Mitigating Murphy´s Law While Test

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- Language: English, German, French

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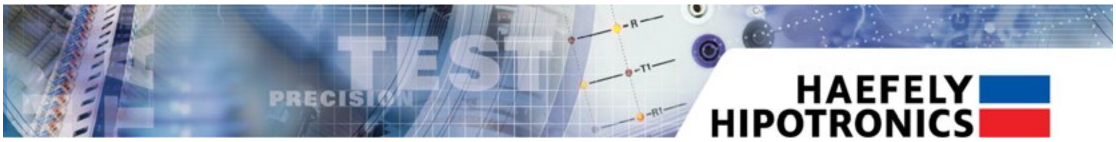


ABSTRACT

Mitigating Murphy’s Law While Test

Frédéric DOLLINGER, Haefely Hipotronics, Birsstrasse 300, CH-4052 Basel, Switzerland

1. Introduction

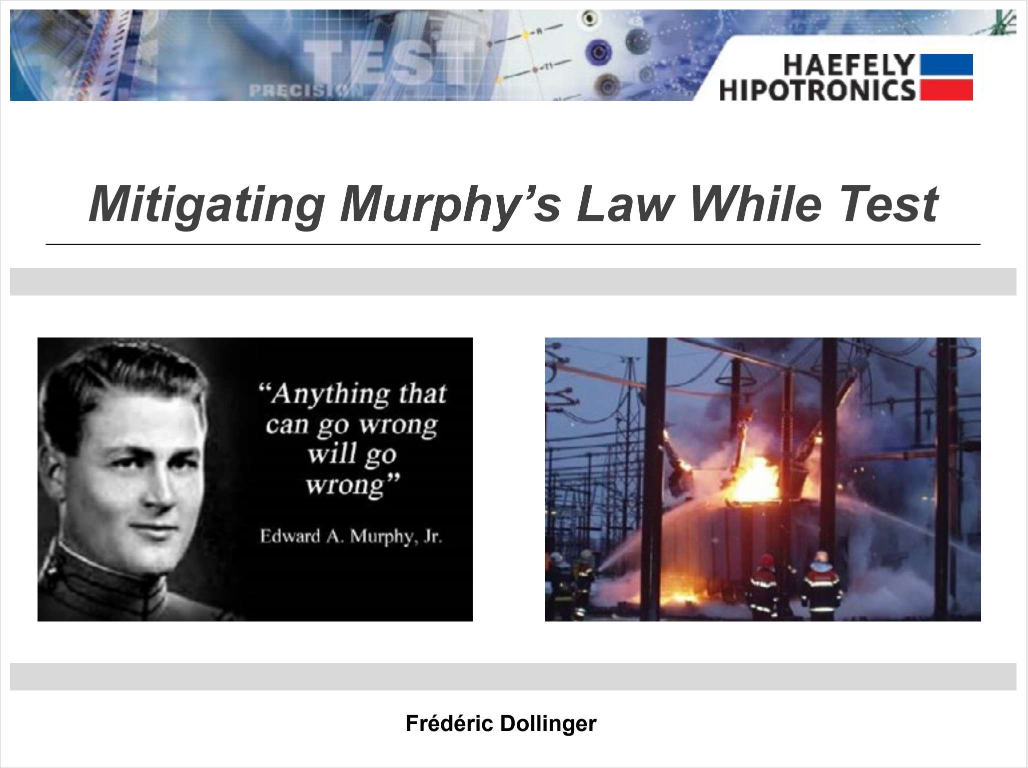
As Haefely Hipotronics, we have very large customer database around the world, in the manufacturing, utility, research & development and university sector, which are linked in the transformer, bushing, motor-generator, cable and capacitor industry.
Working close with our customers, we have seen or even sometime have surprisingly discovered situations, which the test was performed in an improper way: typically Murphy’s Law. Various causes are involved, such as misinterpretation of standard (IEC/IEEE), or misinterpretation of the instrument settings, or inadequate instrumentation. Those can lead to unconform standard (IEC/IEEE) measurements or wrong measurement results, up to even damage the test object or test system. This presentation is a summary of what have been seen onsite, covering tests like partial discharge measurement, C/tanδ measurement, loss measurement and lightning impulse test.

2. Case Study:

For each group of test, most common case is studied with the mention of the cause of the fault, the fault, the consequence and the solution.

Test	Case Study
1: Partial discharge measurement	-Wrong PD setup connection
	-Wrong PD calibration process
	-Wrong setting of the PD detector
	-Misinterpretation of PD measurement
2: C/tanδ measurement	-Wrong connection setup due to multiple grounding point
	-Wrong UST/GST mode
	-Wrong accuracy class of the instrument compared to application
	-Wrong ambient condition
	-Wrong nominal capacitor
3. Loss measurement	-Wrong PT, CT and wattmeter class
	-Too high voltage THD during the measurement
	-Too high voltage asymmetry during the measurement
	-Slightly too high voltage during the measurement
4. Lightning impulse test	-Wrongly connected voltage divider
	-Wrong grounding setup
	-Too long distance between test object and impulse generator
	-Not updated measuring system
	-Wrong divider ratio

Conclusion:
This case study shares what has been seen and experienced over the last decade onsite, in order to **provide important insight** and to extrapolate key results that help **illuminate previously hidden issues**.

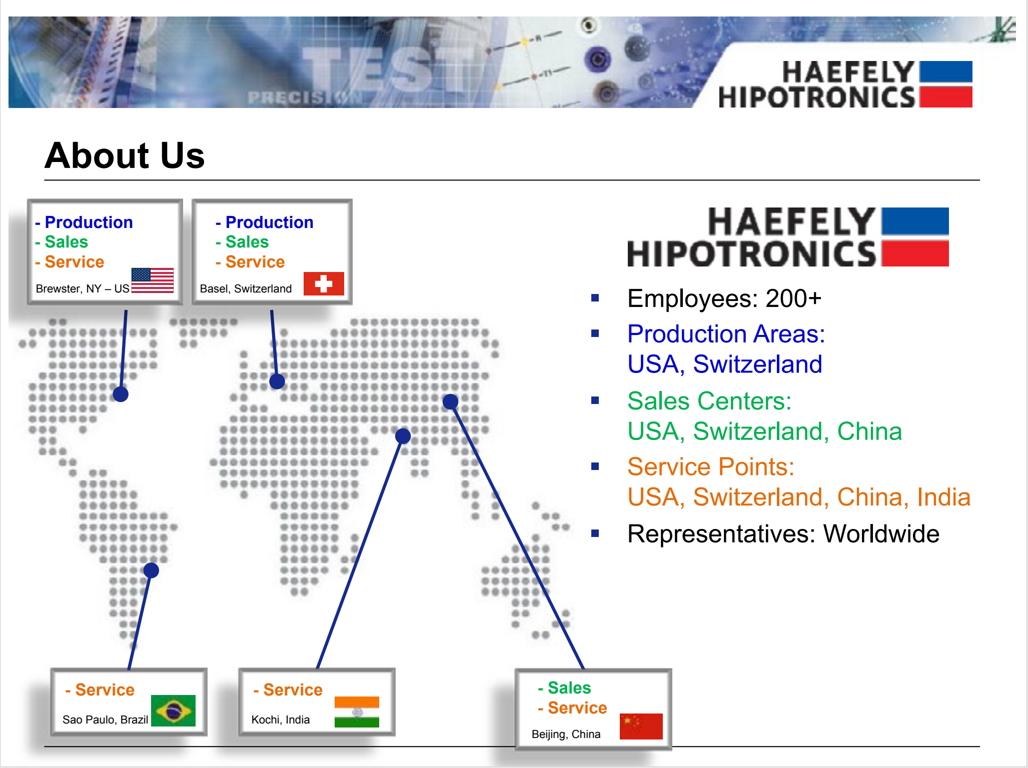


Mitigating Murphy's Law While Test

"Anything that can go wrong will go wrong"

Edward A. Murphy, Jr.

Frédéric Dollinger



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- Sales
- Service

Brewster, NY – US

- Production
- Sales
- Service

Basel, Switzerland

- Service

Sao Paulo, Brazil

- Service

Kochi, India

- Sales
- Service

Beijing, China

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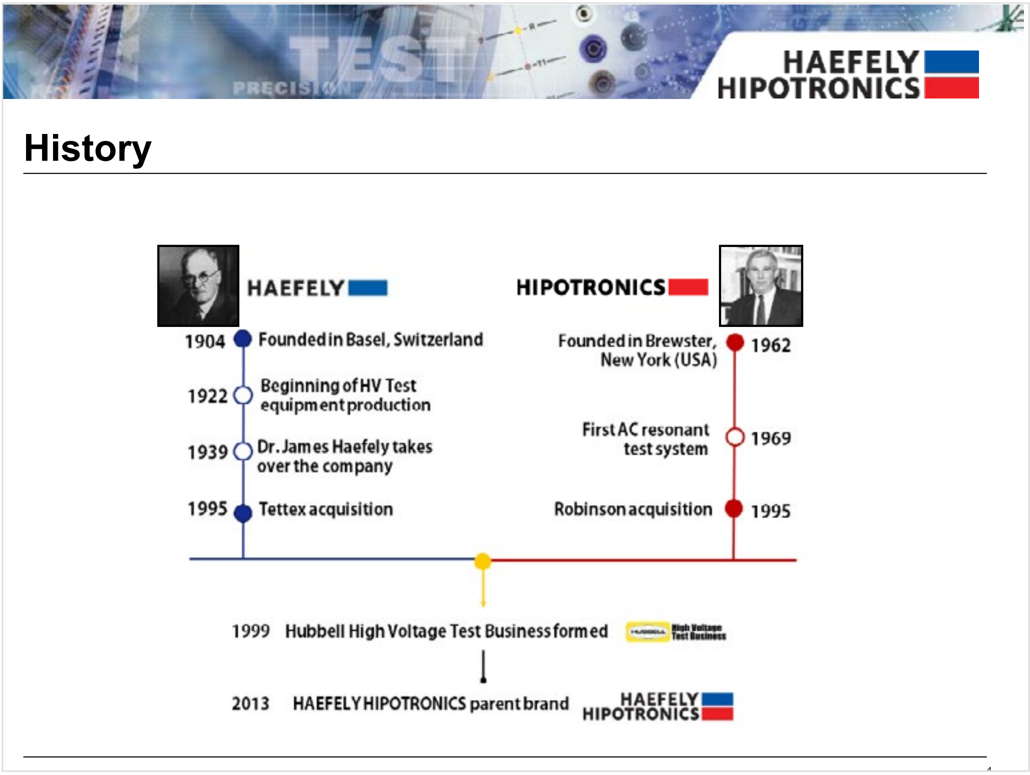
- Employees: 200+
- Production Areas: USA, Switzerland
- Sales Centers: USA, Switzerland, China
- Service Points: USA, Switzerland, China, India
- Representatives: Worldwide



History

HAEFELY

1904 Founded in Basel, Switzerland

1922 Beginning of HV Test equipment production

1939 Dr. James Haefely takes over the company

1995 Tettex acquisition

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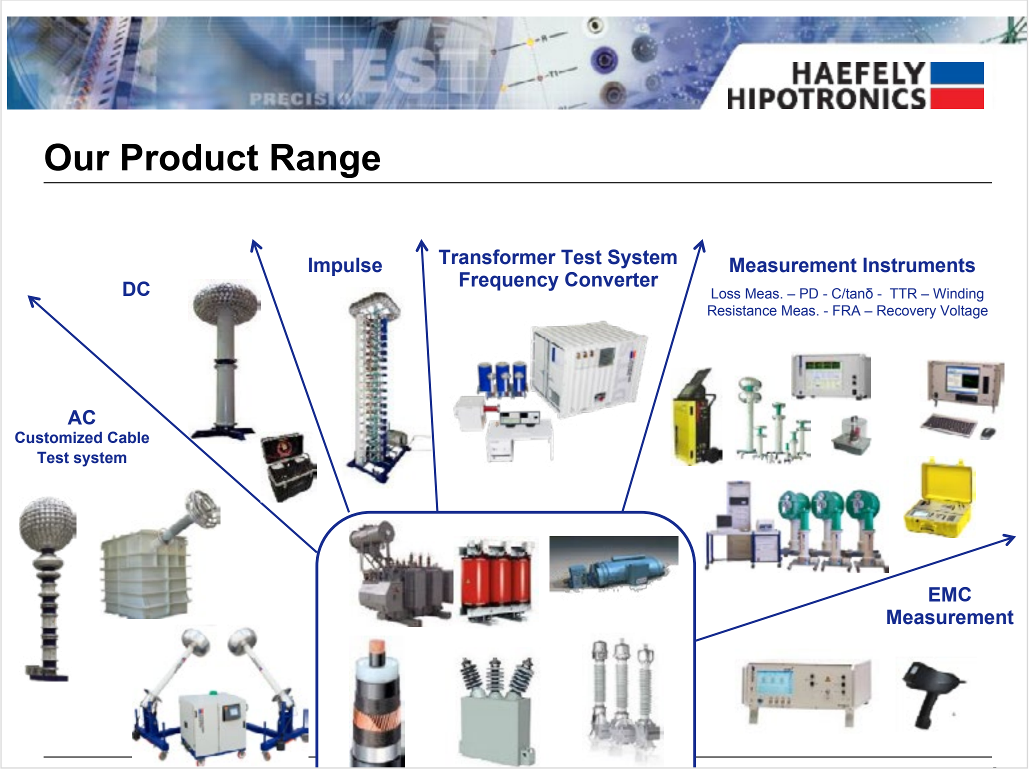
1962 Founded in Brewster, New York (USA)

1969 First AC resonant test system

1995 Robinson acquisition

1999 Hubbell High Voltage Test Business formed

2013 HAEFELY HIPOTRONICS parent brand



Our Product Range

DC

Impulse

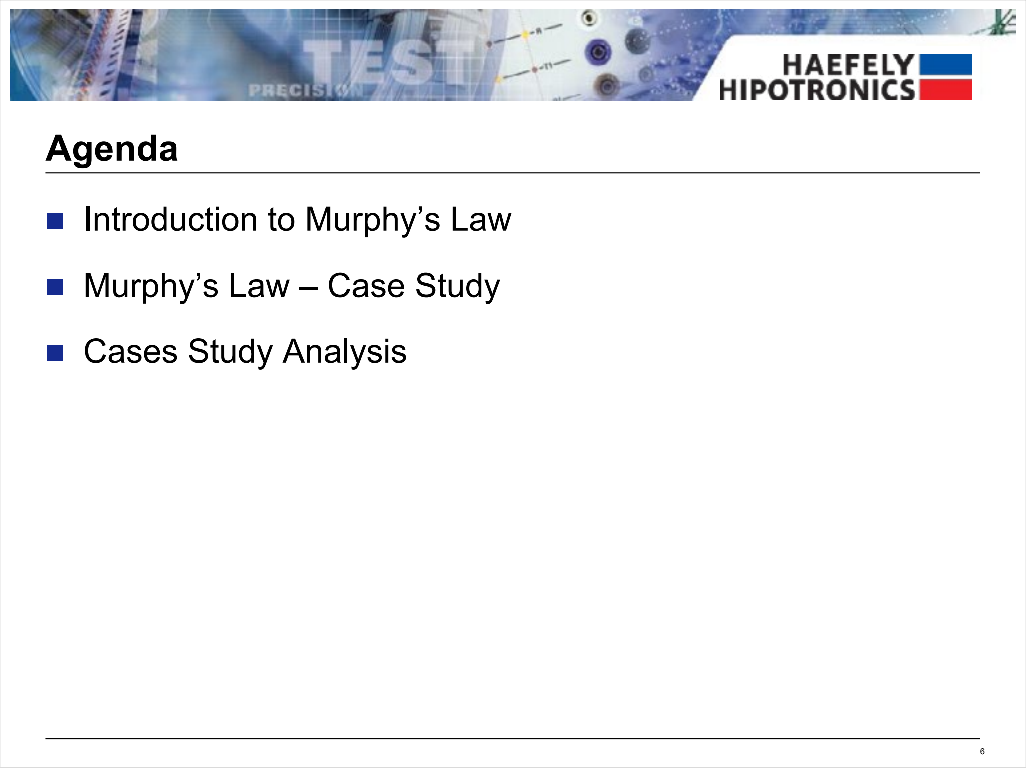
Transformer Test System
Frequency Converter

Measurement Instruments

Loss Meas. – PD - C/tanδ - TTR – Winding Resistance Meas. - FRA – Recovery Voltage

AC
Customized Cable
Test system

EMC
Measurement



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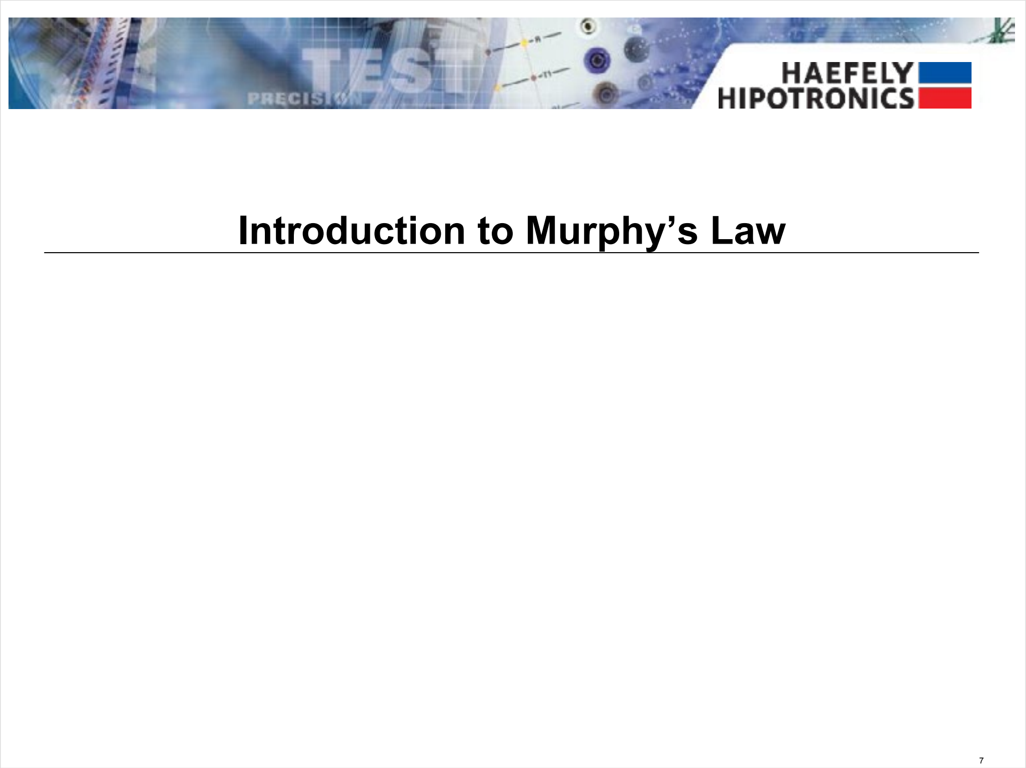
Agenda

- Introduction to Murphy’s Law
- Murphy’s Law – Case Study
- Cases Study Analysis



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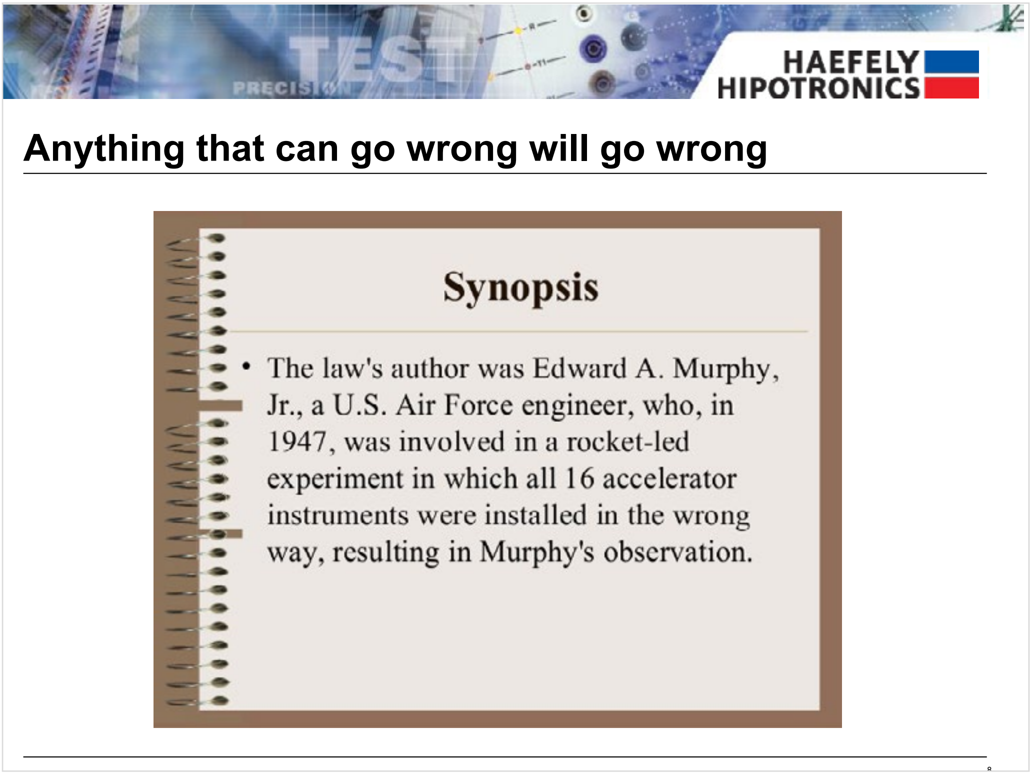
Introduction to Murphy’s Law



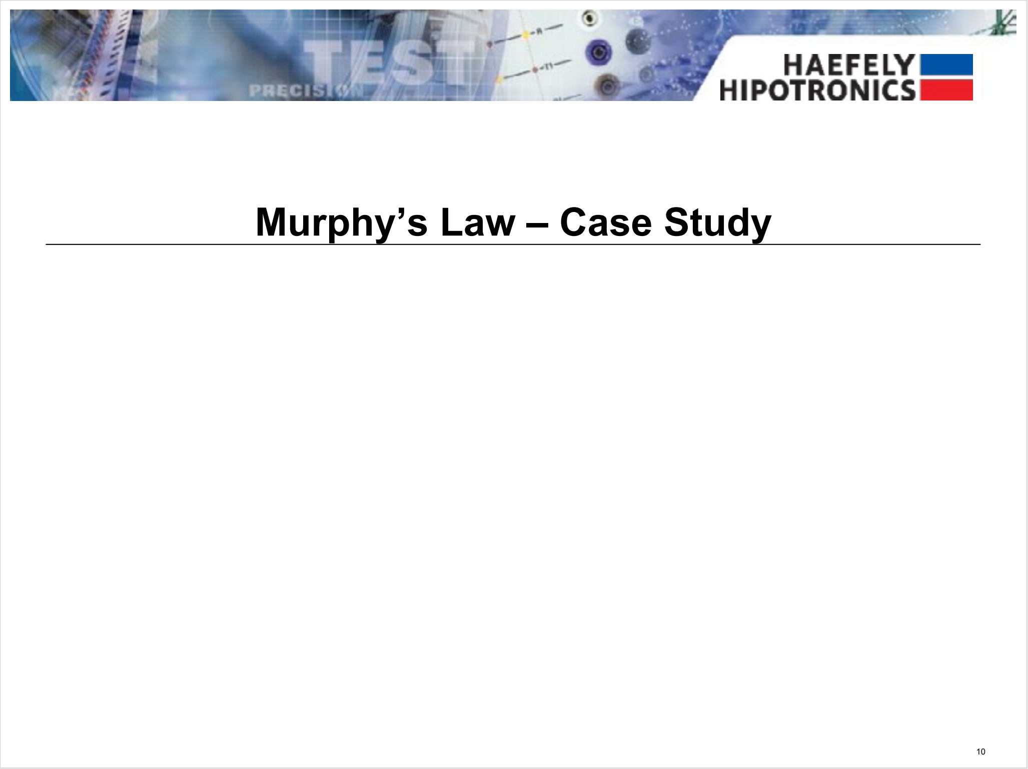
Anything that can go wrong will go wrong

Synopsis

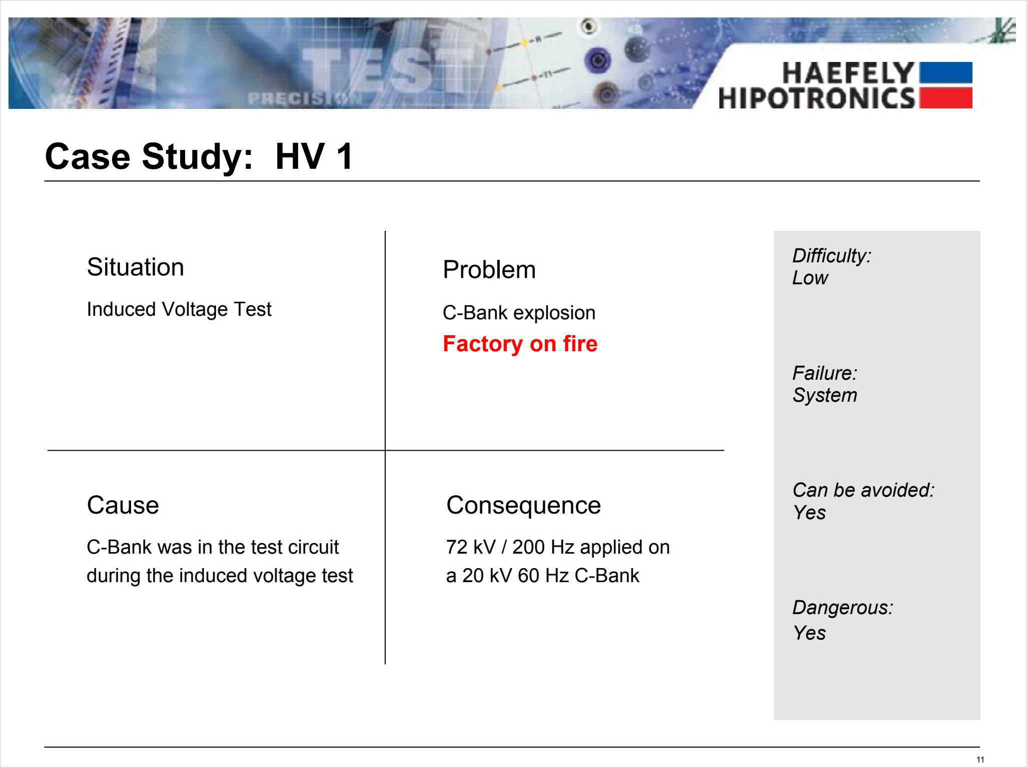
- The law's author was Edward A. Murphy, Jr., a U.S. Air Force engineer, who, in 1947, was involved in a rocket-led experiment in which all 16 accelerator instruments were installed in the wrong way, resulting in Murphy's observation.

Case study

- **Origin:** this study shares what has been seen and experienced onsite from us
- **Target:** provide important insight and illuminate previously hidden issues
- **Systematic approach:** each case is studied with the mention of the fault, the cause of the fault, the consequence and the solution.



Murphy's Law – Case Study



Case Study: HV 1

Situation

Induced Voltage Test

Problem

C-Bank explosion

Factory on fire

Cause

C-Bank was in the test circuit during the induced voltage test

Consequence

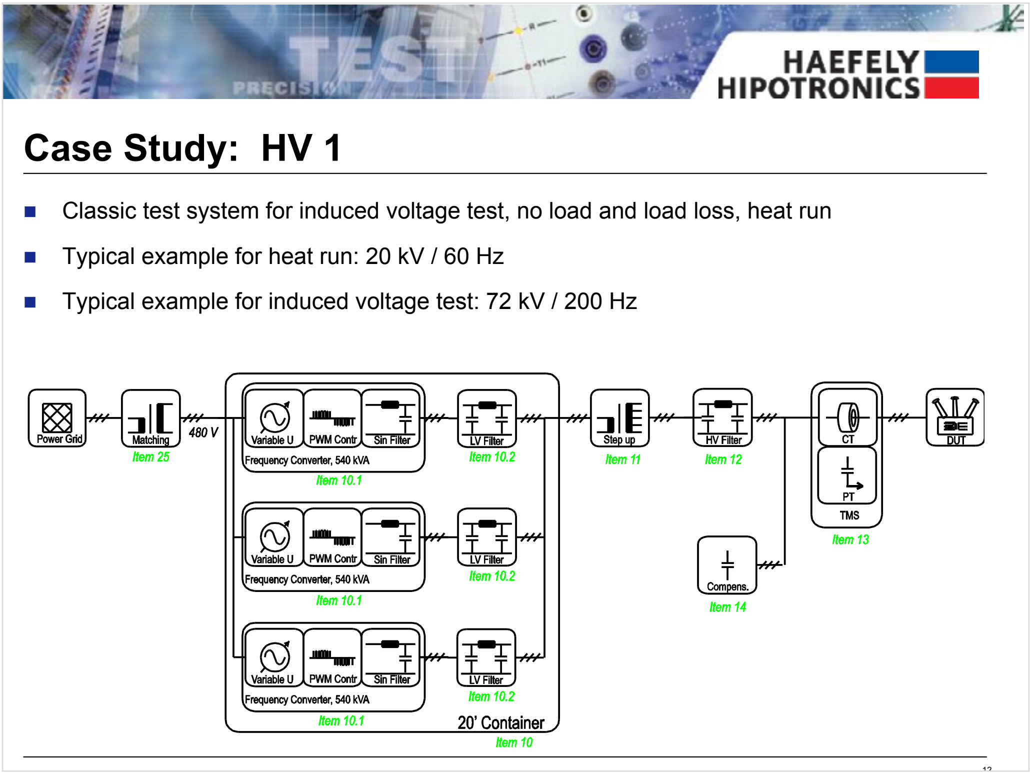
72 kV / 200 Hz applied on a 20 kV 60 Hz C-Bank

Difficulty:
Low

Failure:
System

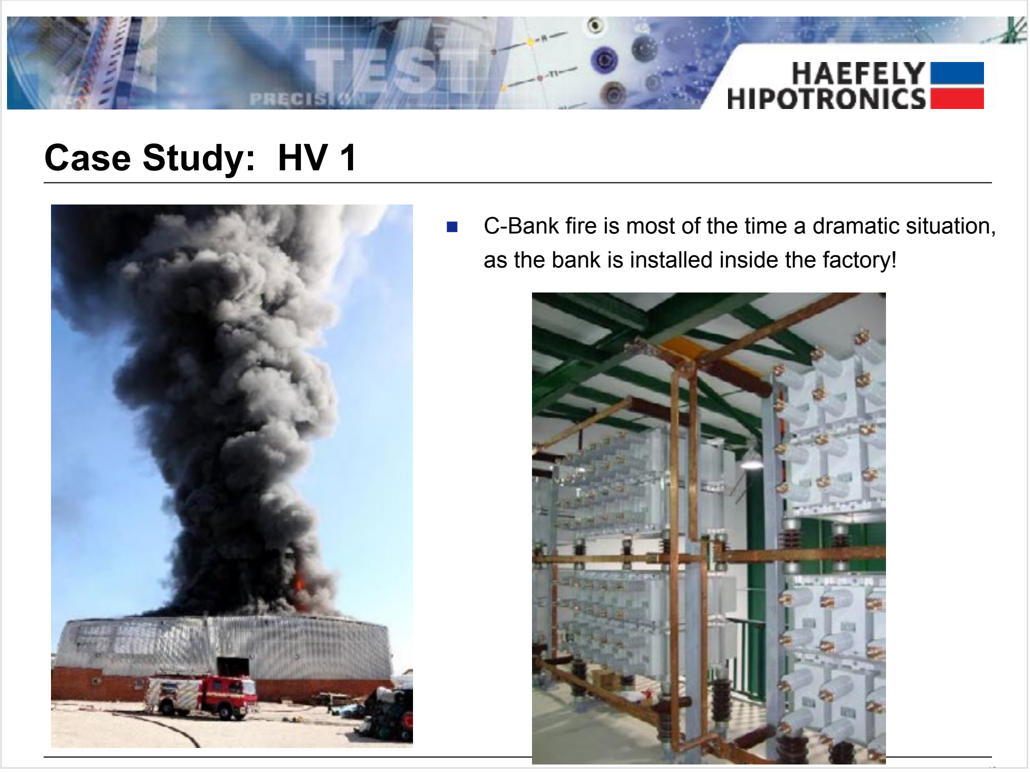
Can be avoided:
Yes

Dangerous:
Yes



Case Study: HV 1

- Classic test system for induced voltage test, no load and load loss, heat run
- Typical example for heat run: 20 kV / 60 Hz
- Typical example for induced voltage test: 72 kV / 200 Hz



Case Study: HV 1

- C-Bank fire is most of the time a dramatic situation, as the bank is installed inside the factory!

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Case Study: HV 1

- Solution: overall test system intelligence should avoid dangerous situation!!

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Case Study: HV 2

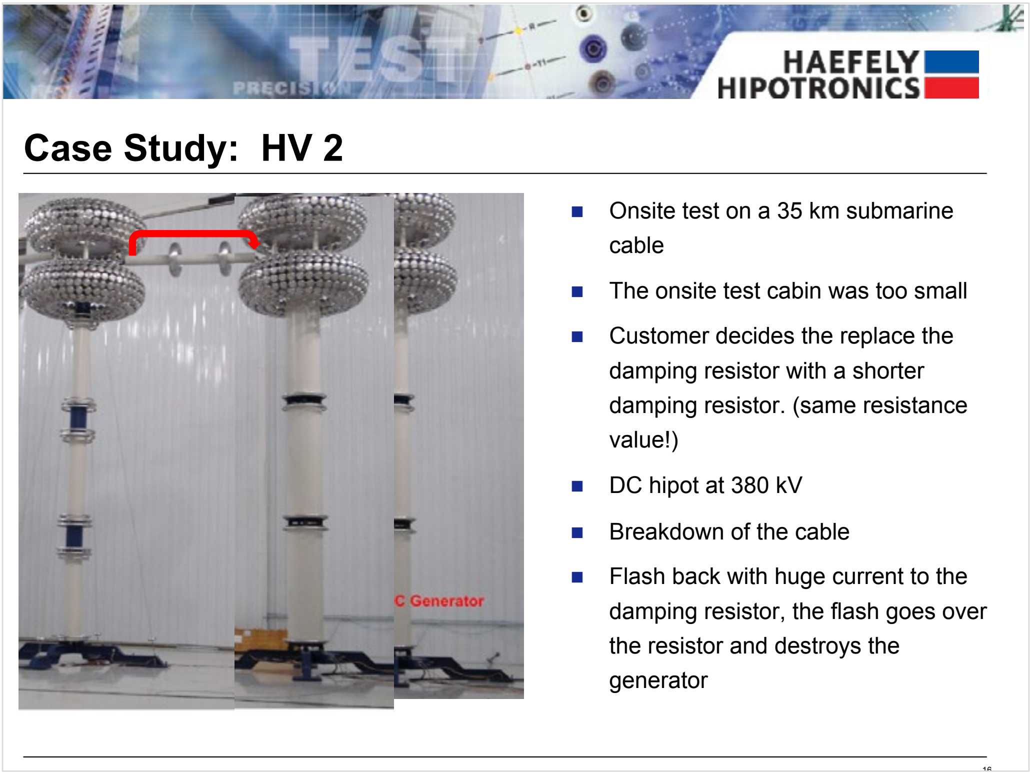
Situation	Problem
Onsite DC Hipot on submarine cable	Ultra high voltage DC generator breaks down
Cause	**Consequence**
Customer replaced the damping resistance, which was wrongly designed	After cable break down, the flash went back to the DC generator, the damping resistance could not stop the high current and the DC generator breaks down

Difficulty:
Low

Failure:
human

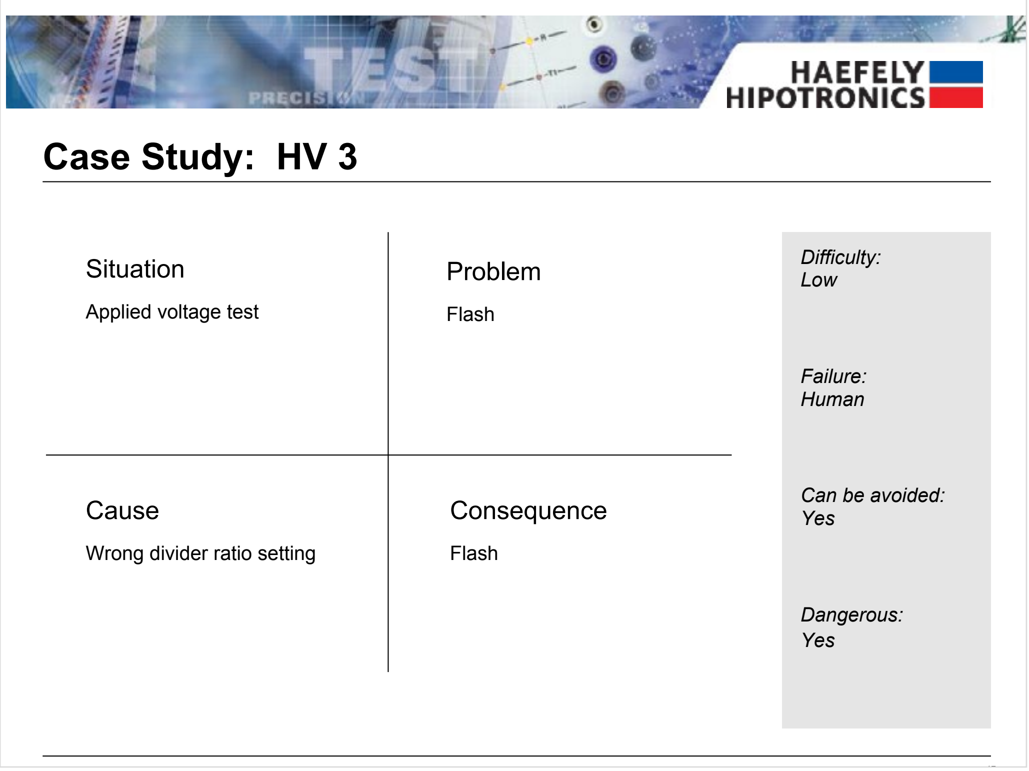
Can be avoided:
Yes

Dangerous:
Yes



Case Study: HV 2

- Onsite test on a 35 km submarine cable
- The onsite test cabin was too small
- Customer decides the replace the damping resistor with a shorter damping resistor. (same resistance value!)
- DC hipot at 380 kV
- Breakdown of the cable
- Flash back with huge current to the damping resistor, the flash goes over the resistor and destroys the generator



Case Study: HV 3

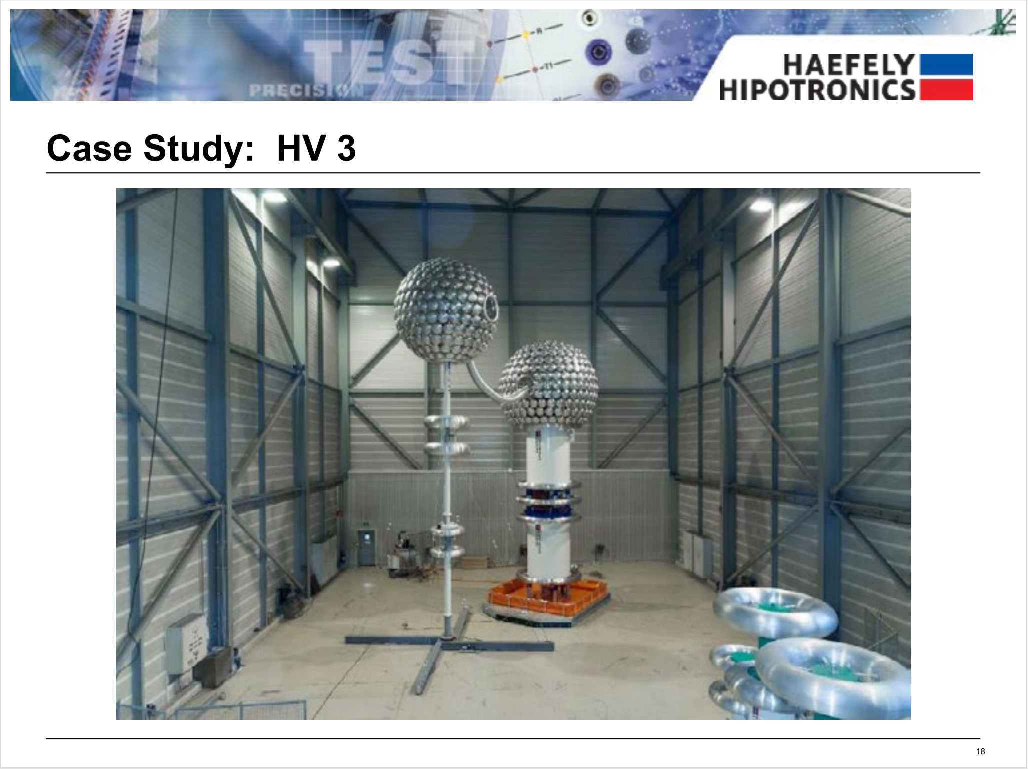
Situation Applied voltage test	Problem Flash
Cause Wrong divider ratio setting	Consequence Flash

Difficulty:
Low

Failure:
Human

Can be avoided:
Yes

Dangerous:
Yes



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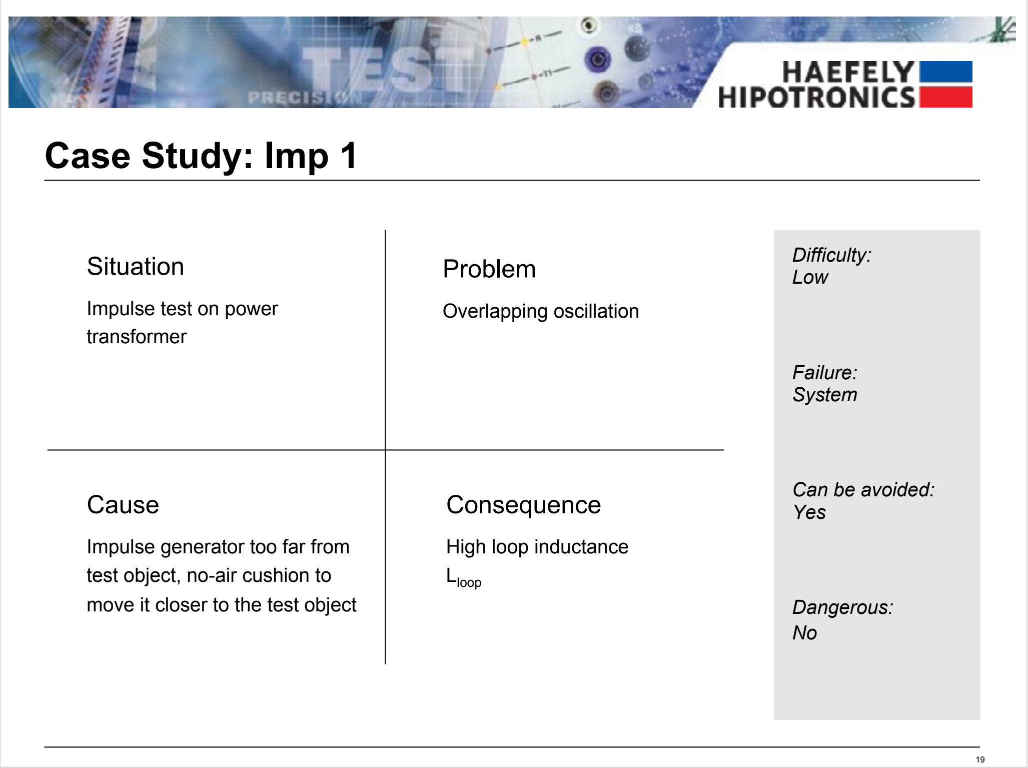
Case Study: HV 3



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Case Study: Imp 1

Situation

Impulse test on power transformer

Problem

Overlapping oscillation

Cause

Impulse generator too far from test object, no-air cushion to move it closer to the test object

Consequence

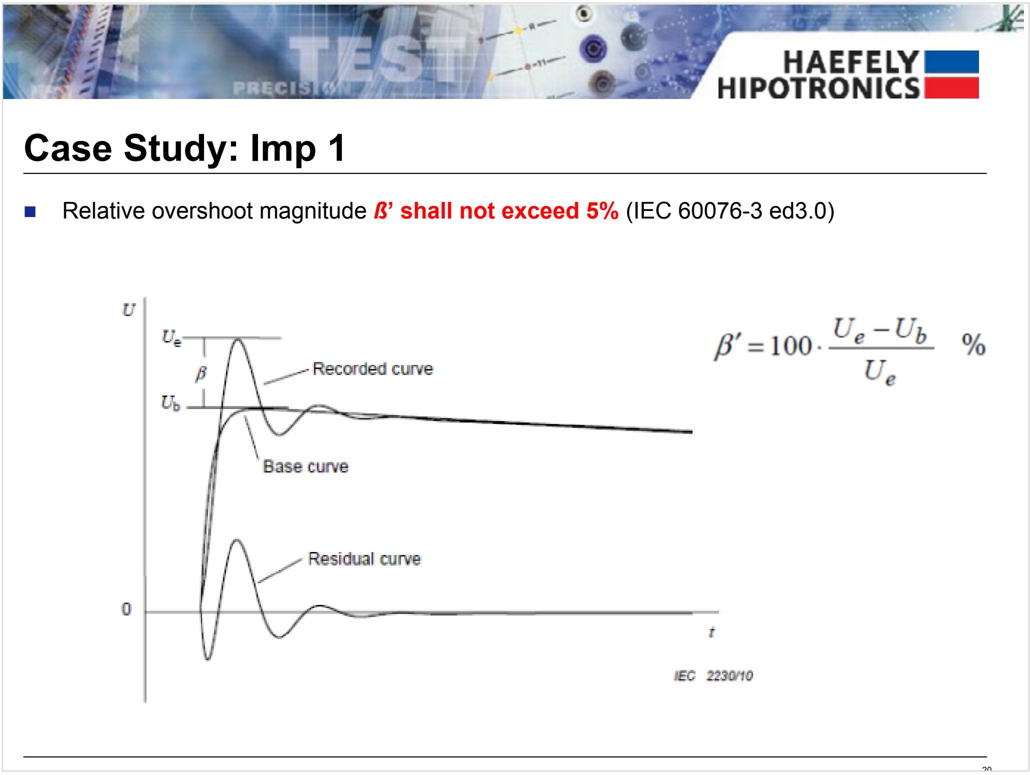
High loop inductance L_{loop}

Difficulty:
Low

Failure:
System

Can be avoided:
Yes

Dangerous:
No



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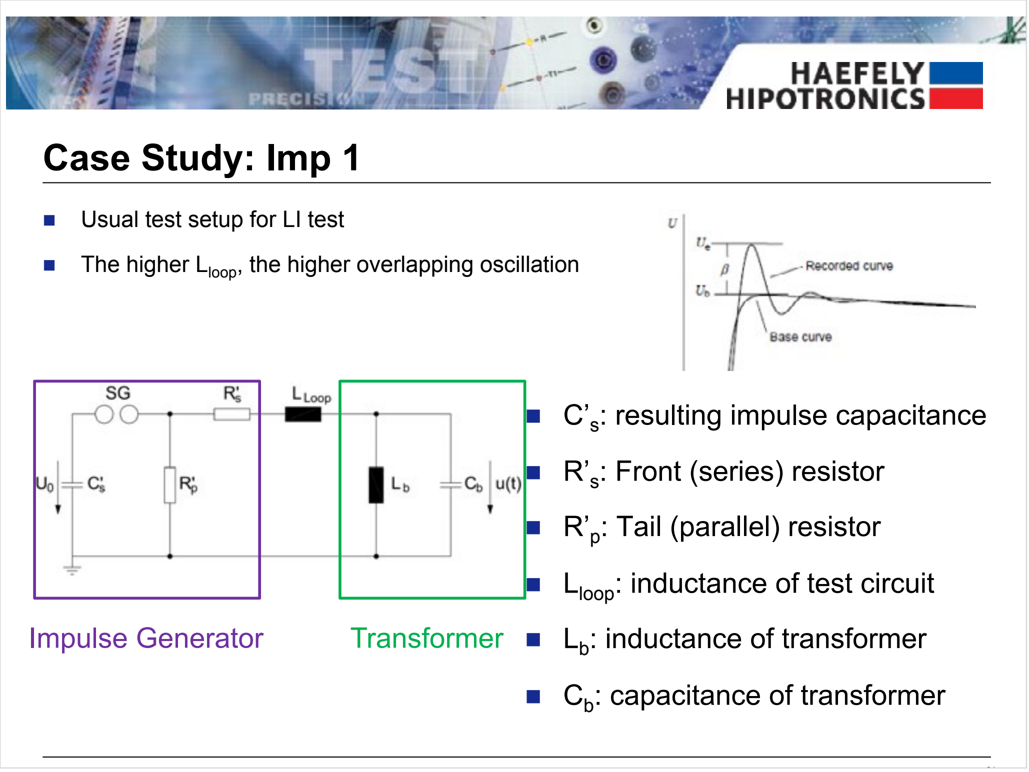
Case Study: Imp 1

- Relative overshoot magnitude **ß' shall not exceed 5%** (IEC 60076-3 ed3.0)

$$\beta' = 100 \cdot \frac{U_e - U_b}{U_e} \quad \%$$



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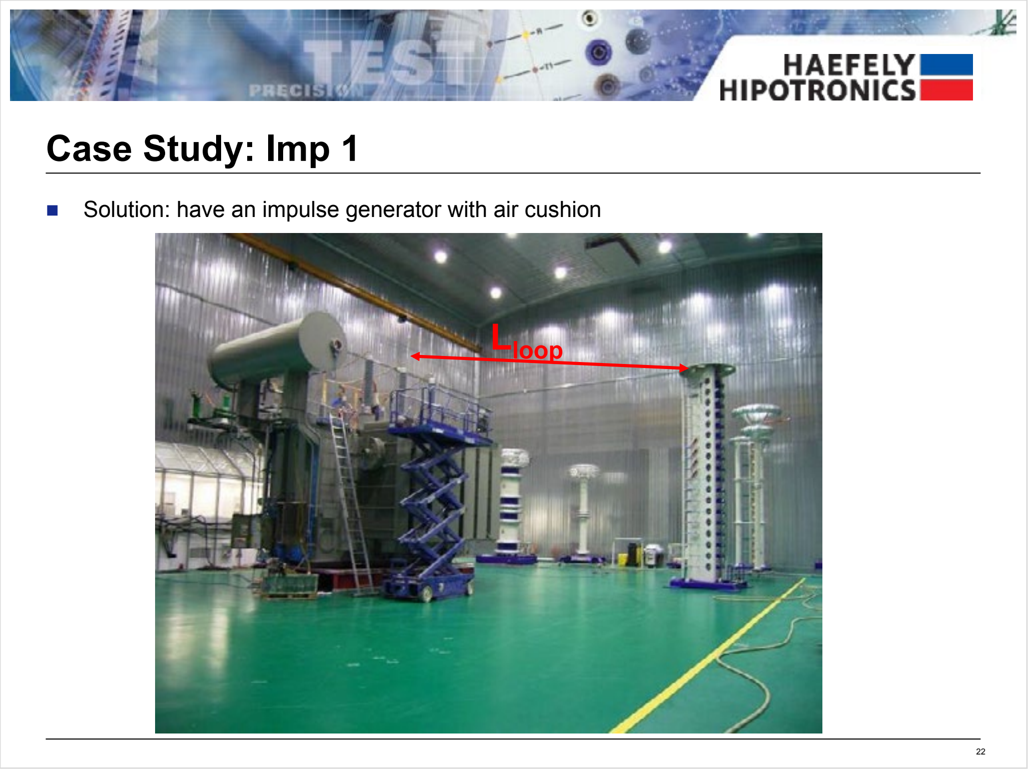
Case Study: Imp 1

- Usual test setup for LI test
- The higher L_{loop}, the higher overlapping oscillation

Impulse Generator

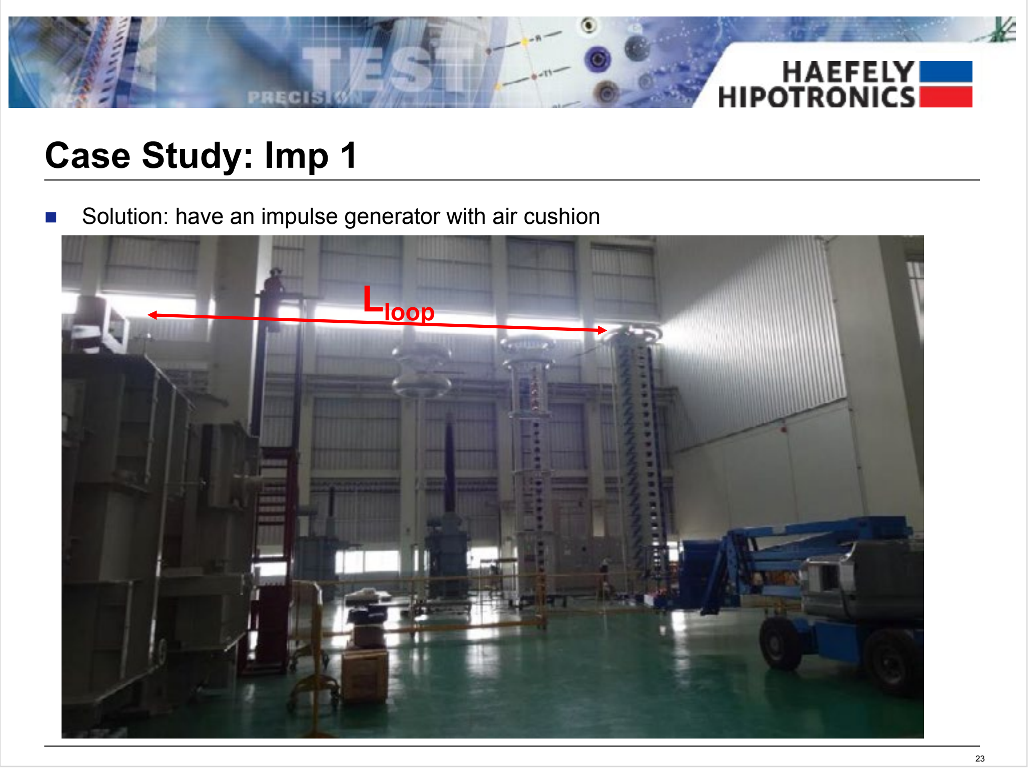
Transformer

- C'_s: resulting impulse capacitance
- R'_s: Front (series) resistor
- R'_p: Tail (parallel) resistor
- L_{loop}: inductance of test circuit
- L_b: inductance of transformer
- C_b: capacitance of transformer



Case Study: Imp 1

- Solution: have an impulse generator with air cushion



Case Study: Imp 1

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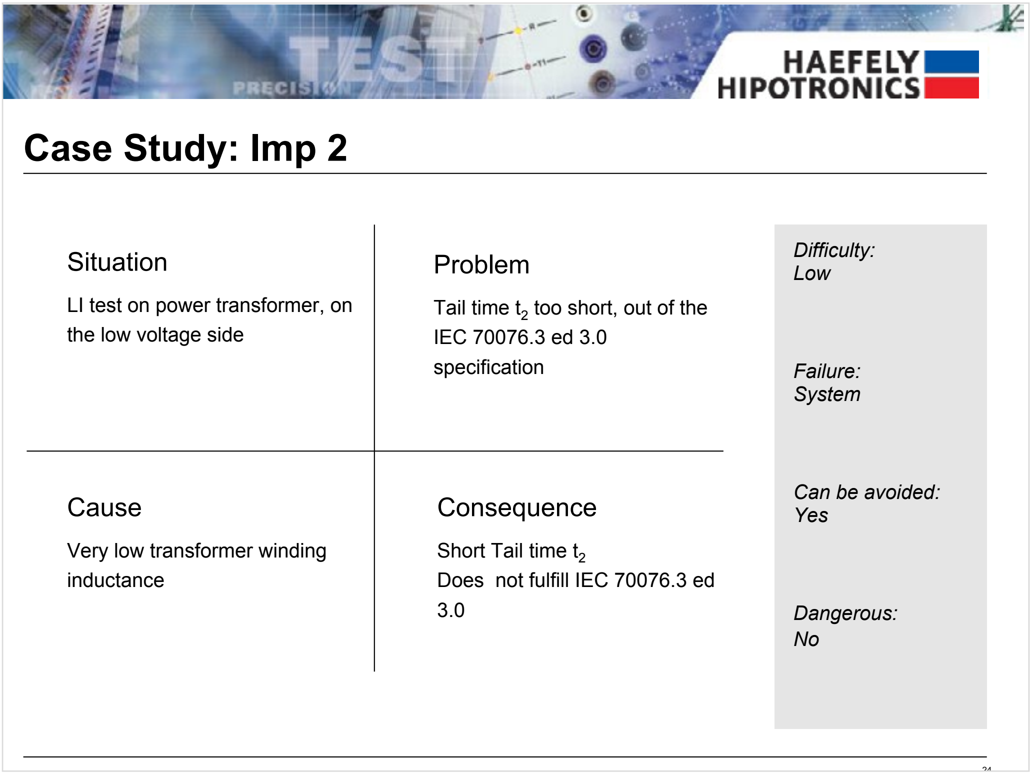

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Case Study: Imp 2

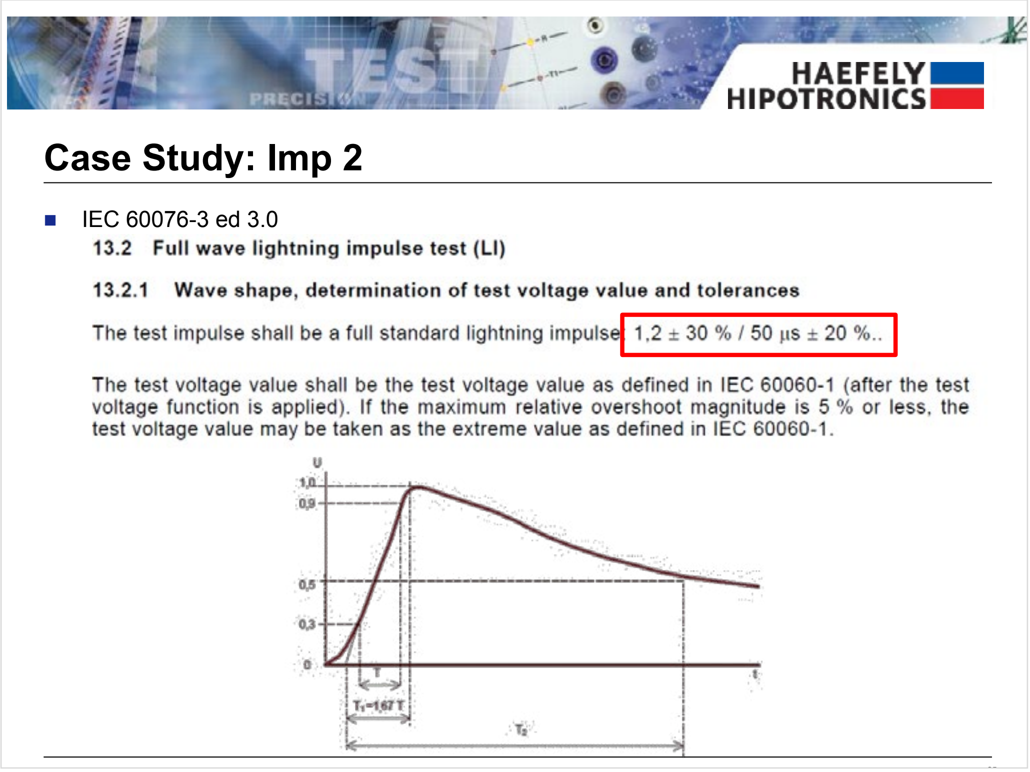
Situation	Problem
LI test on power transformer, on the low voltage side	Tail time t_2 too short, out of the IEC 70076.3 ed 3.0 specification
Cause	**Consequence**
Very low transformer winding inductance	Short Tail time t_2 Does not fulfill IEC 70076.3 ed 3.0

Difficulty:
Low

Failure:
System

Can be avoided:
Yes

Dangerous:
No



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Case Study: Imp 2

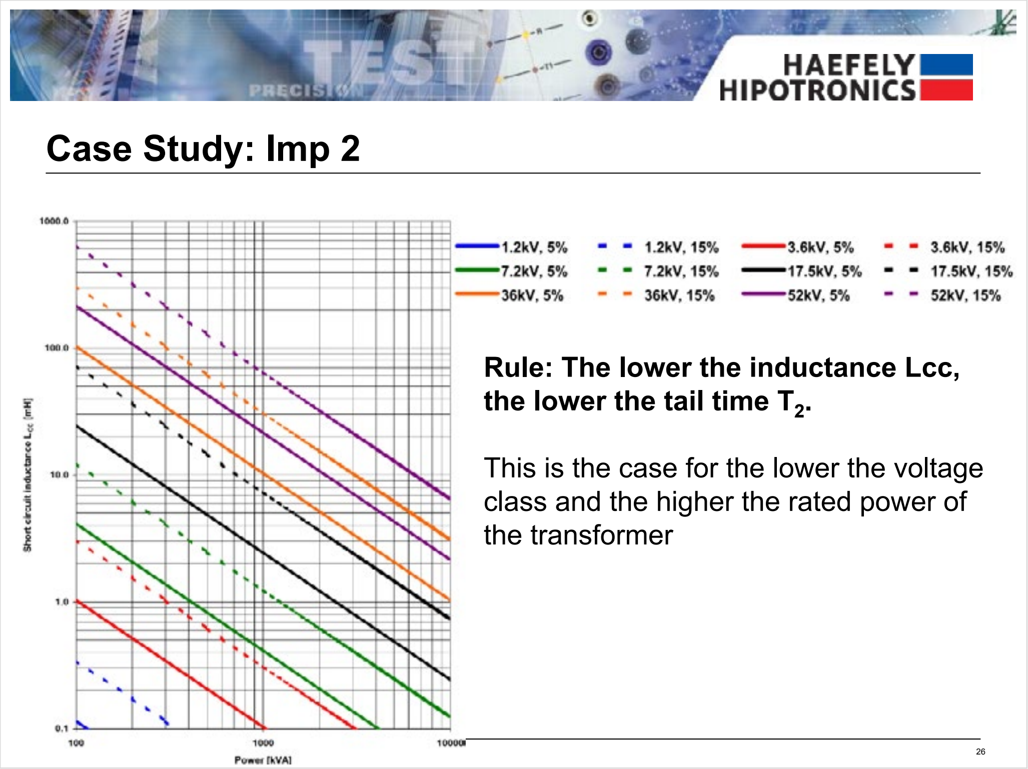
- IEC 60076-3 ed 3.0

13.2 Full wave lightning impulse test (LI)

13.2.1 Wave shape, determination of test voltage value and tolerances

The test impulse shall be a full standard lightning impulse 1,2 ± 30 % / 50 µs ± 20 %..

The test voltage value shall be the test voltage value as defined in IEC 60060-1 (after the test voltage function is applied). If the maximum relative overshoot magnitude is 5 % or less, the test voltage value may be taken as the extreme value as defined in IEC 60060-1.



Case Study: Imp 2

Rule: The lower the inductance Lcc, the lower the tail time T_2.

This is the case for the lower the voltage class and the higher the rated power of the transformer

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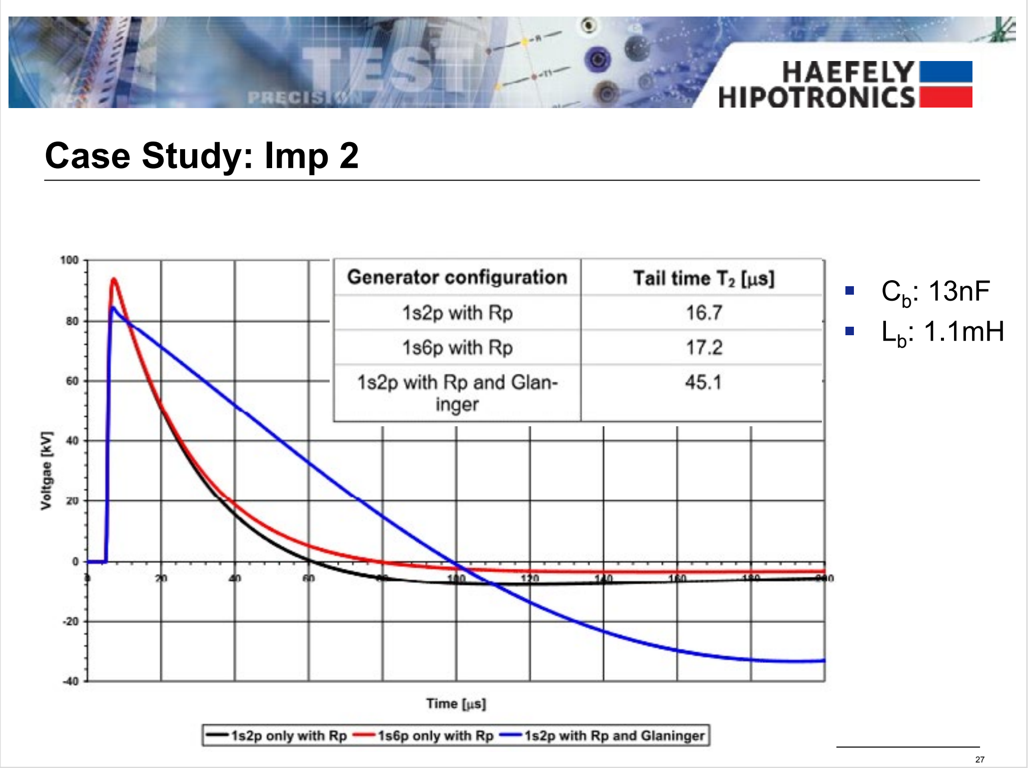

Case Study: Imp 2

Generator configuration	Tail time T_2 [µs]
1s2p with Rp	16.7
1s6p with Rp	17.2
1s2p with Rp and Glan-inger	45.1

- C_b: 13nF
- L_b: 1.1mH

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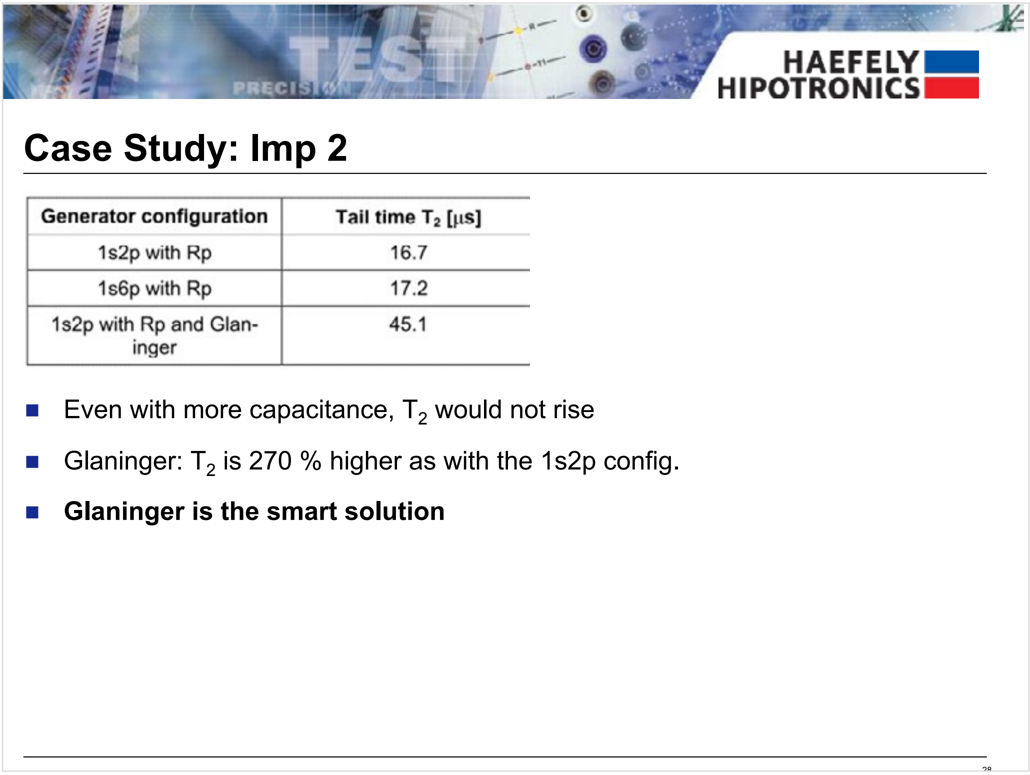

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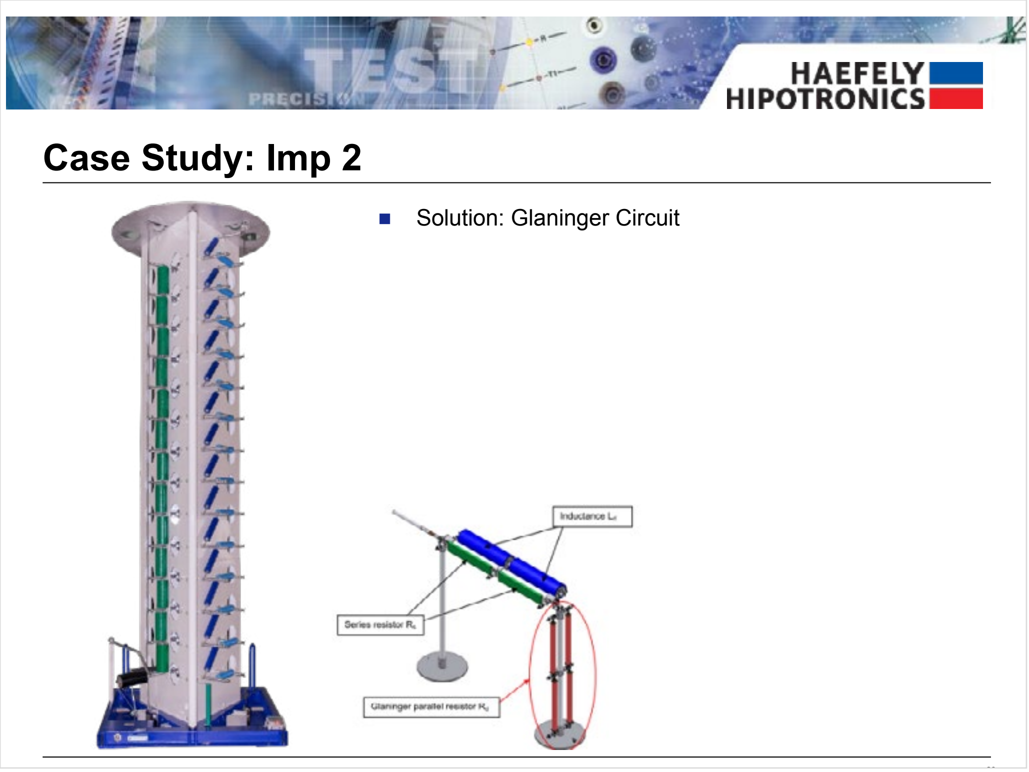
Case Study: Imp 2

Generator configuration	Tail time T_2 [µs]
1s2p with Rp	16.7
1s6p with Rp	17.2
1s2p with Rp and Glaninger	45.1

- Even with more capacitance, T_2 would not rise
- Glaninger: T_2 is 270 % higher as with the 1s2p config.
- **Glaninger is the smart solution**



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Case Study: Imp 2

- Solution: Glaninger Circuit

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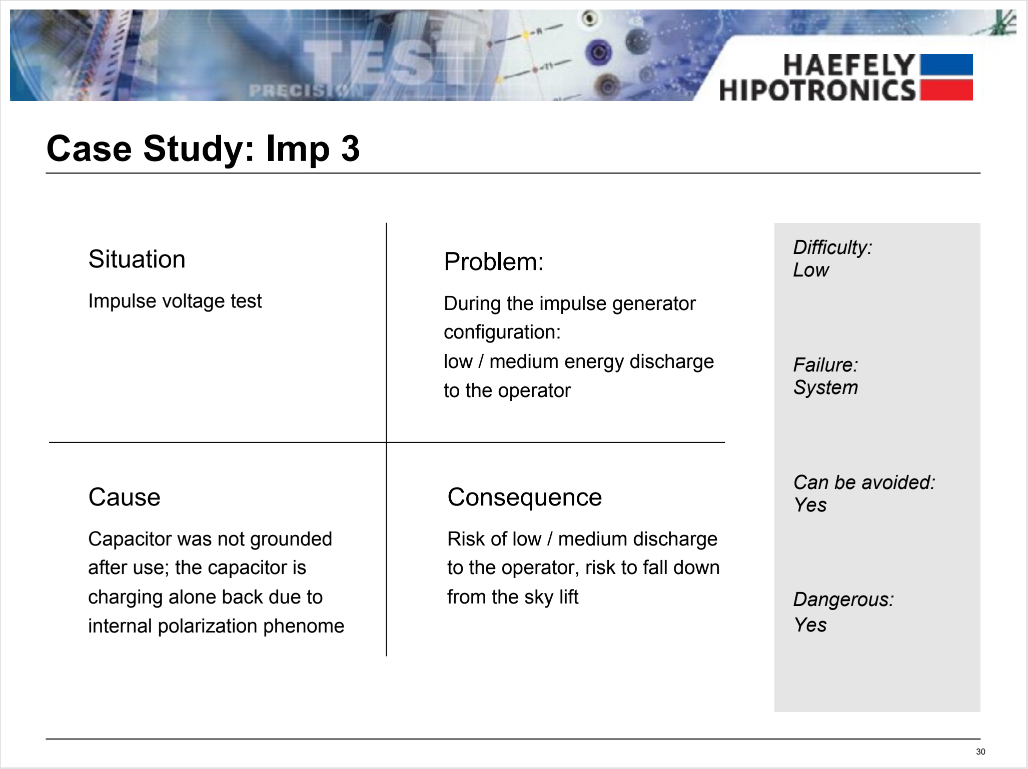

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Case Study: Imp 3

Situation

Impulse voltage test

Problem:

During the impulse generator configuration:
low / medium energy discharge to the operator

Cause

Capacitor was not grounded after use; the capacitor is charging alone back due to internal polarization phenome

Consequence

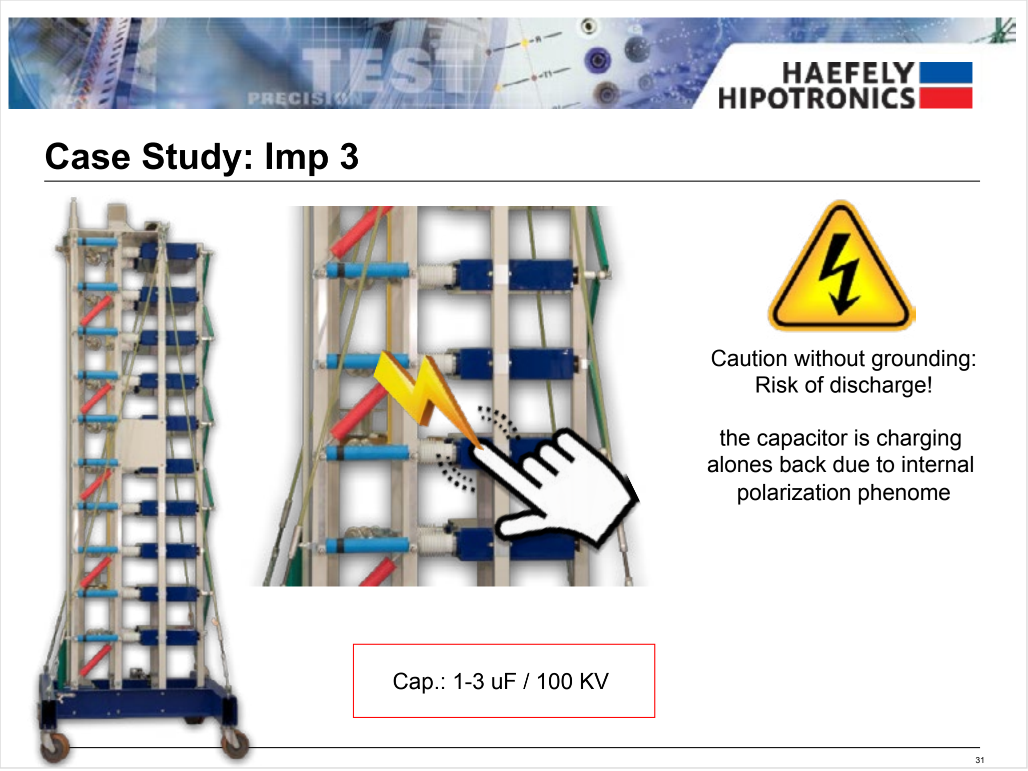
Risk of low / medium discharge to the operator, risk to fall down from the sky lift

Difficulty:
Low

Failure:
System

Can be avoided:
Yes

Dangerous:
Yes



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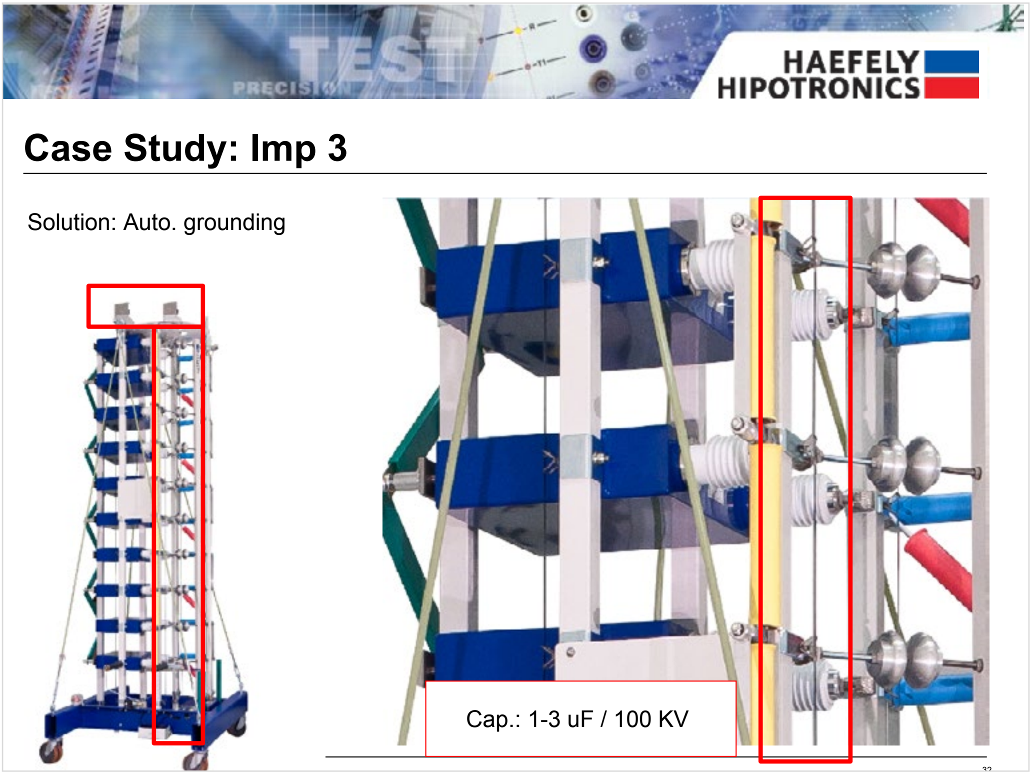
Case Study: Imp 3

Caution without grounding:
Risk of discharge!

the capacitor is charging alones back due to internal polarization phenome

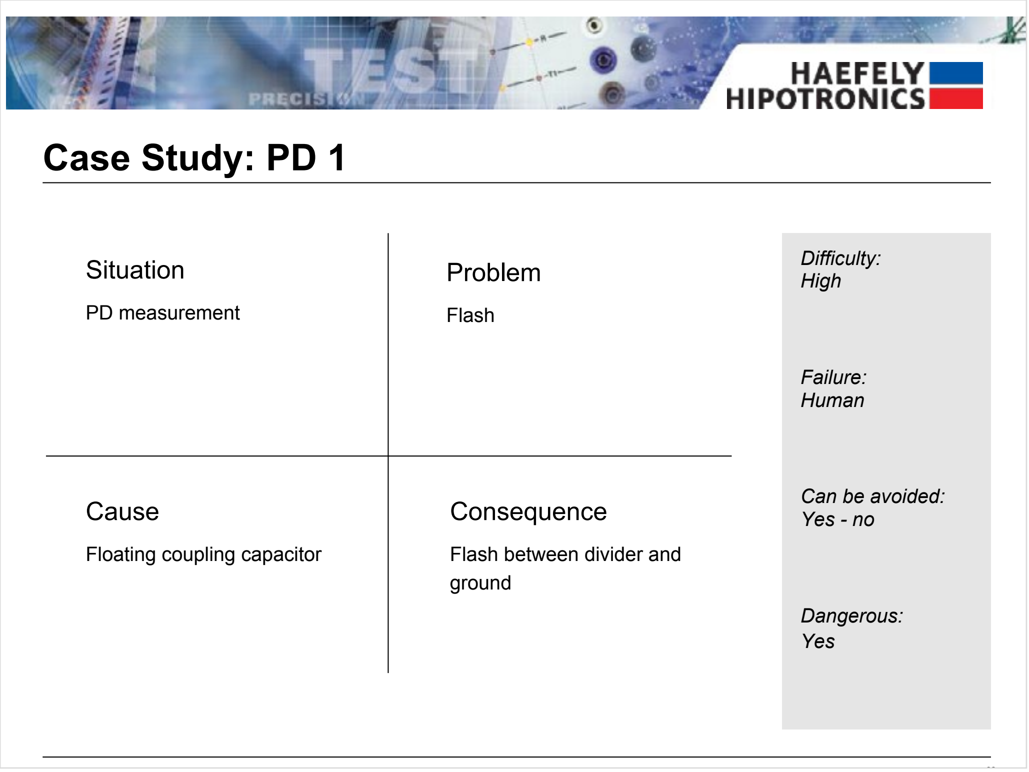
Cap.: 1-3 uF / 100 KV



Case Study: Imp 3

Solution: Auto. grounding

Cap.: 1-3 uF / 100 KV



Case Study: PD 1

Situation PD measurement	Problem Flash
Cause Floating coupling capacitor	Consequence Flash between divider and ground

Difficulty:
High

Failure:
Human

Can be avoided:
Yes - no

Dangerous:
Yes

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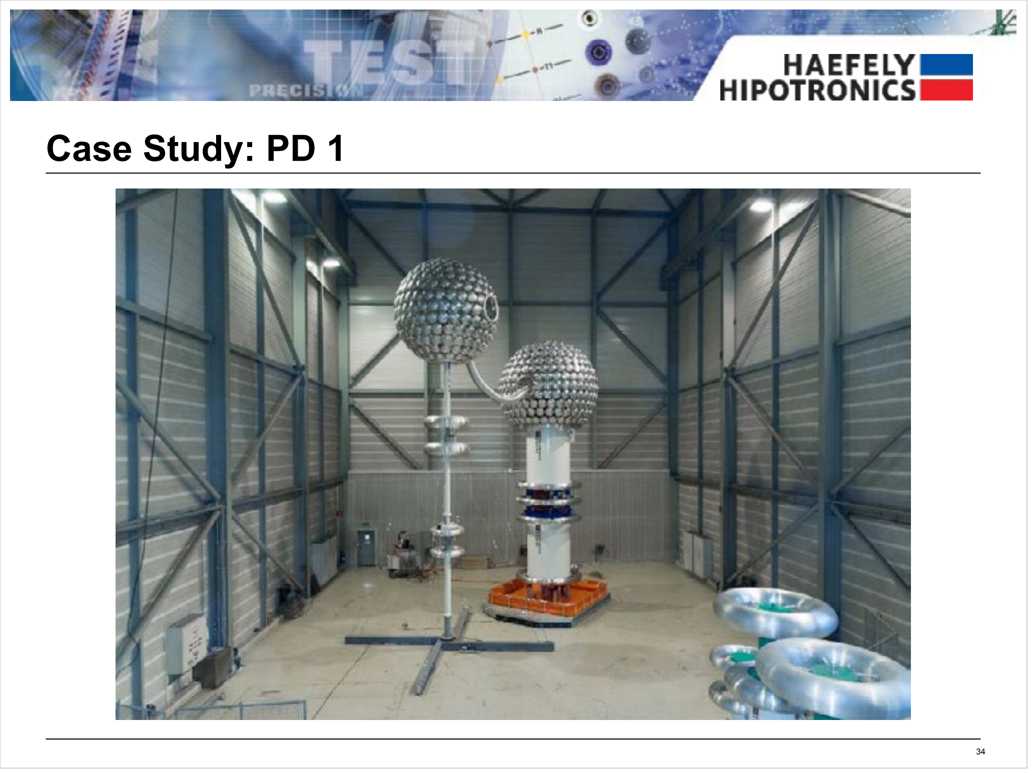
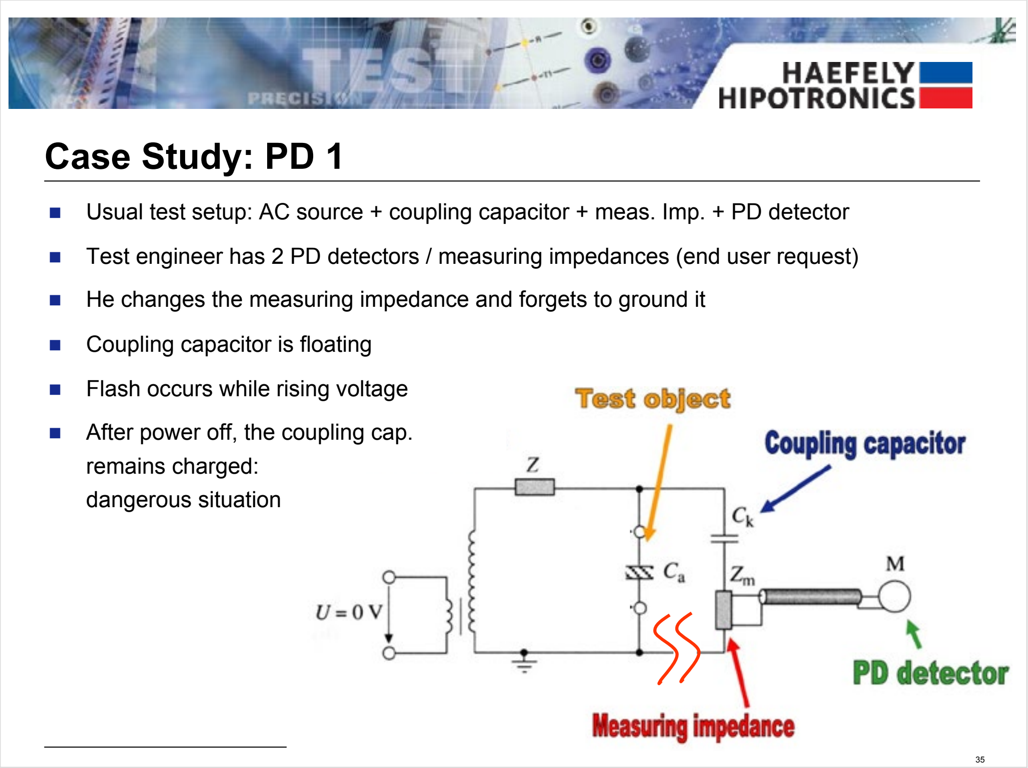
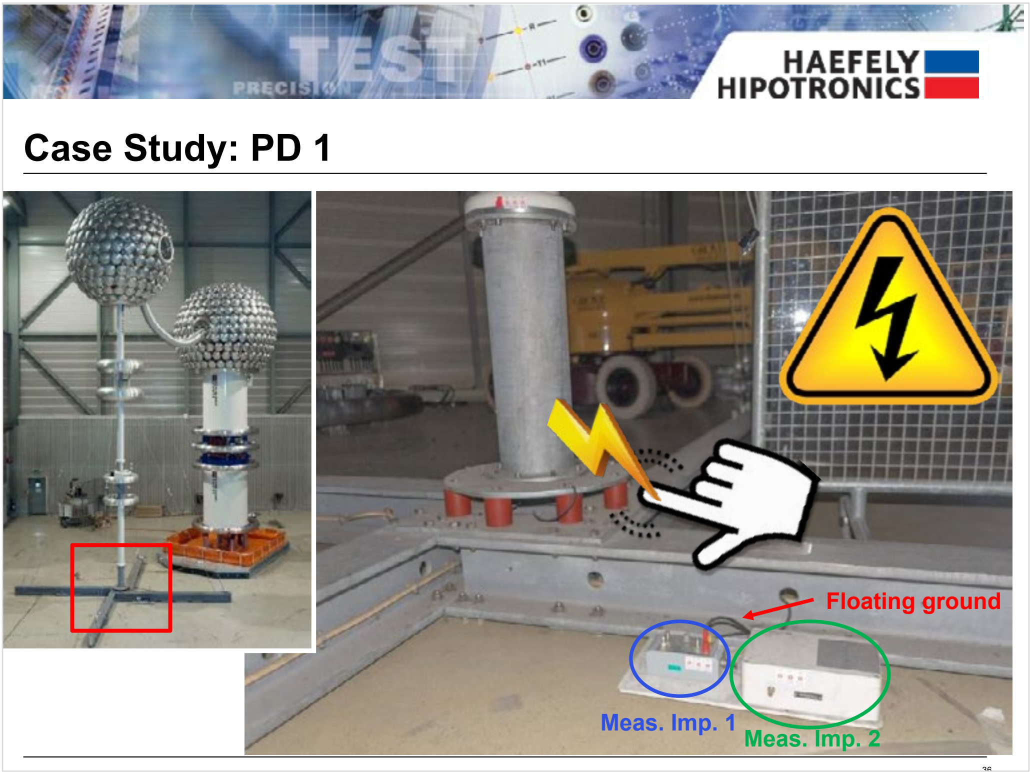


Case Study: PD 1



Case Study: PD 1

- Usual test setup: AC source + coupling capacitor + meas. Imp. + PD detector
- Test engineer has 2 PD detectors / measuring impedances (end user request)
- He changes the measuring impedance and forgets to ground it
- Coupling capacitor is floating
- Flash occurs while rising voltage
- After power off, the coupling cap. remains charged: dangerous situation



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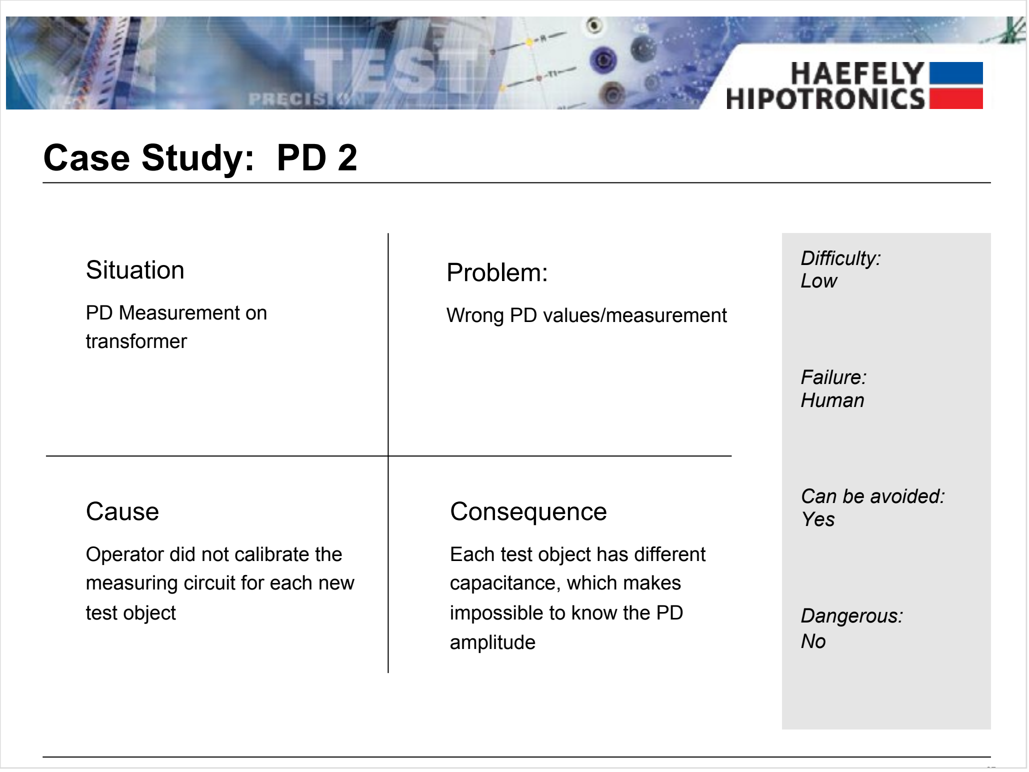
Case Study: PD 1



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Case Study: PD 2

Situation

PD Measurement on transformer

Problem:

Wrong PD values/measurement

Cause

Operator did not calibrate the measuring circuit for each new test object

Consequence

Each test object has different capacitance, which makes impossible to know the PD amplitude

Difficulty:
Low

Failure:
Human

Can be avoided:
Yes

Dangerous:
No

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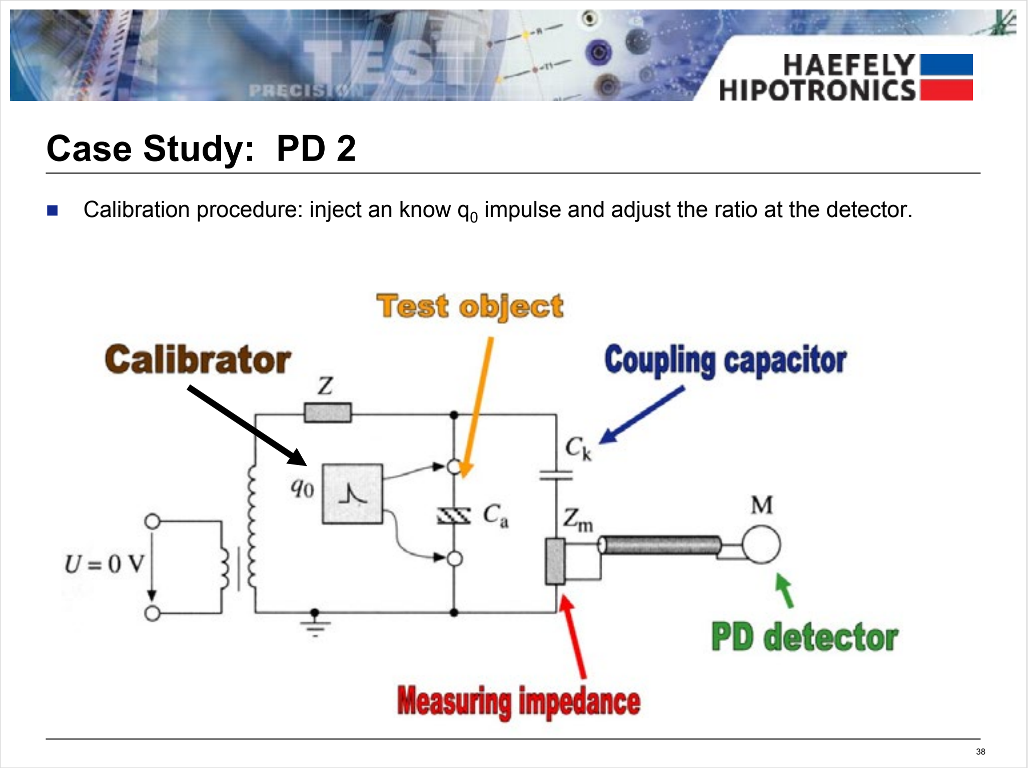

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Case Study: PD 2

- Calibration procedure: inject an know q_0 impulse and adjust the ratio at the detector.

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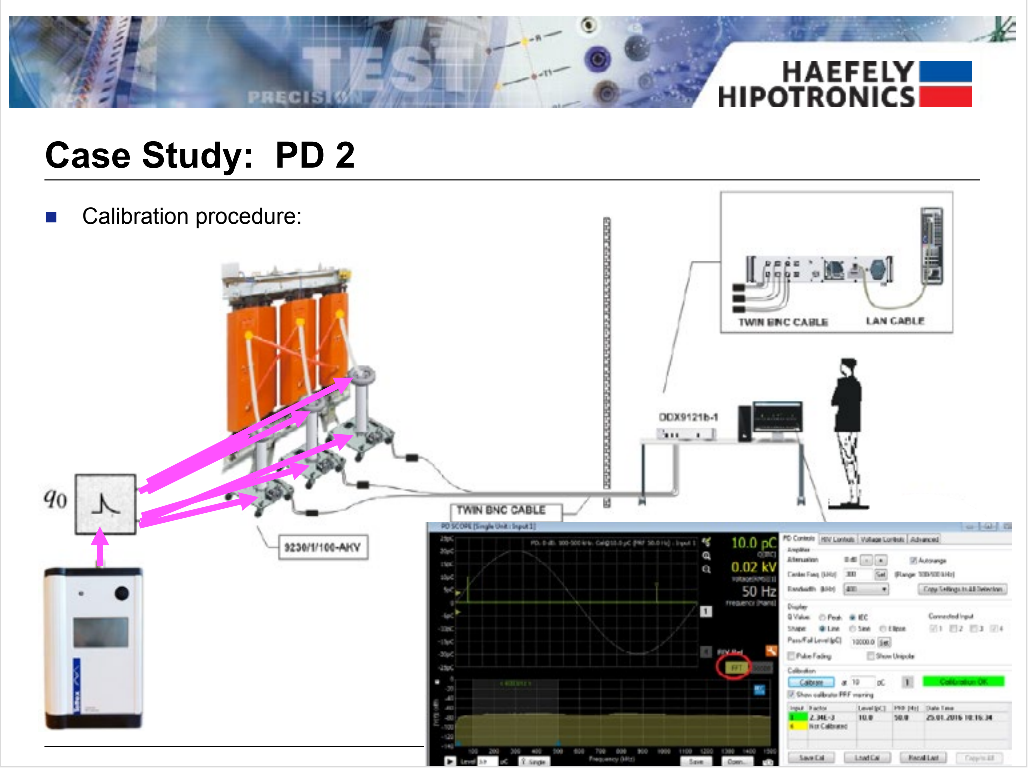

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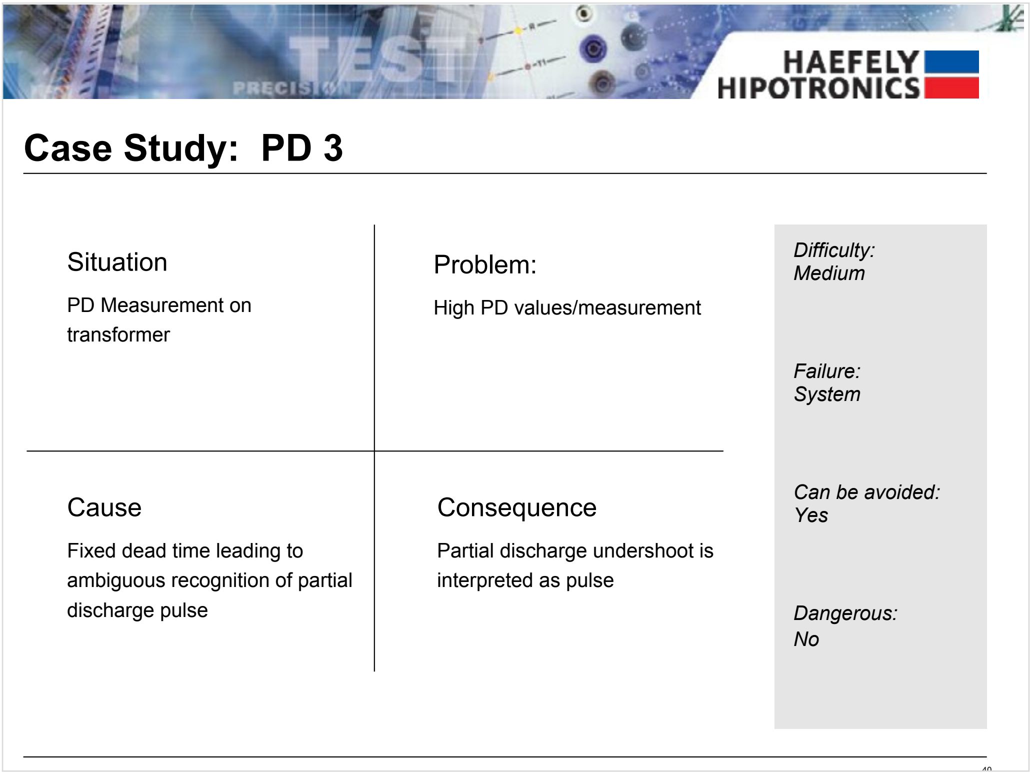
Case Study: PD 2

- Calibration procedure:



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Case Study: PD 3

Situation

PD Measurement on transformer

Problem:

High PD values/measurement

Cause

Fixed dead time leading to ambiguous recognition of partial discharge pulse

Consequence

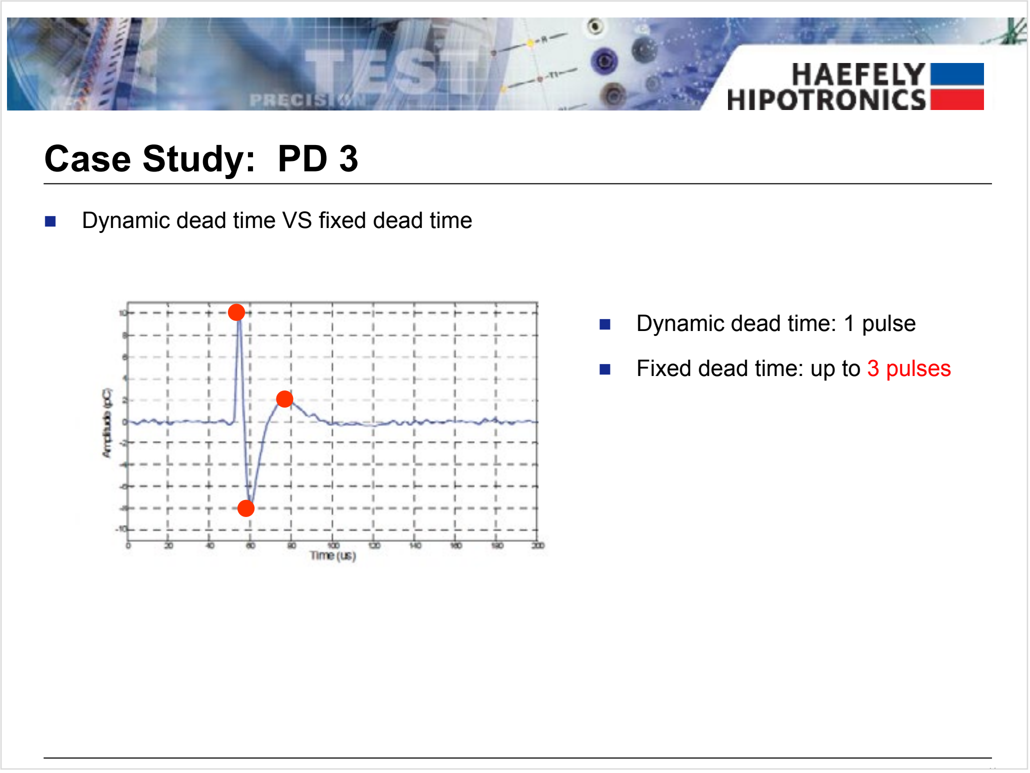
Partial discharge undershoot is interpreted as pulse

Difficulty:
Medium

Failure:
System

Can be avoided:
Yes

Dangerous:
No



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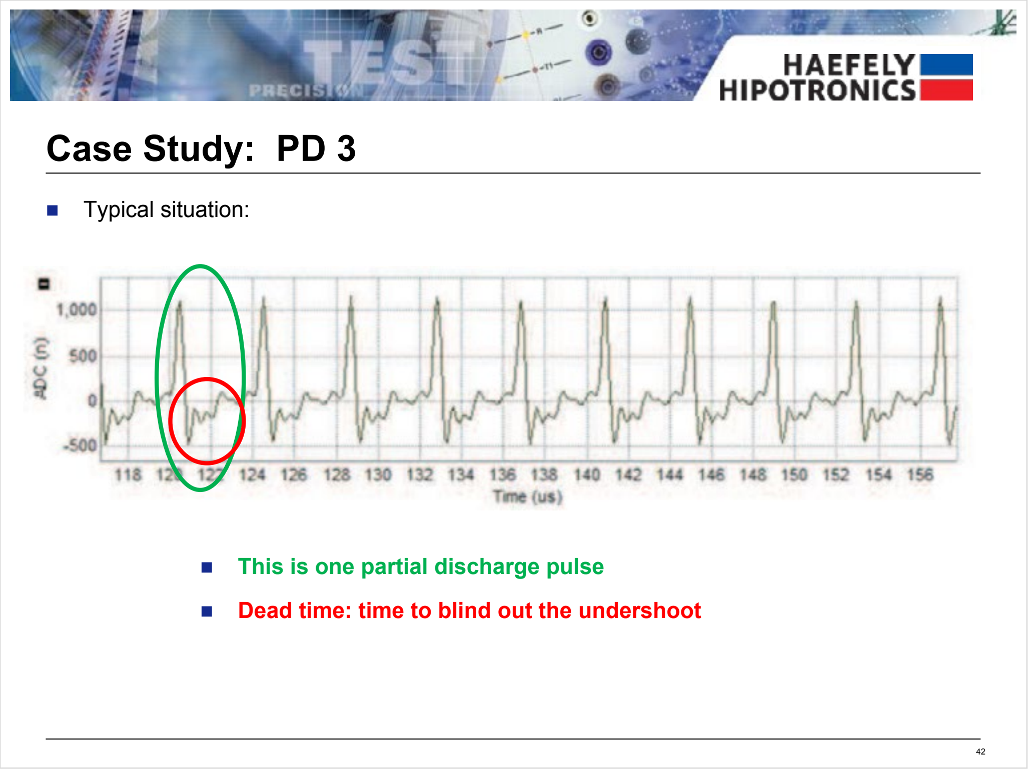
Case Study: PD 3

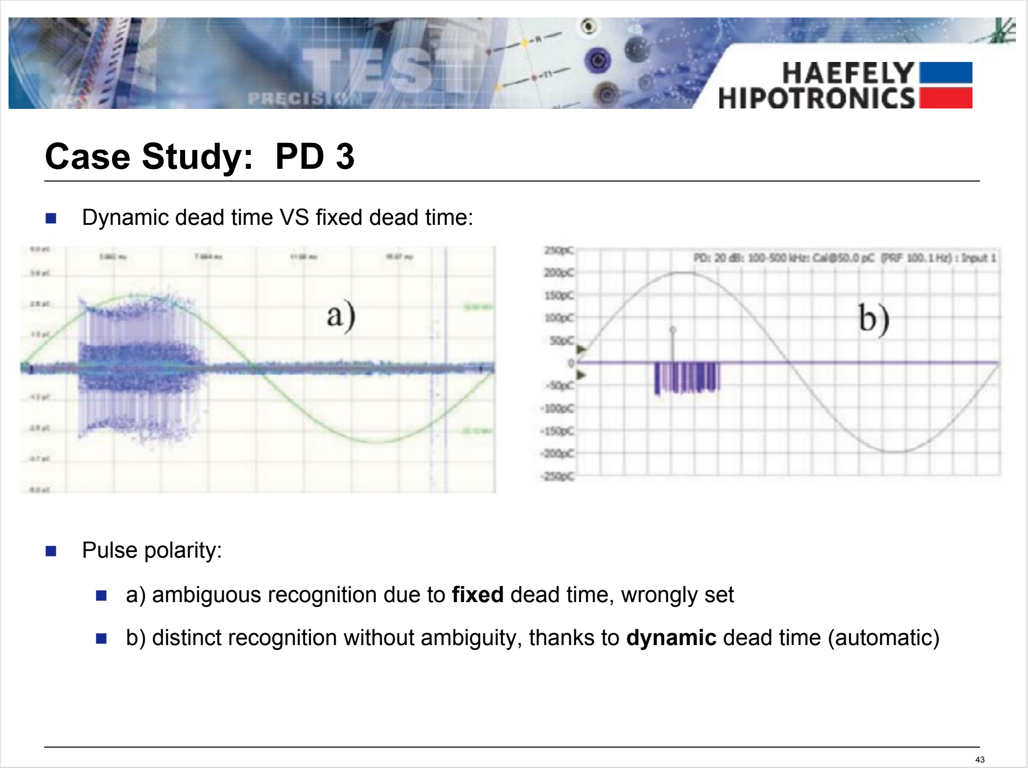
- Dynamic dead time VS fixed dead time

- Dynamic dead time: 1 pulse
- Fixed dead time: up to 3 pulses



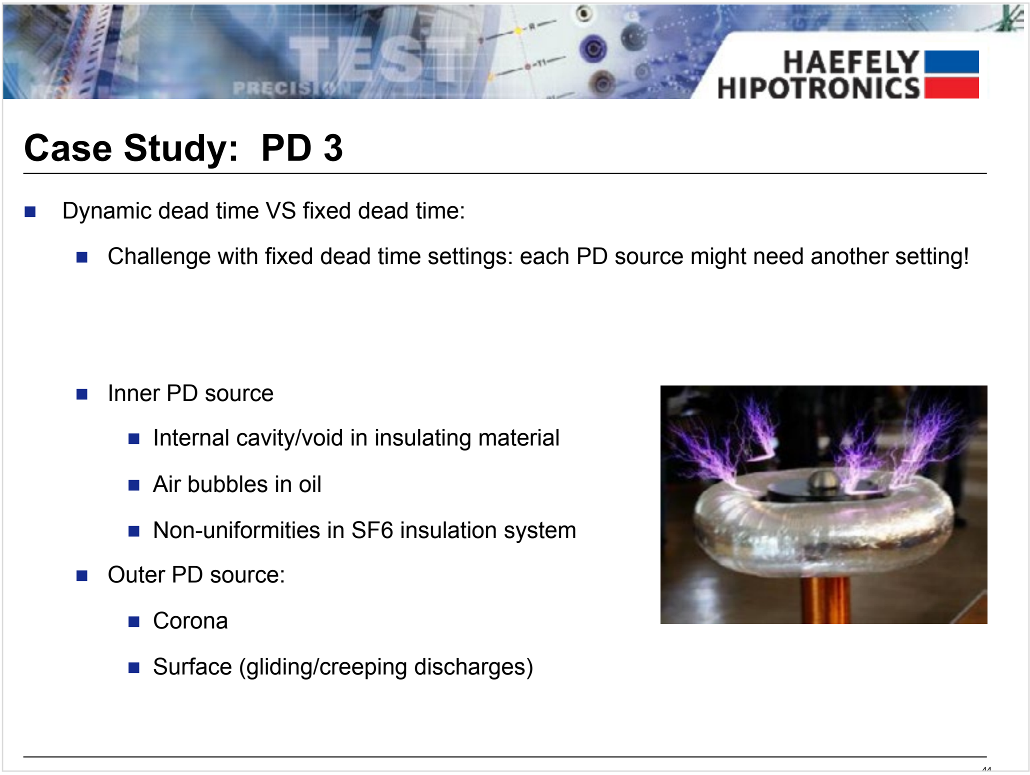
Case Study: PD 3

- Typical situation:
  - This is one partial discharge pulse
  - Dead time: time to blind out the undershoot



Case Study: PD 3

- Dynamic dead time VS fixed dead time:
- Pulse polarity:
  - a) ambiguous recognition due to **fixed** dead time, wrongly set
  - b) distinct recognition without ambiguity, thanks to **dynamic** dead time (automatic)



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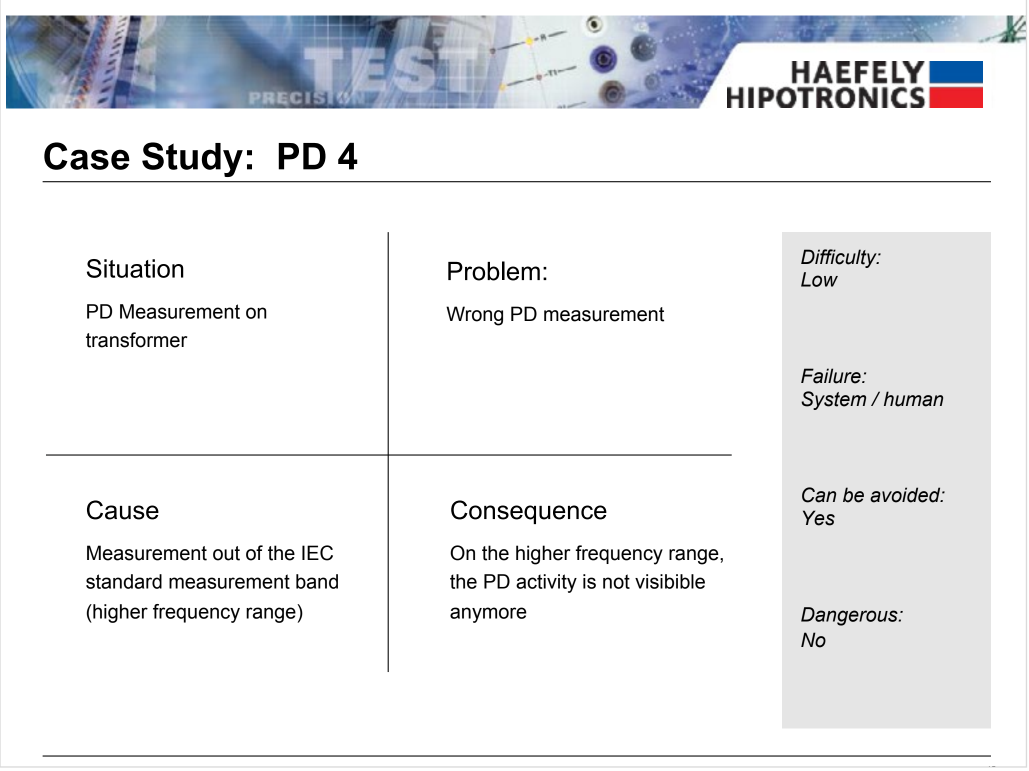
Case Study: PD 3

- Dynamic dead time VS fixed dead time:
  - Challenge with fixed dead time settings: each PD source might need another setting!
  - Inner PD source
    - Internal cavity/void in insulating material
    - Air bubbles in oil
    - Non-uniformities in SF6 insulation system
  - Outer PD source:
    - Corona
    - Surface (gliding/creeping discharges)



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Case Study: PD 4

Situation

PD Measurement on transformer

Problem:

Wrong PD measurement

Cause

Measurement out of the IEC standard measurement band (higher frequency range)

Consequence

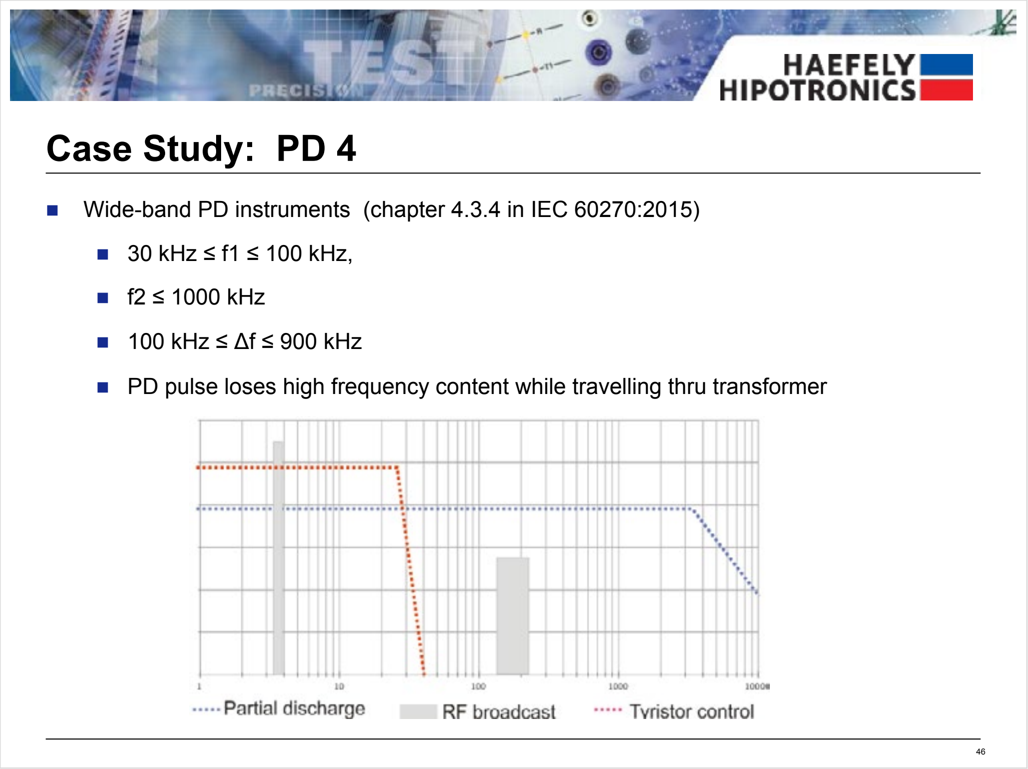
On the higher frequency range, the PD activity is not visibile anymore

Difficulty:
Low

Failure:
System / human

Can be avoided:
Yes

Dangerous:
No



Case Study: PD 4

- Wide-band PD instruments (chapter 4.3.4 in IEC 60270:2015)
  - 30 kHz ≤ f1 ≤ 100 kHz,
  - f2 ≤ 1000 kHz
  - 100 kHz ≤ Δf ≤ 900 kHz
  - PD pulse loses high frequency content while travelling thru transformer

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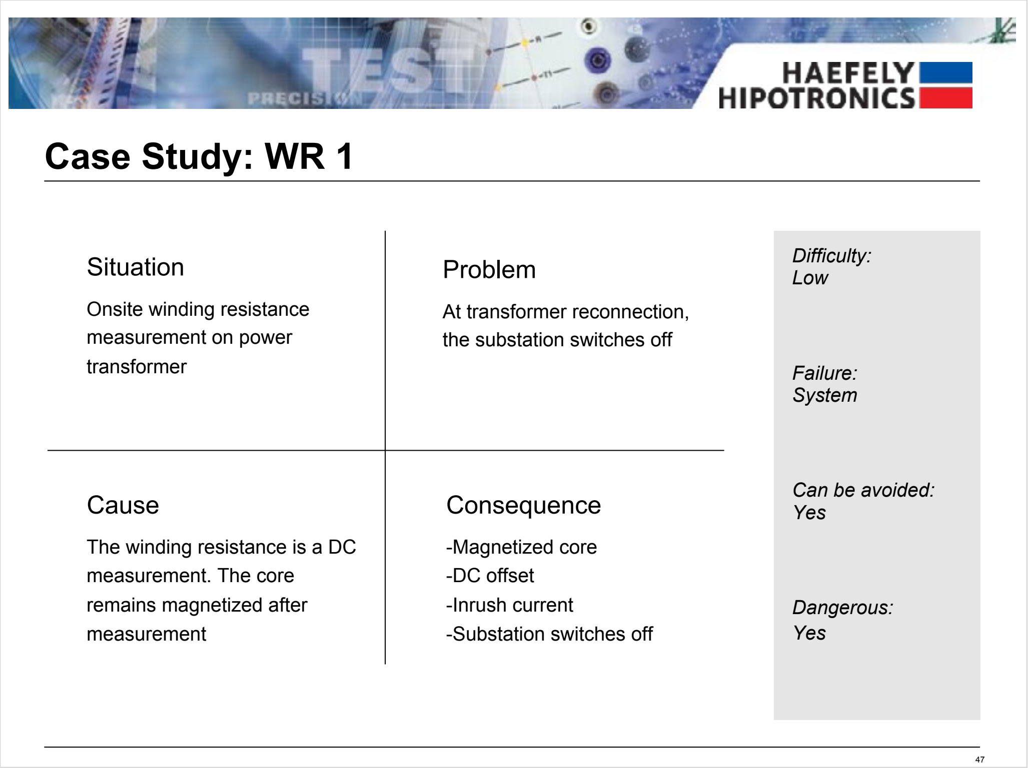

Case Study: WR 1

Situation

Onsite winding resistance measurement on power transformer

Problem

At transformer reconnection, the substation switches off

Cause

The winding resistance is a DC measurement. The core remains magnetized after measurement

Consequence

-Magnetized core
-DC offset
-Inrush current
-Substation switches off

Difficulty:
Low

Failure:
System

Can be avoided:
Yes

Dangerous:
Yes

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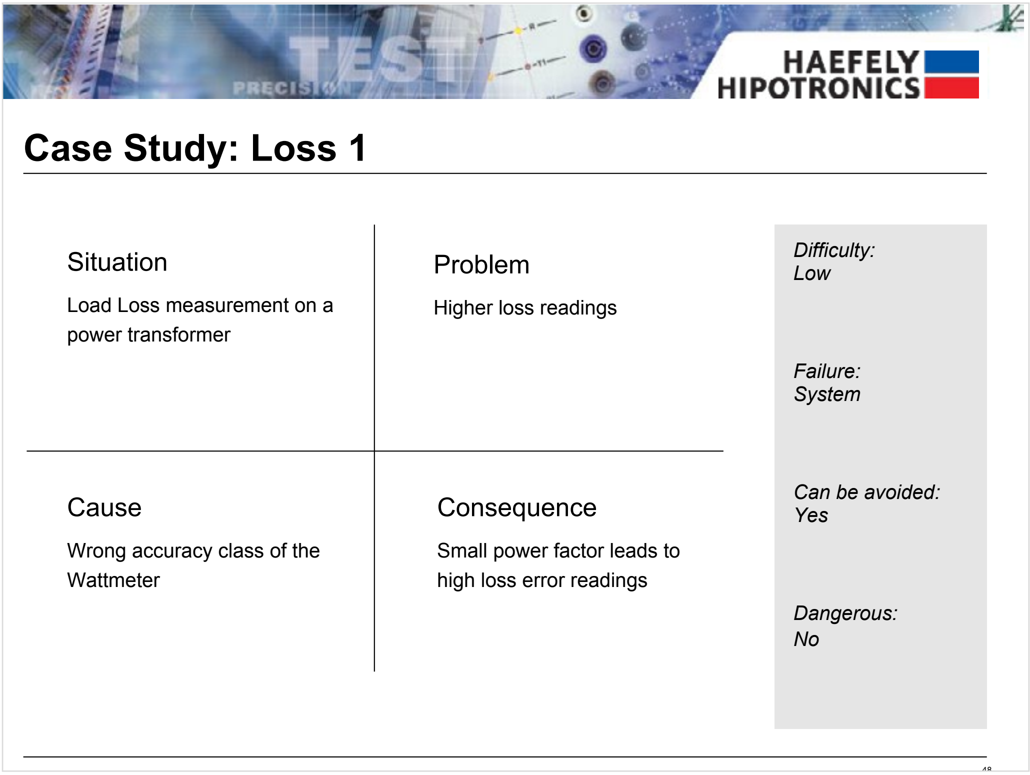


HAEFELY HIPOTRONICS

Case Study: Loss 1

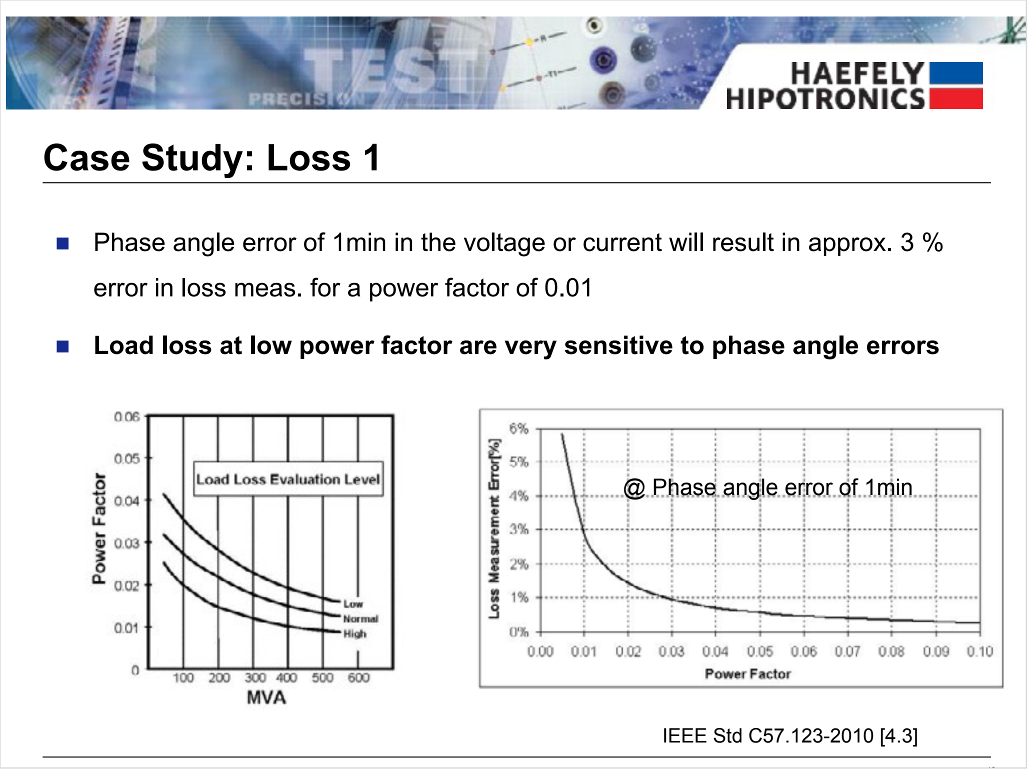
Situation	Problem
Load Loss measurement on a power transformer	Higher loss readings
Cause	**Consequence**
Wrong accuracy class of the Wattmeter	Small power factor leads to high loss error readings

Difficulty:
Low

Failure:
System

Can be avoided:
Yes

Dangerous:
No

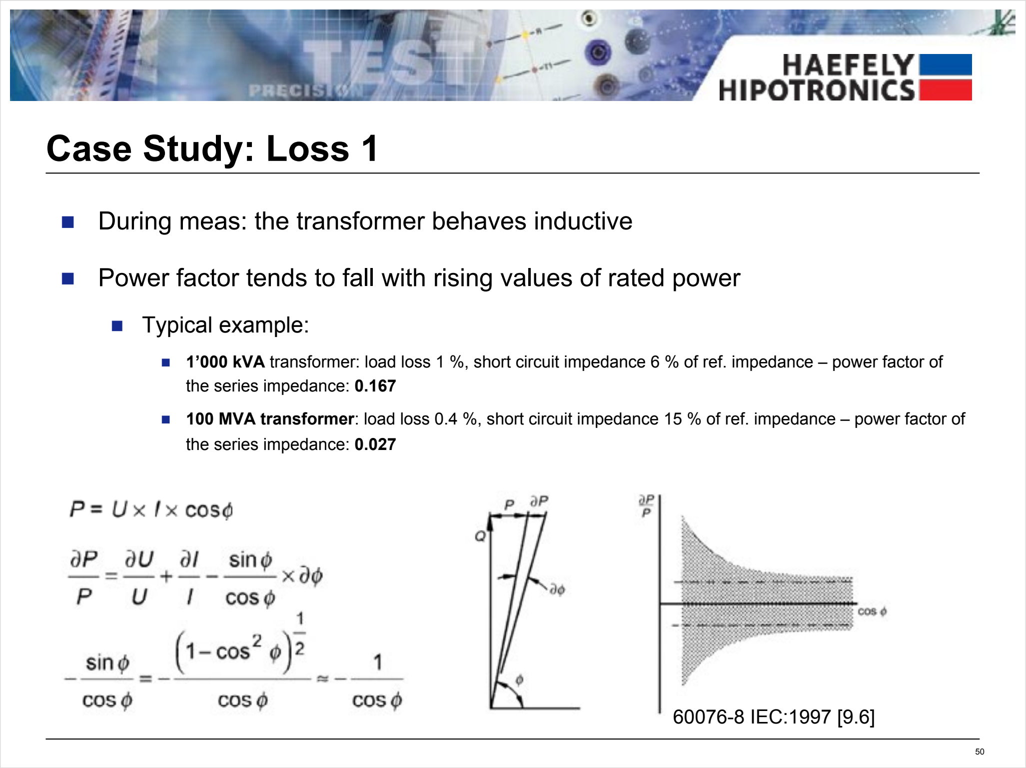


HAEFELY HIPOTRONICS

Case Study: Loss 1

- Phase angle error of 1min in the voltage or current will result in approx. 3 % error in loss meas. for a power factor of 0.01
- **Load loss at low power factor are very sensitive to phase angle errors**

IEEE Std C57.123-2010 [4.3]



HAEFELY HIPOTRONICS

Case Study: Loss 1

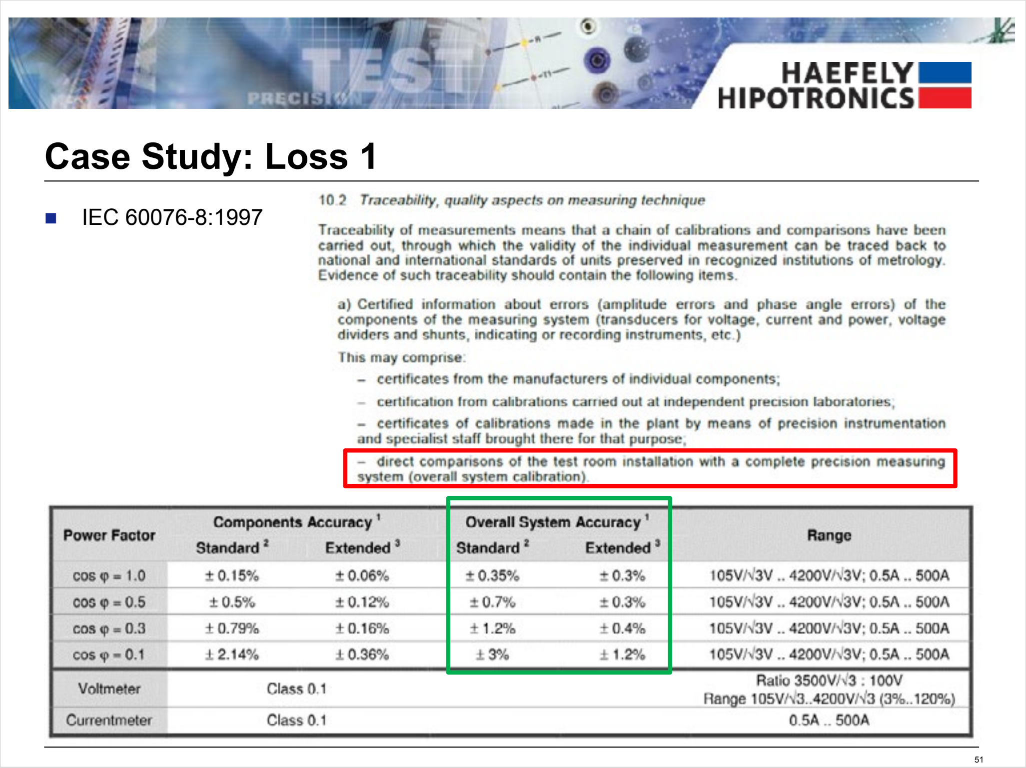
- During meas: the transformer behaves inductive
- Power factor tends to fall with rising values of rated power
  - Typical example:
    - **1'000 kVA** transformer: load loss 1 %, short circuit impedance 6 % of ref. impedance – power factor of the series impedance: **0.167**
    - **100 MVA transformer**: load loss 0.4 %, short circuit impedance 15 % of ref. impedance – power factor of the series impedance: **0.027**

$$P = U \times I \times \cos\phi$$

$$\frac{\partial P}{P} = \frac{\partial U}{U} + \frac{\partial I}{I} - \frac{\sin\phi}{\cos\phi} \times \partial\phi$$

$$-\frac{\sin\phi}{\cos\phi} = -\frac{\left(1-\cos^2\phi\right)^{\frac{1}{2}}}{\cos\phi} \approx -\frac{1}{\cos\phi}$$

60076-8 IEC:1997 [9.6]



HAEFELY HIPOTRONICS

Case Study: Loss 1

- IEC 60076-8:1997

10.2 *Traceability, quality aspects on measuring technique*

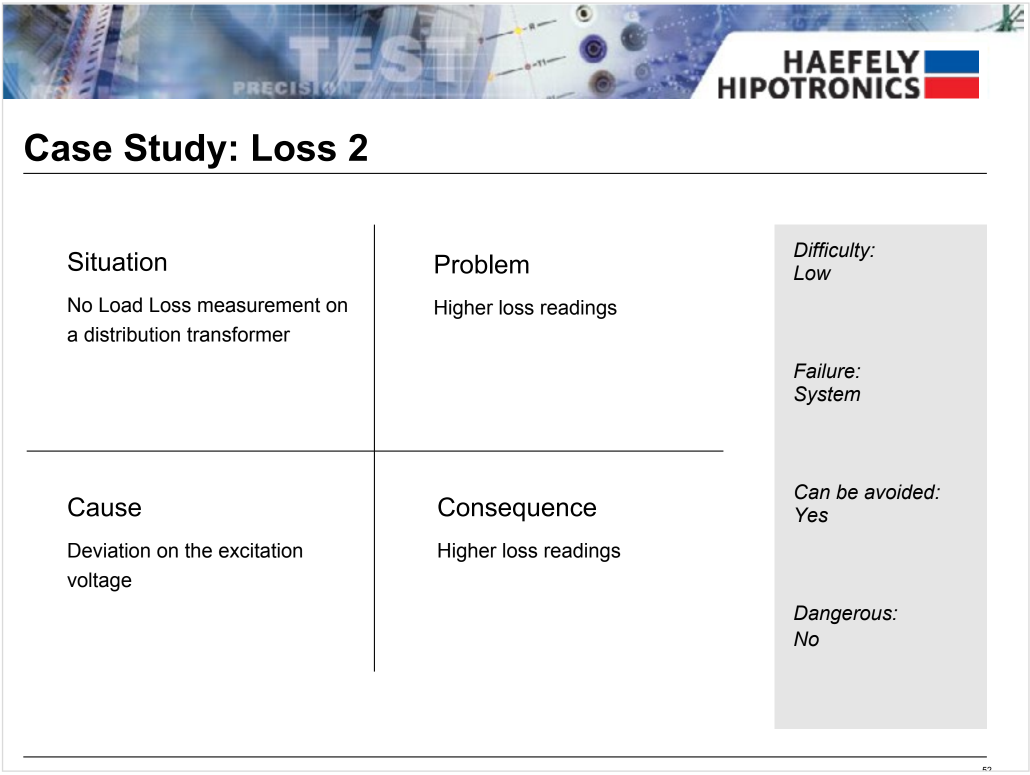
Traceability of measurements means that a chain of calibrations and comparisons have been carried out, through which the validity of the individual measurement can be traced back to national and international standards of units preserved in recognized institutions of metrology. Evidence of such traceability should contain the following items.

a) Certified information about errors (amplitude errors and phase angle errors) of the components of the measuring system (transducers for voltage, current and power, voltage dividers and shunts, indicating or recording instruments, etc.)

This may comprise:

- certificates from the manufacturers of individual components;
- certification from calibrations carried out at independent precision laboratories;
- certificates of calibrations made in the plant by means of precision instrumentation and specialist staff brought there for that purpose;
- direct comparisons of the test room installation with a complete precision measuring system (overall system calibration).

Power Factor	Components Accuracy [1]		Overall System Accuracy [1]		Range
	Standard [2]	Extended [3]	Standard [2]	Extended [3]	
cos φ = 1.0	± 0.15%	± 0.06%	± 0.35%	± 0.3%	105V/√3V .. 4200V/√3V; 0.5A .. 500A
cos φ = 0.5	± 0.5%	± 0.12%	± 0.7%	± 0.3%	105V/√3V .. 4200V/√3V; 0.5A .. 500A
cos φ = 0.3	± 0.79%	± 0.16%	± 1.2%	± 0.4%	105V/√3V .. 4200V/√3V; 0.5A .. 500A
cos φ = 0.1	± 2.14%	± 0.36%	± 3%	± 1.2%	105V/√3V .. 4200V/√3V; 0.5A .. 500A
Voltmeter	Class 0.1				Ratio 3500V/√3 : 100V Range 105V/√3..4200V/√3 (3%..120%)
Currentmeter	Class 0.1				0.5A .. 500A



Case Study: Loss 2

Situation

No Load Loss measurement on a distribution transformer

Problem

Higher loss readings

Cause

Deviation on the excitation voltage

Consequence

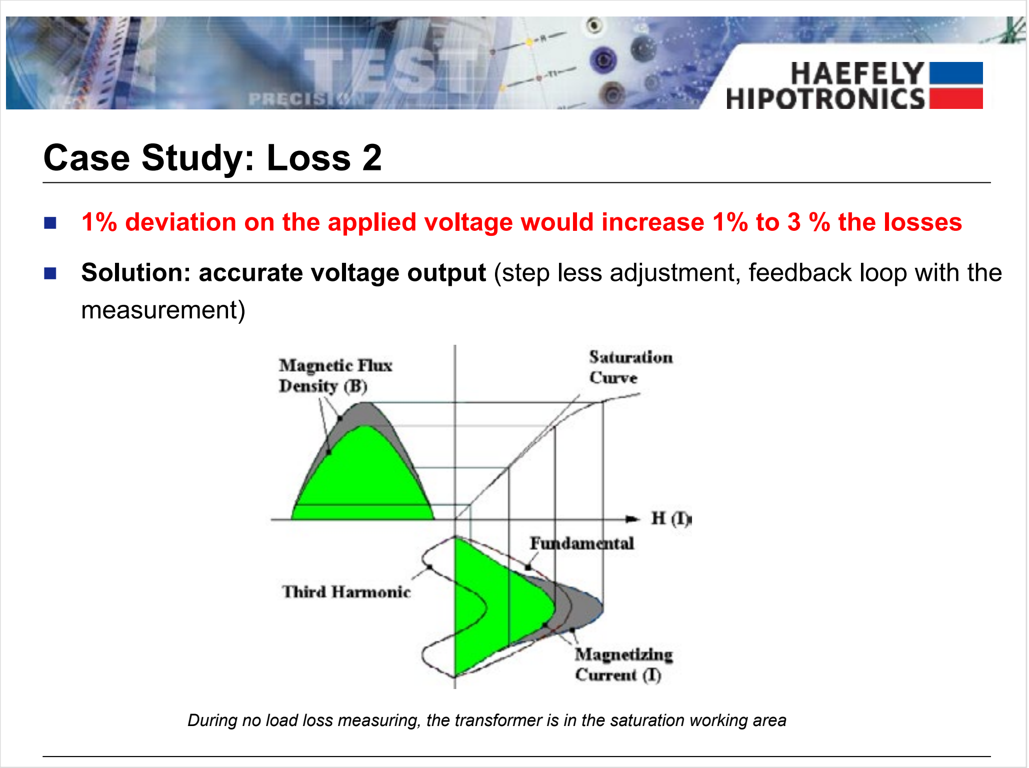
Higher loss readings

Difficulty:
Low

Failure:
System

Can be avoided:
Yes

Dangerous:
No



Case Study: Loss 2

- **1% deviation on the applied voltage would increase 1% to 3 % the losses**
- **Solution: accurate voltage output** (step less adjustment, feedback loop with the measurement)

During no load loss measuring, the transformer is in the saturation working area

HAEFELY HIPOTRONICS

Case Study: Loss 3

Situation

No Load Loss measurement on a distribution transformer

Problem

Higher loss readings

Cause

High THD on the voltage waveshape

Consequence

Higher loss readings

Difficulty:
Low

Failure:
System

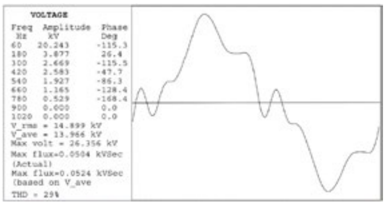
Can be avoided:
Yes

Dangerous:
No

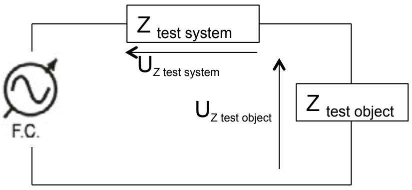
HAEFELY HIPOTRONICS

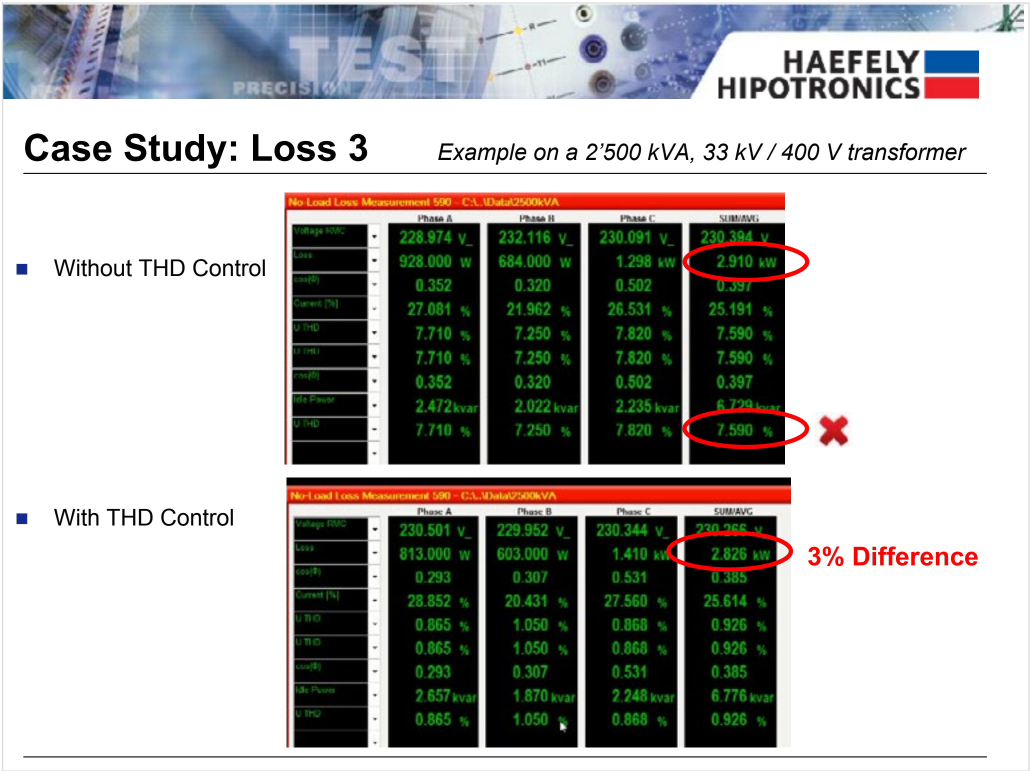
Case Study: Loss 3

- **T.H.D.:** Total Harmonic Distortion
- IEC 60076-1:2011 [11.1.1]: Voltage: THD < 5%
- **T.H.D. cause:**
  T.H.D. on the voltage waveshape comes mainly from the short circuit impedance of the test system
- **T.H.D. problem**:
  Peaked waves with higher r.m.s. **can lead to higher losses**



```
     VOLTAGE
Freq  Amplitude  Phase
 Hz      kV       Deg
60    20.243    -115.3
180    3.877     26.4
300    2.669    -115.5
420    2.583    -47.7
540    1.927    -86.3
660    1.165    -128.4
780    0.529    -168.4
900    0.000     0.0
1020   0.000     0.0
V_rms = 14.899 kV
V_ave = 13.966 kV
Max volt = 26.356 kV
Max flux=0.0504 kVSec
(Actual)
Max flux=0.0524 kVSec
(based on V_ave
THD = 29%
```





Case Study: Loss 3

Example on a 2’500 kVA, 33 kV / 400 V transformer

- Without THD Control

No-Load Loss Measurement 590 - C:\...\Data\2500kVA

	Phase A	Phase B	Phase C	SUM/AVG
Voltage RMC	228.974 V_	232.116 V_	230.091 V_	230.394 V
Loss	928.000 W	684.000 W	1.298 kW	2.910 kW
cos(Φ)	0.352	0.320	0.502	0.397
Current [%]	27.081 %	21.962 %	26.531 %	25.191 %
U THD	7.710 %	7.250 %	7.820 %	7.590 %
U THD	7.710 %	7.250 %	7.820 %	7.590 %
cos(Φ)	0.352	0.320	0.502	0.397
Idle Power	2.472 kvar	2.022 kvar	2.235 kvar	6.729 kvar
U THD	7.710 %	7.250 %	7.820 %	7.590 %

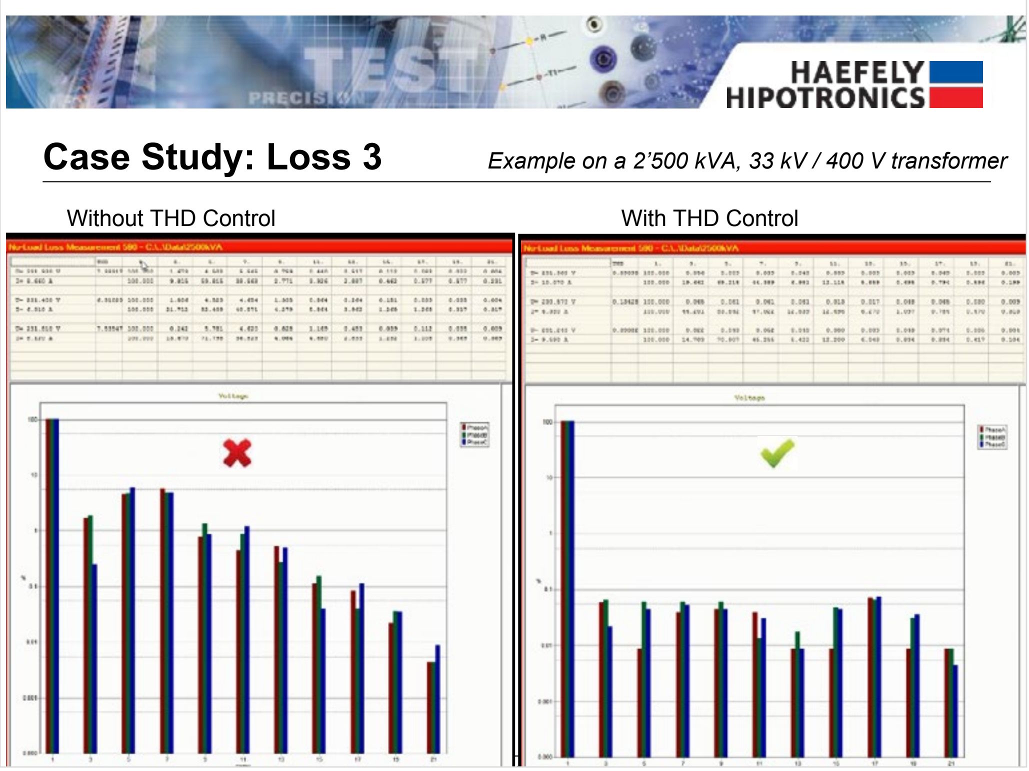
✗

- With THD Control

No-Load Loss Measurement 590 - C:\...\Data\2500kVA

	Phase A	Phase B	Phase C	SUM/AVG
Voltage RMC	230.501 V_	229.952 V_	230.344 V_	230.266 V
Loss	813.000 W	603.000 W	1.410 kW	2.826 kW
cos(Φ)	0.293	0.307	0.531	0.385
Current [%]	28.852 %	20.431 %	27.560 %	25.614 %
U THD	0.865 %	1.050 %	0.868 %	0.926 %
U THD	0.865 %	1.050 %	0.868 %	0.926 %
cos(Φ)	0.293	0.307	0.531	0.385
Idle Power	2.657 kvar	1.870 kvar	2.248 kvar	6.776 kvar
U THD	0.865 %	1.050 %	0.868 %	0.926 %

3% Difference

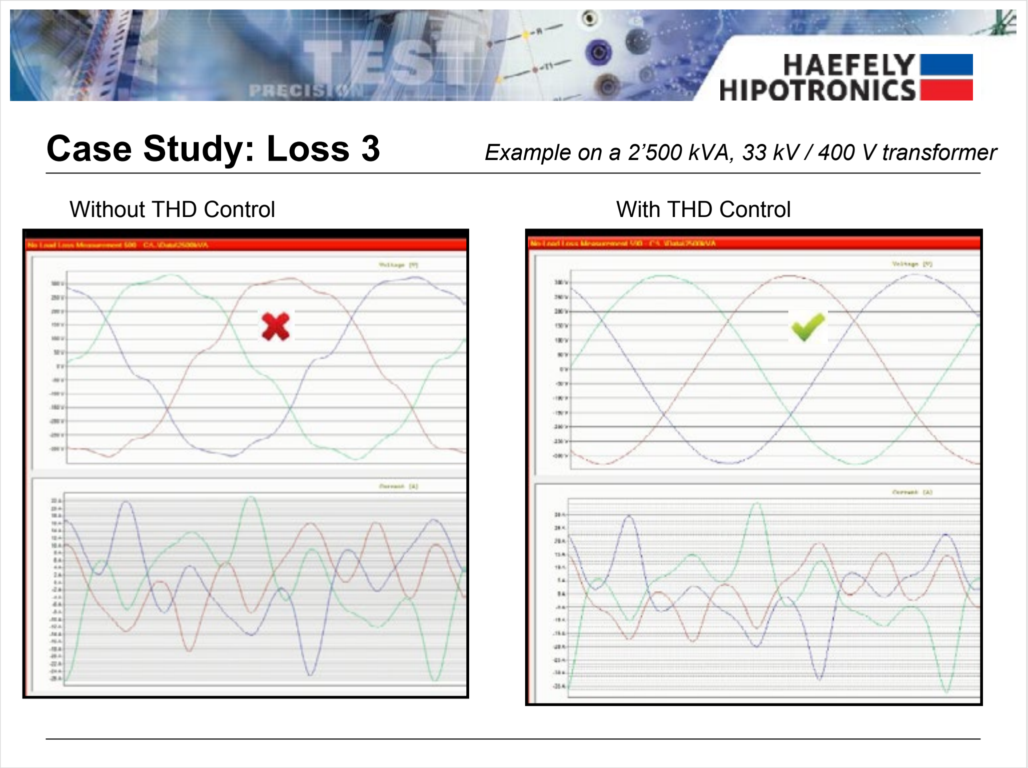


Case Study: Loss 3

Example on a 2’500 kVA, 33 kV / 400 V transformer

Without THD Control

With THD Control



HAEFELY HIPOTRONICS

Case Study: Loss 3

Example on a 2’500 kVA, 33 kV / 400 V transformer

Without THD Control

With THD Control

HAEFELY HIPOTRONICS

Case Study: Loss 4

Situation

No Load Loss measurement on a distribution transformer

Problem

Higher loss readings

Cause

Unsymmetric voltage waveshape

Consequence

Higher loss readings

Difficulty:
Low

Failure:
System

Can be avoided:
Yes

Dangerous:
No

HAEFELY HIPOTRONICS

Case Study: Loss 4

Example on a 2’500 kVA, 33 kV / 400 V transformer

- Without Symmetry Control

No Load Loss Measurement 590 - C:\...\Data\2500kVA

	Phase A	Phase B	Phase C	SUM/AVG
Voltage RMS	232.147 V_	234.035 V_	230.442 V_	232.208 V_
Loss	1.073 kW	546.000 W	1.290 kW	2.909 kW
cos(Φ)	0.328	0.211	0.482	0.343
Current [%]	33.852 %	26.483 %	27.967 %	29.434 %
U THD	2.450 %	2.170 %	2.760 %	2.460 %
U THD	2.450 %	2.170 %	2.760 %	2.460 %
cos(Φ)	0.328	0.211	0.482	0.343
Idle Power	3.087 kvar	2.530 kvar	2.347 kvar	7.963 kvar
U THD	2.450 %	2.170 %	2.760 %	2.460 %

- With Symmetry Control

No-Load Loss Measurement 590 - C:\...\Data\2500kVA

	Phase A	Phase B	Phase C	SUM/AVG
Voltage RMS	230.501 V_	229.952 V_	230.344 V_	230.266 V_
Loss	813.000 W	603.000 W	1.410 kW	2.826 kW
cos(Φ)	0.293	0.307	0.531	0.385
Current [%]	28.852 %	20.431 %	27.560 %	25.614 %
U THD	0.865 %	1.050 %	0.868 %	0.926 %
U THD	0.865 %	1.050 %	0.868 %	0.926 %
cos(Φ)	0.293	0.307	0.531	0.385
Idle Power	2.657 kvar	1.870 kvar	2.248 kvar	6.776 kvar
U THD	0.865 %	1.050 %	0.868 %	0.926 %

3% Difference

HAEFELY HIPOTRONICS

Case Study: Loss 5

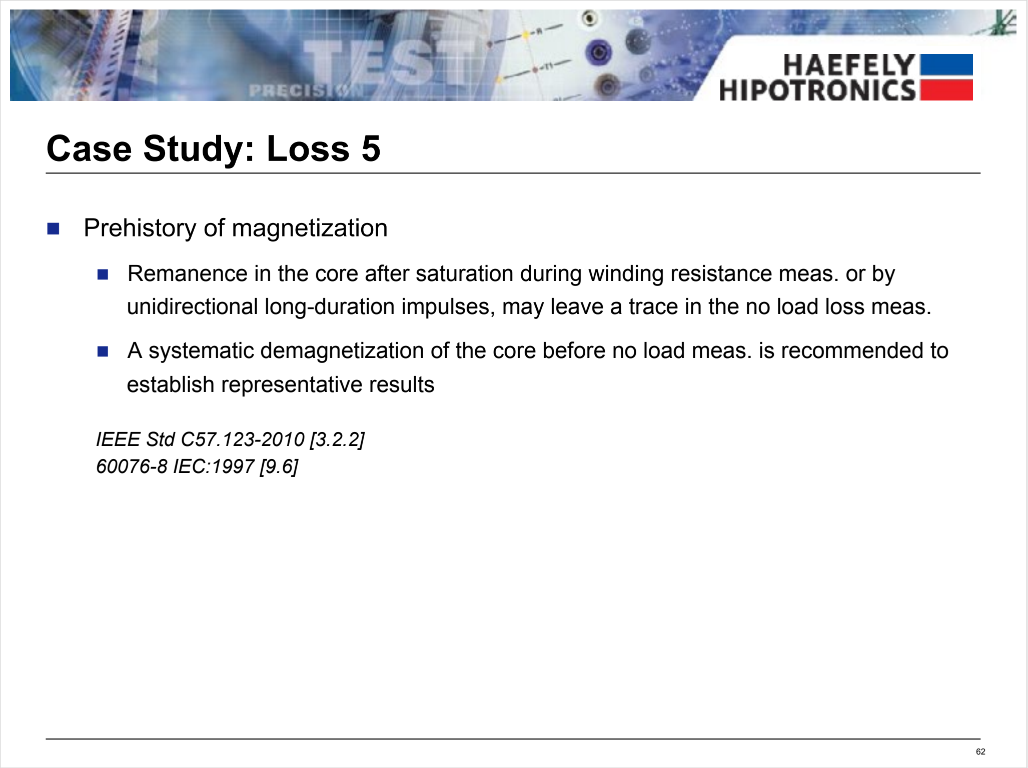
Situation	Problem
No Load Loss measurement on a transformer	Higher loss readings
Cause	**Consequence**
Magnetized core	Higher loss readings

Difficulty:
Low

Failure:
Human

Can be avoided:
Yes

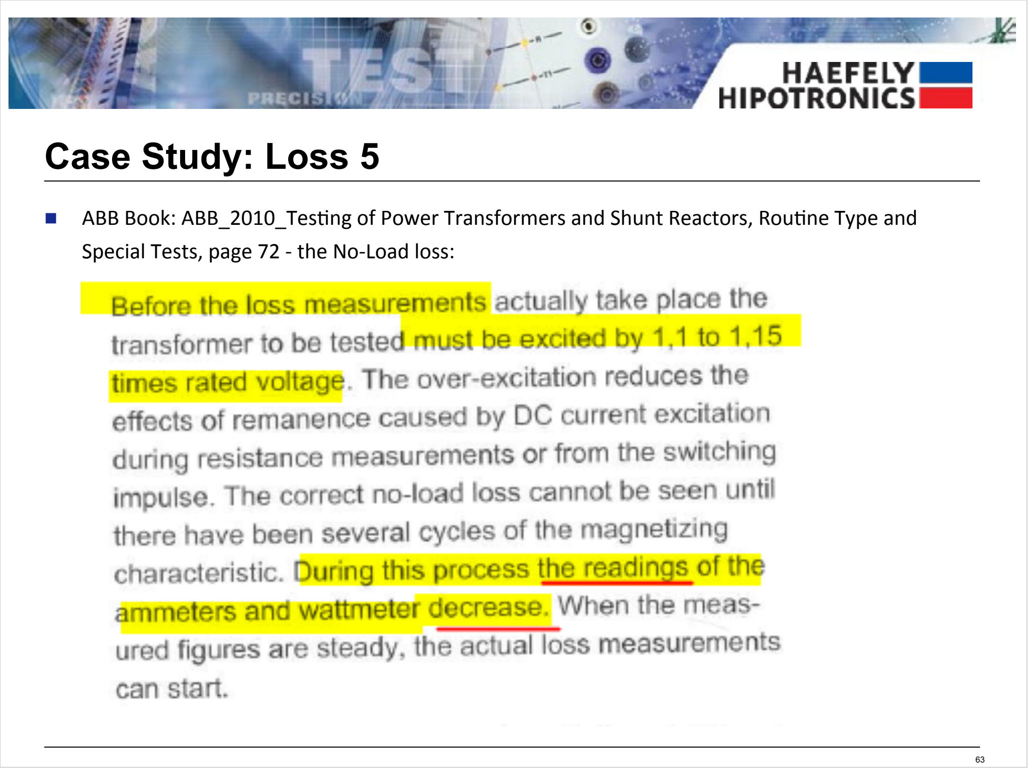
Dangerous:
No



Case Study: Loss 5

- Prehistory of magnetization
  - Remanence in the core after saturation during winding resistance meas. or by unidirectional long-duration impulses, may leave a trace in the no load loss meas.
  - A systematic demagnetization of the core before no load meas. is recommended to establish representative results

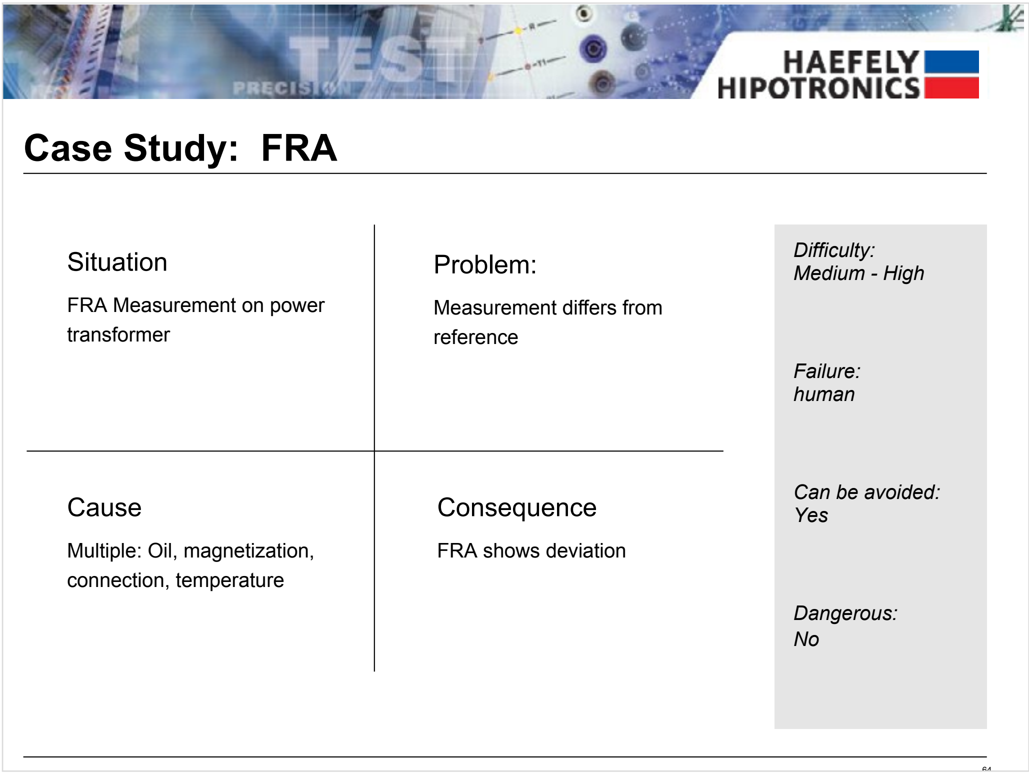
IEEE Std C57.123-2010 [3.2.2]
60076-8 IEC:1997 [9.6]



Case Study: Loss 5

- ABB Book: ABB_2010_Testing of Power Transformers and Shunt Reactors, Routine Type and Special Tests, page 72 - the No-Load loss:

Before the loss measurements actually take place the transformer to be tested must be excited by 1,1 to 1,15 times rated voltage. The over-excitation reduces the effects of remanence caused by DC current excitation during resistance measurements or from the switching impulse. The correct no-load loss cannot be seen until there have been several cycles of the magnetizing characteristic. During this process the readings of the ammeters and wattmeter decrease. When the measured figures are steady, the actual loss measurements can start.



Case Study: FRA

Situation

FRA Measurement on power transformer

Problem:

Measurement differs from reference

Cause

Multiple: Oil, magnetization, connection, temperature

Consequence

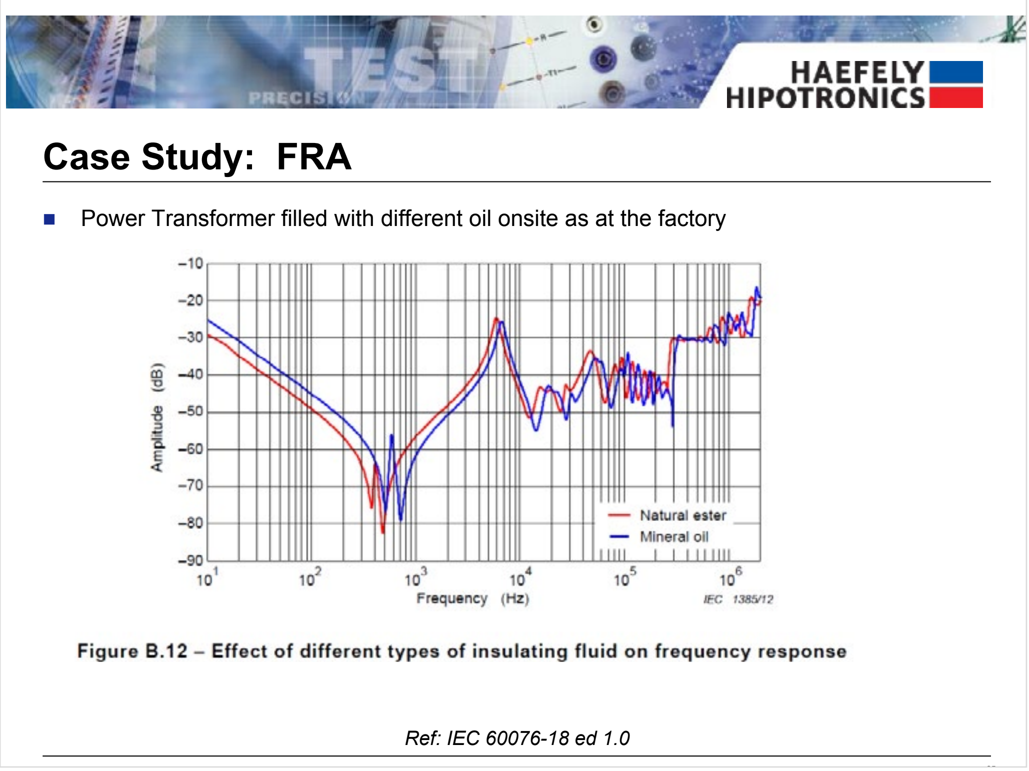
FRA shows deviation

Difficulty:
Medium - High

Failure:
human

Can be avoided:
Yes

Dangerous:
No

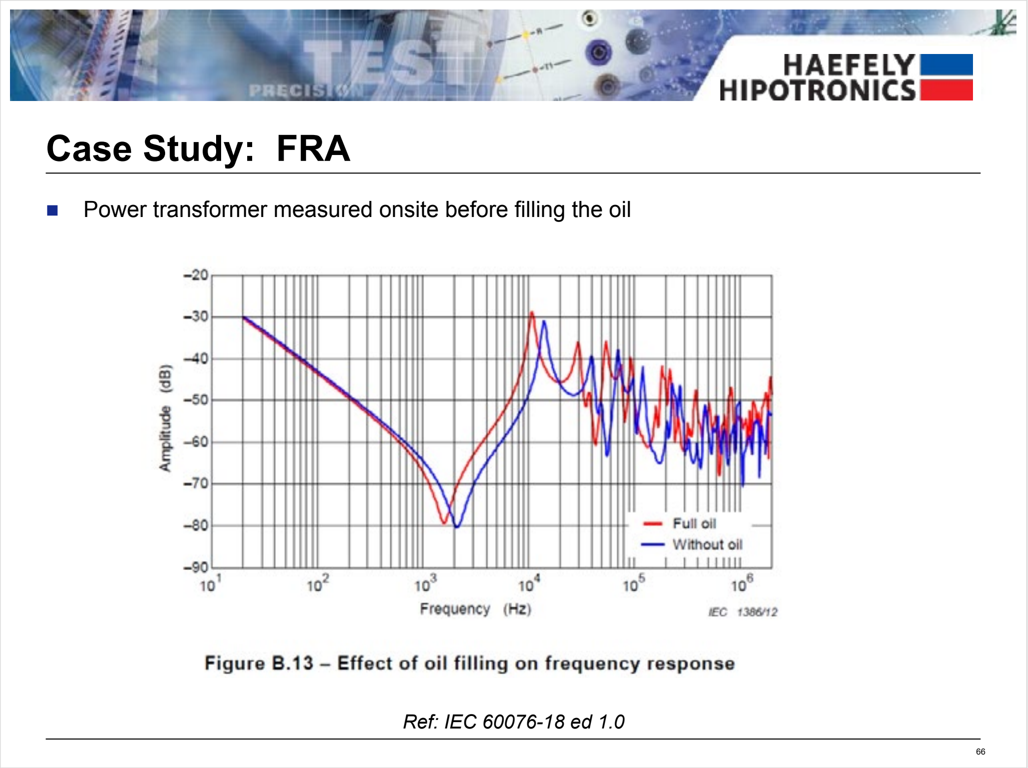


Case Study: FRA

- Power Transformer filled with different oil onsite as at the factory

Figure B.12 – Effect of different types of insulating fluid on frequency response

Ref: IEC 60076-18 ed 1.0



Case Study: FRA

- Power transformer measured onsite before filling the oil

Figure B.13 – Effect of oil filling on frequency response

Ref: IEC 60076-18 ed 1.0

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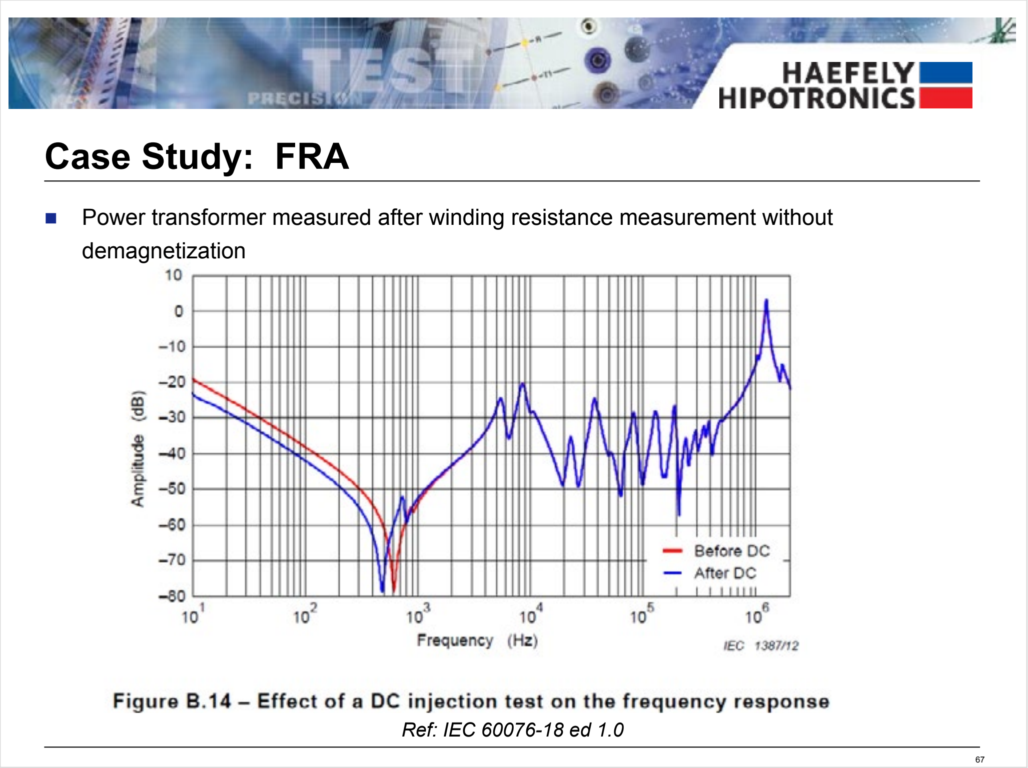

Case Study: FRA

- Power transformer measured after winding resistance measurement without demagnetization

Figure B.14 – Effect of a DC injection test on the frequency response

Ref: IEC 60076-18 ed 1.0

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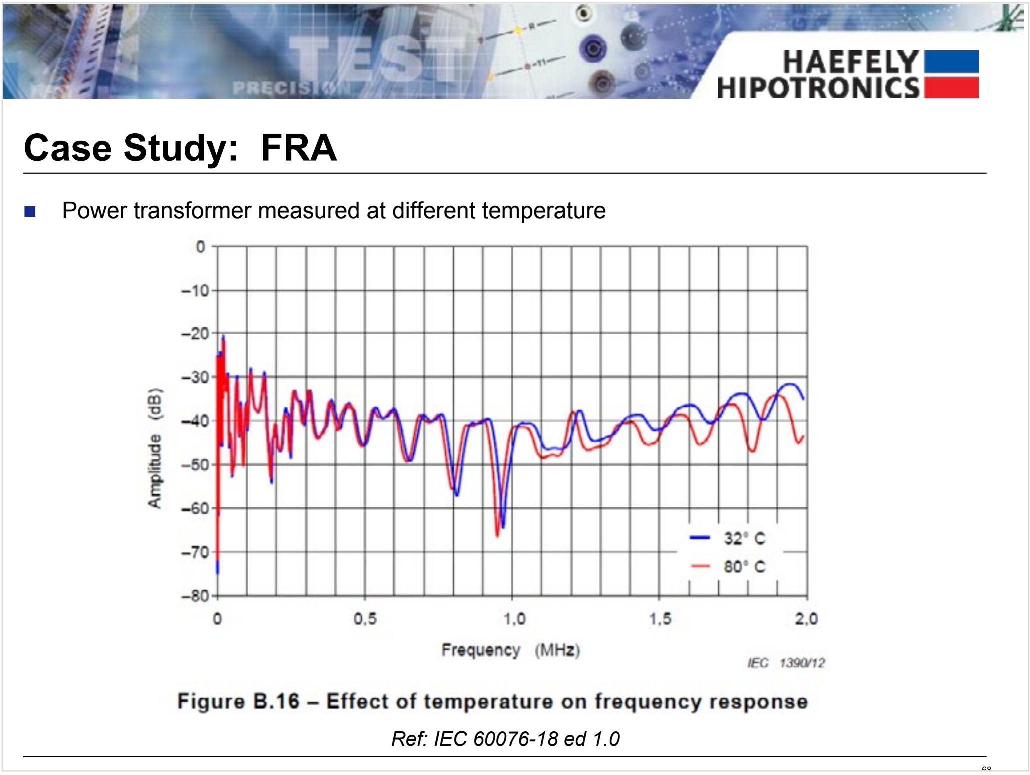
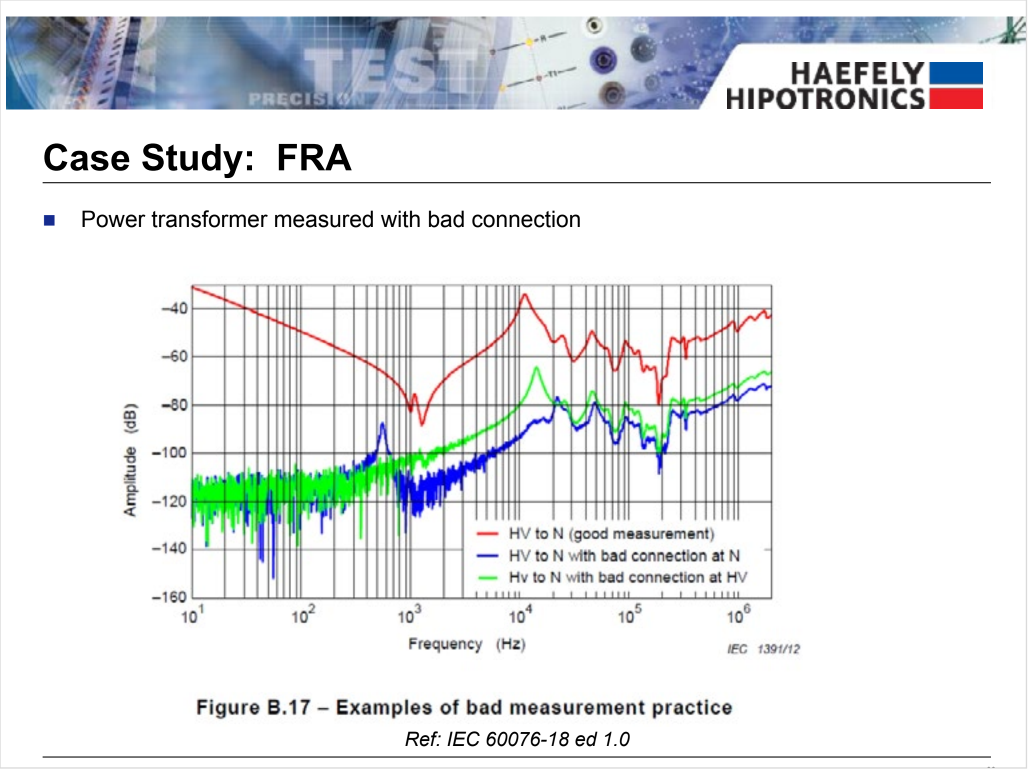


Case Study: FRA

- Power transformer measured at different temperature

Figure B.16 – Effect of temperature on frequency response

Ref: IEC 60076-18 ed 1.0

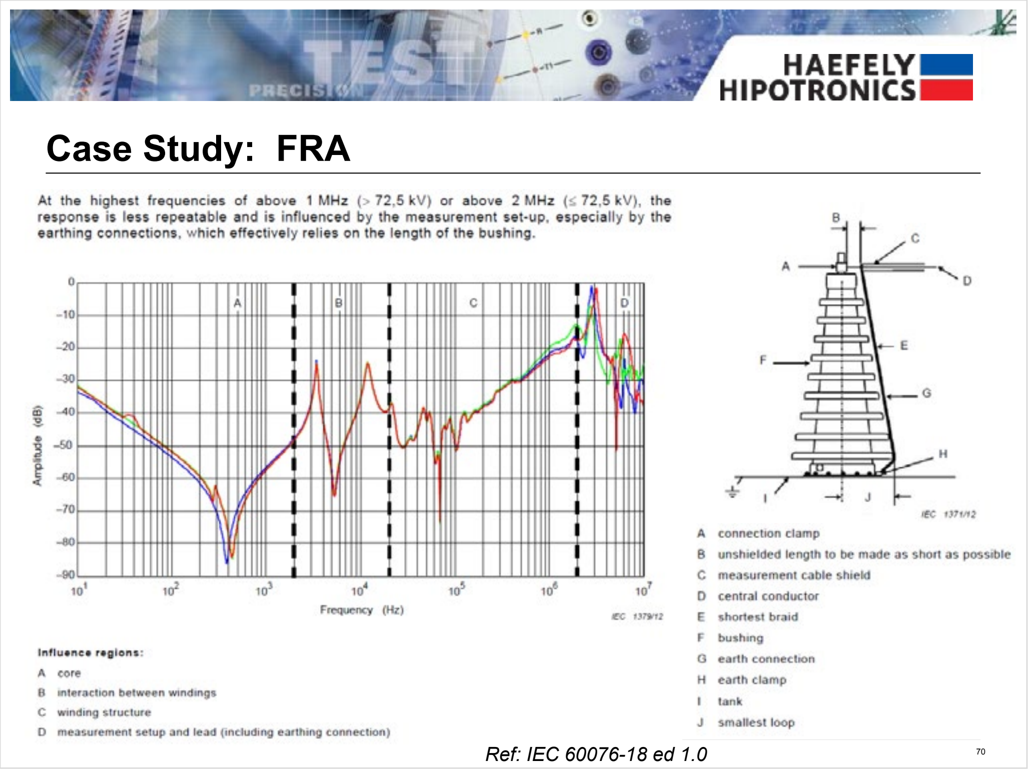


Case Study: FRA

- Power transformer measured with bad connection

Figure B.17 – Examples of bad measurement practice

Ref: IEC 60076-18 ed 1.0



Case Study: FRA

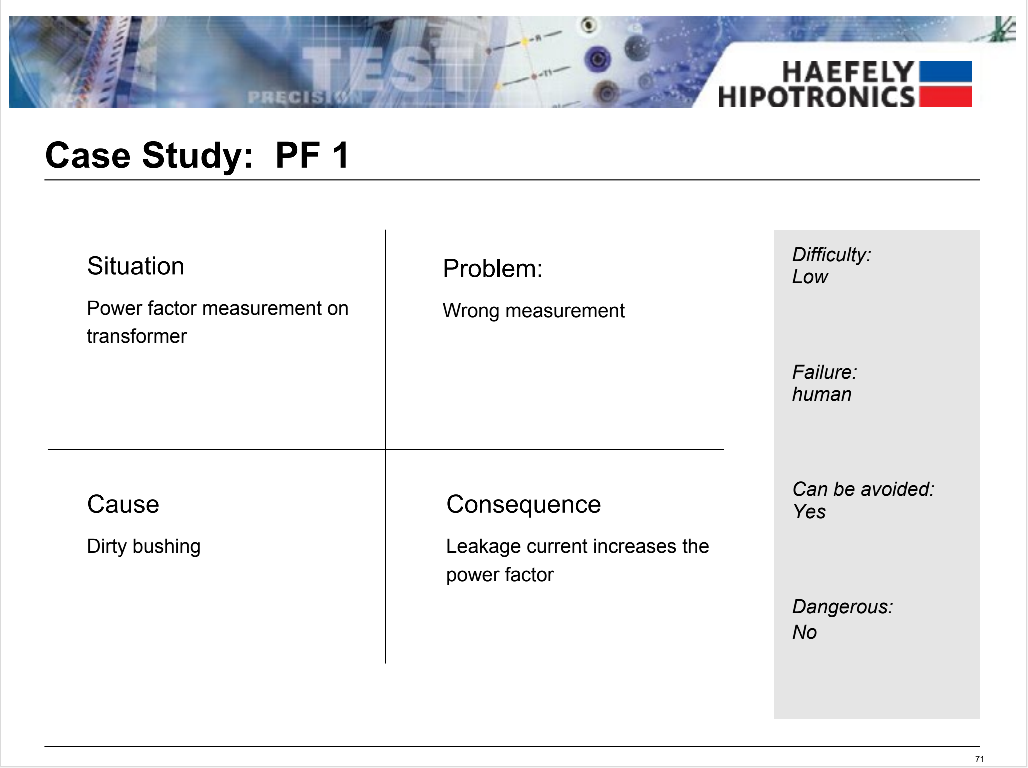
At the highest frequencies of above 1 MHz (> 72,5 kV) or above 2 MHz (≤ 72,5 kV), the response is less repeatable and is influenced by the measurement set-up, especially by the earthing connections, which effectively relies on the length of the bushing.

Influence regions:

A	core
B	interaction between windings
C	winding structure
D	measurement setup and lead (including earthing connection)

A	connection clamp
B	unshielded length to be made as short as possible
C	measurement cable shield
D	central conductor
E	shortest braid
F	bushing
G	earth connection
H	earth clamp
I	tank
J	smallest loop

Ref: IEC 60076-18 ed 1.0



Case Study: PF 1

Situation

Power factor measurement on transformer

Problem:

Wrong measurement

Cause

Dirty bushing

Consequence

Leakage current increases the power factor

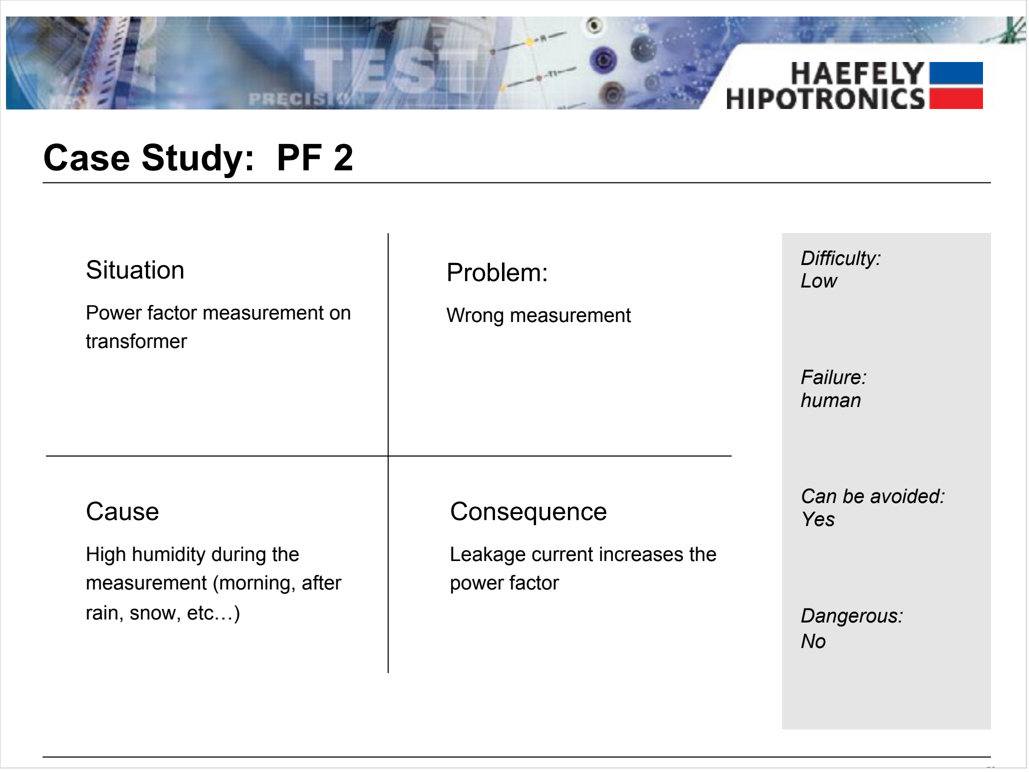
Difficulty:
Low

Failure:
human

Can be avoided:
Yes

Dangerous:
No

Case Study: PF 1



Case Study: PF 2

Situation

Power factor measurement on transformer

Problem:

Wrong measurement

Cause

High humidity during the measurement (morning, after rain, snow, etc…)

Consequence

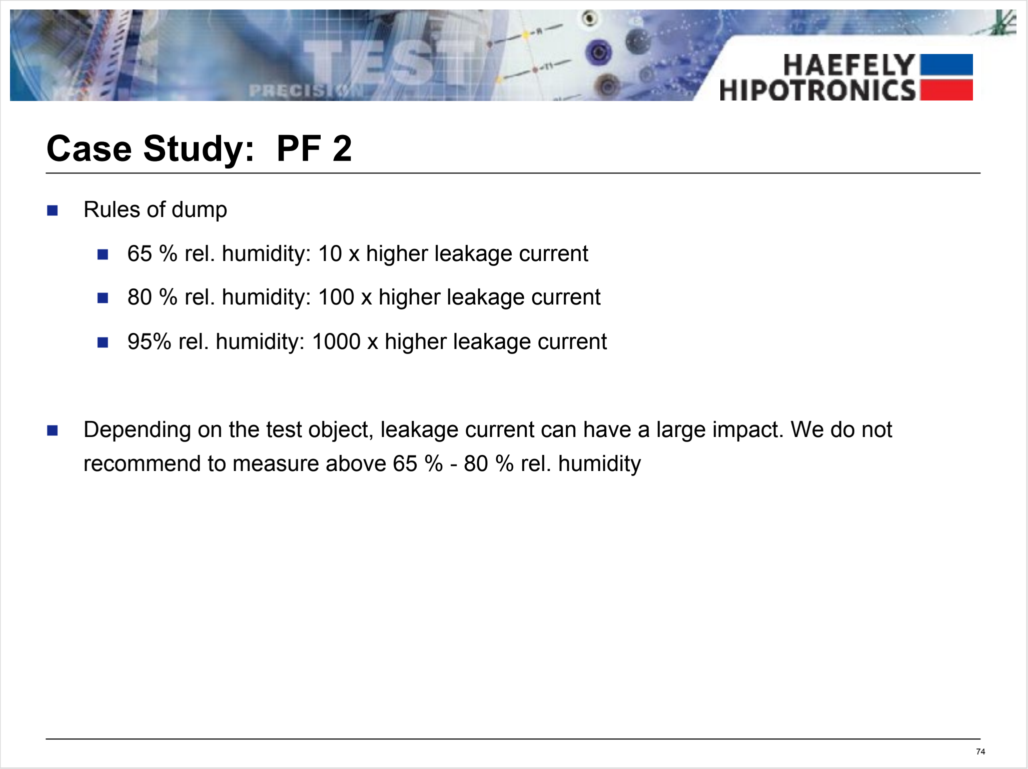
Leakage current increases the power factor

Difficulty:
Low

Failure:
human

Can be avoided:
Yes

Dangerous:
No



HAEFELY HIPOTRONICS

Case Study: PF 2

- Rules of dump
  - 65 % rel. humidity: 10 x higher leakage current
  - 80 % rel. humidity: 100 x higher leakage current
  - 95% rel. humidity: 1000 x higher leakage current
- Depending on the test object, leakage current can have a large impact. We do not recommend to measure above 65 % - 80 % rel. humidity

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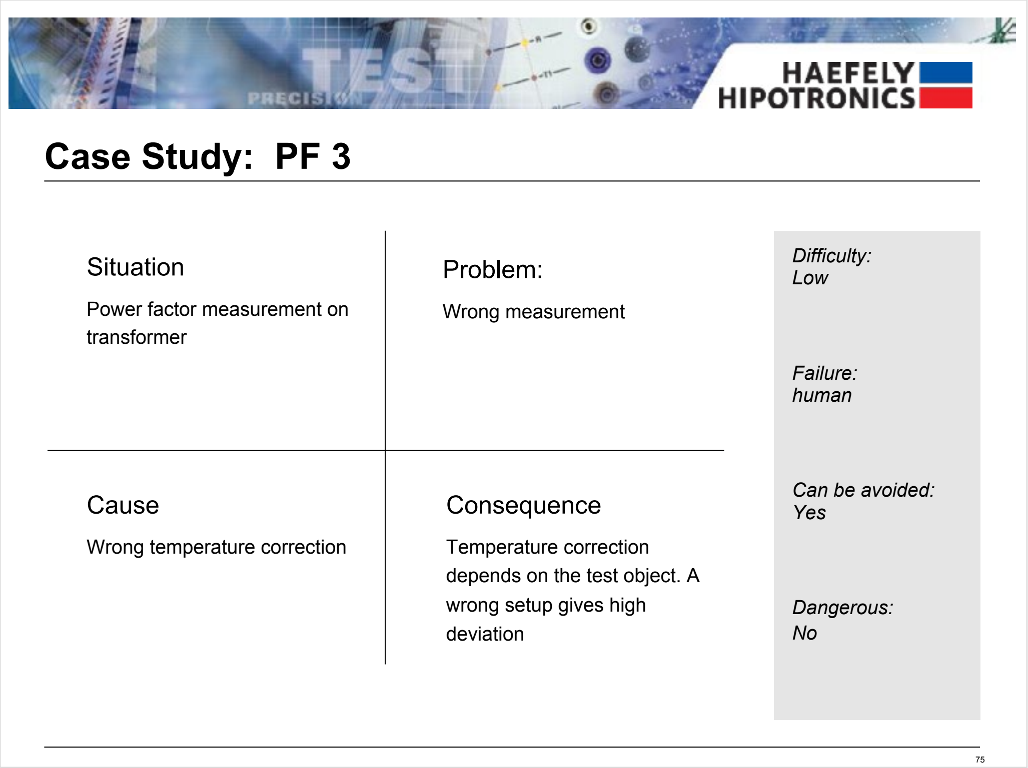

HAEFELY HIPOTRONICS

Case Study: PF 3

Situation

Power factor measurement on transformer

Problem:

Wrong measurement

Cause

Wrong temperature correction

Consequence

Temperature correction depends on the test object. A wrong setup gives high deviation

Difficulty:
Low

Failure:
human

Can be avoided:
Yes

Dangerous:
No

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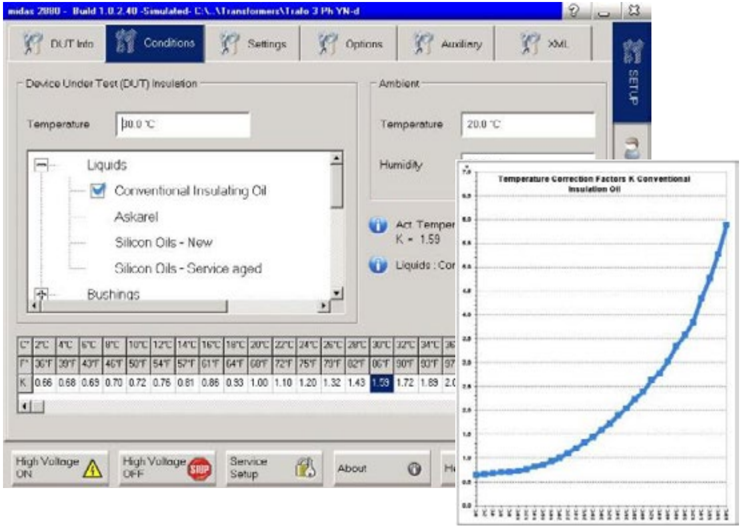
Mitigating Murphy´s Law While Test

Case Study: PF 3

- Temperature correction example



midas 2880 - Build 1.0.2.40 -Simulated- C:\..\Transformers\Trafo 3 Ph YN-d

Device Under Test (DUT) Insulation

Temperature: 30.0 °C

Liquids
- ☑ Conventional Insulating Oil
- Askarel
- Silicon Oils - New
- Silicon Oils - Service aged

Bushings

Ambient

Temperature: 20.0 °C

Humidity

Act. Temper
K = 1.59

Liquids : Cor

C°	2°C	4°C	6°C	8°C	10°C	12°C	14°C	16°C	18°C	20°C	22°C	24°C	26°C	28°C	30°C	32°C	34°C	36
F°	36°F	39°F	43°F	46°F	50°F	54°F	57°F	61°F	64°F	68°F	72°F	75°F	79°F	82°F	86°F	90°F	93°F	97
K	0.66	0.68	0.69	0.70	0.72	0.76	0.81	0.86	0.93	1.00	1.10	1.20	1.32	1.43	1.59	1.72	1.89	2.0

Case Study: PF 4

Situation

Power factor measurement on transformer

Problem:

Impossible to perform correct measurement

Cause

GST setup is needed, but the power supply is not compatible

Consequence

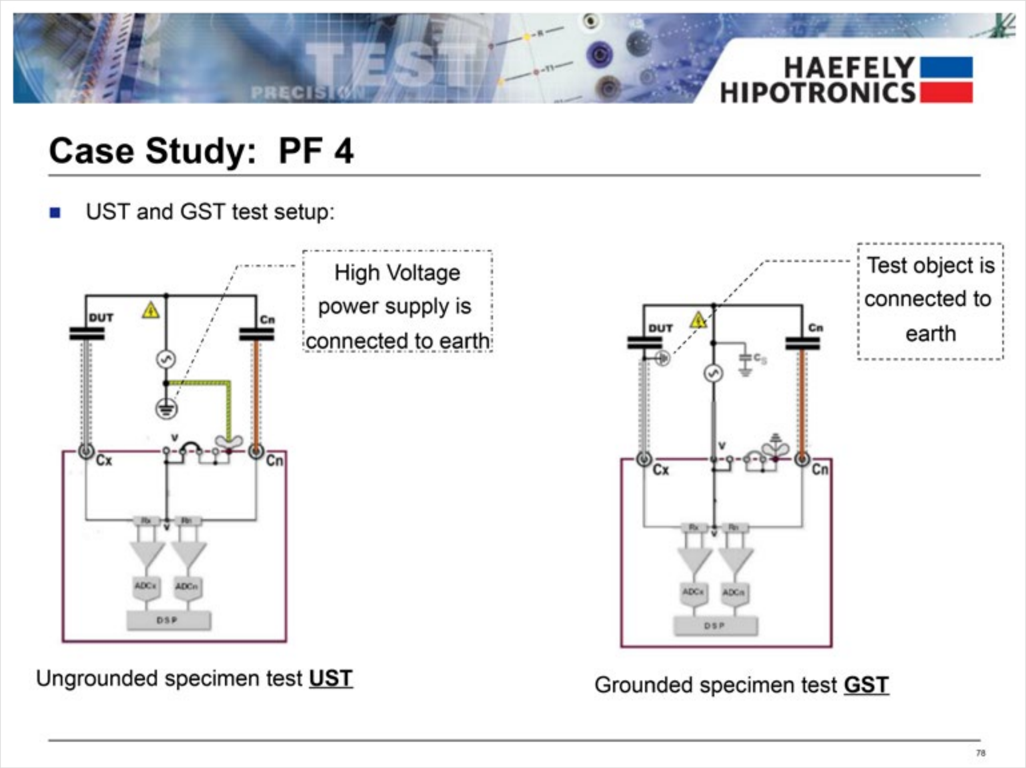
If the power supply does not have a separate ground output, is it impossible to perform a GST measurement.

Difficulty:
Low

Failure:
System

Can be avoided:
Yes

Dangerous:
No



Case Study: PF 4

- UST and GST test setup:

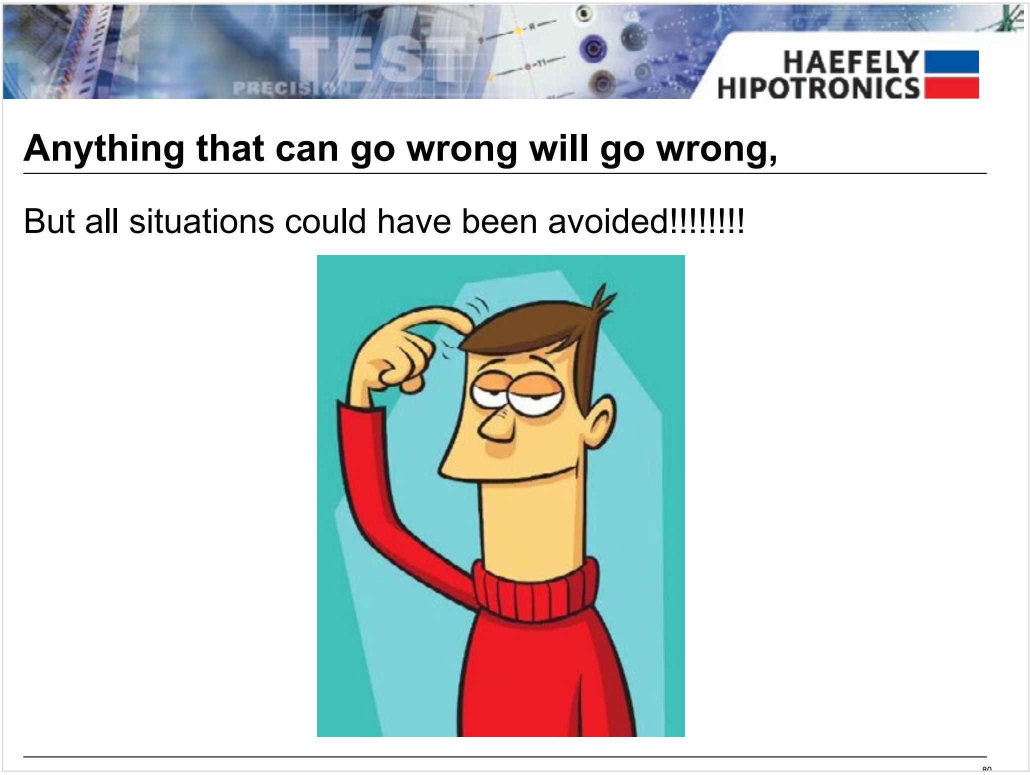
High Voltage power supply is connected to earth

Test object is connected to earth

Ungrounded specimen test **UST**

Grounded specimen test **GST**

Cases Study Analysis



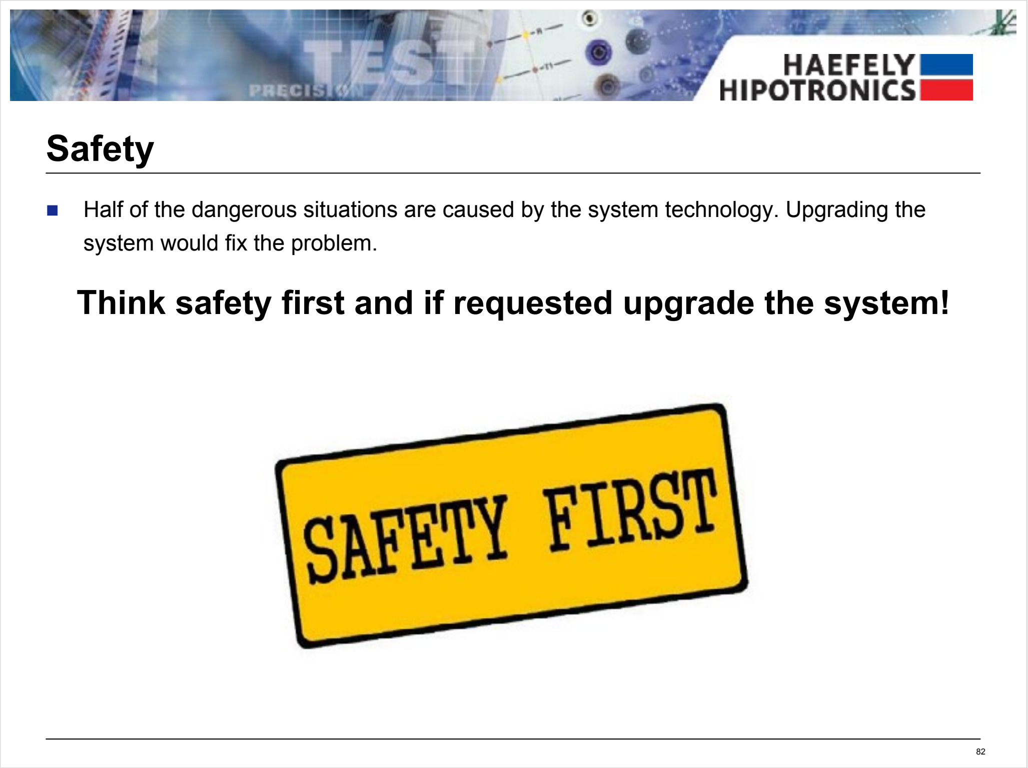
Anything that can go wrong will go wrong,

But all situations could have been avoided!!!!!!!!

Technology level

- If a system is the cause of a fault, upgrading the system would be the solution

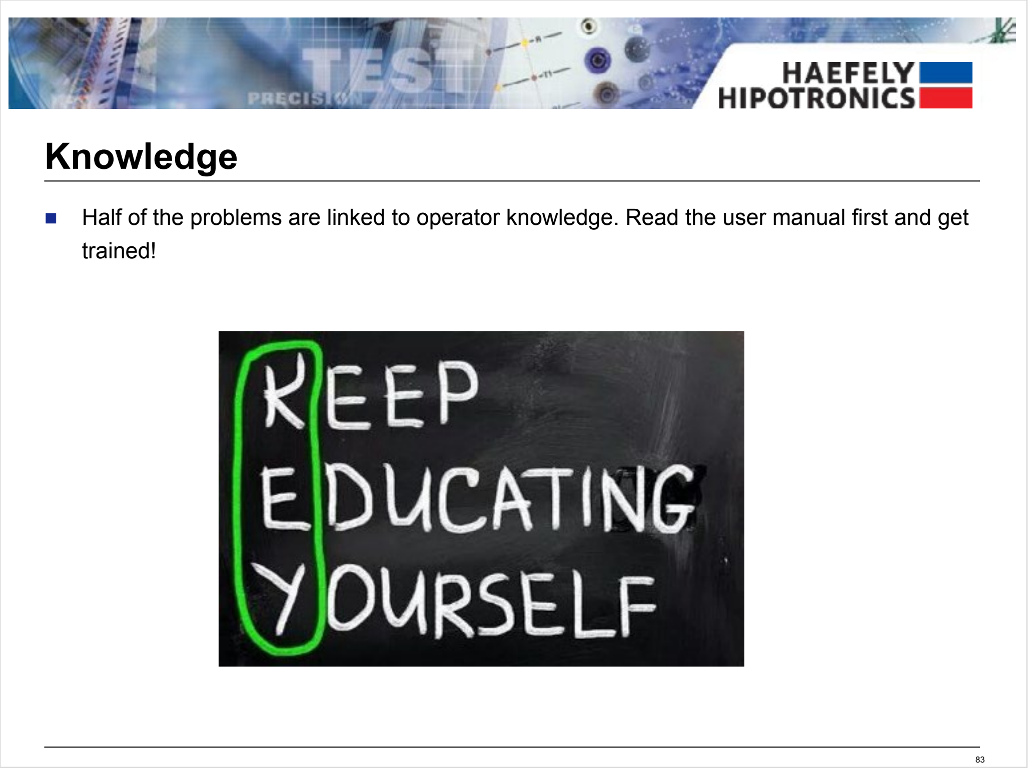
Better technology will avoid system failure!



Safety

- Half of the dangerous situations are caused by the system technology. Upgrading the system would fix the problem.

Think safety first and if requested upgrade the system!



Knowledge

- Half of the problems are linked to operator knowledge. Read the user manual first and get trained!

감사합니다 Natick

Grazie Danke Ευχαριστίες Dalu Obrigado

Thank You Köszönöm

Tack

Спасибо Dank Gracias

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