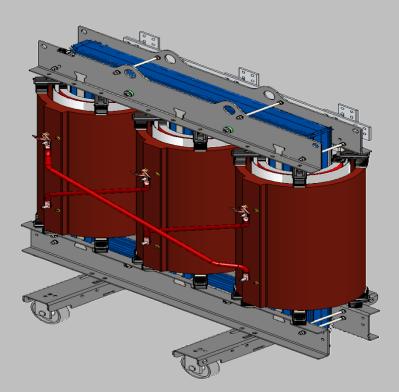
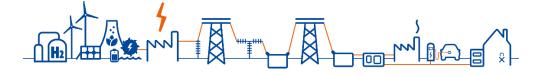


Test description for dry-type transformers chapter for type tests







1.	SCOPE						
2.	STANDARDS						
3.	LIGH	6					
-							
-	.1. .2.	Stan Aim	JARD	6 6			
-	.2.	TEST		6			
J	.s. 3.3.1		Test wave	6			
	3.3.2		Remarks to wave shapes on special cases	6			
	3.3.3		Voltage level (BIL)	7			
	3.3.4		Winding to be tested	7			
	3.3.5		Transformer connection between the test	7			
	3.3.6		Tapping position for test	8			
	3.3.7		Test setup	8			
		3.8.	MARX generator data	8			
		3.9.	Impulse test circuit	9			
		3.10.	Example of resistors for the MARX generator	9			
	3.	3.11.	Example of MARX generator connections	10			
	3.3.1	2.	Test procedure for full-wave impulse	11			
	3.3.1	3.	Test procedure for copped-full-wave on the tail impulse	12			
	3.3.1	4.	Remarks for changing polarity between impulses	13			
	3.3.1	5.	Commonly used measuring devices for testing	13			
	3.3.1	6.	Recorded values for the test	13			
3	.4.	TEST	CRITERIA	13			
4.	TEM	PERA	TURE RISE TEST	14			
4	.1.	Stan	DARD	14			
4	.2.	Аім		14			
4	.3.	MEAS	SUREMENT - GENERAL	14			
	4.3.1		Tapping position for measurement	14			
	4.3.2		Temperature sensors for the measurement	15			
4	.4.		RESISTANCE	16			
	4.4	4.1.	Test setup	16			
4	.5.	No-	LOAD (EXCITATION LOAD) MEASUREMENT	17			
	4.	5.1.	Equivalent circuit diagram for a transformer in no-load	17			
	4.	5.2.	Test setup no - load (excitation load)	17			
	4.	5.3.	Switching off	17			
	4.	5.4.	Hot resistance	18			
4	.6.		MEASUREMENT	19			
		6.1.	Equivalent circuit diagram for transformer in load (short-circuit)	19			
		6.2. 6.3.	Test setup load	20			
		6.4.	Switching off Hot resistance	20 20			
Δ	.7.	-	MONLY USED MEASURING DEVICES FOR MEASUREMENT	20			
	.8.		RDED VALUES FOR THE MEASUREMENT	22			
	.9.		JLATIONS FOR THE MEASUREMENT	22			
4	.9. 4.9.1		Calculation for hot resistance R _{w2}	23			
	4.9.1		Calculation $\Delta\theta e$ (for no-load)	23			
	4.9.2		Calculation $\Delta \theta e$ (for load)	23			
	4.9.5		Calculation $\Delta \theta c$ (joi load) Calculation $\Delta \theta c$ corrected for test current (for load)	24 24			
	4.9.4		Calculation $\Delta\theta c'$ (total)	24 25			
	4.5.5	•		25			



	4.9.6	5. Calculation of the max. temperature on the winding surface	25
	4.10.	TEMPERATURE RISE TEST ON TRANSFORMERS WITH WINDING IN MULTI-TIER DESIGN	25
	4.11.	PROCEDURE AT TEMPERATURE RISE TEST WITH WATER COOLING (AFWF)	26
	4.12.	TEST CRITERIA	26
5.	ΑΡΡΙ	ENDIX	27
	5.1.	EXAMPLE TEST CERTIFICATE	27
	5.2.	COMPARISON OF DIFFERENT METHODS FOR COLD RESISTANCE MEASUREMENT AT TEMPERATURE RISE TEST WITH WAT	ER
	COOLING	i (AFWF)	37
	5.3.	EXAMPLE CALIBRATION LIST	38
	5.4.	Test lab layout	39
	5.5.	LIST OF PICTURES, FORMULAS, TABLES AND SOURCES	40



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1. Scope

This is a general test description for dry-type transformers at SGB and will apply if no specific customer requirements are given for the individual tests.

Special customer standards or values are not included in this description.

If not indicated, the description is exemplary for a three-phase transformer with two winding systems. Auxiliary parts of the transformer are also not included, except as indicated e.g., temperature sensors.

The scope of this chapter describes "type" tests, this means the standard require these tests for a new design or significant design changes (see IEC 60076-1:2011 chapter 3.11.2).

Transformer type means e.g.:

- > representative electrical values (e.g., voltage, power)
- representative design

Design variations that are clearly irrelevant to a particular type test would not require that type test to be repeated.

Design variations that cause a reduction in values and stresses relevant to a particular type test do not require a new type test if accepted by the purchaser and manufacturer.



2. Standards

Part 11: Dry-type transformers IEC 60076-11:2018

Replacement for DIN EN 60726 (VDE 0532-726):2003-10

with reference to:	
IEC 60076-1:2011	Power transformers – General
IEC 60076-2:2011	Temperature rise for liquid-immersed transformers
IEC 60076-3:2013	Insulation levels, dielectric test's and external clearances in air
IEC 60076-4:2002	Guide to the lightning impulse and switching Impulse testing –
	Power transformers and reactors
IEC 60076-16:2011	Transformers for wind turbine application
IEC 60060	High voltage test techniques
IEC 60310:2004	Railway applications –
	Traction transformers and inductors on board rolling stock
IEC 50329:2010	Railway applications – Fixed installations – Traction transformers
IEC 60529:1989	Degrees of protection provided by enclosures (IP code)



3. Lightning impulse test

3.1. Standard

IEC 60076-11:2018 clause 14.3.1 // part 3 clause 13

3.2. Aim

The lightning impulse voltage test is executed as a type test to prove the constructive coordination of the transformer (e.g., insulation in the winding turn-to-turn, layer-to-layer, terminal-to-constructive parts, etc.). The impulse also reproduces the stress peaks and switching surges in the net.

3.3. Test

3.3.1. Test wave

The test can be executed with various parameters, usually it is:

```
Full-wave in positive polarity with 100 % BIL level
```

```
Wave shape T_1 = 1.2 \ \mu s \pm 30 \ \% T_2 = 50 \ \mu s \pm 20 \ \%
```

> Full-chopped-wave on the tail in negative polarity with 100% or 110 % BIL level

Wave shape $T_1 = 1.2 \ \mu s \pm 30 \ \%$ $T_2 = 4.5 \ \mu s \pm 34 \ \%$

> Full-chopped- wave on the tail in positive polarity with 100% or 110 % BIL level Wave shape $T_1 = 1.2 \ \mu s \pm 30 \ \%$ $T_2 = 4.5 \ \mu s \pm 34 \ \%$

Also, technically possible but not practical with our generator configuration (special tests, only on customer request)

- Switching impulse
- Front of wave chopped

3.3.2. Remarks to wave shapes on special cases

For some transformers, it is necessary to apply a resistor on the windings which are not being tested, separately from the winding upon which testing is taking place

(The maximum resistance therefore is 400 Ω).

Remark: In all circumstances, the voltage appearing during the impulse test at the other line terminals shall not be more than 75 % of their rated lightning impulse withstand voltage for star-connected windings, or 50 % for delta-connected windings. The lowest value of impedance at each terminal needed to achieve the required wave shape shall be used.

During the testing of the neutral (special tests, only upon customer request) the T1 has a maximum time of 13 μ s. Also, the transformer is always to be switched to the maximum possible voltage during this test.

For certain test circuits and test objects, e.g., testing transformer windings with a very low impedance (generally the low voltage side), it can be extremely difficult within the stated tolerances may be impossible to achieve the IEC required wave form (front time T1, Time to half-value T2 or overshoot ß). In these cases, larger tolerances will be acceptable, the test will be carried out <u>based</u> on the relevant standard.

A time to chopping of between 2 μ s and 3 μ s can be accepted per an agreement between the supplier and customer, provided that the peak value of the lightning impulse wave is achieved before the chop.



3.3.3. Voltage level (BIL)

The voltage level is chosen with the corresponding Um, according to

- IEC 60076-11:2018 (clause 11.1, table 3, List 1 or List 2)
- Or for special requirements (only upon customer request)
 - IEC 60076-16:2011 (clause 4.6, table 1, List 2 or List 3)
 - IEC 60076-3:2013 (table 2)

The tolerance for the voltage level is \pm 3 % of the BIL.

3.3.4. Winding to be tested

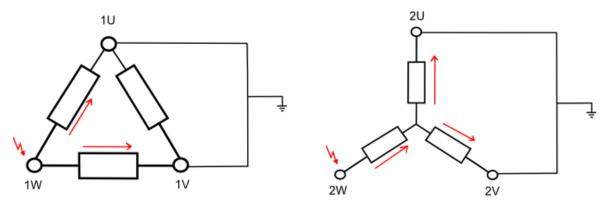
Impulse testing is required on all winding connections/terminals (e.g., U, V, W) which have a rated voltage \geq 3.6 kV or with higher insulation coordination through a special standard or an agreement between supplier and purchaser.

3.3.5. Transformer connection between the test

The test is executed with the winding interconnection e.g., in delta, star or zig-zack.

Through this, it is ensured that all coils will be tested on both the upper and lower terminals.

Remark: Impulse on a neutral terminal is a special test and must be explicitly ordered.



picture 1: impulse-test voltage distribution between the interconnections

All other terminals and the core and frame of the transformer including the temperature sensors, will be shorted and grounded.



3.3.6. Tapping position for test

If the tapping range is \pm 5 % or less, then the lightning impulse tests shall be made with the transformer connected on the principal tapping.

If the tapping range is larger than \pm 5 % then, unless otherwise agreed, the two extreme tapping's and the principal tapping shall be tested, one tapping for each of the three individual phases of a three-phase transformer or the three single-phase transformers designed to form a three-phase bank (e.g., phase U tap 1, phase V tap 3 and phase W tap 5).

3.3.7. Test setup

For the test, the terminal to be tested will be connected with a MARX generator. The terminals which are not to be tested are connected through the ground of the generator via a shunt (measuring of current). Using various resistors, the time for the wave shape could be influenced.

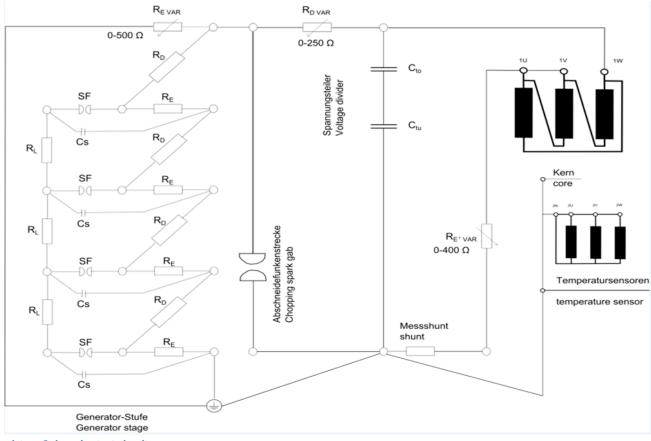
Between the generator and the tested winding is a voltage divider to measure the impulse voltage.

3.3.8. MARX generator data

Stages	4
Maximum voltage	400 kV
Maximum Impulse capacitance	4000 nF
Total charging energy	20 kJ
Voltage divider	2 nF
Chopping spark gap maximum voltage	300 kV







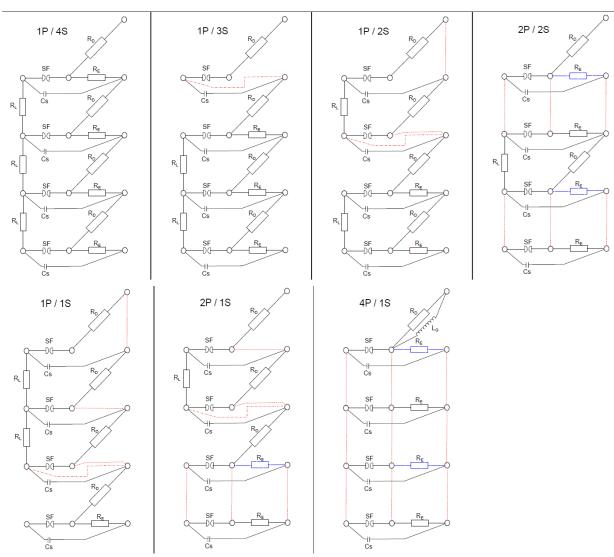
picture 2: impulse test circuit

3.3.10. Example of resistors for the MARX generator

use	pulse form [µs]	pieces	resistance [Ω]	rated energy W _R [kJ]	length *) [mm]	cross section [mm]	identifying color	remarks
RD	1.2/50	1	122	5	470	14 x 60	light blue	
RD	1.2/50	4	43	5	470	14 x 60	yellow	
RD	1.2/50	4	30	5	470	14 x 60	orange	
RD	1.2/50	4	22	5	470	14 x 60	light brown	
RE	1.2/50	4	66	5	350	14 x 80	red	stage energy WS = 5 kJ
R _E	1.2/50	4	120	10	350	Ø 80	light brown	stage energy WS = 10 kJ
RL	1.2/50	3	40000	-	270	Ø 75	dark brown	
R _{LV}	-	1	40000	-	445	Ø 100	dark brown	
R _{ERD}	-	1	4900	-	290	Ø 75	dark brown	charg. energy (generator) W < 25 kJ
LG	Glanninger coil	1	130µH	-	470	Ø 70	black	

table 1: resistors for the MARX generator





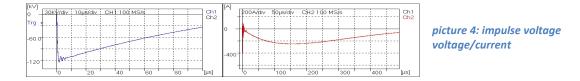
3.3.11. Example of MARX generator connections

picture 3: MARX generator connections



3.3.12. Test procedure for full-wave impulse

Usually the full-wave impulse will be executed with a negative polarity. As a reference, the first impulse is **between 50 % and 75 %** of the BIL. **1xRW** Then it is followed by **three 100 %** impulses. **3xFW**

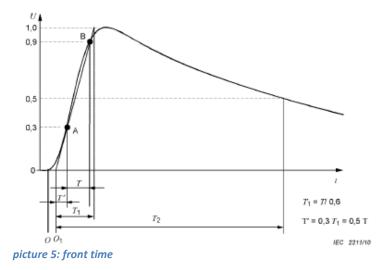


The time of the wave shape should be:

front time:

T₁ = 1.2 μs ± 30 % (0.84 μs – 1.56 μs)

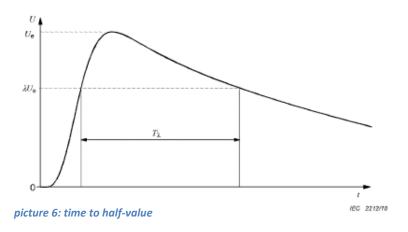
(Ascending time between 30 % to 90 % of the voltage has been reached)

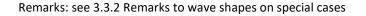


time to half-value

T₂ = 50 μs ± 20 % (40 μs – 60 μs)

(Descending time from T1 until the wave has reduced to 50 % of the peak value)







3.3.13. Test procedure for copped-full-wave on the tail impulse

This test is to be conducted only at the explicit wish of the client. In the IEC 60076-3 it is noted as a special test.

Here after the wave has reached its maximum voltage, using a sphere spark gap on the generator, a "clipping" is conducted. It is basically a controlled flash-over.

This simulates a case of load with a voltage spike in the net when a lightning arrestor responds.

[k∨] 0 Trg	30kW/div 1µs/div iCH1:100.045/s	A]	200 ¹ /div Susidiv CH2:100 ¹ /MS/s Ch2 100 ¹ /div CH2:100 ¹ /div CH2:100 ¹ /div CH2:100 ¹ /div CH2 100 ¹ /div CH2:100 ¹ /div CH2:100 ¹ /div CH2:100 ¹ /div CH2 100 ¹ /div CH2:100 ¹ /div CH2:10 ¹ /div CH2
-60.	1		
-120		400	000

Usually the full-wave impulse will be executed with a negative polarity.				
As a reference the first impulse is between 50 % and 75 % of the BIL.				
Followed with a single 100 % full-wave impulse.	1 xFW			
Then a reference chopped wave which is				
between 50 % and 75 % of the BIL.	1xCRW			
Followed with two 100 % chopped impulses.	2xCFW			
Lastly, two 100 % full-wave impulses will take place.				

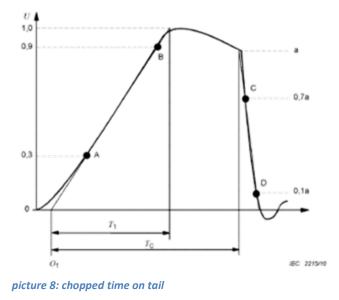
The time of the wave shape shall be:

front time	T_1 (see 3.3.12 Test procedure for full-wave impulse)
time to half-value	T_2 (see 3.3.12 Test procedure for full-wave impulse)

chopped time on tail

T_c = 4.5 μs ± 34 % (3 μs – 6 μs)

(Descending time from 70 % until the wave has only 10 % of the peak value)



Remarks: see 3.3.2 Remarks to wave shapes on special cases



3.3.14. Remarks for changing polarity between impulses

Due to the static charge on the surface on the winding, several reduced impulses shall be made with the different polarity before a 100 % impulse.

measuring devices	manufacturer	type	range / accuracy	frequency	class
Impulse voltage test-system	High Volt	SMC 2000-400 MIAS 100-14-2B	10 - 400 kV 20 kJ	n.a.	n.a.
Hygro-/Thermo- /Barometer	Greisinger electronic	GFTB 200	- 50 – 100 °C 0 % - 100 % rel. humidity 10.0 – 1100.0 hPa	n.a.	n.a.

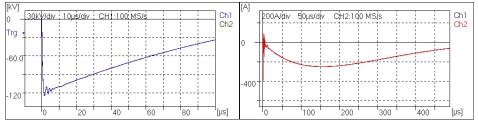
3.3.15. Commonly used measuring devices for testing

 Table 2: Commonly used measuring devices

3.3.16. Recorded values for the test

Both the voltage and the current peaks are documented, additionally the wave form through the T1 and T2 will be recorded.

For each impulse, voltage and current diagrams are to be chronicled as seen below.



picture 9: impulse voltage/current

The climate conditions have an influence on the testing therefore they will be recorded: ambient temperature in [°C], the relative humidity in [%] and the air pressure in [hPa].

3.4. Test criteria

If during testing, one of the impulses has an outer flash-over on the transformer or the oscilloscopic record for the voltage or current is seen as having an unacceptable deviation, this impulse will be discarded and another impulse has to be conducted.

The test is successful if the following is achieved:

- A complete testing sequences
- Wave form that falls within acceptable IEC pre-prescribed values
- The absence of notable differences between the voltage and current graphs recorded during the reference impulse and the full impulses.



4. Temperature rise test

4.1. Standard

IEC 60076-11:2018 clause 14.3.2 // part 2 clause 7

4.2. Aim

The aim of this measurement is to prove that the transformer does not exceed with the required load conditions the temperature requirements given by the standard for the necessary insulation class or the customer specification. Exceeding these temperatures for an undefined/long period could age the transformer faster.

4.3. Measurement - general

In general, there are methods of temperature rise measurement (according to IEC 60076-11:2018, clause 14.3.2.2.1):

- Simulated load method
- Back-to-Back method
- Direct loading method

Back-to-Back method and direct loading method are not always possible.

The standard procedure at SGB is, to execute the measurement in the "Simulated load method". For this one measurement is taken in no-load (excitation load), and another one in load condition.

If the transformer has multiple cooling types for continuous load e.g., AN and AF, SGB is testing at the highest of these values, due to the fact that this is the rated power.

4.3.1. Tapping position for measurement

The temperature rise limits shall apply to the principal tapping corresponding to the rated voltage for a tapping range does not exceed ±5 %.

If the tapping range exceeds ± 5 %, the temperature rise limits shall apply to the minimum voltage tap at the appropriate tapping power. The standard at SGB in this case is considering the rated power as tapping power.



4.3.2. Temperature sensors for the measurement

- ➢ For the cooling medium:
 - Around the transformer or enclosure, four PT100 sensors will be placed in oil filled bottles, at half height of the winding or enclosure, at a distance of around 2 meters to measure the ambient temperature.
 - In case of cooling systems using water-air heat exchanger, the cooling medium temperature will be measured at the intake of the cooling equipment/heat exchanger.
- > For the core:
 - On the transformer core a PT100 sensor shall be placed on the center of the upper core yoke.
- For the windings:
 - In the windings, a PT100 sensor is placed in the center phase of each tested winding-system (e.g., 1V, 2V). They are located on the upper part of the winding (around 10 cm below the edge) in the cooling duct (if available, otherwise on the inner surface of the winding).
- Additional Sensors:
 - In case of cooling systems using water-air heat exchanger: cooling fluid outlet and cooling fluid rate [in m³/h]
 - In case of cooling systems with water-air or air-air heat exchangers: housing air in, housing air out

NOTE 1: If the winding phase-to-phase voltage exceeds 6.3 kV no direct temperature measurement possible (except for e.g., fibre-opticalsensors). This is for example the case on the HV winding at the no- load (excitation load) condition.

NOTE 2: The term water is used generally throughout this document considering and including all cooling fluids.



4.4. Cold resistance

Before measurement, the external cooling medium temperature shall not have changed more than 3 °C in 3 hours before testing. Furthermore, it needs to be ensured that the transformer which needs to be tested, was stored in an ambient temperature close to this at least for 12 h before starting the measurement. This is necessary to ensure stable conditions between the cold resistance and its reference temperature.

The resistance measurement at cold (ambient) state R_{W1} is done between a central and an outer phase line terminal. The actual cooling medium temperature θa_1 will be recorded.

Note: In case of cooling systems using water-air heat exchanger, the ambient temperature and the water temperature will be measured. The cold resistance value will be measured at ambient temperature and corrected to the noted water temperature. The standard specifications are thus fully met. Detailed information and test reports on the procedure are available on request.

To keep the influence of the reactance as low as possible, the measurement is conducted with direct current.

The measurement is conducted with a resistance measurement bridge either manually or an automatic program.

Both systems are based on current-voltage measurements.

For this measurement, a steady current is fed through one connection, on the other connection amperage and voltage are measured. Finally, the resistance is calculated using Ohm's law as shown in the formula below.

$R = \frac{1}{I}$ R= ohmic resistance U=voltage I=current

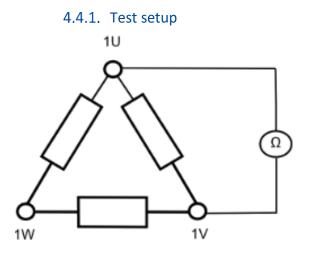
formula 1: ohmic law

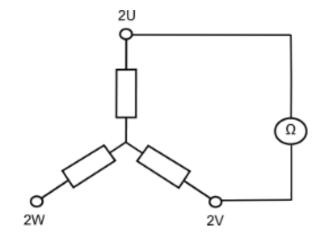
The fed current is about 1/15 of the rated current.

Because HV and LV is measured simultaneously, the current direction with reference to the winding interconnection e.g., in delta, star or zig-zack has to be chosen.

Approximately, the first 30 seconds of the resistance measurement are not valid, because the current flowing through the turns must stabilize.

The connection for the measurement is basically as close as possible to the winding.





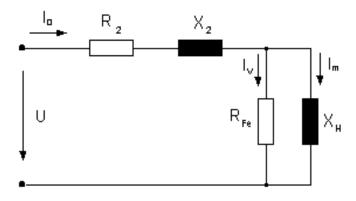
picture 10: phase to phase resistance



4.5. No - load (excitation load) measurement

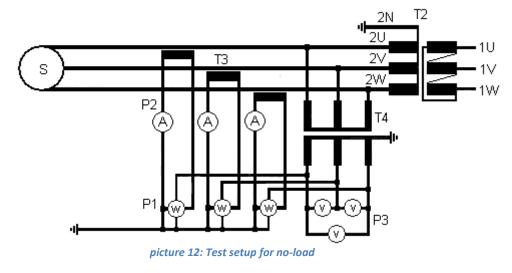
This test is conducted much like a no-load losses measurement (chapter for routine tests, clause 6). It is carried out the rated frequency f_R and the measurement voltage is applied as close as possible to the rated voltage U_R .

4.5.1. Equivalent circuit diagram for a transformer in no-load



picture 11: transformer in no-load

4.5.2. Test setup no - load (excitation load)



- S: electricity supply
- T2: transformer to be tested T3: current transformer T4: voltage transformer
- P1: wattmeter P2: amperemeter (I_{RMS}) P3: voltmeter (U_{RMS})

4.5.3. Switching off

The measurement can be switched off when the transformer has reached a "steady state condition". According to IEC 60076-11:2018 (clause 14.3.2.4) this is when the temperature rise (from core and windings) does not exceed more than 1 K per hour.



4.5.4. Hot resistance

Due to the fact that the resistance at hot (at shutdown) state R_{W2}, changes directly with the cooling of the transformer after the switching off, it cannot directly be measured (Some time is needed to disconnect the transformer feeding and connect the resistance measurement). Therefore, the resistance over a time period of 12.5 minutes in 30 second intervals is measured and the R_{W2} is calculated with a linear extrapolation.

The cooling medium temperature at hot (at shutdown) state θa_2 will also be recorded.

It is necessary that the resistance measurement is taken in the same manner as described in chapter 4.4 Cold resistance. This means using the same connection point on the terminals, measuring range of the Resistance-Bridge, etc.



4.6. Load measurement

This test is conducted much like the load losses measurement (chapter for routine tests, clause 7) (but always with 100 % current).

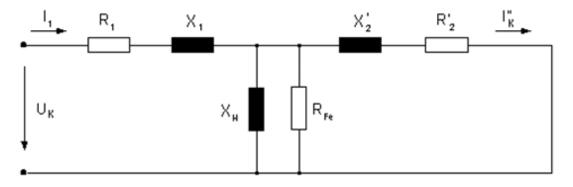
If the transformer is to encounter especially strong harmonics during operation than this can be considered (IEC 60076-11:2018, chapter 4.2 d)). If the total harmonic content of the load current exceeds 5 %, then the extra losses due to these harmonic currents shall be considered by increasing the test current for the temperature rise test.

Note: The mean value is used for the individual allowances for each winding system during the test. The winding systems are afterwards calculated based on the individual test performance.

In the case of overload classes for EN 50329, IEC 62695 or IEC 60146, short-term overloads will not be tested. Depending on the standard, an equivalent overload or only the long-term overload will be tested. For this purpose, the transformer is tested with the respective load for continuous operation (including any harmonic surcharges) until steady state (see 4.6.3 Switching off). Then the load is increased according to the overload.

Note: A long-term overload correspond a time from 480 sec. till 7200 sec.

The system with the lower current (e.g., HV) is fed and another system/s are short-circuited. This is also dependent on the loading cases of the transformer.

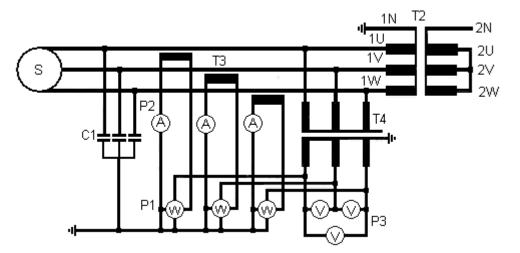


4.6.1. Equivalent circuit diagram for transformer in load (short-circuit)

picture 13: transformer in short-circuit



4.6.2. Test setup load



picture 14: test setup for load measurement

S: electricity supplyT2: transformer to be testedT3: current transformerT4: voltage transformer

C1: capacitor bank P1: wattmeter P2: amperemeter (I_{RMS}) P3: voltmeter (U_{RMS})

4.6.3. Switching off

The measurement can be switched off when the transformer has reached a "steady state condition". According to IEC 60076-11:2018 (clause 14.3.2.4) this is when the temperature rise (from core and windings) does not exceed more than 1 K per hour.

4.6.4. Hot resistance

Due to the fact that the resistance at hot (at shutdown) state RW2, changes directly with the cooling of the transformer after the switching off, it cannot directly be measured (because some time is needed to disconnect the transformer feeding and connect the resistance measurement). Therefore, the resistance over a time period of 12.5 minutes in 30 second intervals is measured and the RW2 is calculated with a linear extrapolation.

The cooling medium temperature at hot (at shutdown) state θa_2 will also be recorded.

It is necessary that the resistance measurement is taken in the same manner as described in chapter 4.4 Cold resistance. This means using the same connection point on the terminals, measuring range of the Resistance-Bridge, etc.



measuring devices	manufacturer	type	range / accuracy	frequency	class
Micro Ohmmeter	IBEKO Power AB - DV Power	RMO40T	0.1 μΩ - 2kΩ -> ±(0.1 % rgd + 0.1 % FS) 2 kΩ - 10 kΩ -> ±(0.2 % rgd + 0.1% FS) 5 mA - 40A DC	DC	n.a.
Micro Ohmmeter	IBEKO Power AB - DV Power	RMO60T	0,1 μΩ – 2 kΩ 5 mA – 60 A DC ±(0.2 % rgd + 0.2 % FS)	DC	n.a.
Precision Power Analyzer	ZIMMER	LMG 500	U rms 1000 V / I rms 32 A U pk 3200 V / I pk 120 A	DC - 10 MHz	0.01-0.03
Precision Power Analyzer	ZIMMER	LMG 310	U rms 1000 V / I rms 30 A U pk 2000 V / I pk 60 A	DC - 1 MHz	0.05
LV-current-transf.	H&B	Ti 48	2.5-500 A/5 A	50/60 Hz	0.1
LV-current-transf.	epro	NCD 3000d	10 - 3000 A	50/60 Hz	0.1
HV-voltage- transf.	epro	NVRD 40	2-40 kV/100 V	50/60 Hz	0.02
HV-current- transf.	epro	NCO 60	1-600 A/5 A	50/60 Hz	0.01
Data Acquisition Unit	YOKOGAWA	DA100-13-1F 2x DU100-12 DT300-11	0-250°C / 0.1 K	50/60 Hz	n.a.
Temperature recorder	Logoscreen nt		0-250°C / 0.1 K	50/60 Hz	n.a.

4.7. Commonly used measuring devices for measurement

Table 3: Commonly used measuring devices



4.8. Recorded values for the measurement

Between a central and an outer phase line terminal

- > Resistance at cold (ambient) state R_{W1} at ambient temperature θa_1
- > Resistance at hot (at shutdown) state R_{W2} at ambient temperature θa_2
- > All voltages [V], amperages [A] and losses [W] (in R.M.S.) during the measurement are recorded.
- > Temperatures of core and windings θ_{core} , $\theta_{winding \ 1V}$, $\theta_{winding \ 2V}$

REMARKS: All Values are recorded separately for no-load and load condition. Except cold resistance (only before the first measurement) and $\theta winding \ 1V$ (only between load condition, if applicable [see 4.3.2])

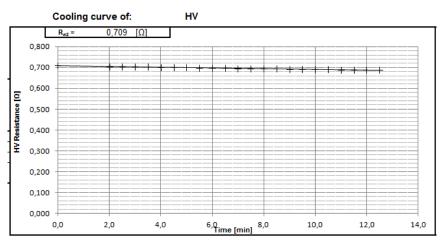


4.9. Calculations for the measurement

For the first step, the average winding temperature rise for all windings-systems, will be calculated separately for no-load and load measurement (according to IEC 60076-2:2011 clause 7.6).

4.9.1. Calculation for hot resistance R_{W2}

Therefore, the hot resistance R_{W2} is needed. The calculation is done by a linear extrapolation (see picture below).



picture 15: cooling curve example

4.9.2. Calculation $\Delta \theta e$ (for no-load)

$$\Delta \theta_e = \frac{R_{W2}}{R_{W1}} * (\theta_k + \theta_{a1}) - (\theta_k + \theta_{a2})$$

formula 2: calculation $\Delta \theta e$

- R_{W1} cold resistance, in [Ohm]
- R_{w2} hot resistance from no-load measurement, in [Ohm]
- θa_1 ambient temperature at the measurement of the cold resistance, in [°C]
- θa_2 ambient temperature at the measurement of the hot resistance, in [°C]
- θ_k material constant copper \triangleq 235 aluminum \triangleq 225
- $\Delta \theta_e$ average winding temperature in no-load condition, in [K]



4.9.3. Calculation $\Delta \theta c$ (for load)

$$\Delta \theta_{c} = \frac{R_{W2}}{R_{W1}} * (\theta_{k} + \theta_{a1}) - (\theta_{k} + \theta_{a2})$$

formula 3: calculation $\Delta \theta c$

- R_{W1} cold resistance, in [Ohm]
- R_{W2} hot resistance from load measurement, in [Ohm]
- θa_1 ambient temperature at the measurement of the cold resistance, in [°C]
- θa_2 ambient temperature at the measurement of the hot resistance, in [°C]
- θ_k material constant copper \triangleq 235 aluminum \triangleq 225
- $\Delta \theta_c$ average winding temperature in load condition, in [K]

4.9.4. Calculation $\Delta \theta c$ corrected for test current (for load)

If the testing current used does not meet the correct testing current or a harmonic content should be considered (see 4.6 Load measurement) then a correction is allowed according to this formula.

Note: Only in a range for current between \pm 10 % (according to IEC to 60076-11:2018, clause 14.3.2.3).

$$\Delta \theta_{c,cor} = \Delta \theta_c * \left(\frac{I_r}{I_t}\right)^q$$

formula 4: calculation Δθc (corrected)

- $\Delta \theta_{c,cor}$ temperature rise of the winding at the rated load condition
- $\Delta \theta_c$ temperature rise of the winding at the test current

I_r rated value of current

I_t input test current

q factor for cooling = 1.6 for AN

<u>1.8</u> for AF, AFAF or AFWF



4.9.5. Calculation $\Delta \theta c'$ (total)

Finally, the total winding temperature rise shall be calculated (according to IEC to 60076-11:2018, clause 14.3.2.2.2)

$$\Delta \theta_{c'} = \Delta \theta_{c,cor} \left[1 + \left(\frac{\Delta \theta_e}{\Delta \theta_c} \right)^{1/K1} \right]^{K1}$$

formula 5: calculation $\Delta \theta c'$ (total)

$\Delta heta_e$	average winding temper	ature in no-load condition	, in [K]				
$\Delta heta_{c,cor}$	average winding temperature in load condition, in [K]						
or if applicable	$\Delta \theta w c$ corrected for test current (for load)						
or	$\Delta \theta wc$ corrected for harmonics (for load)						
$\Delta heta_{c'}$	total average winding te	mperature, in [K]					
K1	factor for cooling =	<u>0.8</u> for AN	<u>0.9</u> for AF, AFAF or AFWF				

4.9.6. Calculation of the max. temperature on the winding surface

The maximum temperature to be expected on the winding surface is given as additional information. However, the Temperature rise test only serves to determine the winding temperature rise and therefore there is no guarantee for the maximum temperature on the winding surface!

$$\theta w_{MAX} = \Delta \theta_{c'} + \left(\theta_{W,load} - \theta_{a,load} - \Delta \theta_{c} \right) + \theta a_{MAX}$$

Θw, max	maximum temperature to be expected on the winding surface, in [°C]
$\Delta heta_{c'}$	total average winding temperature, in [K]
Θw, load	winding temperature measured via temperature sensor
	(see 4.3.2 Temperature sensors for the measurement), in [°C]
Θa, load	temp. of cooling medium in load condition, in [°C]
$\Delta \theta_c$	average winding temperature in load condition <u>uncorrected</u> , in [K]
Θa, max	Max. temp. of cooling medium, in [°C]

4.10. Temperature rise test on transformers with winding in multi-tier design

The individual LV systems will be measured for hot resistance separately. For calculation of 4.9.5 Calculation $\Delta \theta c'$ (total) the average temperature rise value will be used.



4.11. Procedure at temperature rise test with water cooling (AFWF)

A linear operating curve is assumed for all conversions of the water temperature.

The procedure below is applied to fulfil IEC 60076-11:2018 chapter 10.1 and 14.3.2.1 in a practical method.

For direct water-cooled systems only:

- > The maximum available water fluid rate is $4.5-5 \text{ m}^3/\text{h}$.
- > The water inlet temperature depends on the season and varies between 5-25 °C.

For the cold resistance, the actual *cooling fluid inlet* temperature (water temperature) will be used as reference temperature instead of the ambient air temperature (see 4.3.2 Temperature sensors for the measurement).

The procedure at SGB for this is to measure, the cold resistance at ambient air temperature, with the transformer being placed in this ambient for at least 12h and converted to the temperature of the water inlet temperature by recalculation with the method described in 4.9.2 or 4.9.3, which can be applied equally for recalculation of two cold resistance with different ambient reference temperatures.

Note: It was ensured by measurements (see 5.2 Comparison of different methods for cold resistance measurement at temperature rise test with water cooling (AFWF)) that, there is no difference to the measurement of the cold resistance with running cooling system up to stability with cooling fluid inlet as reference, in comparison to:

- Measuring the cold resistance at winding in steady state without cooling system and converted the resistance to the water inlet temperature.
- Using the ambient air temperature as reference for the cold resistance measurement at winding in steady state without cooling system.

For the hot resistance calculation, the actual *cooling fluid inlet* temperature will be used instead the ambient air temperature in the described formulars in chapter 4.5.4 & 4.6.4 & 4.8 & 4.9.2 & 4.9.3.

<u>Any changes to the above procedure must be specified during the tender stage and require a separate</u> <u>confirmation!</u>

4.12. Test criteria

The test is successful if the following is achieved:

 \blacktriangleright The measured / calculated average winding temperature rise $\Delta \theta c'$

does not exceed the specified value for the insulation system according to IEC 60076-11:2018 (clause 10.1, table 2). e.g., class F = 100 K

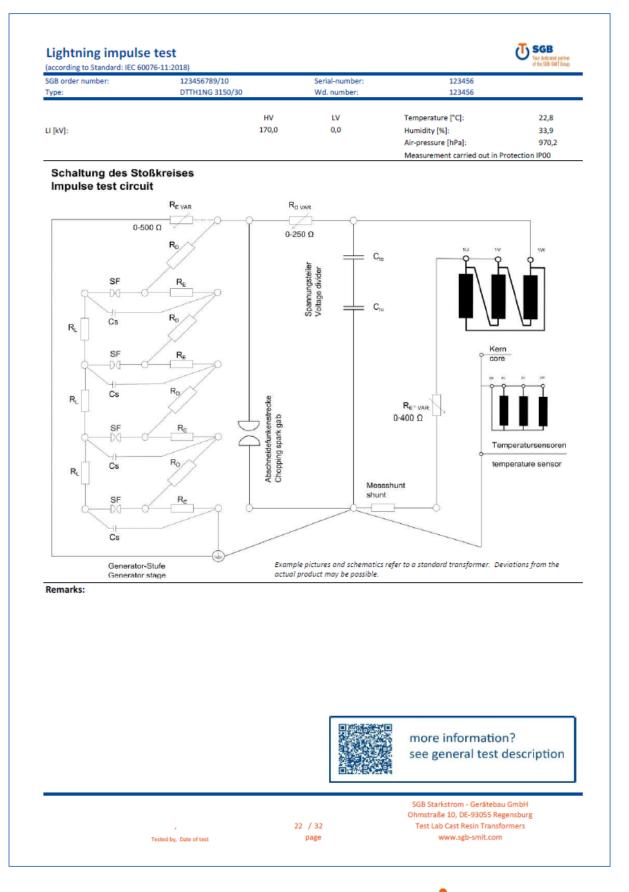
or lower value by agreement between supplier and purchaser.

If transformer installation altitude is higher than 1000 m the average winding temperature rise $\Delta\theta c'$ shall be corrected according to IEC 60076-11:2018 (clause 10.3). Per 100m above 1000m 0.5% for AN 1% for AF, AFAF or AFWF Any altitude correction shall be rounded to the nearest whole number of K.



5. Appendix

5.1. Example test certificate





Lightn	ing	impul	se	test
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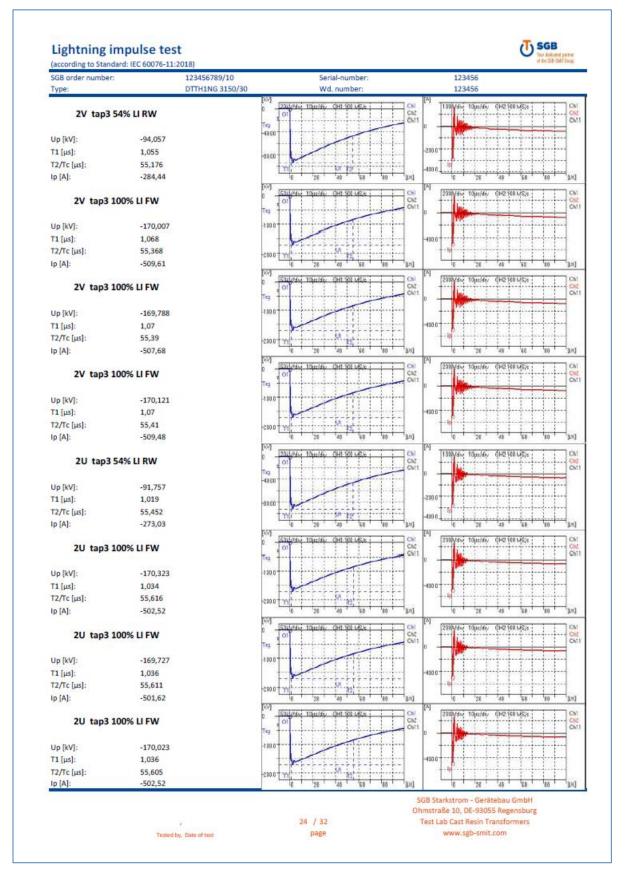
Lightning impulse tes (according to Standard: IEC 60076-11:						SGB Your dedicated particle of the SEB-SMIT Broop
SGB order number: Type:	123456789/10 DTTH1NG 3150/30		Serial-number: Wd. number:		123456 123456	
2V tap3 54% LI RW	Up [kV] -94,057	T1 [μs] 1,055	T2/Tc [μs] 55,176	de fed	RW= reduced full wave CRW= chopped reduced wave	
2V tap3 100% LI FW 2V tap3 100% LI FW	-170,007 -169,788	1,068 1,070	55,368 55,390	-509,61 -507,68	FW= full wave CFW= chopped wave	
2V tap3 100% LI FW 2U tap3 54% LI RW	-170,121 -91,757	1,070 1,019	55,410 55,452	-509,48		
2U tap3 100% LI FW 2U tap3 100% LI FW	-170,323	1,034	55,616 55,611	-502,52		
2U tap3 100% LI FW	-170,023	1,036	55,605	-502,52		
2W tap3 54% LI RW 2W tap3 100% LI FW	-91,292 -170,303	1,186 1,210	54,871 55,064	-293,58 -543,38		
2W tap3 100% LI FW 2W tap3 100% LI FW	-169,702 -169,958	1,209 1,205	55,090 55,129	-541,06 -541,84		

Tested by, Date of test

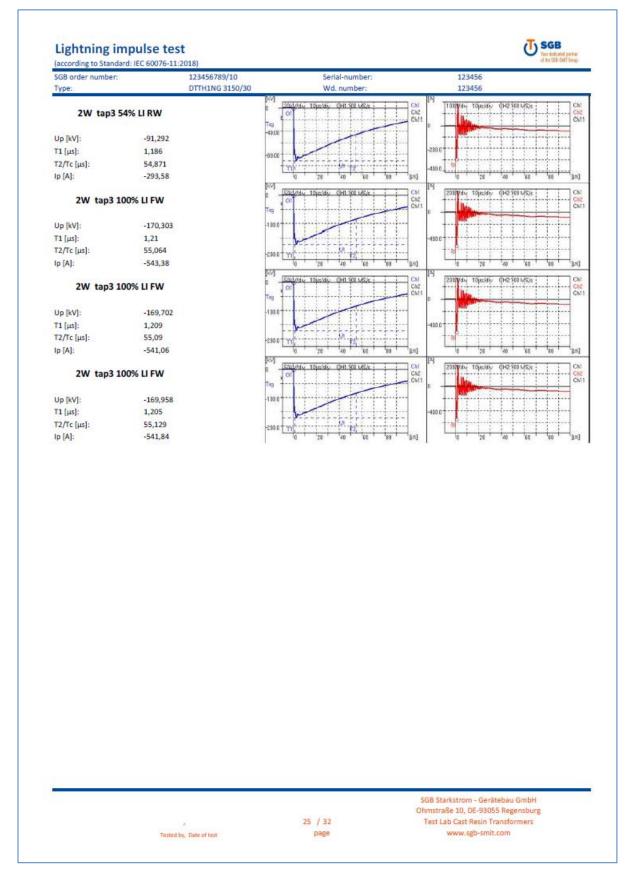
23 / 32 page

SGB Starkstrom - Gerätebau GmbH Ohmstraße 10, DE-93055 Regensburg Test Lab Cast Resin Transformers www.sgb-smit.com











(according to IEC 60076-11:20	- 1500 ASSAULTING TALAHAM			120150-012	of the 168-5481 biesp
SGB order number: Type:	123456789/10 DTTH1NG 3150/30		Serial-number: Wd. number:	123456	
	errante statujali				
Testing power [kVA]: 3900 //	3900		at 100% Rated power		
Testing voltage [V]: 30000 // 6			Measurement in tap 3		
Testing current [A]: 75 // 3263	3	1	at Protection IP00 & Cooli	ing AF	
Results of heat run test at Loan	ding method excitation loss:				
winding temperature rise∆Θe	HV [K]:	1,2			
winding temperature rise ∆Θe		4,0			
Results of heat run test at Loa	ding method load loss:				
winding temperature rise∆⊖c		70,8	100,2%		
winding temperature rise∆⊖c	LV [K]:	54,8	100,2%		
,	lest results were subjected to a co	alculation that refle	ects the harmonic losses		
Results of heat run test	at Loading method load lo	ss and excitati	on loss:		
winding temperature rise∆⊖c'					
	70,8*[1+(1,2/70	.8)^1.11]^0.9	= 71.5 K		
		,-, -,, 0,5			
winding temperature rise ΔΘc′					
	54,8*[1+(4/54,	8)^1,11]^0,9 =	57,4 K		
T <mark>emperature at Max. te</mark>	mp. of cooling medium 55	°C:			
Øw HV [°C]: 126	5,5	Θw LV [°C]:	112,4		
Remarks:					
					(a) ora
				more informat	
				see general tes	st description
				5.25	<i>W.</i>
				SGB Starkstrom - Gerätel	nau GmbH

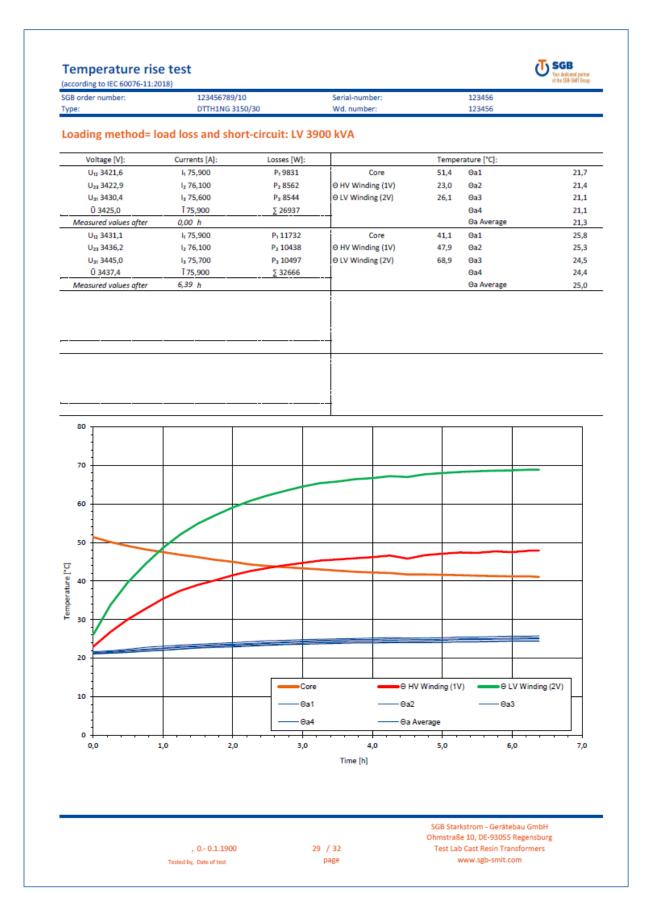


23456789/10 Serial-number: 123456 TTH1NG 3150/30 Wd. number: 123456	
loss at connection: LV 690 V	
[A]: Losses [W]: Temperature [*C]:	
00 P ₁ 1489 Core 22,1 Oa1	22,0
00 P ₂ 1159 Θa2	21,8
00 P ₃ 1895 O LV Winding (2V) 21,8 Oa3	21,6
0 Σ 4543 Θa4	21,6
Oa Average 00 P, 1416 Core 56,1 Oa1	21,8 20,8
00 P2 1122 0a2	20,8
00 P ₃ 1822 Ø LV Winding (2V) 24,8 Øa3	20,1
0 <u>Σ</u> 4359 Θa4	20,2
Oa Average	20,4
Θa Average	
	<u> </u>
20,0 30,0 40,0 50,0 60,0	70,0
Time [h]	
SGB Starkstrom - Gerätebau GmbH	
Ohmstraße 10, DE-93055 Regensbur	re .
SGB Starkstrom - Gerätebau G	



(according to SGB order nur Type:		12345	6789/10 ING 3150/30		Serial-numbe Wd. number			123456 123456			
	nethod=	excitation lo		ction: L							
		tion of winding			Cooling curve	e HV Rw2 = 1	1,7 [mΩ]				
			1 = Swite		2,000						
		1) - (Ok+Oa2)	2 = Shut	down	1,800						•
Rw1					1,400						
∆⊖e = winding	z temperatur	e rise Oa = tempera	ture of cooling n	nedium	1,200						
Θk = Material				u = 235	0,800						
ok - Material			/	N = 225	0,600						
Time [min]	HV	LV	Θa [°C	1	0,200						
R _{w1}	R [mΩ] 1,727	R [mΩ] 0,383	21,5		0,000	I	I	I	1	1	
0,0	1,728	0,387	20,4		0,0	2,0	4,0	6,0	8,0	10,0	12,0
1,9	1,728	0,387			Cooling curve	e LV Rw2 = 0),387 [mΩ]				
2,4	1,728	0,387			0,450						
2,9	1,728	0,388			0,400						•
3,4	1,728	0,388			0,300						
4,4	1,728	0,387			0,250						
4,9	1,728	0,387			0,200						
5,4	1,728	0,388			0,100						
5,9 6,4	1,728	0,388			0,050						
6,9	1,728	0,388			0,000	20		60	*0	10.0	12.0
7,4	1,728	0,388			0,0	2,0	4,0	6,0	8,0	10,0	12,0
7,9	1,728	0,388									
8,4	1,728	0,389									
9,4	1,728	0,388									
9,9	1,728	0,387									
10,4	1,728	0,388									
10,9	1,728	0,388									
11,4	1,728	0,388									
winding temp	1,2										
									Gerätebau G 33055 Rege		







GB order nur Type:	mber:		123456789/1 DTTH1NG 31		Serial Wd. r					23456 23456			
	nethod=	load los			V 3900 kVA								
		tion of win					rve HV Rw2	= 2,3 [m(1				
				1 = Switch on	2,500								
		1) - (Ok+Oa	2)	2 = Shutdown	2,000			****	••••		••••	••	
Rw1					1								
Oc = winding	temperatur	e rise Øa = te	mperature of	cooling medium	1,500	+							
9k = Material				Cu = 23		+							
2K = Material				Al = 22									
Time [min]	HV	LV		Oa [°C]	0,500	T							
R _{w1}	R [mΩ] 1,727	R [mΩ] 0,383		21,5	0,000		1				1	1	
0,0	2,257	0,585		21,5		0,0	2,0	4,0	6,0	8,0	10,0	12,0	14,0
2,2	2,248	0,473			Cooli	ng cu	rve LV Rw2	= 0,475 [r	nΩ]				
2,7	2,246	0,473			0,500							••	
3,2	2,243	0,473			0,450								
3,7	2,241	0,472			0,400								
4,2	2,238	0,473 0,472			0,300								
5,2	2,230	0,472			0,250								
5,7	2,233	0,470			0,150								
6,2	2,229	0,471			0,100								
6,7	2,226	0,471			0,050								
7,2	2,224	0,470			-,	0,0	2,0	4,0	6,0	8,0	10,0	12,0	14,0
7,7	2,222	0,470	·•										
8,2	2,220	0,469											
9,2	2,215	0,469	·•										
9,7	2,213	0,468											
10,2	2,211	0,468											
10,7	2,209	0,468											
11,2	2,207	0,468											
11,7	2,205	0,467											
winding temp	72,1 erature rise I 55,8	LV [K]:											
									B Starkstro hstraße 10				



SGB order number:	123456789/10	Serial-number:		123456		
Type:	DTTH1NG 3150/30	Wd. number:		123456		
Test results / 3.1 A	cceptance test certificate a	ccording to DIN EN 1	0204:2004			
Routine testing						Test pa
Dielectric tests						
Induced AC withstand voltage test L	V:		1,38 [kV]; 2	00 [Hz]; 30 [sec.]		1
		Guarantee values:	tolerance:	Measured values:	deviation:	
Measurement of voltage ratio a Ratio at connection HV / LV [%]:	and check of phase displacement	30000/	690 ± 0,50	-0,03		~
Measurement of winding resist	ance at 22,0 °C					
Measurement of winding resistance Measurement of no-load loss a				-		-
Po [W]: lo [%]:	ind current at 50 Hz	4750) +0,0%	4507 0,155	-5,12%	4
	mpedance and load loss at 120 °C					
Pl at 3900 kVA; HV/LV [W]: ez at 3900 kVA; HV/LV [%]:		3403		32543 11,30	-4,37% 7,10%	~
Po + PI [W]:		3878	1 +0,0%	37050	-4,46%	~
PEI (at k[PEI] 0,37 = 1451 kVA) [%]:		99,34	8	99,379	0,03%	<u> </u>
Measurement of partial dischar PD max. HV at 1,3 x Rated voltage []	-	\$10		1		~
Measurement of A-weighted s	ound level by sound pressure method at	no load				
Lp / 1m [dB(A)] AN:				55,1		-
Lp / 1m [dB(A)] AF:				64,1		1
Lw [dB(A)] AN:		94	0	71,0 79,9	-24,51%	×.
Lw [dB(A)] AF: Lightning impulse test				79,9		
Up [kV]		170	±3%	170,323	0,19%	~
Τ1 [μs]		1,2	±30%	1,019	-15,08%	-
Τ2 [μs]		50	±20%	55,616	11,2%	~
Temperature rise test						
winding temperature rise $\Delta\Theta c'$ HV [85		71,5		1
winding temperature rise ΔΘc' LV [)	q:	85		57,4		1



5.2. Comparison of different methods for cold resistance measurement at temperature rise test with water cooling (AFWF)

Note: Cold resistance measurement was done without running cooling system with windings at ambient air temperature of the test lab. According to the calculation method, described in "02.04.80-11.005 - Test description for dry-type-transformers for type tests" the measured cold resistance is calculated to the cold resistance at water inlet temperature, which is used for the calculation of the winding temperature rise. The measured cold resistance value below is given for information only and not directly used in the evaluation.

Time [min]	HV	LV		0a [°C]
nine (nini)	IN] R [mΩ] R [mΩ]	ea [-c]		
R _{w1}	435,1	0,916		20,1

Time [min]	HV	LV	⊖a [°C]
nine (minj	R [mΩ]	R [mΩ]	oa[.c]
R _{w1}	422,2	0,889	12,8
0,0	601,0	1,218	12,2

picture 16 example for recalculation in test report

101,3*[1+(4,3/101,3)^1,11]^0,9 = 104,1 K

winding temperature rise ΔΘc' LV [K]:

winding temperature rise ΔΘc' HV [K]:

88,6*[1+(9,7/88,6)^1,11]^0,9 = 95,4 K

Temperature at Max. temp. of cooling medium 38°C:

 Øw HV [°C]: 154,6
 Øw LV [°C]: 141,7

Results of heat run test at Loading method load loss and excitation loss:

winding temperature rise ΔΘc' HV [K]:

101,9*[1+(4,7/101,9)^1,11]^0,9 = 104,9 K

winding temperature rise ∆Θc' LV [K]:

89,3*[1+(10,3/89,3)^1,11]^0,9 = 96,5 K

Temperature at Max. temp. of cooling medium 38*C:

 Øw HV [°C]: 154,9
 Øw LV [°C]: 142,1

Results of heat run test at Loading method load loss and excitation loss: winding temperature rise $\Delta \Theta c'$ HV [K]:

101,9*[1+(4,7/101,9)^1,11]^0,9 = 104,9 K

winding temperature rise ΔΘc' LV [K]:

89,3*[1+(10,3/89,3)^1,11]^0,9 = 96,5 K

Temperature at Max. temp. of cooling medium 38°C:

Ow HV [°C]: 154,9

Ow LV [°C]: 142,1

picture 17 calculation for AFWF temperature rise test method 1

Transformer condition: in steady state with cooling in operation

Reference for cold resistance: Water inlet

Reference for hot resistance: Water inlet

picture 18 calculation for AFWF temperature rise test method 2

Transformer condition: in steady state without cooling in operation (windings at ambient temperature)

Reference for cold resistance: Ambient air temperature

Reference for hot resistance: Water inlet

picture 19 calculation for AFWF temperature rise test method 3

Transformer condition: in steady state without cooling in operation (windings at ambient temperature)

Cold resistance measured at ambient air temperature and calculated to water inlet temperature.

Reference for cold resistance: Water inlet

Reference for hot resistance: Water inlet



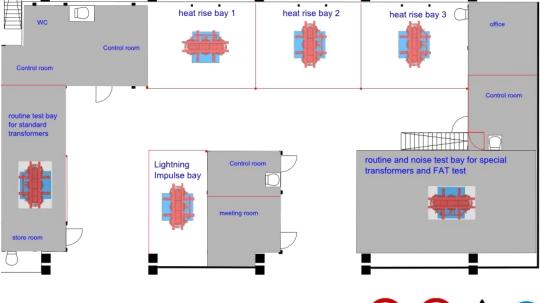
5.3. Example calibration list

		Cal		Kalibrierung von N neasuring equipm			ormor				Q see	
		Kenteller	The literation of the	neasuning equipm K-Ma	ent in test heid di Melbeekh	Requera	Name (Standort	Lette Kalibrierung	Nilschute Kal.		
Melgeräte KS-Span-Wandler	Measuring devices HV-voltage-transf.	Manufactur epito	type MVRD 40	Sec. 6.1 (XXXX5153	Range 2-40 kV/300 V	frequency SQ/60 Hz	dass 0,02	location Routine	Calibration 28.12.2052	Next cal. Dec 2016	STATUS In Ordnung	Kalbrierungant
KS-Span,-Wandler	Wwoitage-transf.	epro	NVRD 40	206/5158	2-40 kV/100 V	50/60 Hz	0,02	Routine	28.12.2053	Dec 2016	In Ordnung	000
KS-Stron-Wandler KS-Stron-Wandler	HV-current-transf.	epro epro	NCO 60	2/05/5347	2-40 KV/300 V 5-600 A/5 A	50/50 Hz	9,02	Routine Routine	27.12.2013	Dec 2016	in Ordnung In Ordnung	čio čio
HS-Strom-Wandler HS-Strom-Wandler	HV-current-transf. HV-current-transf.	epro epro	NCO 60 NCO 60	2/08/5348	5-600 A/S A 5-600 A/S A	50/50 Hz 50/50 Hz	9,05	Routine	27.12.2053	Dec 2016	in Ordnung In Ordnung	čio čio
KS-Strom-Wandler KS-Strom-Wandler	LV-current-transf.	-	14	81 X 163 81 X 164	2,5-500 A/5 A	50/50 Hz	9,1	Routine Routine	23.12.2013	Dec 2016	In Ordnung	0x0
Ki-Ston-Wander	W-current-transf.	-	14	01 X 165	2,5-500 A/5 A	50/50 Hz	9,1	Routine	23.12.2053	Dec 2016	In Ordnung	000
KS-Span,-Wandler KS-Span,-Wandler	Wwoltage-transf.	epro epro	NVCS 80 NVCS 80	2/05/5345	5-30 KA\200 A 5-30 KA\200 A	SQ/80 Hz SQ/80 Hz	0'05 0'05	Schallmessours, Noise & PD Schallmessours, Noise & PD	28.12.2053	Dec 2016	In Ordnung In Ordnung	čia Čia
KS-Span-Wandler KS-Strone-Wandler	W-construction	6970 6170	NVOS 20 NCO 20	2/05/5345	2-30 KV/100 V	50/50 Hz	0.02	Schallmessmum, Noise & PD Schallmessmum, Noise & PD	23.12.2053	Dec 2016	In Ordnung In Ordnung	000
KS-Strom-Wandler	HV-current-transf.	-	NCO 30	2/08/5340	5-50 A/5 A	50/60 Hz	9,05	Schallmessmuns, Noise & PD	27.12.2013	Dec 2016	In Ordnung	ðia
HS-Strom-Wandler HS-Span-Wandler	HV-current-transf. HV-voltage-transf.	epro MWB	NCO 30 NUZG 35	70000141	5-50 A/S A 3-85 kV/100 V	50/50 Hz 50/50 Hz	0,005	Schallmessmun, Noise & PD Wärmelauf, Heat Rise 1+2	09.10.2053	Dei 2016 Okt 2016	In Ordnung In Ordnung	000
KS-Span,-Wandler KS-Span,-Wandler	Wwoltage-transf.	MAG	NU2615 NU2615	73/45223	3-35 kV/100 V	50/60 Hz	0,005	Wärmelauf, Heat Rice 1+2 Wärmelauf, Heat Rice 1+2	09.10.2053	Okt 2016	In Ordnung In Ordnung	000 000
KS-Strom-Wandler	HV-current-tranef.	MND	170.60	64220264	1400 A/5 A	50/50 Hz	0.05	Wärmelauf, Heat Rise 1+2	07.10.2053	O61 2016	In Ordnung	000
HS-Strom-Wandler HS-Strom-Wandler	HV-current-tranef. HV-current-tranef.	NTW18 RETT2	NOSW 60 M	NIR/201	5400 A/S A 5400 A/S A	50/50 Hz 50/50 Hz	0,05	Wärmelauf, Heat Rice 1+2 Wärmelauf, Heat Rice 1+2	07:10:20:3	O61 2016	In Ordnung In Ordnung	CKD ČKD
KS-Strom-Wandler KS-Strom-Wandler	LV-current-transf. LV-current-transf.	144	11 484 S	8003131	2,5-250 A/5 A 2,5-250 A/5 A	50/50 Hz 50/50 Hz	0,1 0,1	Wärmelauf, Heat Rise 1+2 Wärmelauf, Heat Rise 1+2	17.09.2053	Sep 2016 Sep 2016	In Ordnung In Ordnung	040 040
NS-Strom-Wandler	LV-current-transf.	HAD	TI 48a5	8903130	2,5-250 A/5 A	50/50 Hz	0.1	Wärmelauf, Heat Rice 1+2	17.09.2053	Sep 2016	In Ordnung	δio
KS-Strom-Wandler KS-Strom-Wandler	LV-current-transf.	RITZ RITZ	KSW 73 KSW 73	50343229	3004/5A	50/50 Hz	4	Wärmelauf, Heat Rise 1+2 Wärmelauf, Heat Rise 1+2	29.01.2015	Jan 2018	in Ordnung In Ordnung	Werkskallbrierung
KS-Store-Wandler KS-Store-Wandler	LV-current-transf.	1172	KSW 73 NVRD 40	20243240	200A/SA 2-40 kV/300 V	50/50 Hz 50/60 Hz	0.02 0.02	Wärmelauf, Heat Rice 1+2 Wärmelauf, Heat Rice 3+4	29.01.2055	Jan 2018 Dec 2016	in Ordnung In Ordnung	Werkskallbrierung
KS-Spare-Wandler	Wwoltage-transf.	-	WRD 40	2/05/5353	2-40 kV/100 V	50/60 Hz	0.02	Wärmelauf, Heat Rice 3+4	23.12.2013	Dec 2016	In Ordnung	600
KS-Span,-Wandler KS-Strom-Wandler	HV-current-transf.	egito egito	NVRD 40 NCO 60	2/05/5352	2-40 KV/100 V 1-400 A/5 A	50/60 Hz 50/60 Hz	0.05	Wärmelauf, Heat Rise 3+6 Wärmelauf, Heat Rise 3+6	28.12.2053	Dec 2016	in Ordnung In Ordnung	čia Čia
KS-Strom-Wandler KS-Strom-Wandler	HV-current-transf. HV-current-transf.	epro ecce	NCO 60 NCO 60	2/05/5249	5-600 A/5 A	50/50 Hz	9,05 9,05	Wärmelauf, Heat Rise 3+6 Wärmelauf, Heat Rise 3+6	27.12.2052	Dec 2016	In Ordnung In Ordnung	540 640
KS-Store-Wander	V-current-transf.	-	NCD 3000d	2/01/21/52	10 - 2000 A	50/60 Hz	0.1	Wärmelauf, Heat Rise 3+4	01.10.2053	Okt 2016	In Ordnung	010
KS-Strom-Wandler KS-Strom-Wandler	LV-current-tranef.	egro	NCD 20004	2010154	10-3000 A 10-3000 A	50/60 Hz	6,1 0,1	Wärmelauf, Heat Rice 3+4 Wärmelauf, Heat Rice 3+4	01.10.2013	O612016 O612016	In Ordnung	000 000
NS-Strom-Wandler NS-Strom-Wandler	LV-current-tranef.	RITZ RITZ	KSW 73	509459141 509459147	1504/54	50/50 Hz	ы 11	Wärmelauf, Heat Rice 3+4 Wärmelauf, Heat Rice 3+4	29.01.2005	Jan 2018	In Ordnung In Ordnung	Werkskallbrierung Werkskallbrierung
NS-Strom-Wandler	LV-current-transf.	RITZ	KSW 73	50245243	1504/54	50/60 Hz	μ.	Wärmelauf, Heat Rise 3+4 Wärmelauf, Heat Rise 3+4	29.01.2015	Jan 2018	In Ordnung	Werkskallbrierung
NS-Strom-Wandler NS-Strom-Wandler	LV-current-tranef. LV-current-tranef.	HAA	T dia	0201305	2-2500 A/S A 2-2500 A/S A	50/90 Hz 50/90 Hz	0,1 0,1	Messgeräteschrank Messgeräteschrank	05.09.2053	Sep 2016 Sep 2016	In Ordnung In Ordnung	040 040
NS-Strom-Wandler	LV-currenti-tranel.	HAB	11484	5710365	2-2500 A/5 A	50/50 Hz	0,1	Mecqeditechrank	6205-90.90	Sep 2016	In Ordnung	ðeo
NS-Strom-Wandler NS-Strom-Wandler	V current-tranef.	GOSSEN	56W2 56W2	PT 35 PT 219	5-800 A/S A 5-800 A/S A	50 Hz	ο Ω	Messgeräteschrank Messgeräteschrank	16.09.2012	Sep 2016 Sep 2016	In Ordnung	DKD DKD
NS-Strom-Wandler Schallowerikalibretor	LV-current-tranef. Accurtical Calibrator	GOSSEN	SIW2 4231	ET 258 2229072	5-800 A/S A	50 Hz 5000 Hz	μ 1	Messaedteschrank Schallmessaurs,Noise & PD	16.09.2013	Sep 2016	In Ordnung In Ordnung	DKD
Schwingungskallbrator	Collorator	háx	6394	2-01775	10ma-2/10mma/10am	159,2 Hz	-	Messgeräteschrank	15.04.2056	Apr 2017	In Ordnung	DKD
isolationameligeriit isolationameligeriit	ins, resist, - meter ins, resist, - meter	GCSSEN GCSSEN	Metriao 5000 Metriao 5000 A	PT 1404 CP651	9-20000 MOhm 20 k Ohm - 1 TOhm	DC DC	۵ ~	Routine Messgeräteschrank	06.01.2056	lan 2017 Mrs 2017	In Ordnung In Ordnung	DKD DKD
Hochepennungsprüfer Hochepennungsprüfer	High Voltage Tester	ETL Profestively	UK26A	2.0030210200143	S BV/500 mA	50 Hz	15	Wagen für Vorprüfungen Routine	15.02.2056	Feb 2017	In Ordnung	DED
Multimeter	Multimeter	FLUKE	Rule-87-V	928501.43	1000W/10A	50-60 Hz	0,1-1,0	Routine	07.01.2056	las 2017	In Ordnung	000
Multiveter Multiveter	Multimeter Multimeter	FLUKE	Rule-67-V Rule-67-V	20120313	1000V/10A	50-60 Hz 50-60 Hz	0,1-1,0	Wärmelauf, Heat Rise, aligemein Wagen für Vorprüfungen	09.02.2056	Feb 2017 Nov 2016	In Ordnung In Ordnung	DKD
Multimeter	Multimeter	GOSSEN	Metrahit185	M43911020	2000 V/10 A	50-60 Hz	0.05-0.5	indiontrolle	20.03.2054	Mrs 2017	In Ordnung	DKD
Druck/Terroo/Barometer	Hygro-/Thermo- /Berometer	Greidinger electronic	GFTB 200	34922589	-50-100°C 0% - 100% Rel. Luftfeachte 10,0 - 1100,0 hPa			Stossspannungsplatz	25.01.2006	Jan 2017	In Ondnung	Werkskallbrierung
Feuchternessgerät	Hygro-/Thermometer	Greidinger electronic	GFTHISS	000355-01	6-70 °C 20-85% s. F.			Routine	07.01.2056	Jan 2017	In Ordnung	DKD
Oigitaithermometer	Digitalthermometer	Greidinger electronic	GTHL75	<u>97-9-123</u>	-199,9 - 199,9°C	-	9,1	Wagen für Vorprüfungen	15.02.2056	Feb 2017	In Ordnung	DHD
Obersetzungenemgerät	Transformer Turns Ratio	HADREY / Tettes	TTR 2796	176582	Q.8 - 20000	50/60 Hz	0.05	Wärmelauf, Heat Rise 3+6	17.03.2056	Mrs 2017	In Ordnung	KEMA
Obernetrumenterett	Meter Transformer Tums Ratio	HAIFELY / Tetter	TTR 2766	177491	10,09% - 10,15% 0,8 - 20000	50/80 Hz	0.05	Wärmelauf, Heat Rice 1+2	11.052096		In Ordnung	KEMA
	Meter				10,08% - 10,15%		4444			_		
Wicklungsenalysetor	Winding Analyser	HAIPELY/Tettex	WIA 2290	179742	slehe Zertifikat	50/60 Hz	dehe Zertifi	Routine	24.09.2015	Sep 2016	in Ordnung	KTMA
Wicklungsenalysetor	Winding Analyser	HAIFELY / Tetlex	WA 2293	182721	slehe Zertifikat	50/60 Hz	dehe Zertifi	Wagen für Vorprüfungen	14.01.2006	Jan 2017	In Ordnung	Werkskallbrierung
Webburgschermeter	Mico Obmoster	IBERD Power AB - DV	RMONOT	100418		DC	62	Wärmelauf, Heat Rice 1+2	29.03.2006	Ma 2017	In Ordnung	040
		Power				-						
Wicklungsohmmeter	Micro Ohmmeter	Power AB - DV Power	EMONOT	180-08		DC	φ.	Wärmelauf, Heat Rise 1+2	28.10.2005	0612016	In Onlinung	Werkskellbrierung
Wicklungsohverseter	Micro Ohmmeter	HERD Power AB - DV Power	RMONOT	180-08		BC .	62	Wärmelauf, Heat Rice 1+2	04.03.2056	Mrs 2017	In Ondrung	DKD
Wicklungsohmmeter	Micro Ohmmeter	IBERD Power AB - DV	RMOSOT	2935778	6,5 p.Ohm - 2000 Ohm	BC	μ	Wärmelauf, Heat Rise 3+6	12.01.2056	in=2017	In Ordnung	DKD
18 dimensional	Micro Olymmeter	Power IBERD Power All - DV	IMOSOT	2000740	0,1 p.Ohm - 2000 Ohm	~	12	Wärmelauf, Heat Rise 3+4	01.02.2056	54.000	In Ordnung	80
er samlige som eller		Power					~					
Wicklungschronseter	Micro Ohnmeter	Power AB - DV Power	RMOSET	2005758	0,5 µ.Ohm - 2000 Ohm	DC	a,a	Wärmelauf, Heat Rice 3+4	12.01.2006	Jan 2017	In Ordnung	DKD
Wicklungsohmmeter	Micro Ohmmeter	REED Power AB - DV	RMOSOT	1281058	0,5 µ.Ohm - 2000 Ohm	DC	a i	Wagen für Vorpröfungen	28.05.2015	Mar 2016	In Ordnung	DKD
Wicklungschranster	Micro Ohmmeter	TINGLEY	5855	275/901	0,1µOhm-180 Ohm	DC	0,1	Tectarbeitspists fahrbar	22.05.2055	Mail 2016	In Ordnung	DED
weekungschrenster	unico Chrometer	INGUT	GPC 100	273534 19047207 NF218V	stadow-180 Ohm	0C	61 daha	Routine	11.12.2005	Dec 2016	in Ordnung	640
Universitedgedit	Inthement	Orelaten	CP TES CP 581	ME200V	slehe Zertifikat	siehe Zertifikat	Settliket	Messgeräteschrank	25.08.2055	Aug 2016	In Ordnung	Werkskallbrierung
TE-Kalibrator	PD-Calibrator	Omicron	CAL St2 Version B	1115200	1-100 pC	200 Hz	-	Schallmessmum, Noise & PD	11.07.2055	Jul 2016	In Ordnung	Werkskallbrierung
TE-Kellbrator	PD-Galibrator	MPS	TPK	218114	5-82-byC	200 Hz		Schallmessnum, Noise & PD Schallmessnum, Noise & PD	07.09.2005	Sep 2016	In Ordnung	Werkskallbrierung
Scheitelige nnungsmessgeritt Messkondensetor	Peak voltage meter Measuring capaditor	MPS MPS	SMG MBC200	20107	200 W 200 W	50/60 Hz 50/60 Hz	2,0	Wärmelauf, Heat Rice 3+4	26.10.2015	Obs 2016	in Ordnung	Vor Ort Kallbrierung
Scheitelige nnungsmessgerät Messkandensator	Peak voltage meter Measuring case dior	MPS MWB	SMG	211152	SOO MY	50/60 Hz 50/50 Hz	2,0	Routine	26.10.2015	Obs 2016	In Ordnung	Vor Ort Kallbrierung
Constant and the second se	Date & sector		DA100-13-15	911.010637				Wärmelauf, Heat Rice 1				
Datenerfassungssystem	Data Acquisition Unit	YOROGANIA	2x DU105-12 DT800-11 DA100-18-15	SINGISSIS	6-250°C		din .	Wärmelauf, Heat Rise 1	11.01.2096	_	In Ordnung	DKD
Datenerfassungssystem	Data Acquisition Unit	YOROGANIA	2x DU100-12 DT300-11	911,810533 91,032443 (91,1328417 91,032443 1245,91554	6-250°C		0,3K	Wärmelauf, Heat Rise 2	11.01.2006	les 2017	In Onlineng	DKD
Datemerfassungssystem	Data Acquisition Unit	YOKOGAINA	DA100-13-5F 2x DU100-12	124526554 122410555471524105551 122424545	6-250°C		0,58	Wärmelauf, Heat Rise 3	14.01.2005	Jan 2016	In Ordnung	DND
			DT800-11 DA100-18-5F	1224/24242 91.002418 91.002218 / 011 50224 9			Q.SK	Wärmelauf, Heat Rise 4			In Ordnung	
Datemerfassungunystern	Data Acquisition Unit	YOROGANIA	2x DU106-12 DT800-11	91.5594(4 91.637212791.817212 91.90766917	6-258°C				07.01.2056			DHD
Hidschirzschreiber	Temperature recorder	UMO	Logoscreen st	10230302				Wärmelauf, Heat Rise, allgemein			In Ordnung	DKD
Prilzielane-Leistungs- Messgerät	Digital-powermeter	ZIMMER	LM0.500	015010510	Uma 1000 V / Ima 32 A Upk 3200 V / Ipk 120 A	DC-30MHz	0,05-0,03	Wärmelauf, Heat Rise 4	05.01.2056	ine 2017	In Ordnung	DKD
Prilitikora-Leistunga- Messgarät	Precision Power Analyzer	ZIMMER	LMG 500	12471500	Uma 1000 V / Ima 32 A Upk 3200 V / Ipk 120 A Uma 1000 V / Ima 32 A	DC-10MHz	0,05-0,03	Schallmessmum, Noise & PD	06.08.2055	Aug 2016	In Ordnung	Werkskallbrierung
Prizisiona-Leistunga-	Precision Power Analyzer	ZIMMER	LM0.500	12081-005	Uma 1000 V / Ima 32 A	DC-10MHs	0,05-0,03	Routine	19.05.2006	_	In Ordnung	Werkskalbrierung
Messgerät Präzisione-Leistunge-	Precision Power Analyzer	ZIMINER:	1.443.500	12091408	Upk 3200 V / 1 pk 520 A Umms 1000 V / 1 mms 32 A	DC-10MHs	0,05-0,03	Wärmelauf, Heat Rise 1	18.052096	_	In Ordnung	Werkskalbrierung
Messgerät Präcklone-Leistungs-					U mie 1000 V / 1 mie 32 A	DC-10MHz	0,05-0,08	Wärmelauf, Heat Rise 3	07.01.2056		In Ordnung	DED
Messgerät Präcklone-Leistunge-	Precision Power Analyzer		LMG 500	07920210	Upk 3200 V / 1pk 520 A Umme 1000 V / 1mme 32 A							
Messgerät	Precision Power Analyzer	ZIMMER	1.463.650	00523505	Upk 3200 V/1pk 520 A	DC-SOMHL	0,05-0,03	Messgeräteschrank	05.05.2005		In Ordnung	DKD
	Precision Power Analyzer	ZIMMER	1.003.310	80703497	Ums1000V/Ims30A Upk 2000V/Ipk 68A	DC-1 MHz	1,05	Messgeräteschrank	05.03.2055	Mrs 2016	In Ordnung	DED
Präcklone-Leistunge- Mesogwät												
Heagerit Heagerit Heagerit	Precision Power Analyzer		LMG 310	80104401	Umis 1000 V / Imis 30 A Upik 2000 V / Ipik 60 A	DC-1 MHz	8,05	Wärmelauf, Heat Rise 2	16.02.2056	Feb 2017	In Ordnung	DED
Messgerät Präckdone-Leistunge- Messgerät	Precision Power Analyzer	ZIMMER			U me 1000 V / I me 30 A U pk 2000 V / I pk 60 A 20 - 400 kV	DC - 1 MHz	1,05					
Hangerit Pitzhione Laktunge- Mangerit Fizikapannunger assaystem	Precision Power Analyzer Imp. voltage test system	ZIMMER	LMD 810 SMC 2000-400 MEAS 200-34-28	80104924 804741 904223 904243 .221141	Uma 1000 V / Ima 20 A Upk 2000 V / Ipk 60 A 10 - 400 W 20 M	DC-1MHz SH2-2MHz	1,05	Wärmelauf, Heat Rise 2 Stoscopennungsplatz	16.02.2056 27.30.2055 17.07.2055	C612016	In Onlinung In Onlinung In Onlinung	DKD Vor Ort Kallbrierung DKD

calibration list SGB cast resin Regensburg 15.07.2010



5.4. Test lab layout



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picture 20: test lab layout



picture 21: routine and heat rise bays

picture 22: PD and sound chamber



5.5. List of pictures, formulas, tables and sources

LIST OF PICTURES:	
PICTURE 1: IMPULSE-TEST VOLTAGE DISTRIBUTION BETWEEN THE INTERCONNECTIONS	7
PICTURE 2: IMPULSE TEST CIRCUIT	9
PICTURE 3: MARX GENERATOR CONNECTIONS	10
PICTURE 4: IMPULSE VOLTAGE VOLTAGE/CURRENT	11
PICTURE 5: FRONT TIME	11
PICTURE 6: TIME TO HALF-VALUE	11
PICTURE 7: CHOPPED IMPULSE VOLTAGE VOLTAGE/CURRENT	12
PICTURE 8: CHOPPED TIME ON TAIL	12
PICTURE 9: IMPULSE VOLTAGE/CURRENT	13
PICTURE 10 : PHASE TO PHASE RESISTANCE	16
PICTURE 11: TRANSFORMER IN NO-LOAD	17
PICTURE 12: TEST SETUP FOR NO-LOAD	17
PICTURE 13: TRANSFORMER IN SHORT-CIRCUIT	19
PICTURE 14: TEST SETUP FOR LOAD MEASUREMENT	20
PICTURE 15: COOLING CURVE EXAMPLE	23
PICTURE 16 EXAMPLE FOR RECALCULATION IN TEST REPORT	37
PICTURE 17 CALCULATION FOR AFWF TEMPERATURE RISE TEST METHOD 1	37
PICTURE 18 CALCULATION FOR AFWF TEMPERATURE RISE TEST METHOD 2	37
PICTURE 19 CALCULATION FOR AFWF TEMPERATURE RISE TEST METHOD 3	37
PICTURE 20: TEST LAB LAYOUT	39
PICTURE 21: ROUTINE AND HEAT RISE BAYS	39
PICTURE 22: PD AND SOUND CHAMBER	39
LIST OF FORMULAS:	
FORMULA 1: OHMIC LAW	16
FORMULA 2: CALCULATION $\Delta \Theta E$	23
formula 3: calculation $\Delta \Theta c$	24
FORMULA 4: CALCULATION $\Delta \Theta C$ (CORRECTED)	24
formula 5: calculation $\Delta \Theta c'$ (total)	25
LIST OF Tables:	
TABLE 1: RESISTORS FOR THE MARX GENERATOR	9
TABLE 2: COMMONLY USED MEASURING DEVICES	13
TABLE 3: COMMONLY USED MEASURING DEVICES	21

list of sources:

- D.J. Kraaij Die Prüfung von Leistungstransformatoren
- Wikipedia
- ► IEC