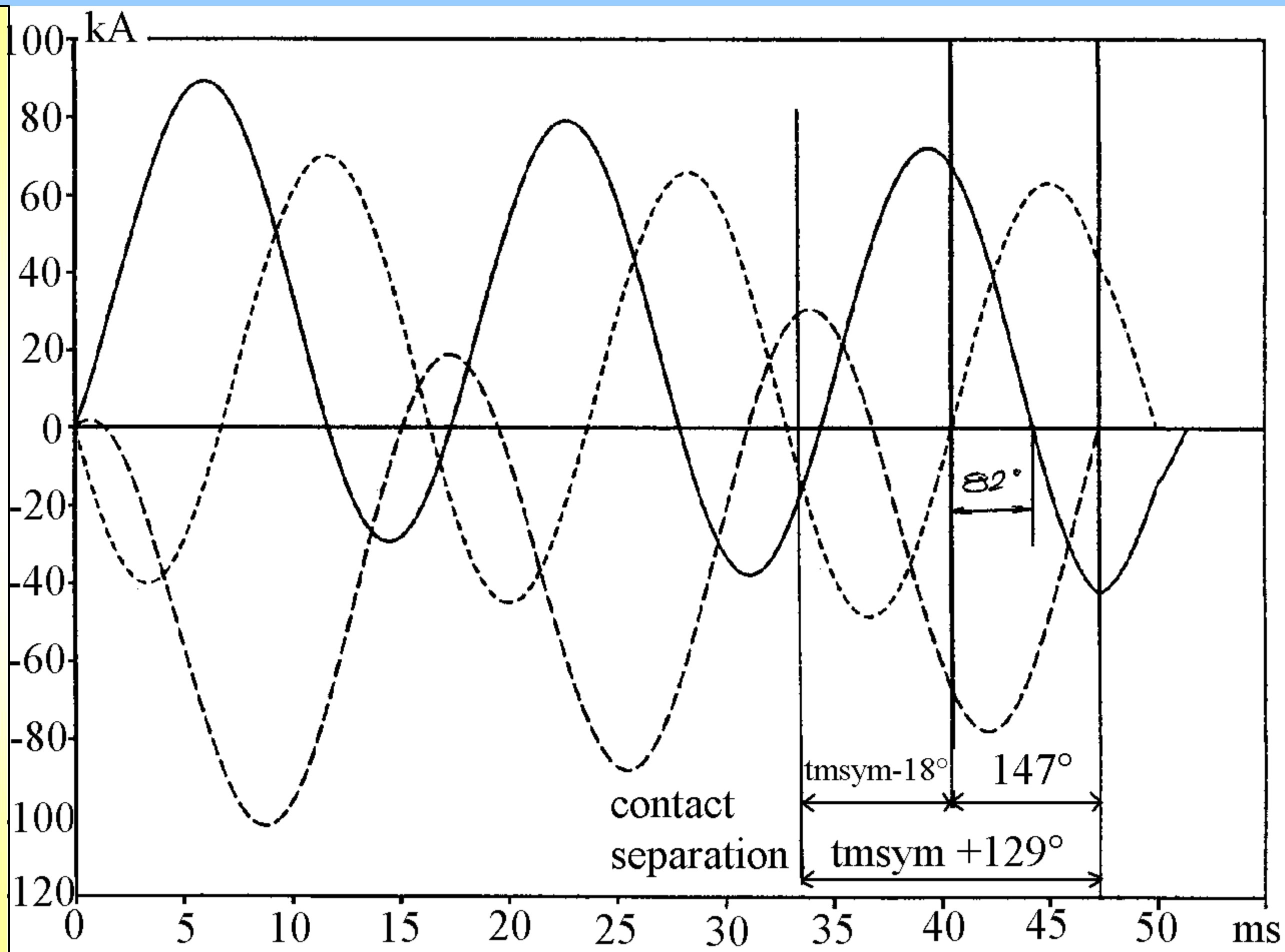
Asymmetrical currents during 3-phase short-circuit interruption of 40 kA-60Hz by 2-cycle circuit breaker with kpp=1.3. Interruption of the first pole to clear after a major loop.



Transient Recovery Voltage during 3-phase short circuit interruption of 40 kA-60 Hz by 2-cycle circuit breaker with kpp=1.3. Interruption of the first pole to clear after a major loop.



Asymmetrical currents during 3-phase short-circuit interruption of 40 kA-60 Hz by 3-cycle circuit breaker with kpp=1.3. Interruption of the first pole to clear factor after a major loop.



THREE-PHASE SHORT-CIRCUIT TESTING OF HIGH-VOLTAGE CIRCUIT-BREAKERS USING SYNTHETIC CIRCUITS

NETWORKS WITH GROUNDED NEUTRAL

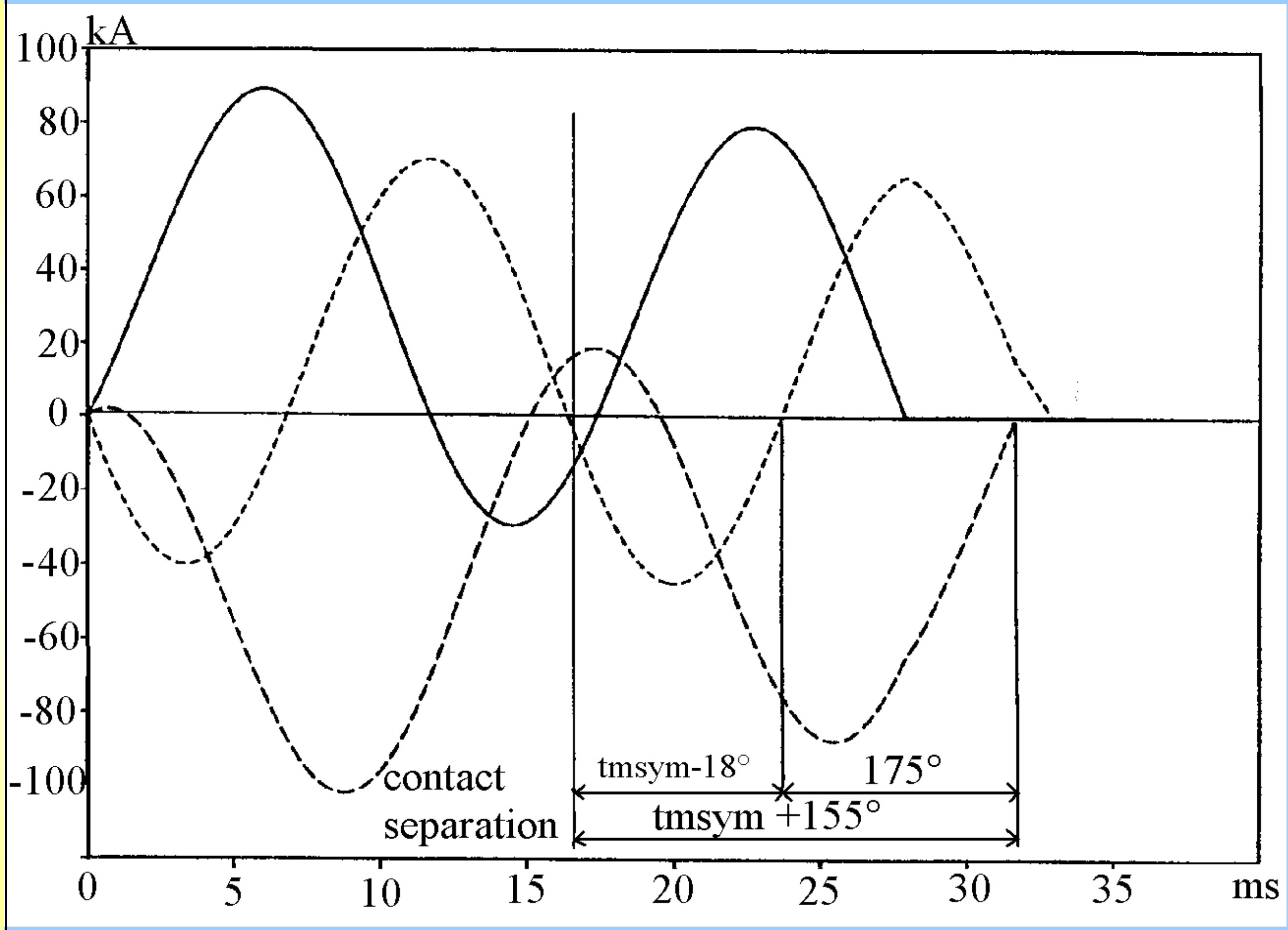
Case 2 : interruption by the 2nd pole to clear after a major loop of current with the required asymmetry.

The second pole must interrupt with arcing time :

t1 = t0 (minimum symmetrical) + 155° el. (2 cycle c.b.)

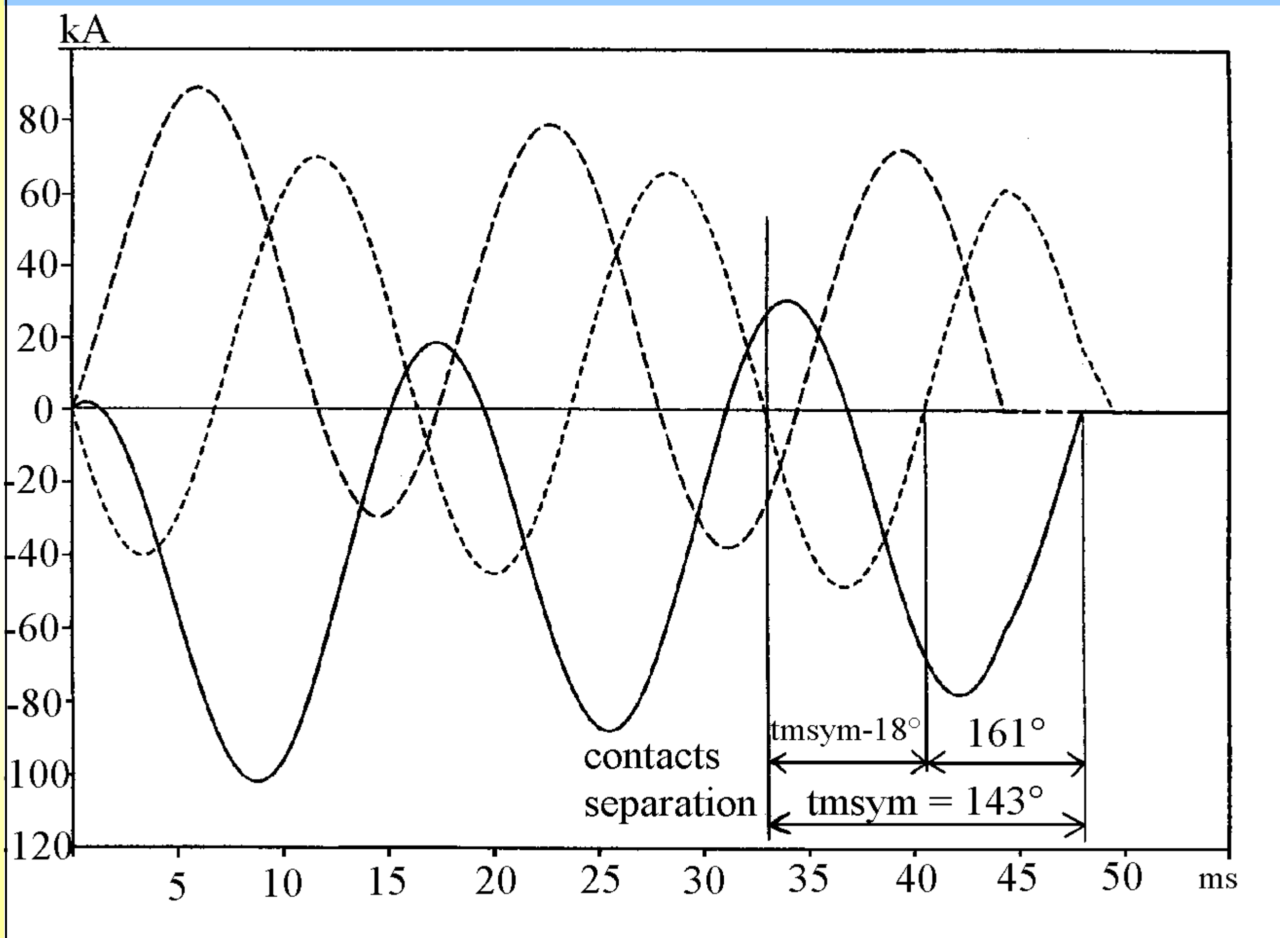
t1 = t0 (minimum symmetrical) + 143° el. (3 cycle c.b.)

Asymmetrical currents during 3-phase short-circuit interruption of 40 kA-60Hz by 2-cycle circuit breaker with kpp=1.3. Interruption after a major extended loop by the second pole to clear.



ALSTOM

Asymmetrical currents during 3-phase short-circuit interruption of 40 kA-60Hz by 3-cycle circuit breaker with kpp=1.3. Interruption after a major extended loop by the second pole to clear.



ALSTOM

THREE-PHASE SHORT-CIRCUIT TESTING OF HIGH-VOLTAGE CIRCUIT-BREAKERS USING SYNTHETIC CIRCUITS

NETWORKS WITH UNGROUNDED NEUTRAL

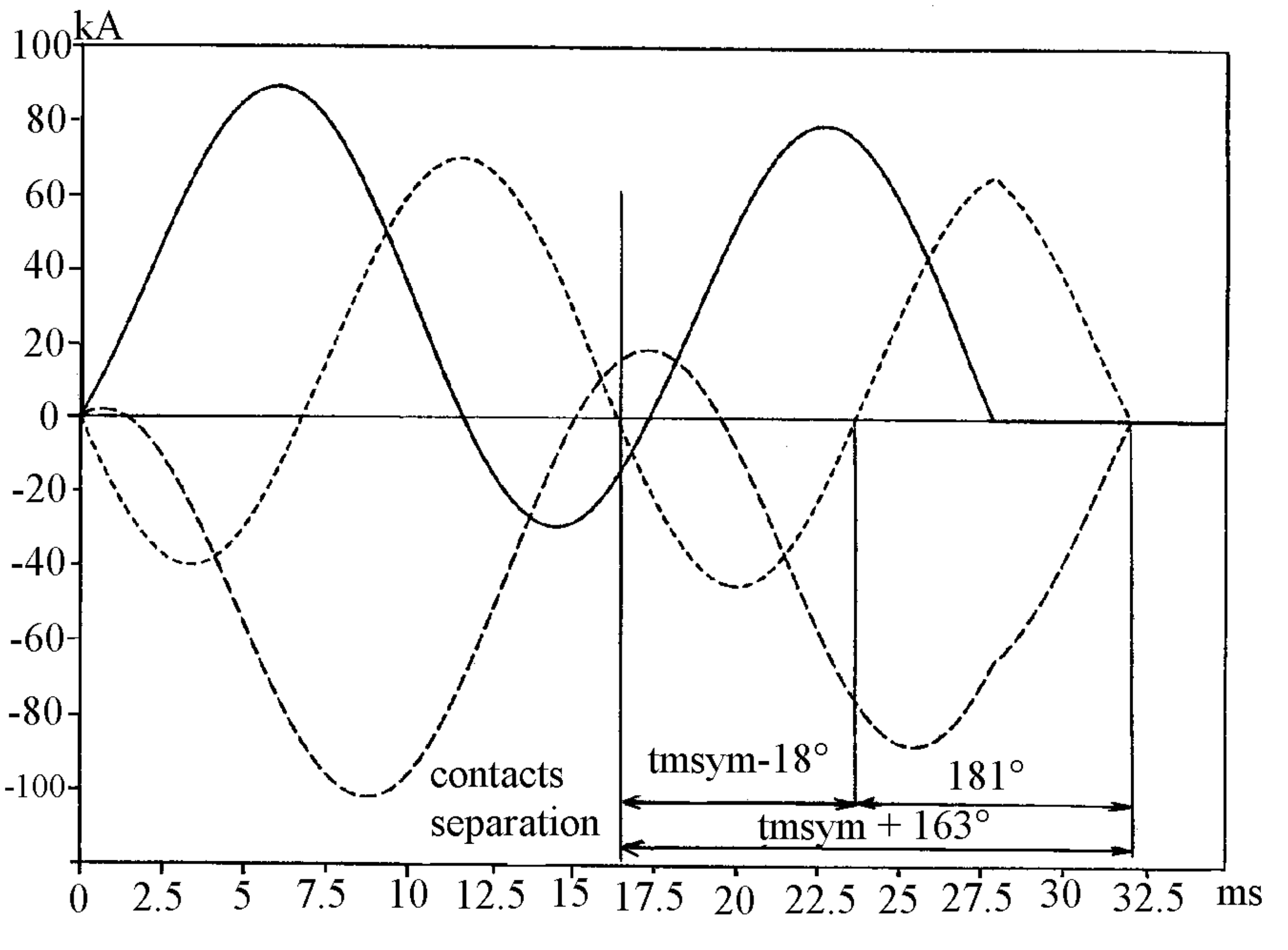
– testing of 1st pole to clear after a major loop of current : same as with grounded networks

– testing of 2nd pole to clear after a major extended loop of current with the same method:

maximum arcing time = t0 + 163° el. (2 cycle c.b.)

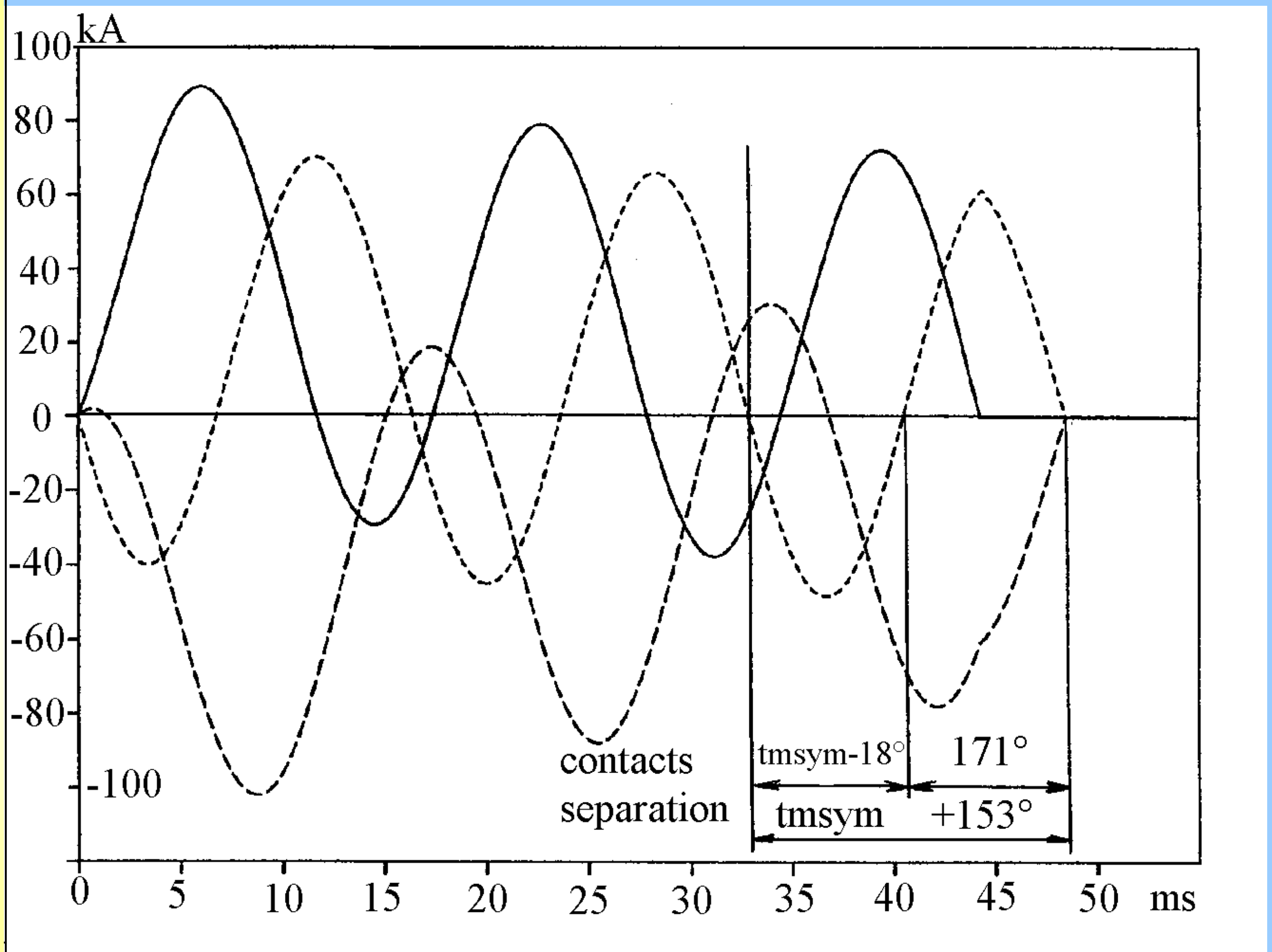
t0 + 153° el. (3 cycle c.b.)

Asymmetrical currents during 3-phase short-circuit interruption of 40 kA-60Hz by 2-cycle circuit breaker with kpp=1.5. Interruption after a major extended loop by the second pole to clear.



ALSTOM

Asymmetrical currents during 3-phase short-circuit interruption of 40 kA-60Hz by 3-cycle circuit breaker with kpp=1.5. Interruption after a major extended loop by the second pole to clear.



THREE-PHASE SHORT-CIRCUIT TESTING OF HIGH-VOLTAGE CIRCUIT-BREAKERS USING SYNTHETIC CIRCUITS

APPLICATION TO STANDARDS

a) 1 test with interruption of 1st pole to clear after a major loop of current and required asymmetry:
arcing time = tmin sym. + 60° el.

if the circuit-breaker fails to interrupt do (b) and (c)
if the circuit-breaker interrupts do (c) and (d)

b) repeat (a) with arcing time = tmin sym. + 135° el.

the circuit-breaker must interrupt after the major loop or the subsequent minor loop.

THREE-PHASE SHORT-CIRCUIT TESTING OF HIGH-VOLTAGE CIRCUIT-BREAKERS USING SYNTHETIC CIRCUITS

c) 1 test with interruption of the 2nd pole to clear after a major extended loop and required asymmetry:

arcing time = tmsym + 150° el. (grounded neutral)

arcing time = tmsym + 160° el. (ungrounded neutral)

d) when (a) and (c) are both successful, a 3rd test is done to verify that (c) is the condition with the longest arcing time contact separation is advanced by 30° el.

1st pole must interrupt at a previous current zero (after a symmetrical or minor loop).

THREE-PHASE SHORT-CIRCUIT TESTING OF HIGH-VOLTAGE CIRCUIT-BREAKERS USING SYNTHETIC CIRCUITS

CONCLUSION :

a standard method is needed for 3-phase synthetic testing of HV circuit-breakers : no IEC or IEEE/ANSI procedure today.

– a method is proposed to demonstrate interruption in the most severe cases.

– It is strongly encouraged that the IEEE Switchgear Committee should take the lead in standardizing a test procedure.

THREE-PHASE SHORT-CIRCUIT TESTING OF HIGH-VOLTAGE CIRCUIT-BREAKERS USING SYNTHETIC CIRCUITS

IEEE #

PE-052-PWRD-0-03-1999