Planning, Specification & Testing of Controlled Switching Systems

Mark Waldron

CIGRE A3.07

National Grid

Summary

- **Planning.**
  - Aim, suitability of controlled switching, benefits & risks, pre-existing constraints.
- **Specification.**
  - Performance, operating environment, component vs system performance, integration, life management.
- **Testing.**
  - Circuit-breaker capabilities, controllers, sensors & auxilliaries, total functionality.

Planning - Overview

- **Maintain/achieve adequate performance**
- **Optimised lifetime cost of installation**
- **Define the “problem” - transient control**
- **Suitability of controlled switching - ideal**
- **Availability of alternatives - pros & cons**
- **Pre-existing constraints**
- **Risk assessment - real systems including P(failure) & consequences**

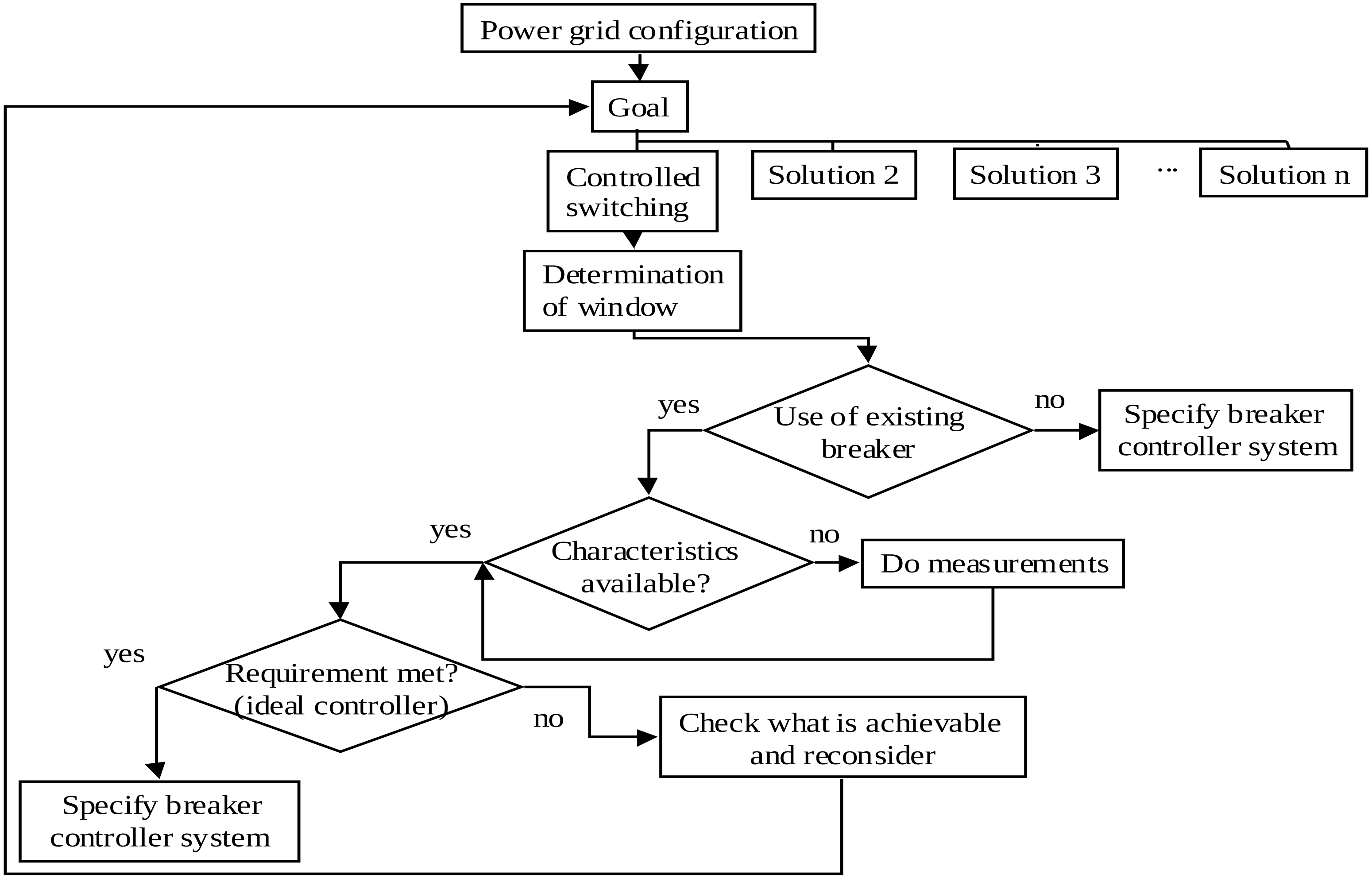
Planning - Alternatives to CS

- **Avoidance - can the scheme be avoided?**
- **Power system modification/re-enforcement**
- **Dynamic resistance/inductance**
- **Fixed inductance**
- **Surge arresters**
- **Re-enforcement of secondary systems**

Planning - Risk Assessment

- Non-ideal systems have P(failure)
- Nature & consequence of failure depend on application
- Safety risks followed by commercial risks
- Levels of redundancy to achieved acceptable levels of risk
- Structured design approach e.g. IEC 61508

Planning - Decision tree



Specification - Overview

- Controlled switching installations must be considered as a whole - breaker + controller + auxiliaries
- Interaction between functionalities
- Operating environment - electrical, climatic, regime . . . . .
- Performance $\Rightarrow$ System $\Rightarrow$ Components
- Support & lifetime management - not fit & forget

Specification - Power System

- **Nature of the power system:**
  - Frequency
  - Earthing
  - Connection arrangements
  - Reference signals
  - Normal & abnormal system conditions
- **Actual duty on switching device - non-idealised case**

Specification - Accuracy & Consistency

- **Ideal making target + acceptable tolerance**
- **Temperature range $\Rightarrow$ Compensation?**
- **Drive & insulation operating range $\Rightarrow$ Compensation?**
- **Auxiliary voltage**
- **Electrical environment**
- **Maximum/minimum idle time**
- **Reference signals - accuracy & availability**
- **Adaption routines**

Specification - Reliability & Failure Performance

- Failure mode, P() & effects considered
- Failure to operate on command
- Incorrect operation - no warning
- Operate without command
- Inability to operate (within tolerance)
- Loss of reference &/or supply
- Rigorous assessment - IEC 61508?

Specification - Installation Philosophy & Interfaces

- **Permissive or definite operation**
- **Redundancy - protection philosophy?**
- **HMI - local and/or remote**
- **Integration with basic protection & control**
- **Self diagnostics & self verification**
- **Complexity**
- **Communication, protocols etc**

Specification - Lifetime Issues

- **Commissioning**
- **Maintenance for continued accuracy**
- **Adaptability - self adjustment on basis of operation**
- **Software/hardware support**
- **Component interactions throughout lifetime**

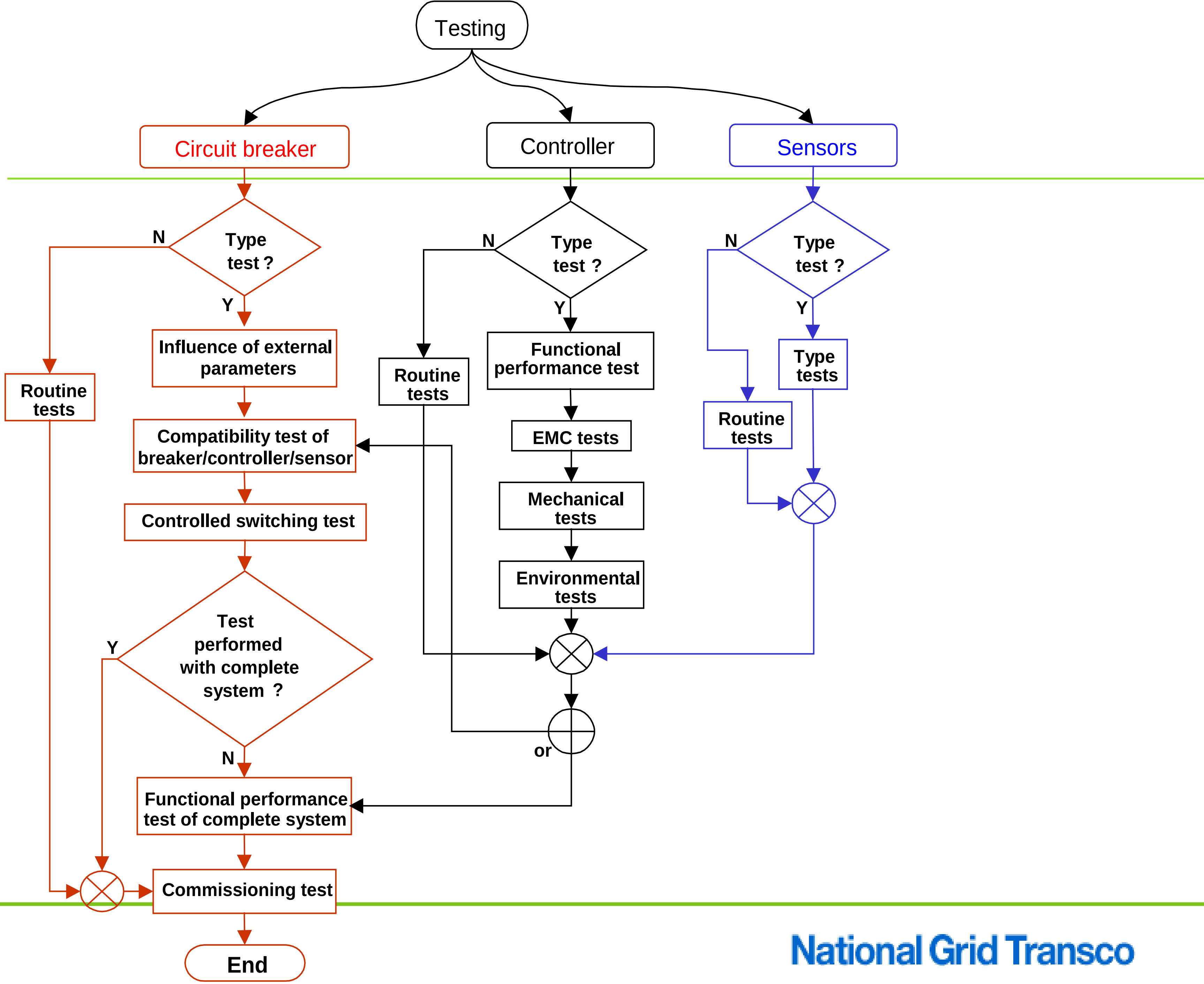
Specification - Non-standard duties

- **Application of controlled switching can "create" additional duties**
- **Non-simultaneous poles affect asymmetric making and breaking**
- **Extreme case but should be considered**

	Pole spread on closing (ms)										
	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5
τ = 45ms	2.55	2.62	2.69	2.76	2.82	2.87	2.92	2.95	2.98	3	3.01
τ = 60ms	2.61	2.69	2.77	2.83	2.9	2.95	2.99	3.03	3.06	3.09	3.09
τ = 90ms	2.68	2.76	2.84	2.91	2.98	3.03	3.08	3.11	3.14	3.16	3.17
τ = 120ms	2.72	2.8	2.88	2.95	3.02	3.07	3.12	3.16	3.19	3.2	3.21
τ = infi-nite	2.83	2.92	3.01	3.08	3.15	3.21	3.26	3.3	3.32	3.34	3.35

Testing - Overview

- **Circuit-breaker characteristics**
- **Controller characteristics**
- **Sensor characteristics**
- **Auxiliary performance**
- **Taken together $\Rightarrow$ System Performance**



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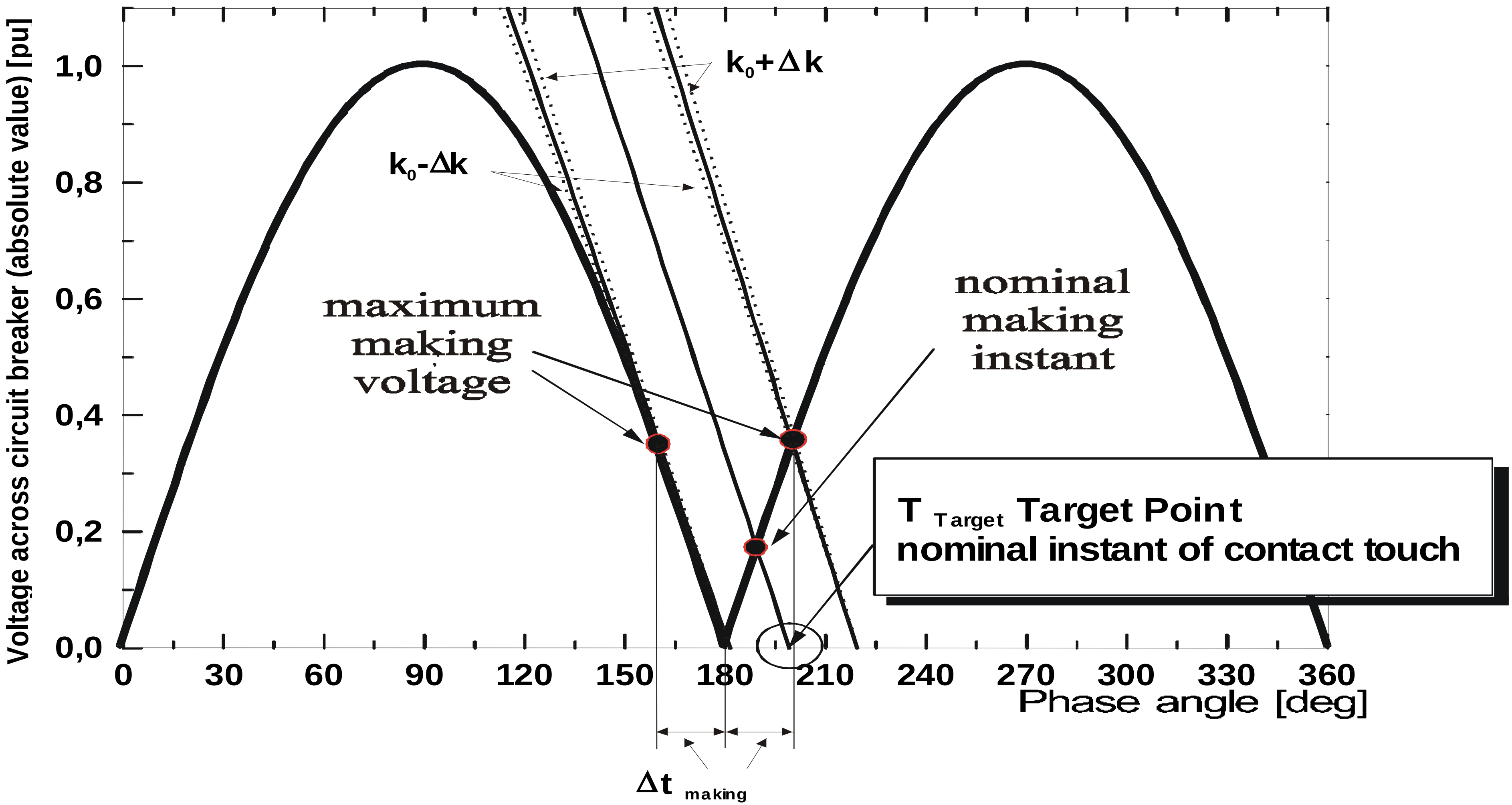
Testing - Controller

- **Functional performance - scatter, compensation, adaption, alarms & signalling, self diagnostics, communication**
- **Hardware conformance - EMC, mechanical & environmental - existing standards.**
- **Software reliability - especially for Safety Critical Systems**

Testing - Circuit-breaker

- **Key parameters:**
  - RDDS
  - Mechanical scatter, variations & idle time
  - RRDS (can be derived from C & L switching)
- **Permit definition of optimum target point for any duty - closing or opening**
- **Direct measurement of optimum target point for particular case**
- **Controlled switching test**

Testing - Voltage zero making



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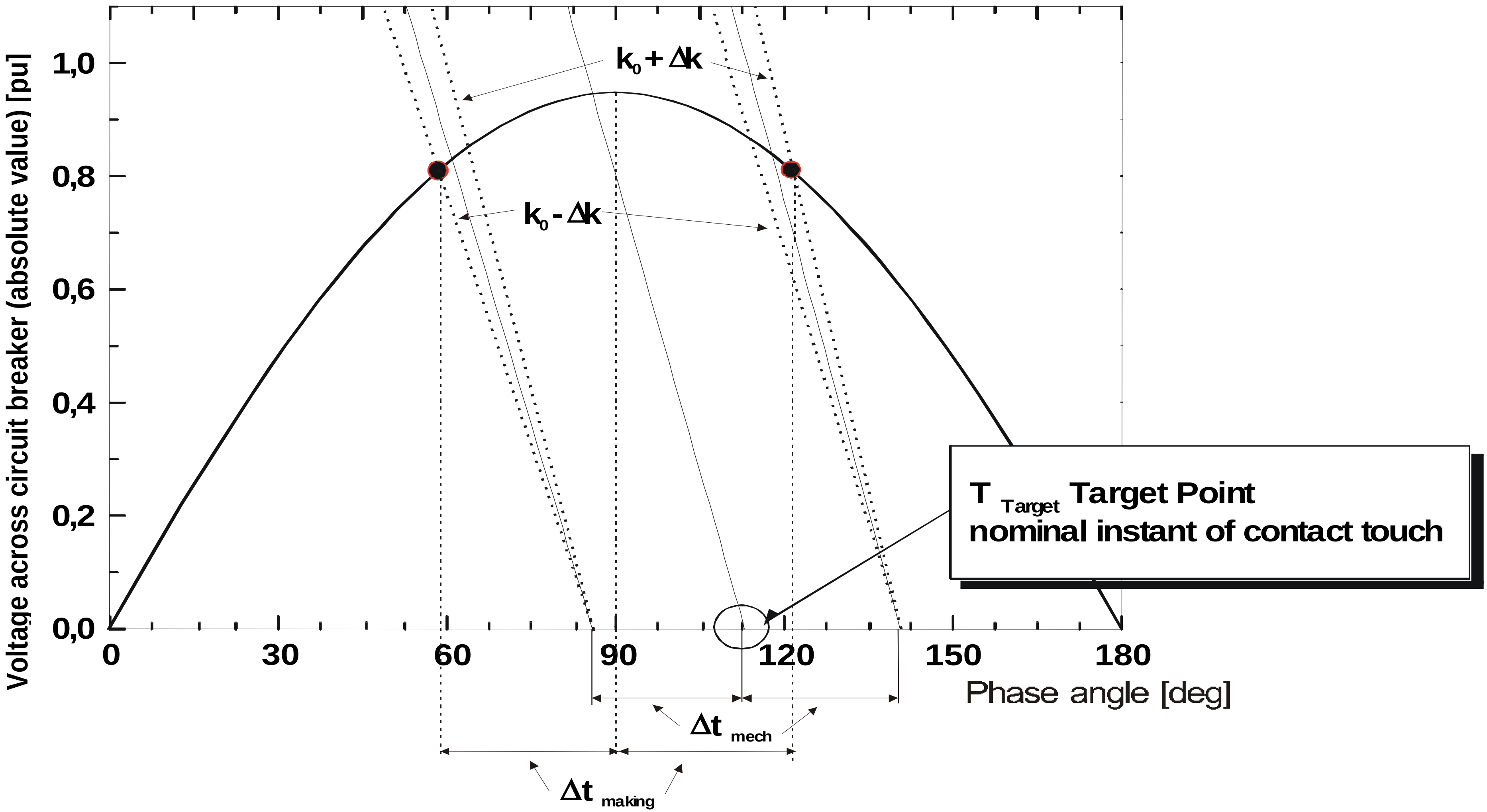
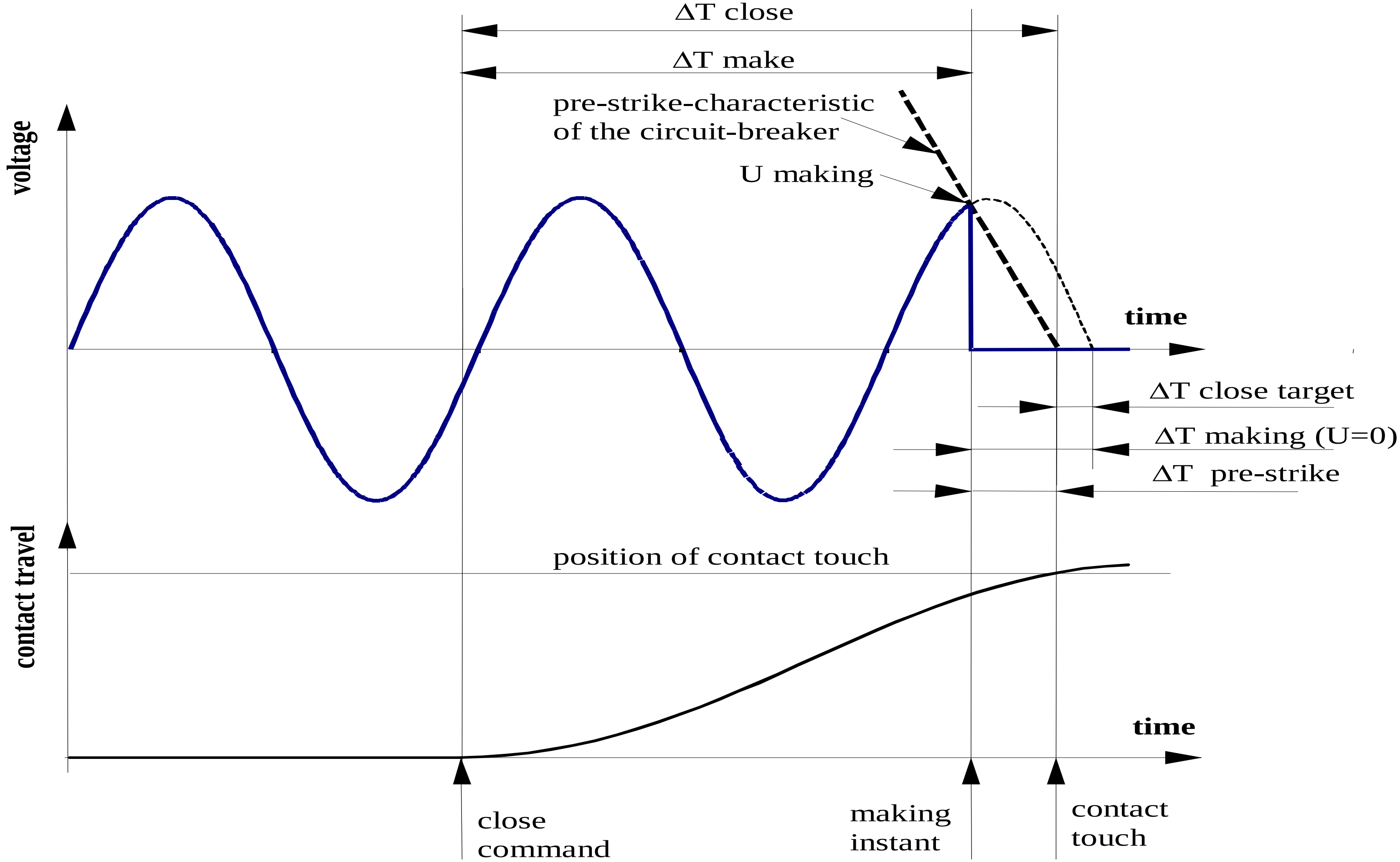
Testing - Voltage peak making



Testing - Basic derivation of RDDS



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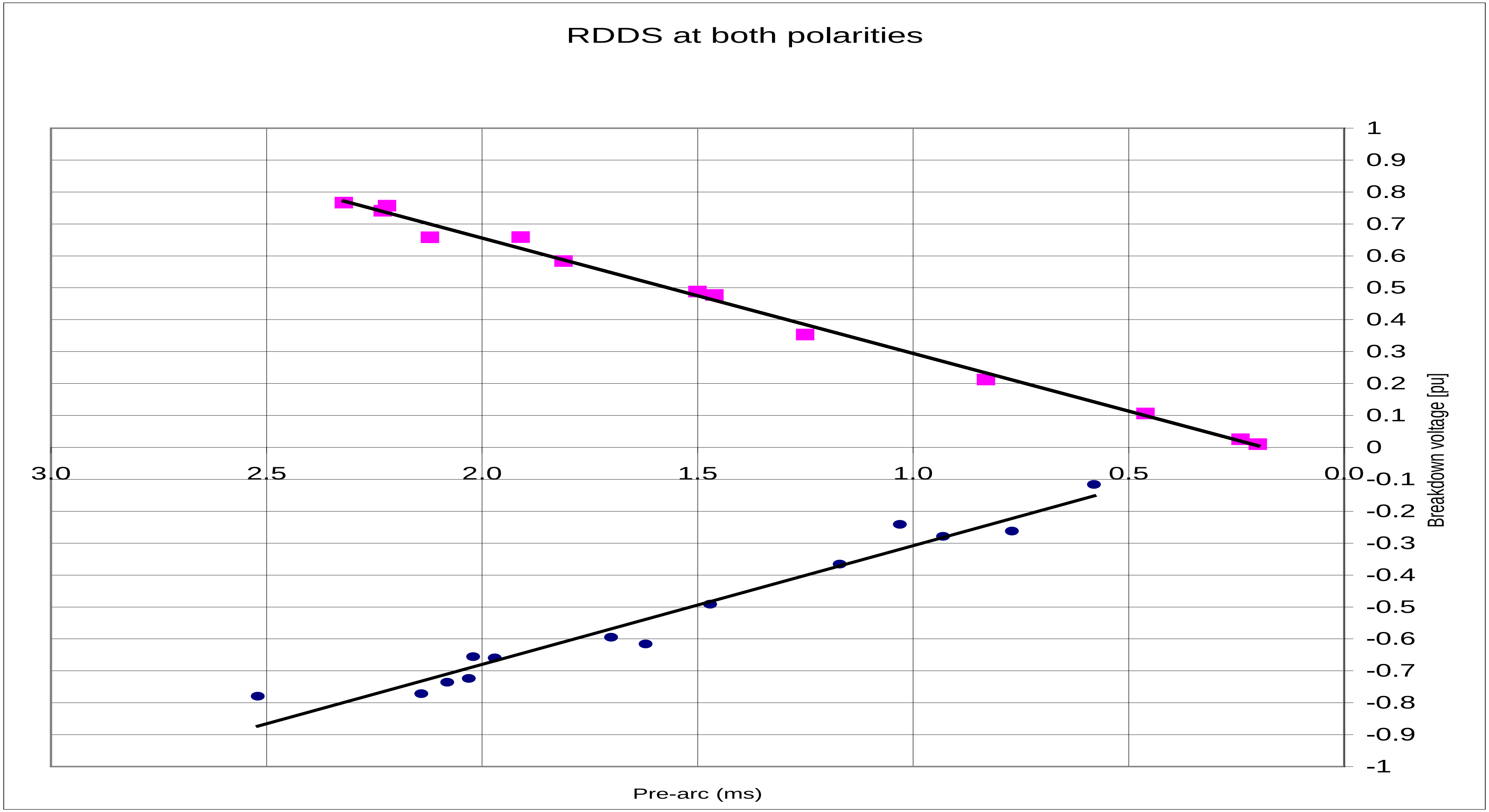
Testing - RDDS test sequence

- **4 making tests per setting**
- **15 degree steps**
- **Pre-strike voltage & pre-strike time measured**
- **Polarities considered separately**
- **Influence of contact burn-off to be verified**

Testing - Typical RDDS test result



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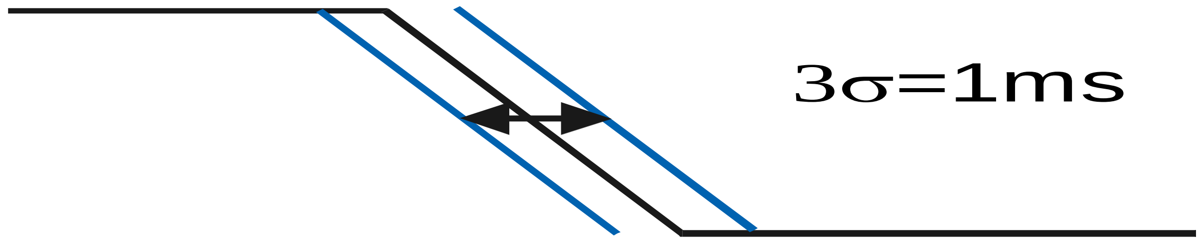
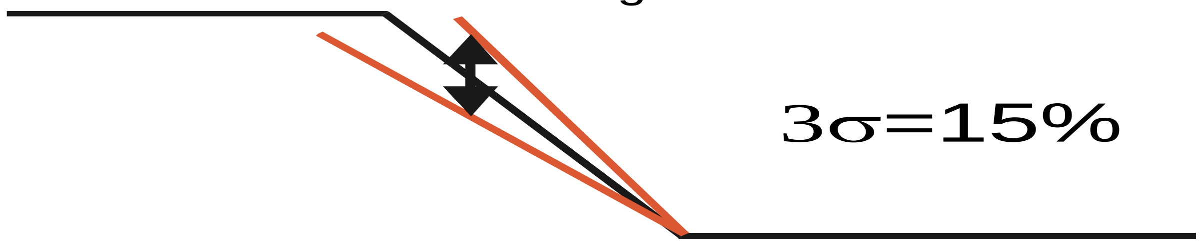
Testing - RDDS variations

Variation of the begining of the movement



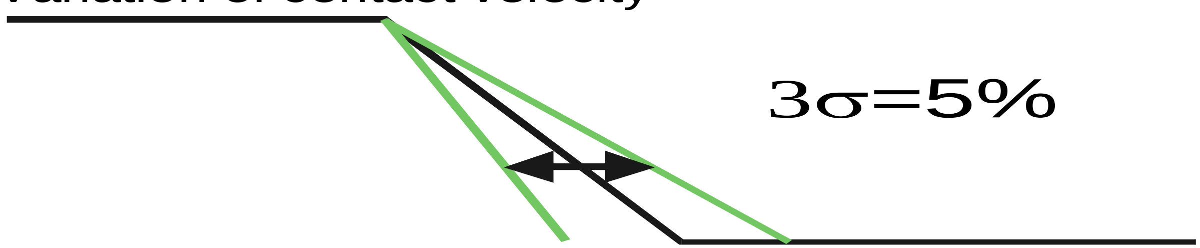
$3\sigma=1ms$

Variation of dielectric strength



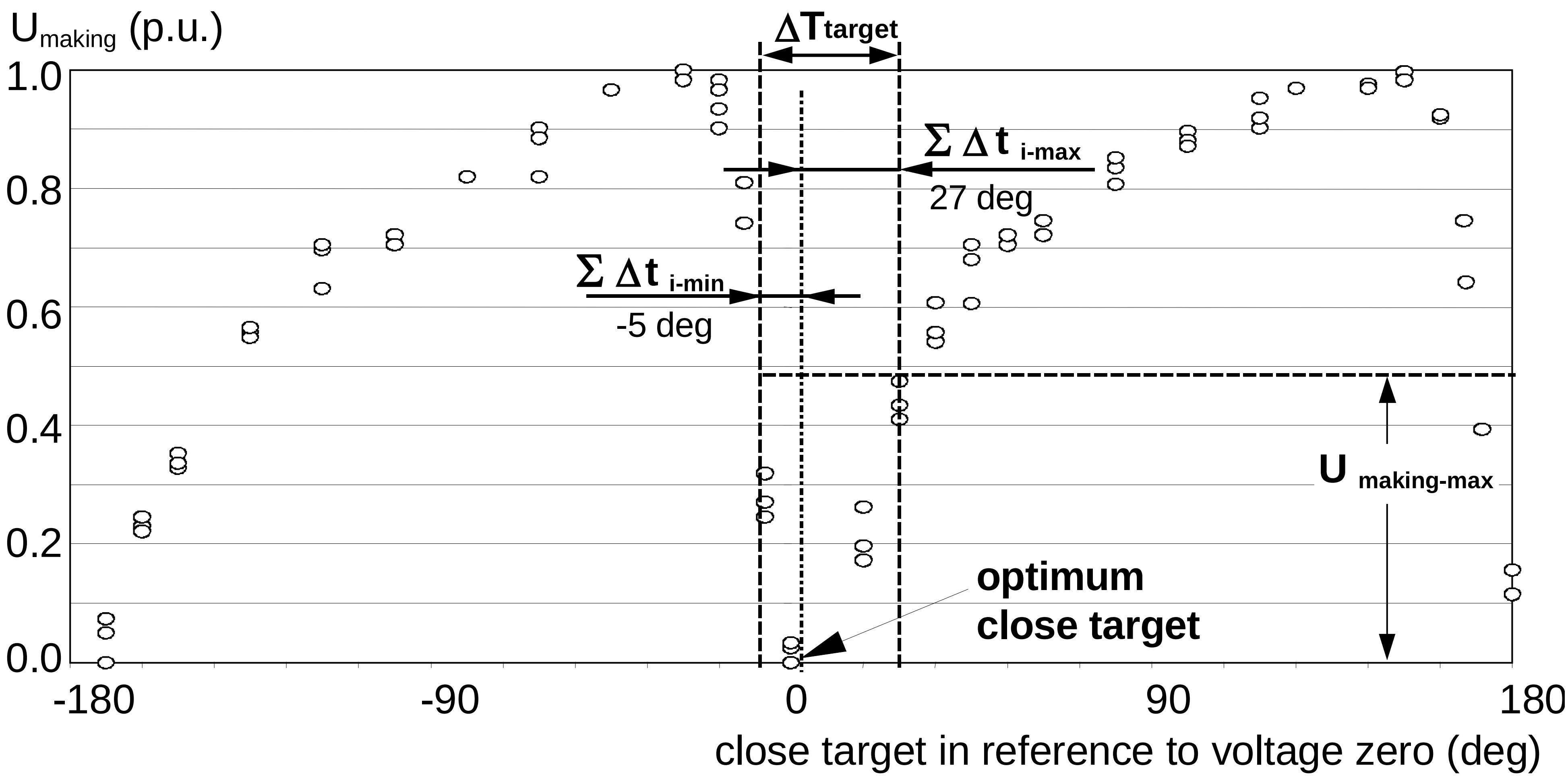
$3\sigma=15\%$

Variation of contact velocity

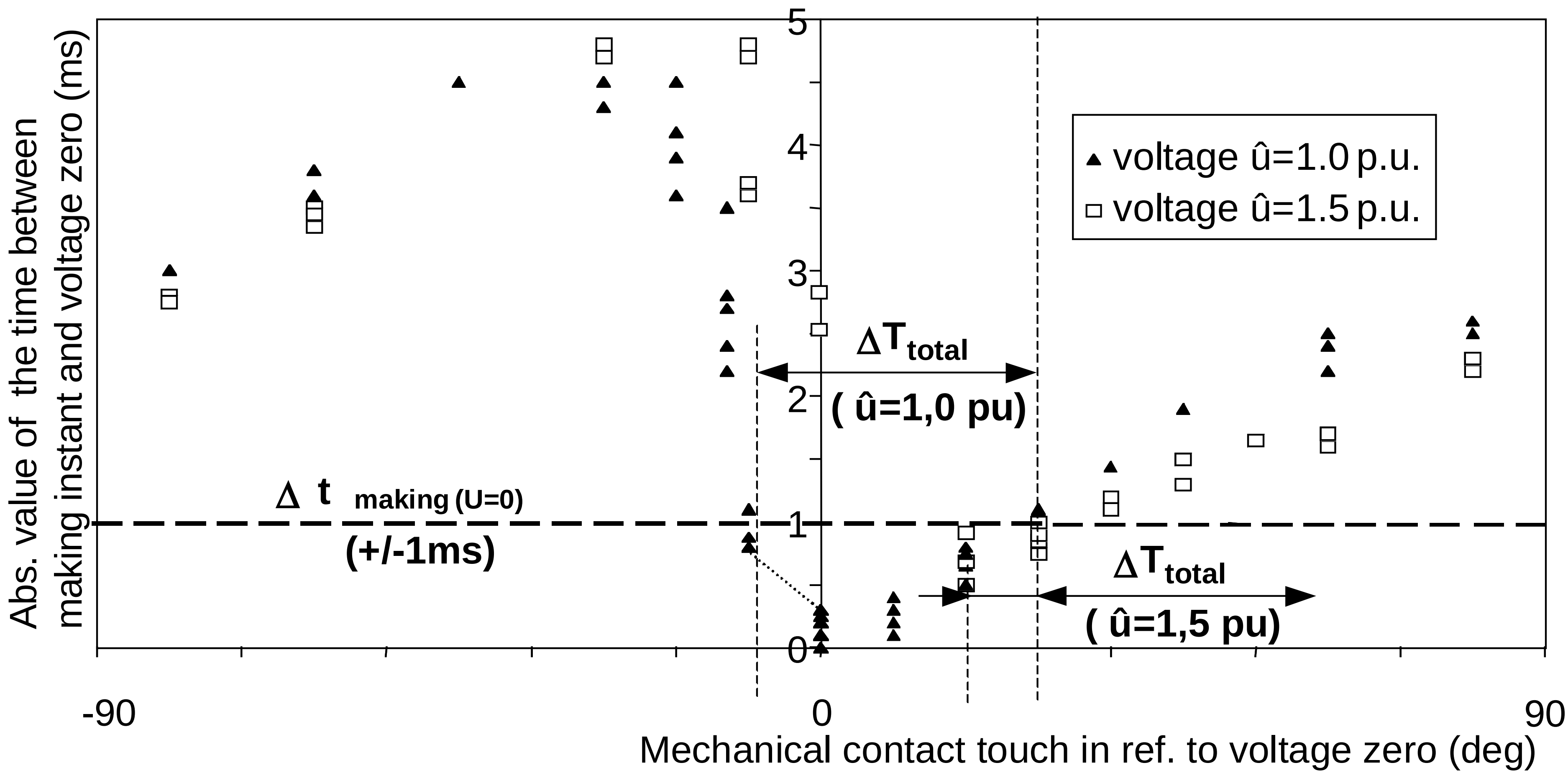


$3\sigma=5\%$

Testing - Close target vs making voltage



Testing - Close target vs making instant



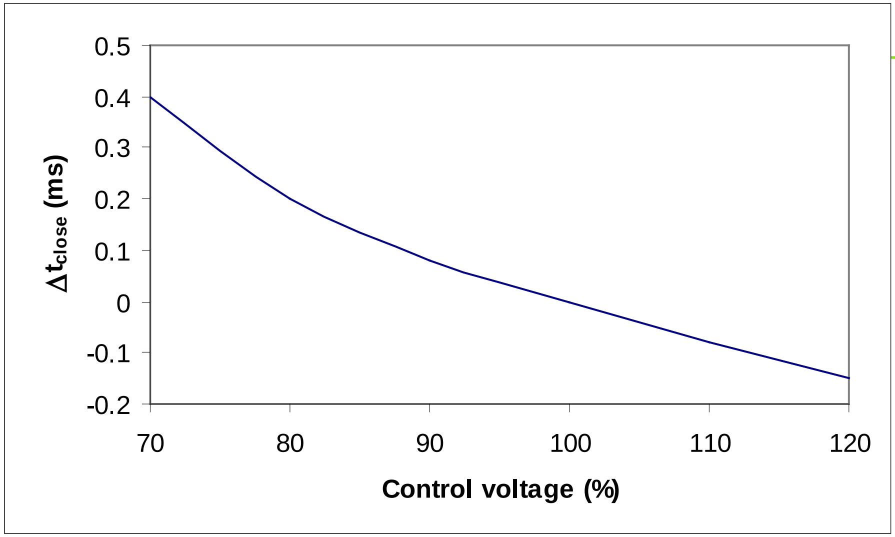
Testing - Mechanical variations

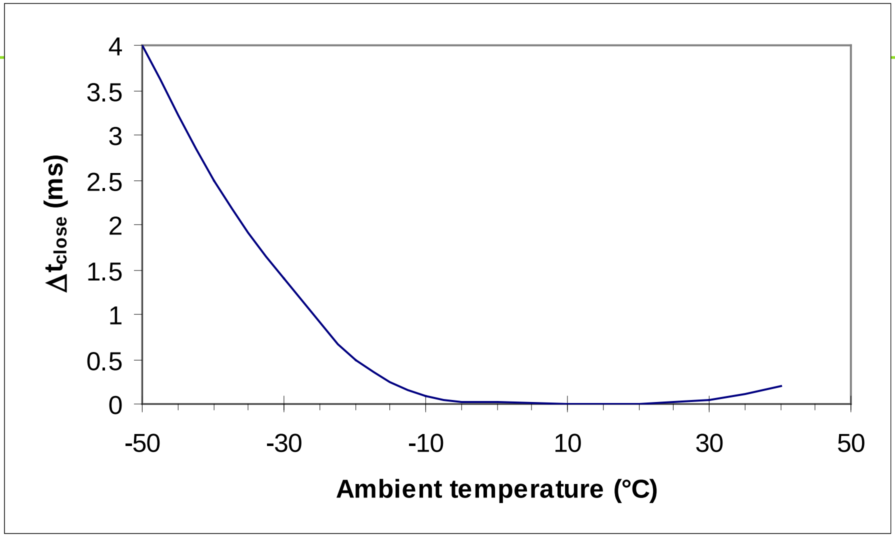
- **Basic mechanical testing (IEC 62271-100)**
- **Tests over expected range of:**
  - Ambient temperature
  - Drive condition
  - Control voltage
  - Idle time
  - Phase spacing (mechanical linkage only)
- **Determines need for compensation**

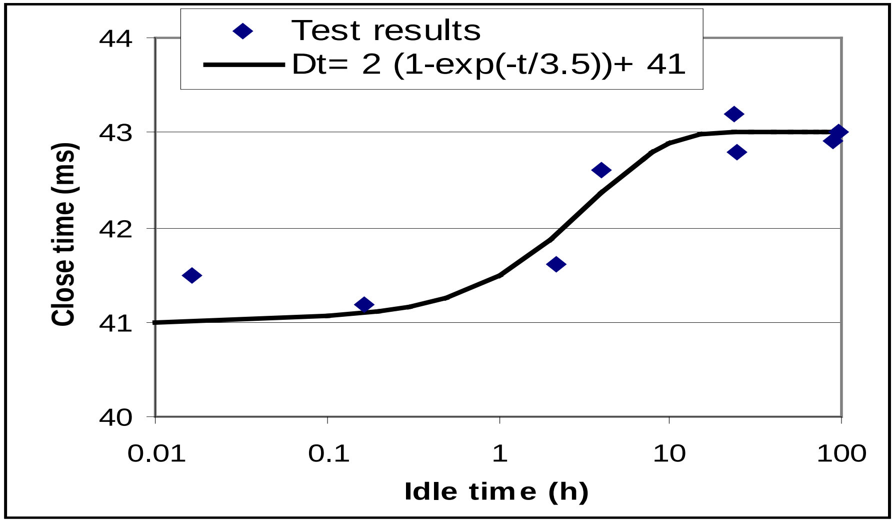
Testing - Idle time test

- **C - 1min - O - 1min - C - 1min - O (C/O interchangeable)**
- **Idles of:**
  - 1 hour
  - 8 hours
  - 16 hours
  - 64 hours
  - 104 hours
  - 232 hours
  - 720 hours

Testing - Typical relationships







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Testing - Controlled closing test

- Test on full circuit-breaker
- Verify actual performance for voltage peak & voltage zero switching
- Realistic power frequency condition, earthing factors etc
- Extremes of variable parameters considered either directly or indirectly
- 4 test series - 6 operations per test series at each voltage zero and each voltage peak.
- 96 tests in total

Testing - Controlled closing test

		Operating conditions	
Directly considered (extreme values must be directly applied in the tests)	SF_6 gas pressure	Lockout	Rated
	Drive energy	Lockout	Rated

a) Operating conditions applied in the tests

		Minimum	Maximum
Indirectly considered (extreme values considered by means of close/open target)	Control voltage	$\Delta T_{1\text{-}min}$	$\Delta T_{1\text{-}max}$
	Ambient temperature	$\Delta T_{2\text{-}min}$	$\Delta T_{2\text{-}max}$
	Idle time	$\Delta T_{3\text{-}min}$	$\Delta T_{3\text{-}max}$
Extreme variations of close/open times for testing		$\Delta t_{min} = \sum_{i=1}^{3} \Delta T_{i-\min}$	$\Delta t_{max} = \sum_{i=1}^{3} \Delta T_{i-\max}$

b) Operating conditions that can be represented by variations of the close/open targets (refer to Figure 4-7).

$\Delta T_{i\text{-}min}$ = *(minimum close/open time variation from the respective characteristic curve)*

$\Delta T_{i\text{-}max}$ = *(maximum close/open time variation from the respective characteristic curve)*

Remark: parameters compensated by the controller shall not be considered.

Testing - Controlled closing test

Test series	Close at voltage zero	Close at voltage peak
1	Lockout SF_6 pressure, rated drive energy: $t_{target\_zero} = t_{target\_zero\_rated} + \Delta t_{min}$	Lockout SF_6 pressure, rated drive energy: $t_{target\_peak} = t_{target\_peak\_rated} + \Delta t_{min}$
2	Rated SF_6 pressure, lockout drive energy: $t_{target\_zero} = t_{target\_zero\_rated} + \Delta t_{max}$	Rated SF_6 pressure, Lockout drive energy: $t_{target\_peak} = t_{target\_peak\_rated} + \Delta t_{max}$
3 (most critical case)	Lockout SF_6 pressure, Lockout drive energy: $t_{target\_zero} = t_{target\_zero\_rated} + \Delta t_{min}$	Lockout SF_6 pressure, lockout drive energy: $t_{target\_peak} = t_{target\_peak\_rated} + \Delta t_{min}$
4	Rated SF_6 pressure, rated drive energy: $t_{target\_zero} = t_{target\_zero\_rated} + \Delta t_{max}$	Rated SF_6 pressure, rated drive energy: $t_{target\_peak} = t_{target\_peak\_rated} + \Delta t_{max}$

Testing - Complete system checks

- **Compatibility**
- **Functional performance check - like controlled closing test**
- **System assembled & tested as early as possible**
- **Commissioning procedure is critical to account for system aspects**
- **Regular review**

Concluding remarks

- **Consider controlled switching <u>system</u>**
- **Performance reliant on component parameters & testing + compatibility**
- **Reliability & failure performance/effect dictate levels of redundancy**
- **Lifetime management of the system - component & system changes**