IEC 60255-1xx Standards

Relay Protection Applications, Real Time Power System Simulation Tests

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SEMINAR | May 11th, 2017

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2013: IEC 1906 Award for the work on Distance Protection Standard

Andrea Bonetti:

Member of TC 95 / MT4 since 2006
IEC 1906 Award in 2013

IEC 1906 AWARD

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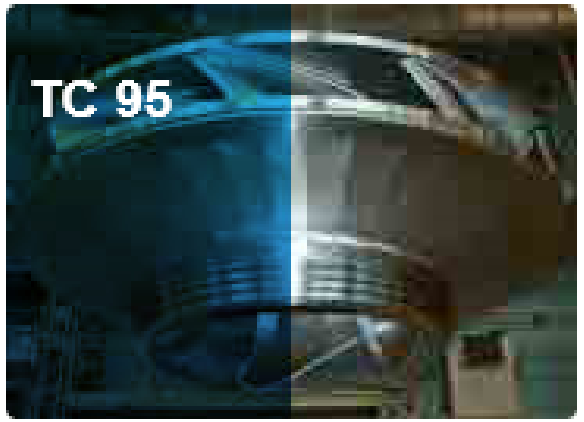
TC 95 – MT4 (Maintenance Team 4)

TC 95 Measuring relays and protection equipment

Scope | Structure | Projects / Publications | Documents | Votes | Meetings | Collaboration Tools

TC 95 Scope

Standardization of measuring relays and protection equipment used in the various fields of electrical engineering covered by the IEC, taking into account combinations of devices to form schemes for power system protection including the control, monitoring and process interface equipment used with those systems.
Excluded are the following:
All devices covered by standards prepared by other IEC technical committees, for example instrument transformers.



PUBLISHED STANDARDS BY TC 95 – MT4

STANDARD	EDITION / STATUS	TITLE
IEC 60255-151:2009	Edition 1.0 (2010-04-27)	Functional requirements for over/under current protection
IEC 60255-127:2010	Edition 1.0 (2010-04-27)	Functional requirements for over/under voltage protection
IEC 60255-149:2013	Edition 1.0 (2013-07-30)	Functional requirements for thermal electrical relays
IEC 60255-121:2014	Edition 1.0 (2014-03-07)	Functional requirements for distance protection

STANDARDS ON THEIR WAY TO GET APPROVED 2017/2018

STANDARD	EDITION / STATUS	TITLE
IEC 60255-181 ED1	95/362/CD	Functional requirements for frequency protection
IEC 60255-187-1	95/351/CD	Functional requirements for restrained and unrestrained differential protection of motors, generators and transformers

CLOSE LOOK AT IEC 60255-121: DISTANCE PROTECTION

The standard specifies the minimum requirements for functional and performance evaluation of the distance protection.

It defines how to document and publish the results of performance tests in a uniform method.

..... the data shall be published in accordance with the format given by Table 1. .....

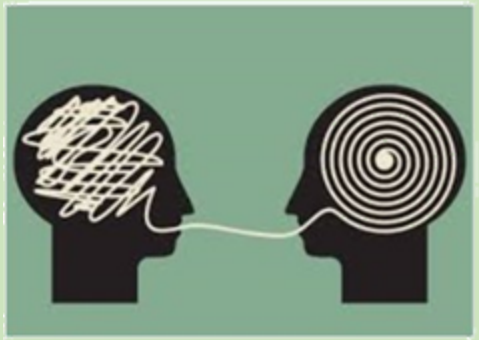
Table 1 – Example of effective and operating ranges of distance protection

Quantity	Effective range	Operating range
Current	20 % to 1 000 % of rated current	20 % to 4 000 % of rated current
Voltage	5 % to 150 % of rated voltage	2 % to 200 % of rated voltage
Frequency deviation	-2 % to +2 % of rated frequency	-5 % to +5 % of rated frequency

Minimum requirements for relay type test certificates!

WHY?

Many and different methodologies were used to specify and measure the distance protection relay performances.



Too many misunderstandings for users in selecting relays for the specific application

difficulties in comparing relays from different manufacturers.

delays at commissioning due to different interpretation of relay data and test results

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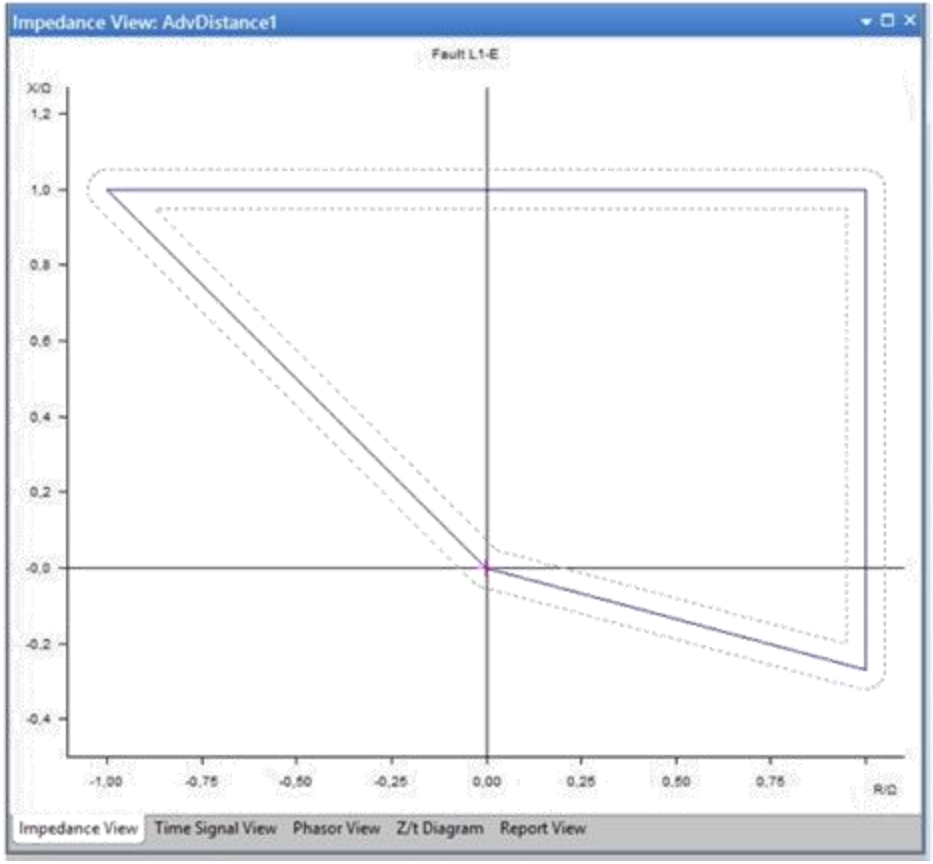
DISTANCE PROTECTION CHARACTERISTIC… BEFORE

In the past most manufacturers published the characteristic accuracy only at the protected line angle. This created difficulties at commissioning of the distance protection relays, where different relay test sets applied different definitions of the so called "tolerance bands".



Tolerance lines

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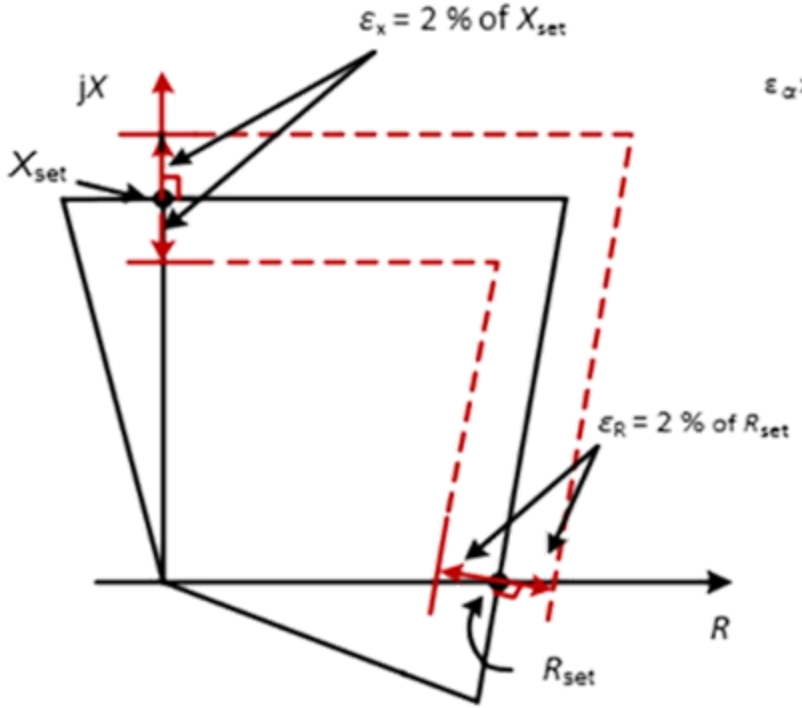
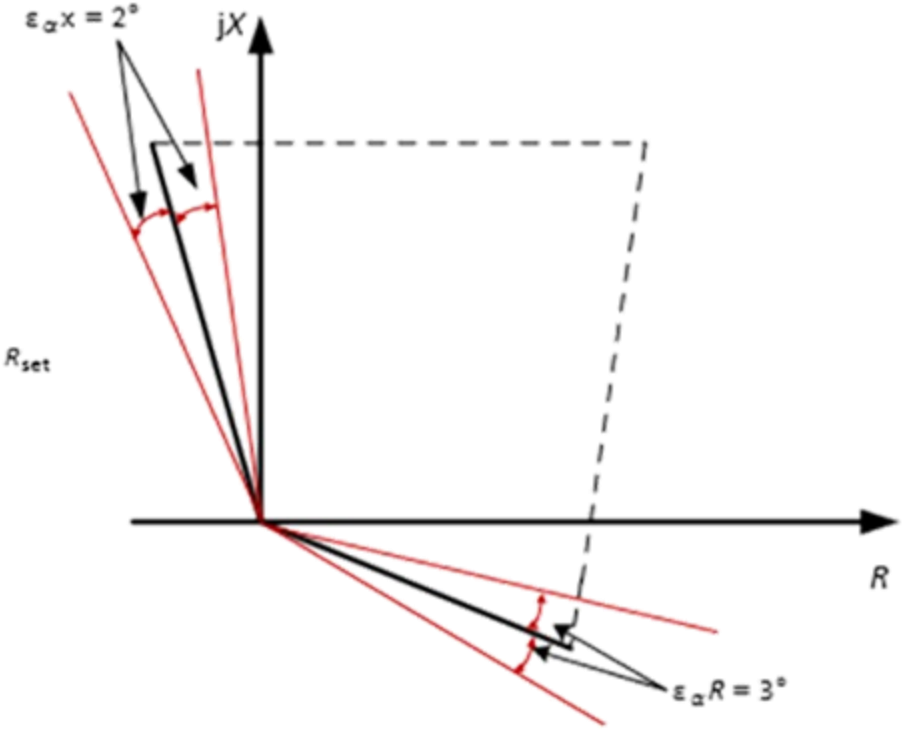
DISTANCE PROTECTION CHARACTERISTIC… IEC 60255-121

Characteristics published for 1ph-earth, 2-ph and 3-ph faults and in the preferred domain by the manufacturer (Ω/loop, Ω/phase or combinations).

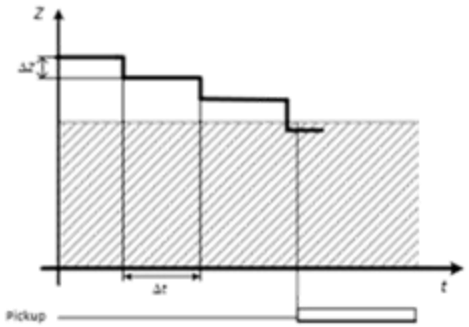




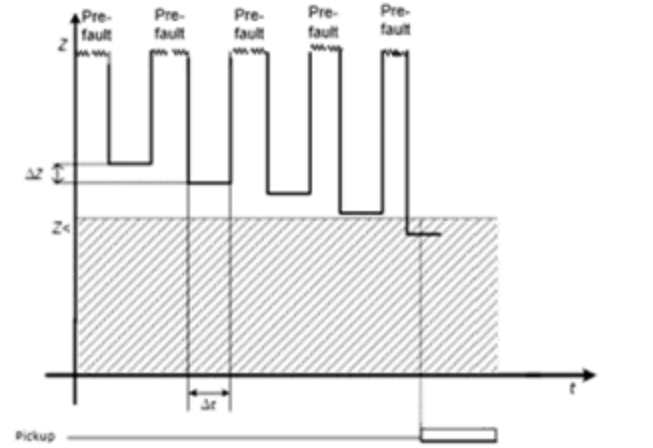
Basic Accuracy is defined for the entire "shape"

DISTANCE PROTECTION CHARACTERISTIC… IEC 60255-121

Standardized test methods to test the accuracy.



Pseudo-continuous ramp showing impedance step change and the time step



Ramp of shots showing impedance step change and the time step

The two test methods may give different test results, the **manufacturer has to declare the basic accuracy together with the chosen test method.**

When validating the test results, **the relay characteristic needs to be verified with the same test method declared by the manufacturer.**

The relay test sets must be able to perform the test methods described in the standard

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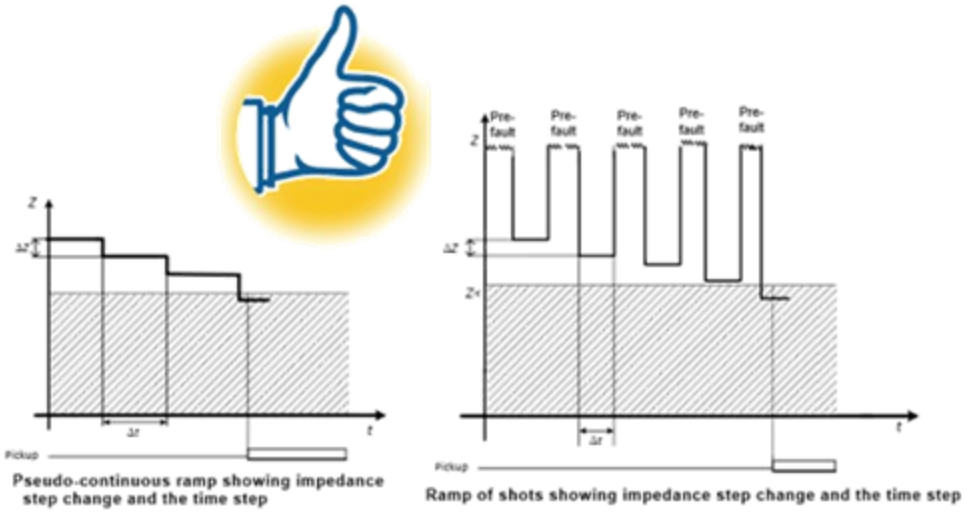
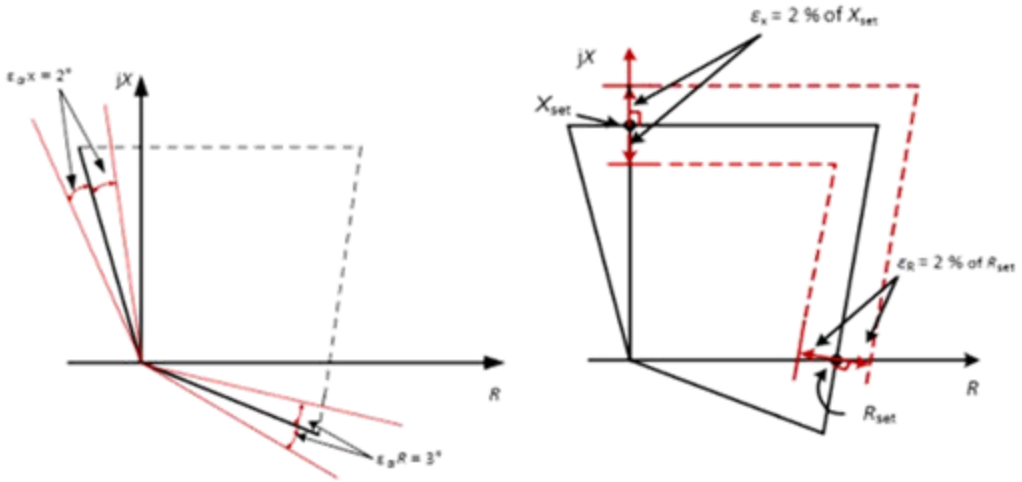
DISTANCE PROTECTION CHARACTERISTIC… IEC 60255-121

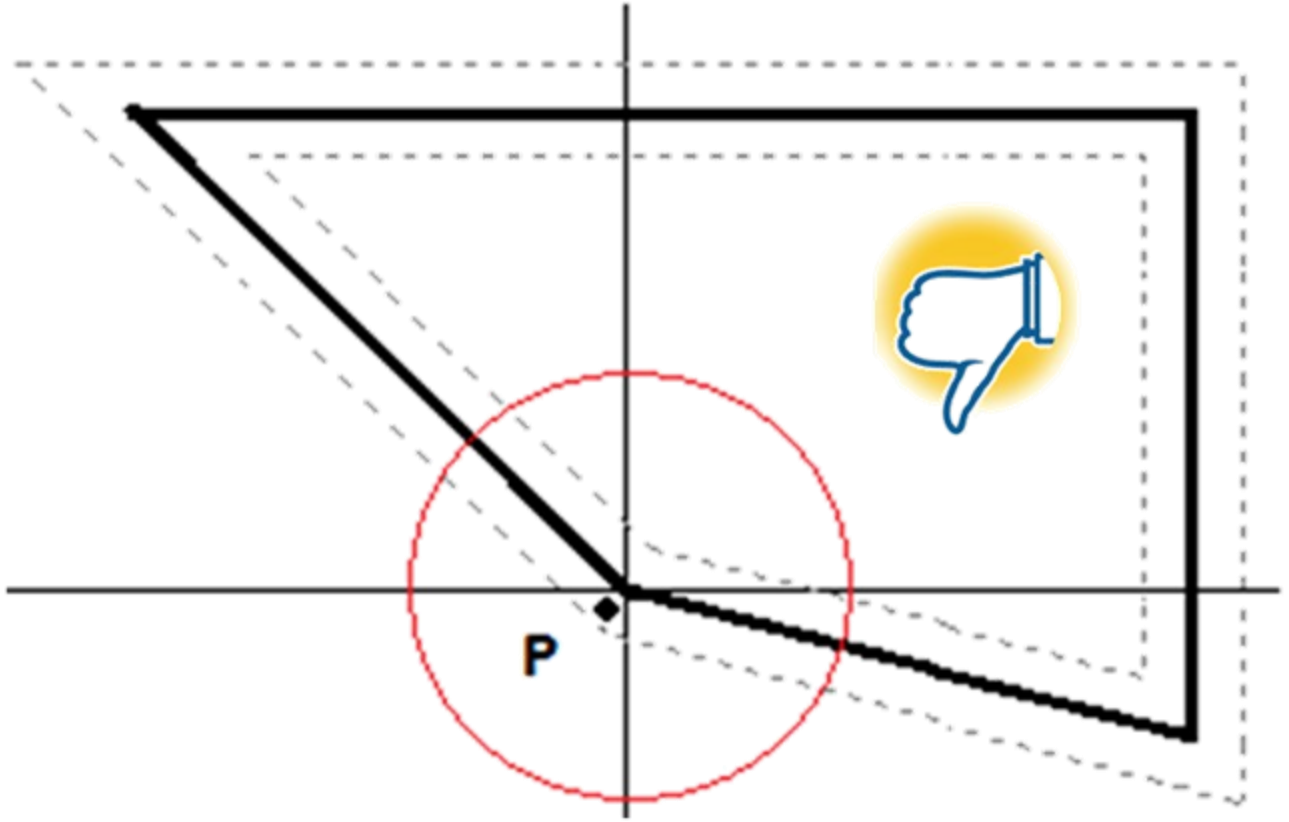
Less misunderstandings at commissioning / acceptance tests!



Pseudo-continuous ramp showing impedance step change and the time step

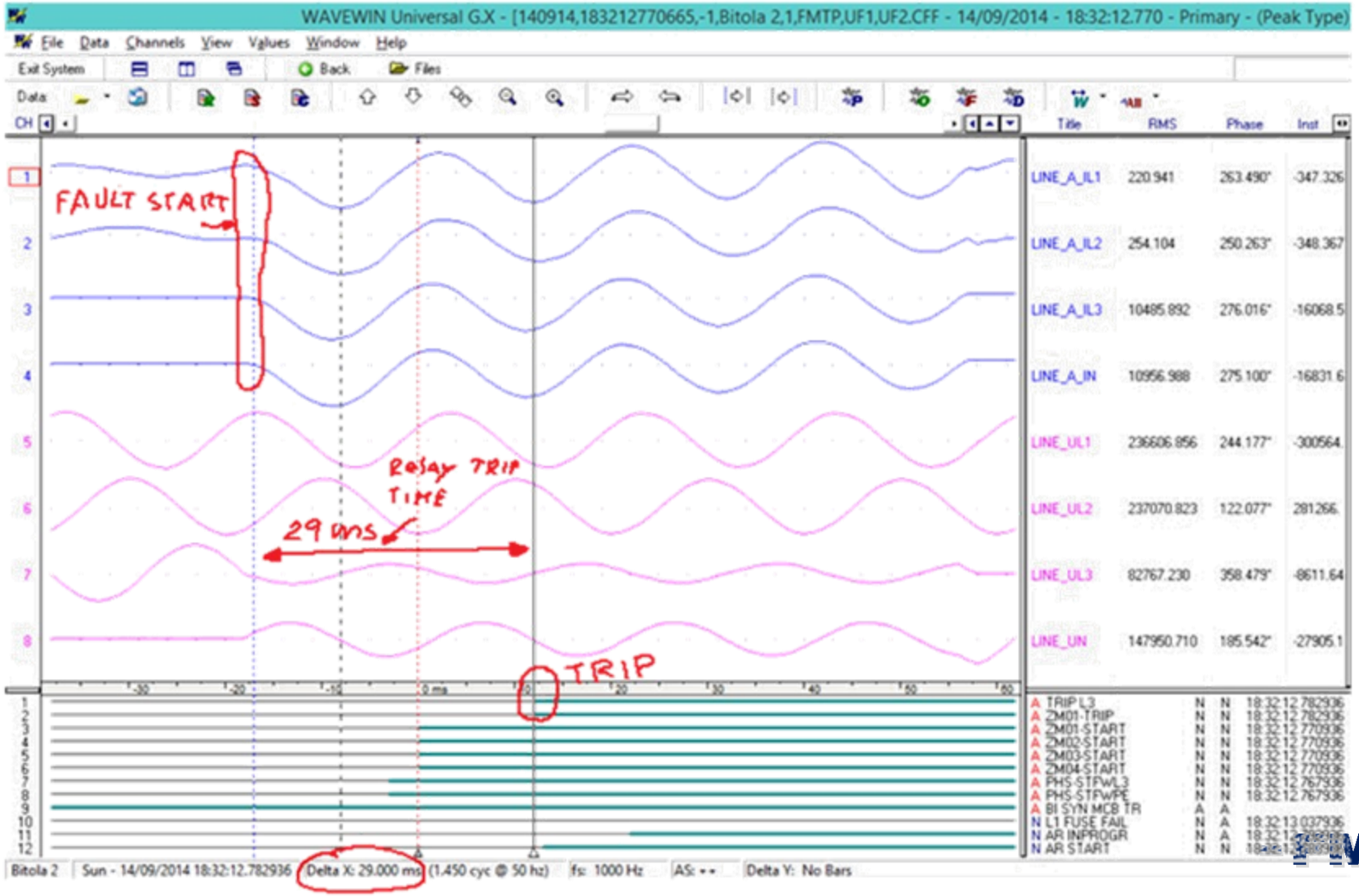
Ramp of shots showing impedance step change and the time step





DEFINITION OF OPERATE TIME AND TYPICAL OPERATE TIME

Clear definition of what operate time means:

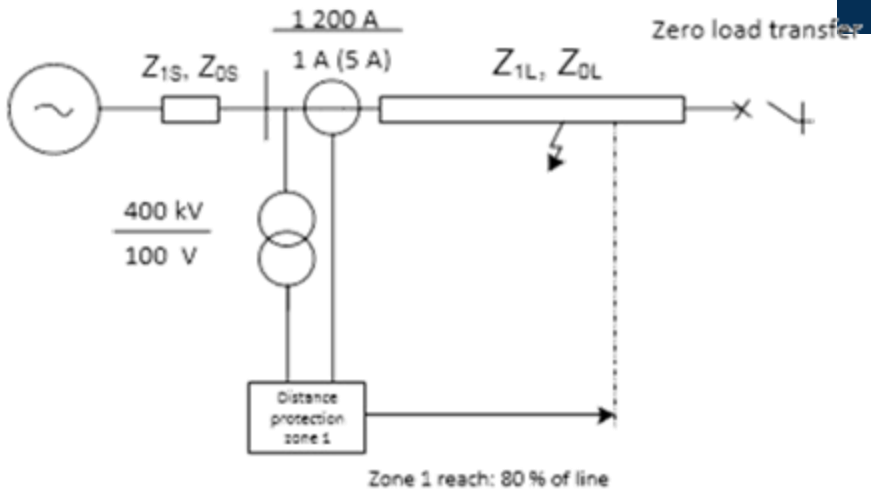


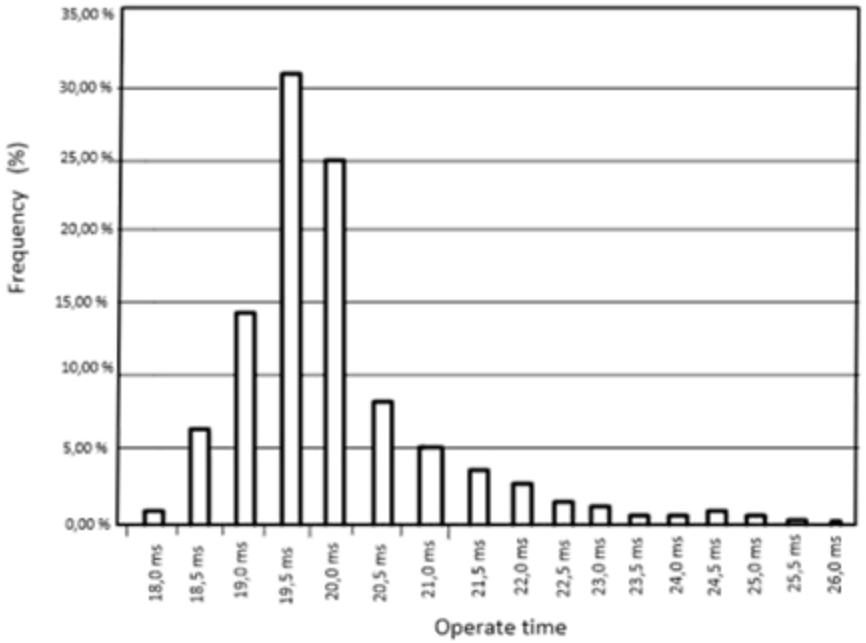
The standard defines the relay operate time as **the time interval from when the power system fault starts to when the relay operates** .

DEFINITION OF OPERATE TIME AND TYPICAL OPERATE TIME

Clear definition of typical operate time and its test methodology.

Statistical approach and realistic tests are used to test and report the typical operate time.



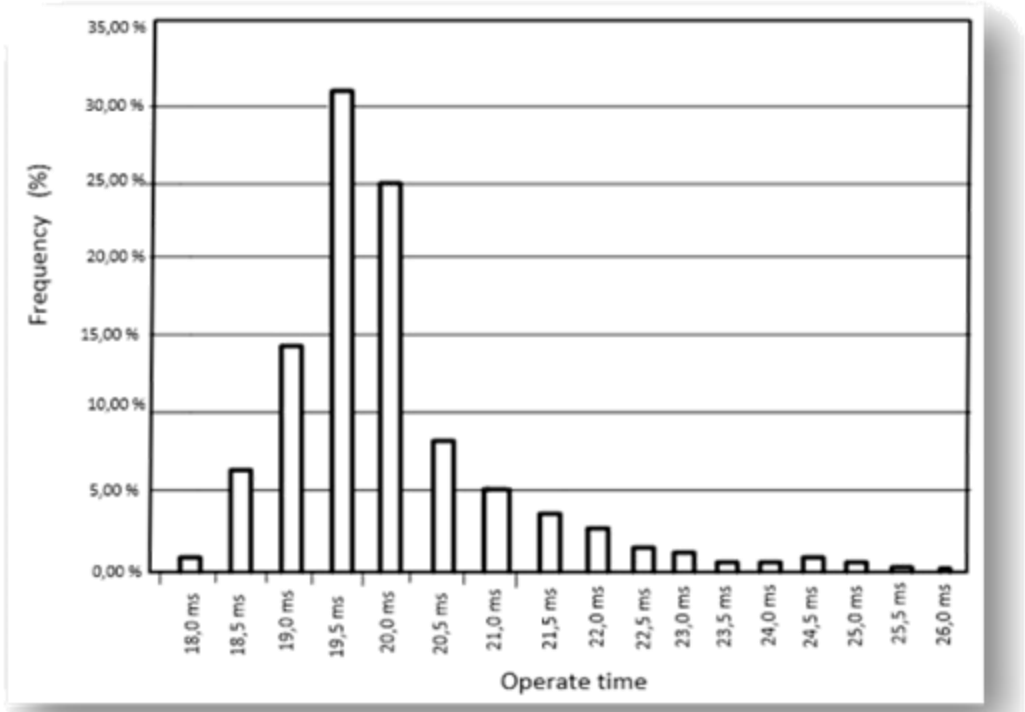


Typical operate time	
Mode (most frequently measured value)	19,5 ms
Median (typical time) (central value: 50 % of the measured values are below the median, and 50 % are above the median)	19,8 ms
Mean (average value of the measured trip times)	22,2 ms

DO WE HAVE TOOLS TO PERFORM THE REQUIRED TESTS?

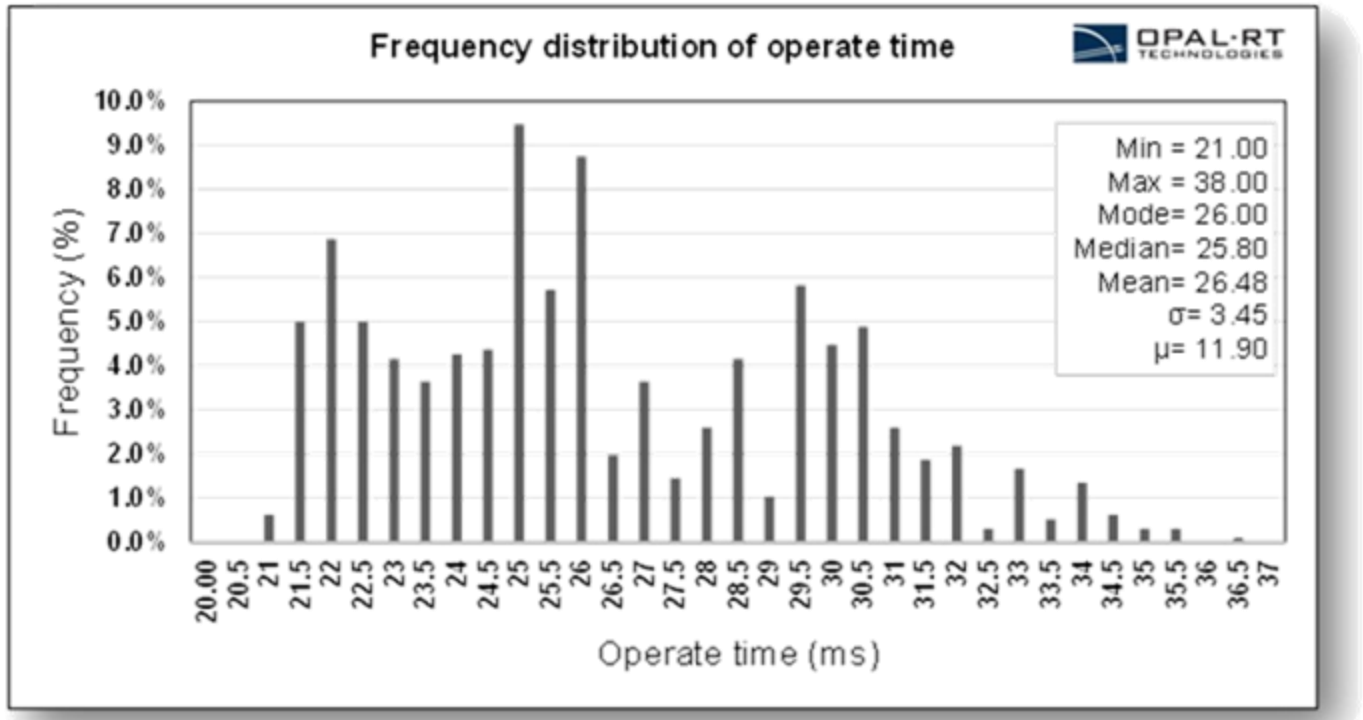
The "Theory" (from the standard)

2014



The "Reality" (from the test system and tool)

2017



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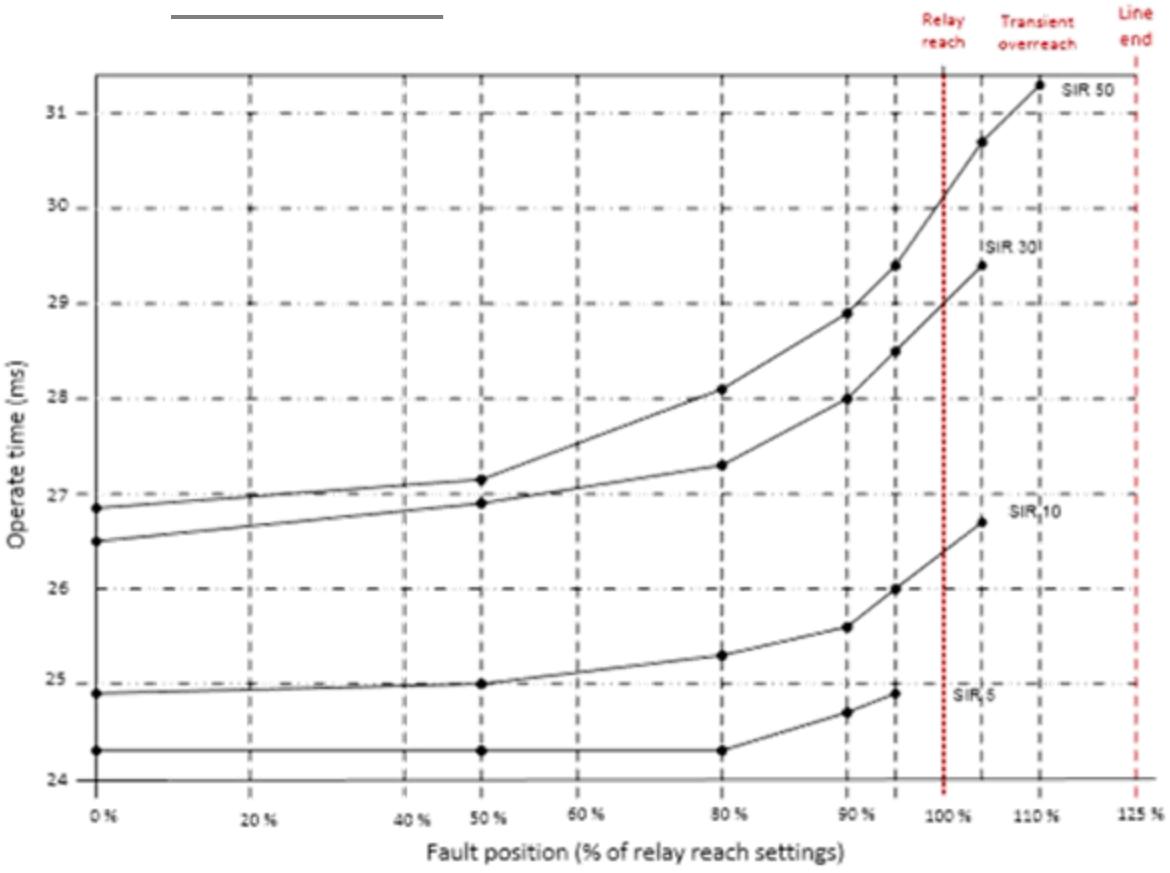
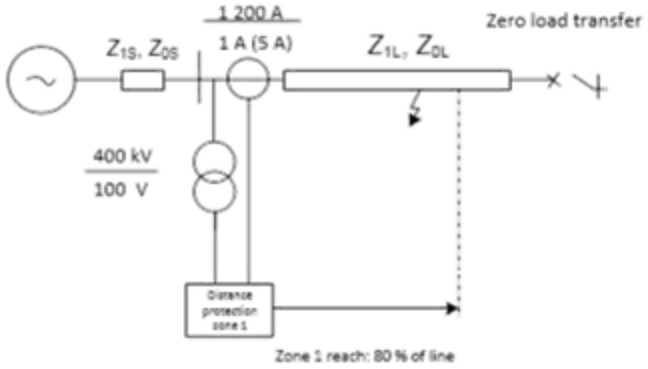
SIR Diagrams



SIR diagrams show the relay "trip time" as function of:
- fault position
- impedance ratio

(between eq. source impedance and the relay reach)

SIR Diagrams are the result of standardized realistic network simulation tests

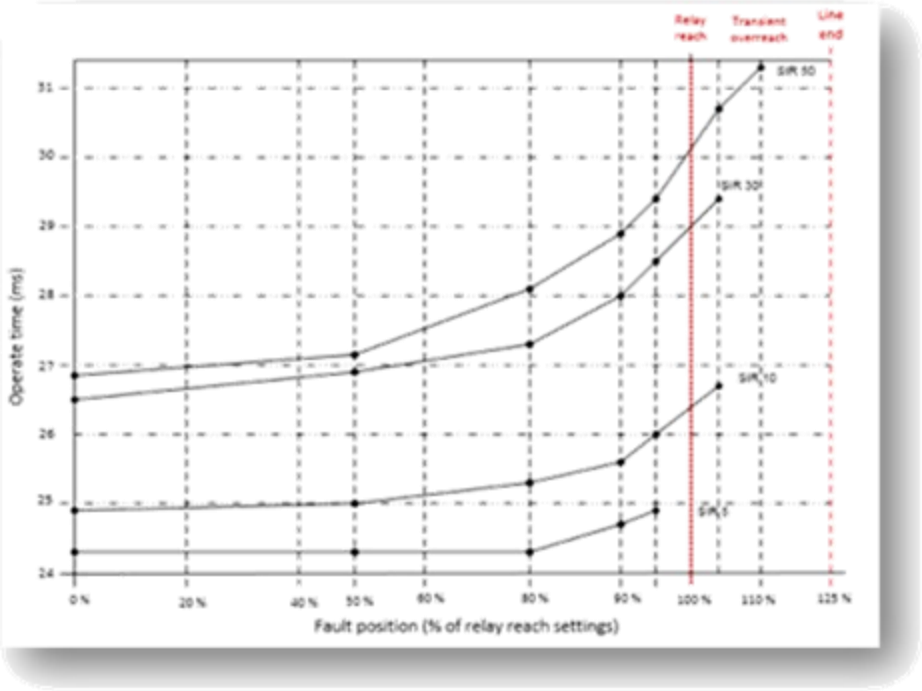


Phase-phase-earth faults are also simulated

DO WE HAVE TOOLS TO PERFORM THE REQUIRED TESTS?

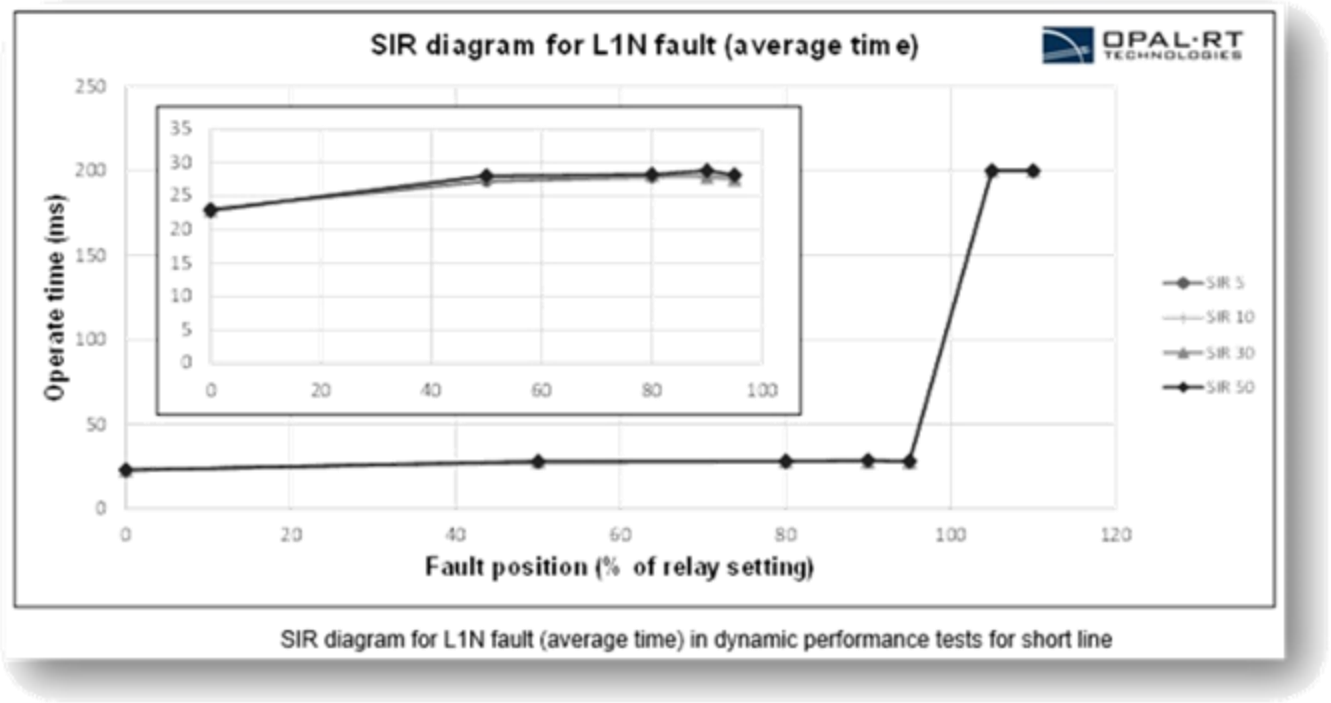
The "Theory" (from the standard)

2014



The "Reality" (from the test system and tool)

2017

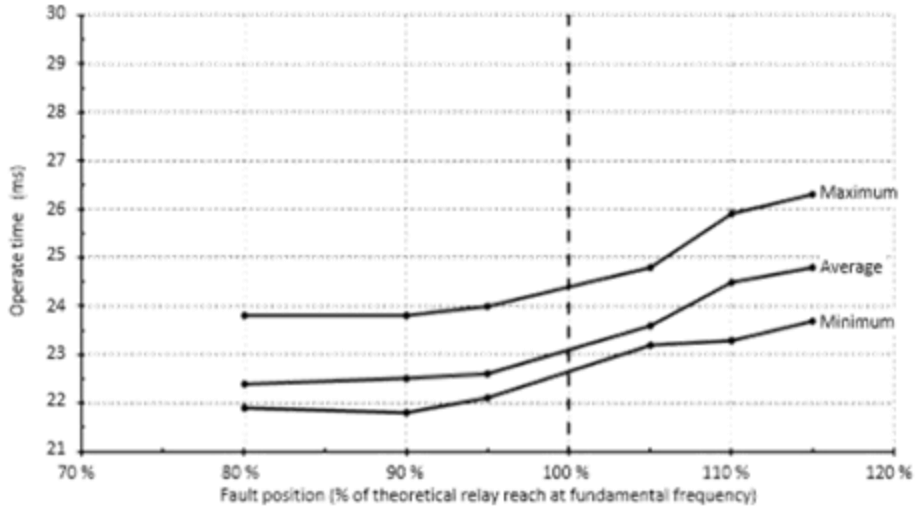


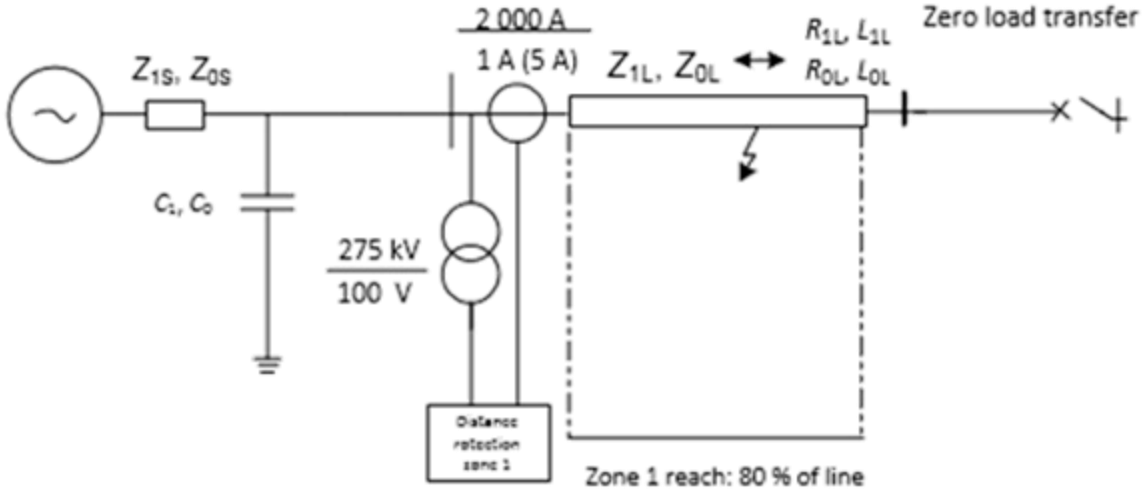
SIR diagram for L1N fault (average time) in dynamic performance tests for short line

HARMONICS DURING FAULTS

The "**Transient LC oscillation tests**" are intended to verify the effect of harmonics under fault conditions on the relay operate time and transient overreach. To generate harmonics during fault conditions a resonant RLC circuit is used. In this model the capacitance is positioned behind the relay connection point and the inductance and resistance are represented by the fault impedance.

Relay operate time and transient overreach investigated with harmonics presence on fault conditions:





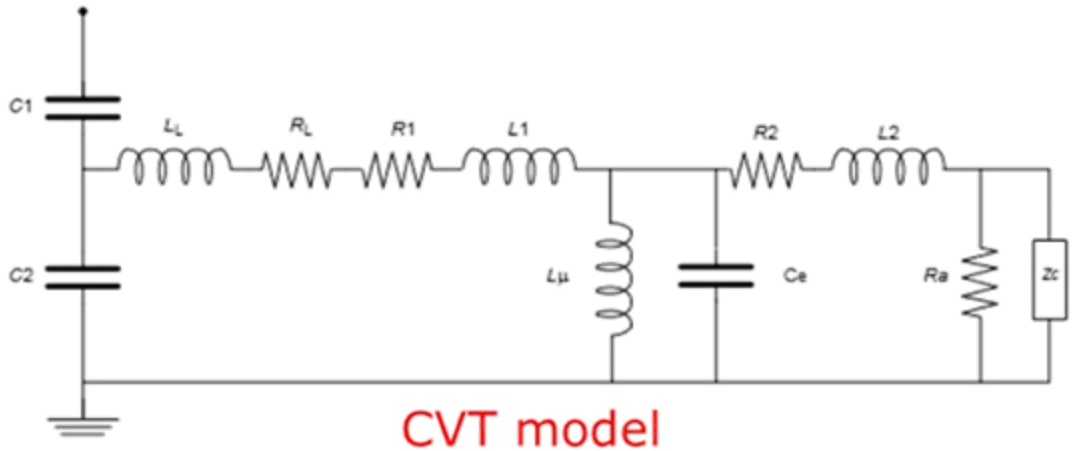
Results are shown with SIR diagrams.

CVT-SIR DIAGRAMS

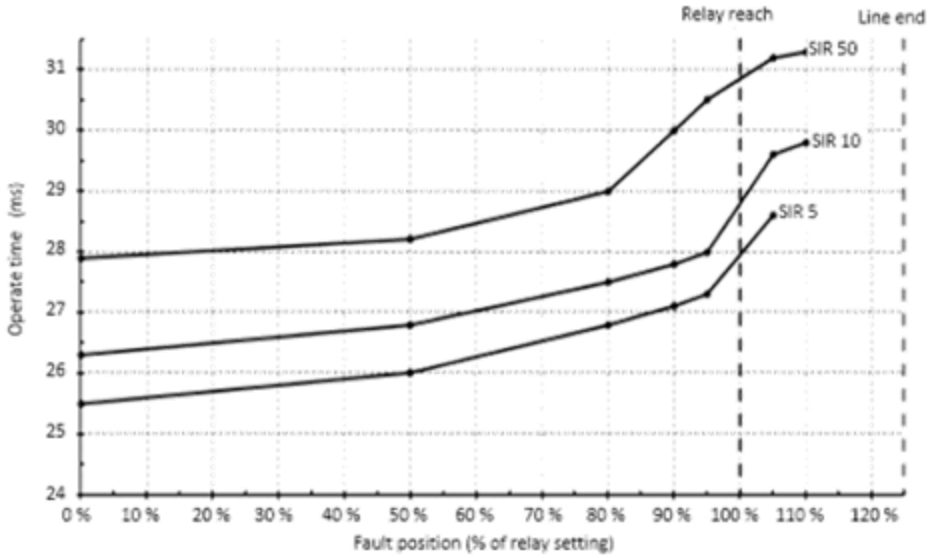
Capacitive Voltage Transformers (CVT) may have an impact on the operate time and transient overreach of the distance protection relay

The standard proposes a CVT model which is used to simulate the CVT transients generated during power system faults.

By executing standardized tests, the so called CVT-SIR Diagrams are obtained.



CVT model



CVT-SIR Diagram

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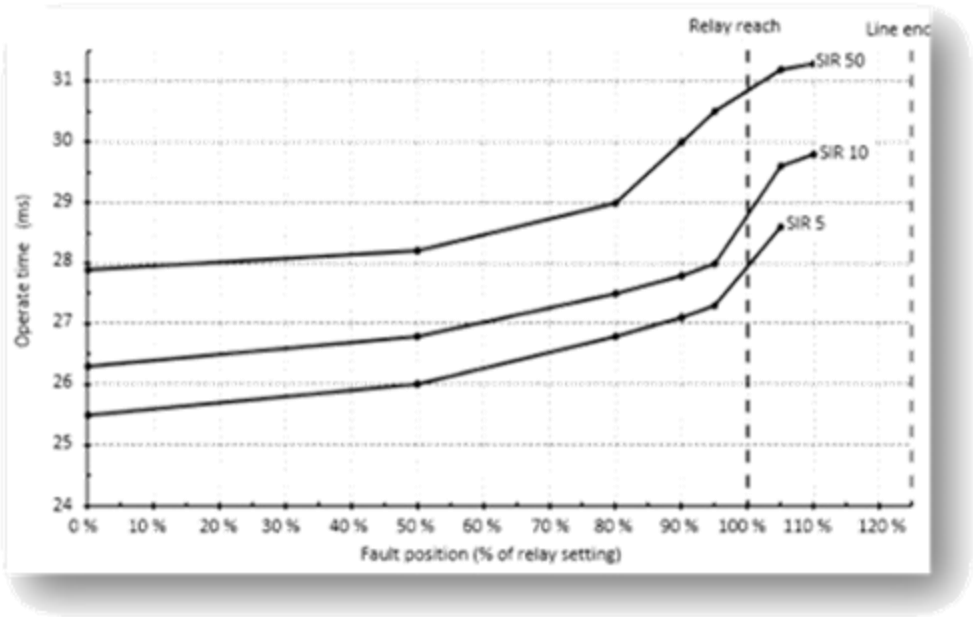
DO WE HAVE TOOLS TO PERFORM THE REQUIRED TESTS?

The ”Theory” (from the standard)

2014



The ”Reality” (from the test system and tool)

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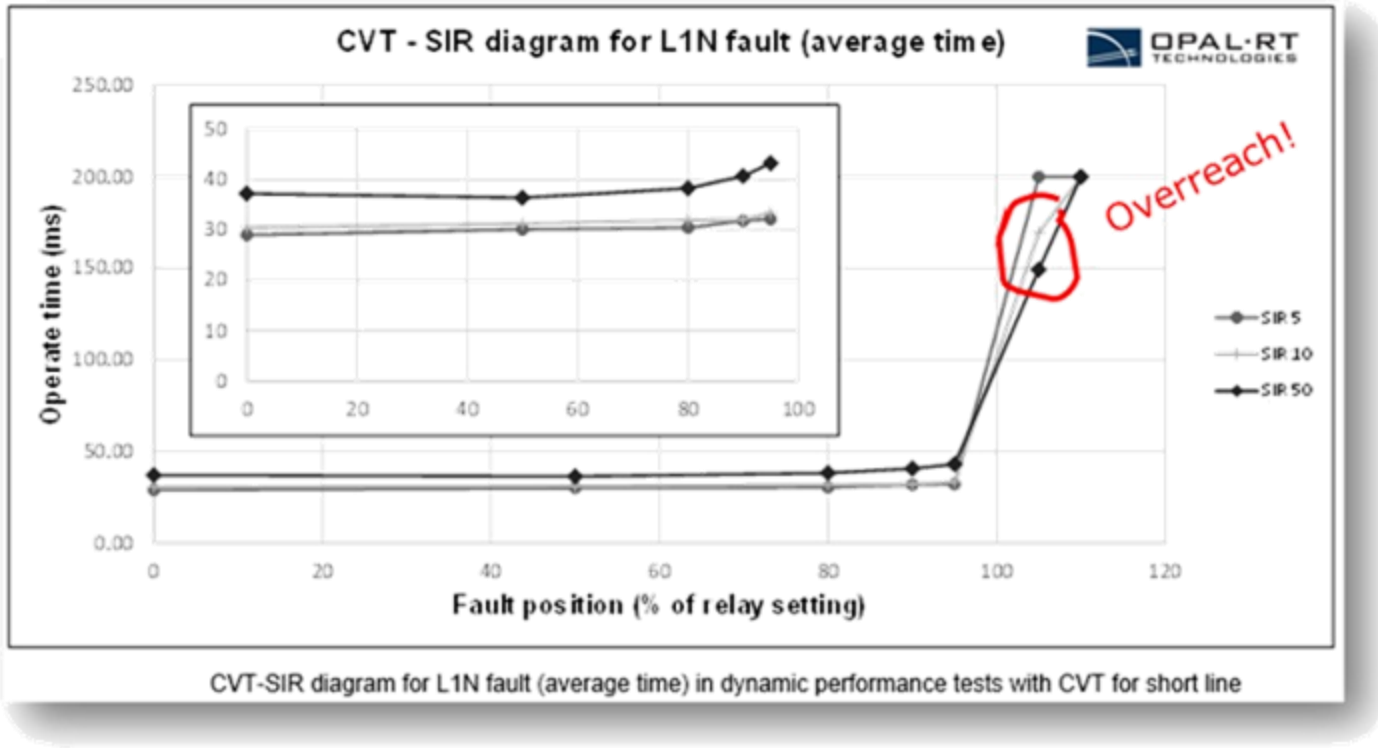


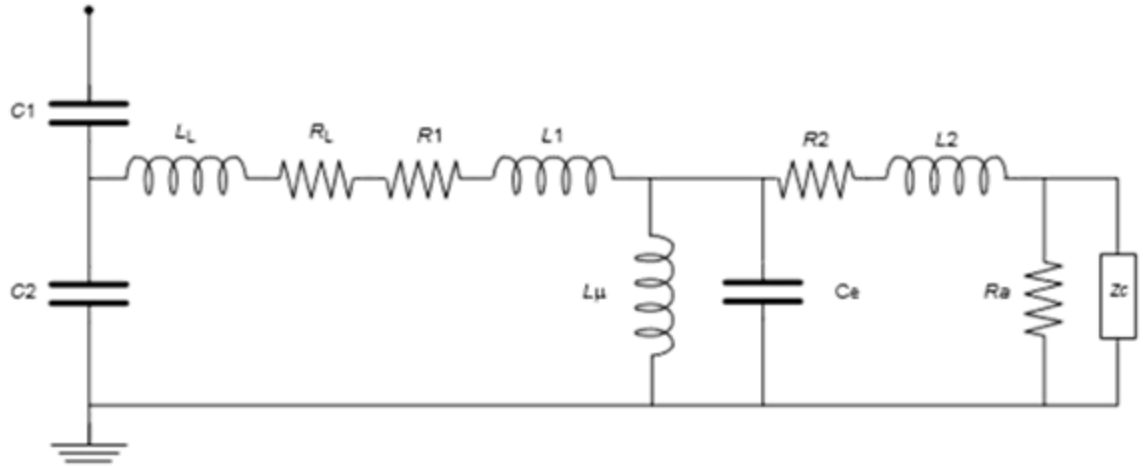
CVT-SIR diagram for L1N fault (average time) in dynamic performance tests with CVT for short line

PLEASE DO NOT FORGET…

CVT Model available in the Standard, for fair comparison of relay performances!

Relay manufacturer are supposed to perform many more tests with many more CVT models!

Make sure that relay algorithms consider many other CVT models and not only the one proposed by IEC 60255-121!



ONE CVT MODEL IS NOT ENOUGH!

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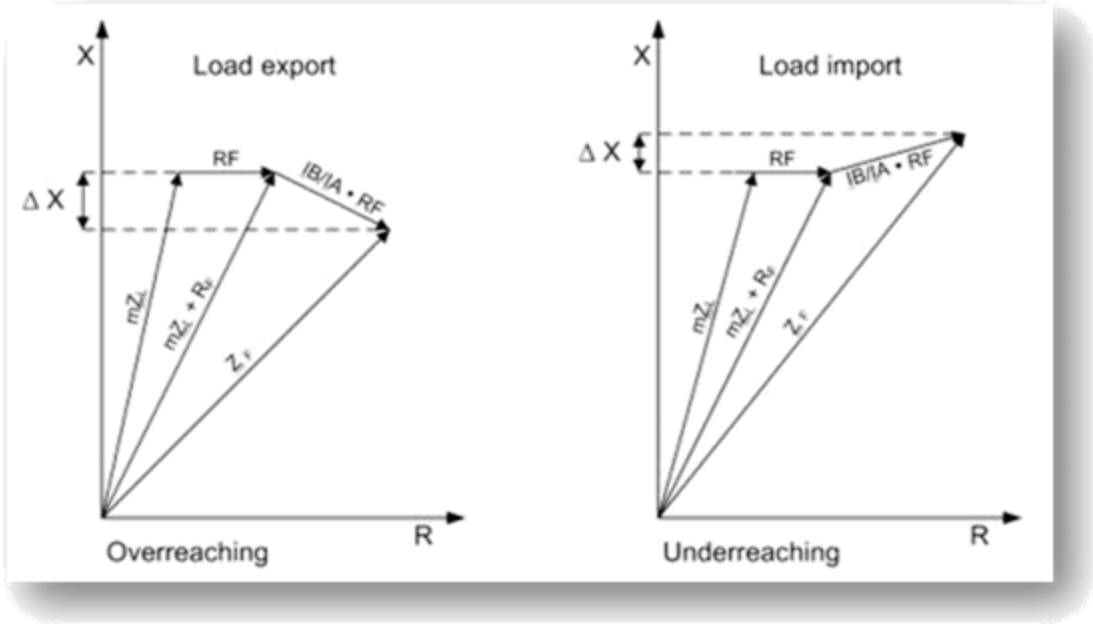
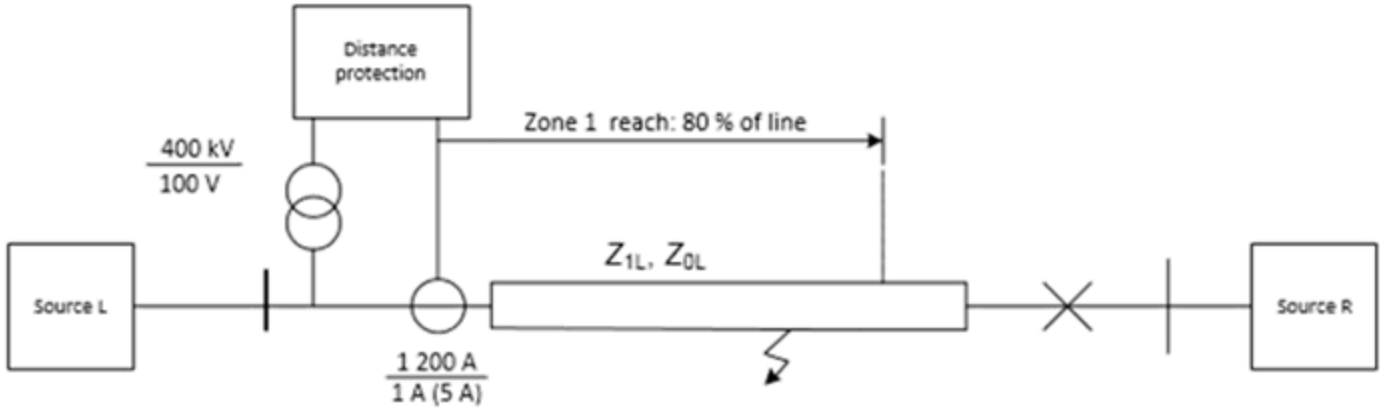
DOUBLE INFEED TESTS

The standardized tests with double-infeed power system configuration show the relay performance for faults with fault resistance and in presence of superimposed pre-load conditions (exporting load or importing load).

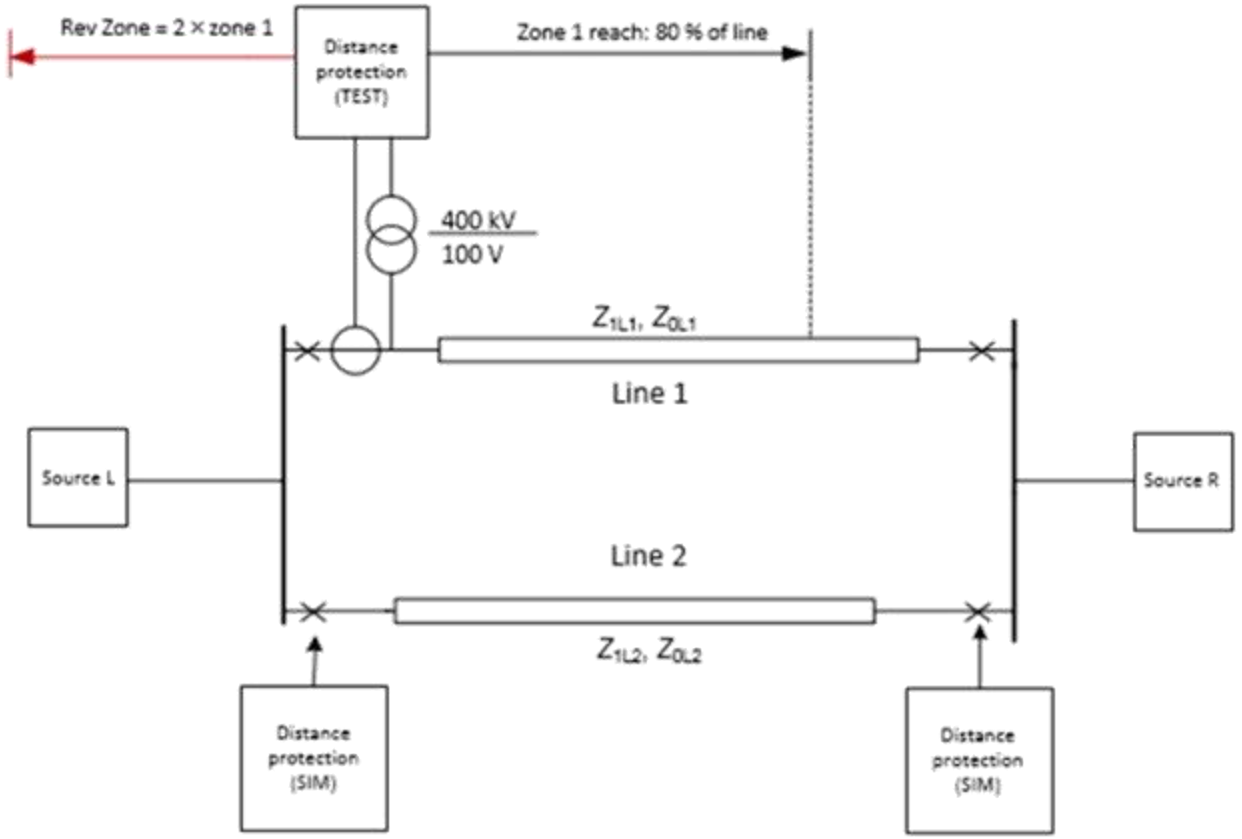
The tests can also detect underreaching or overreaching behaviors and can also indicate wrong phase selection in the relay operation (multi-phase operation instead of single-phase operation).





DOUBLE INFEED TESTS

The double infeed tests are performed for single line and double line configurations.



For the double line configuration these tests can determine the relay behavior under:

- current-reversal conditions
- directionality detection with the presence of the superimposed load
- evolving faults (evolving faults from one type to another type in one line, or evolving faults from one line into the parallel line).

DOUBLE INFEED TESTS

In order to perform these tests, a real time power system simulator is required, which can simulate the behavior of the remote relay(s) and circuit breaker(s), and also to simulate the power system on the direct behavior of the relay under tests (operation for only one phase, operation for all the phases for instance).

The test results are reported with a sort of "Time Event Log".

Fault no.	Test description	Description	Opera-te L1 (ms)	Opera-te L2 (ms)	Opera-te L3 (ms)	Start L1 (ms)	Start L2 (ms)	Start L3 (ms)	Start ground (ms)	Comment
1	L1N, 70 %,long	Fast trip L1	20 ms	-	-	20 ms	-	-	20 ms	--
2	L1N, 70 %,long	Fast trip L1	...							--
3	...									
4	...									

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DOUBLE INFEED TESTS

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1	L1N, 70 %,long	Fast trip L1	20 ms	-	-	20 ms	-	-	20 ms	--
2	L1N, 70 %,long	Fast trip L1	...							--
3	...									
4	...									

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CT REQUIREMENTS

The Standard details how relay manufacturers shall declare the requirements for the CT sizing

$$E_{alreq} = \frac{I_f}{I_{pr}} \cdot K_{tot} \cdot I_{sr} \left(R_{ct} + R_{ba} \right)$$

Users are able to verify that the used CTs are ok for the given application, or are able to size them in the initial project phase.

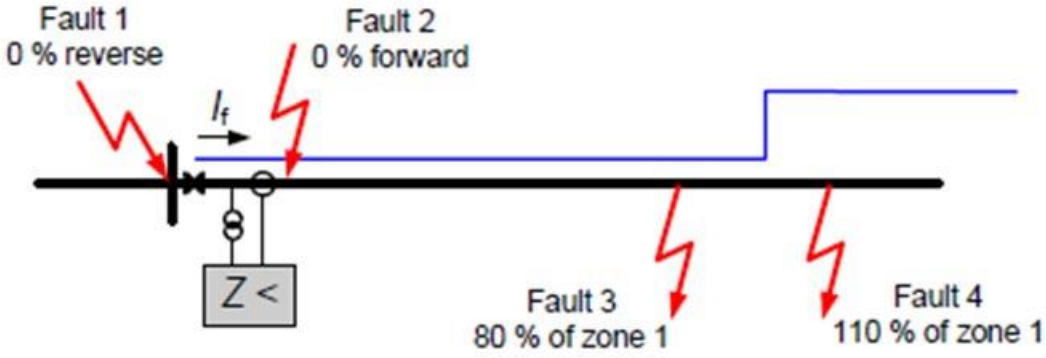

Figure F.1 – Fault positions to be considered

CT REQUIREMENTS

The Standard requires that for correct operations of the distance protection relay a minimum level of saturation voltage from the connected current transformers must be ensured.

The CTs must have a minimum rated equivalent limiting secondary e.m.f. Eal according to IEC 61869-2.

The required rated equivalent limiting secondary e.m.f. Ealreq depends on the design of the relay and on the application:

$$E_{alreq} = \frac{I_f}{I_{pr}} \cdot K_{tot} \cdot I_{sr} \left(R_{ct} + R_{ba} \right)$$

CT REQUIREMENTS

CT Dimensioning

$$E_{alreq} = \frac{I_f}{I_{pr}} \cdot K_{tot} \cdot I_{sr} \left(R_{ct} + R_{ba} \right)$$

I_f	is the maximum primary steady-state short-circuit CT current for the considered fault case	***Application***
I_{pr}	is the CT rated primary current	
I_{sr}	is the CT rated secondary current	
K_{tot}	is the total over-dimensioning factor (including the transient dimensioning factor and the remanence dimensioning factor)	***Provided by the relay manufacturer***
R_{ct}	is the CT secondary winding resistance	*CT Dimensioning*
R_{ba}	is the total resistive burden, including the secondary wires and all relays in the circuit.	***Application***

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CT REQUIREMENTS

The relay manufacturers need to perform comprehensive tests to determine the necessary over-dimensioning factor Ktot for the different cases.

There is no mandatory test method specified and the standard does not state in details which CT models shall be used to decide the CT requirements.

As the relay manufacturer has detailed information about the relay design and about the relay measuring and protection algorithms, it is left to the manufacturer to perform the necessary amount of tests to fulfill the criteria and conditions stated in the standard.

However, the standard provides an informative guide describing example

CT REQUIREMENTS … BEFORE

In the past there was no formal requirement for the relay manufacturers to take the responsibility and specify the CT requirements for their distance protection relays.

Some manufacturers have never provided any method for the user to make sure that the correct CTs are applied to the relay.

CONCLUSION

The IEC 60255-121:2014 standard specifies the minimum requirements for functional and performance evaluation of distance protection function and the described tests are mandatory part of the type-test for the protection relay.

Relay manufacturers are requested to conduct extensive testing.

It is expected to see the standard as a reference for relay **acceptance tests** requested by the end-users. Needs of third part validations ("Kema", TÜV..)?

pass/fail criteria are not specified: **users** are expected to specify their own acceptance criteria/requirements according to their application.

The standard provides detailed discussion on CVT transients and requirement on CT sizing.

The standard specifies NO commissioning/routine tests:
Several tests and definitions in the Standard can be reasonably applied to them.


THANK
YOU !