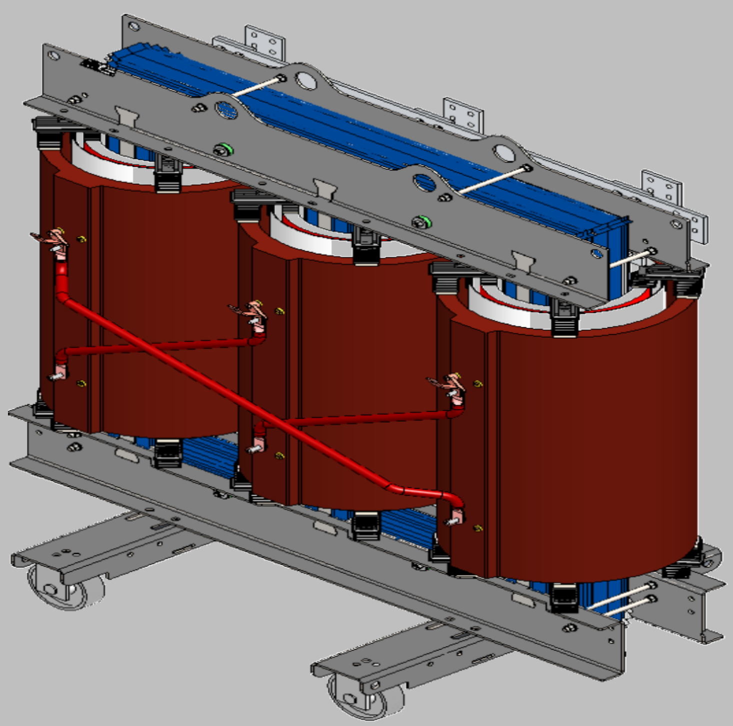
Test description for dry-type transformers chapter for special tests



Issued by:
Starkstrom-Gerätebau GmbH
Test lab cast resin transformers
Christopher Kammermeier GTTP
Document No.: 02.04.80-11.006 Rev J on 20.12.2022

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 “special” tests, this means the standard does not require these tests (see IEC 60076-1:2011 chapter 3.11.3).
They are carried out only upon customer request (if applicable).

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 60076-3:2013	Insulation levels, dielectric tests and external clearances in air
IEC 60076-10:2016	Determination of sound levels
IEC 60076-16:2011	Transformers for wind turbine application
IEC 60076-18:2012	Measurement of frequency response
IEC 60060-1:2010	High voltage test techniques – General definitions and test requirements

3. Lightning impulse test

The lightning impulse voltage test with chopped waves or neutral impulse test is described in the “Test description for dry-type-transformers for type tests”.

4. Sound level measurement

4.1. Standard

IEC 60076-11:2018 clause 14.4.2 // part 10

4.2. Aim

Determination of the guaranteed sound level values e.g.:

- $L_{P(A)}$ sound pressure level (A-weighted)

L_P = ten times the logarithm to the base 10 of the ratio of the square of the r.m.s. sound pressure to the square of the reference sound pressure ($p0 = 20 * 10^{-6}\ Pa$).

$$Lp = 10 * \log\frac{p^2}{p0^2}$$

formula 1: calculation of Lp

- $L_{W(A)}$ sound power level (A-weighted)

L_W = ten times the logarithm to the base 10 of the ratio of a given r.m.s. sound power to the reference sound power ($w0 = 1 * 10^{-12}\ W$).

$$Lw = 10 * \log\frac{W}{W_0}$$

formula 2: calculation of Lw

4.3. Theoretical principal

Basically, a measurement at no-load and load is possible.

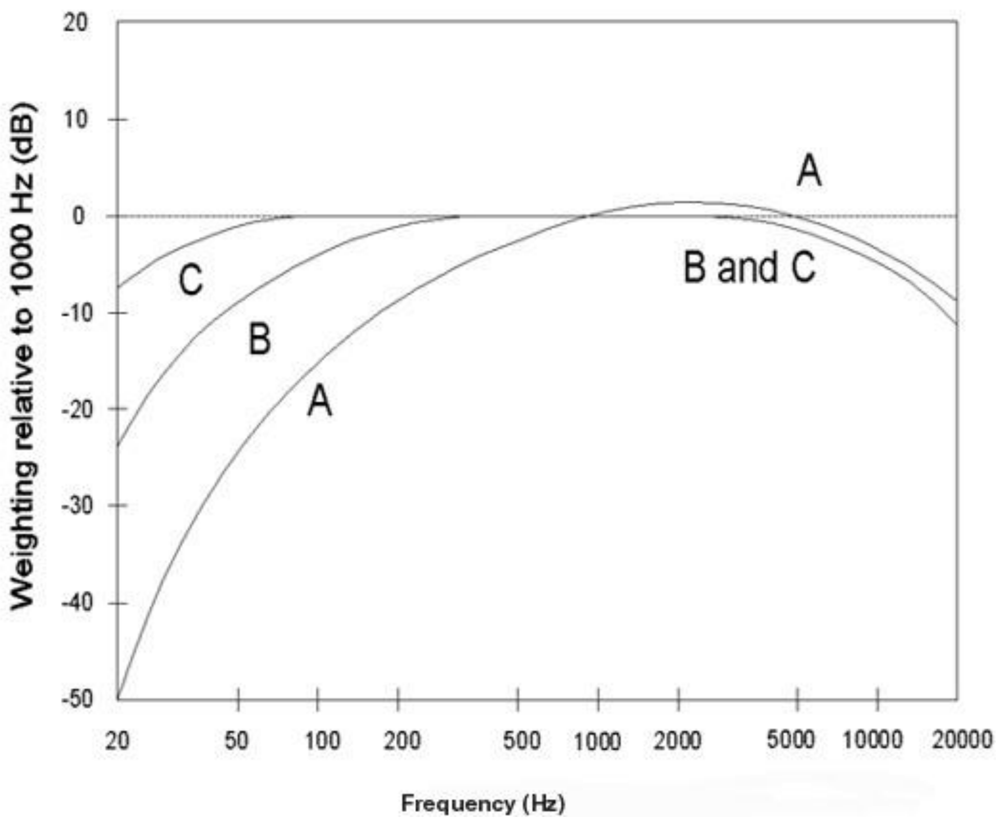
Due to the sizes of our transformers, the noise level measurement in loaded operation is not performed as it has no significant influence.

Usually we perform this measurement as:

<u>Measurement of A-weighted sound level by sound pressure method at no load</u>
<u>(based on IEC 60076-10:2016)</u>

This means:

- We only measure a sound pressure
- A sound power will be calculated using the measured sound pressure
- We measure in an A-weighted sound spectrum (see picture below)
- We only measure in no-load (excitation) condition
- It´s based on standard because we do not use correction factors for the recorded values (the measurement result would be lower).



picture 1: sound level meter response characteristics for the A, B, and C weighting

4.4. Measurement

The measurement of the sound level is made using the same test setup as for the no-load measurement (chapter for routine tests, clause (6)). It is carried out with the rated voltage U_R and the rated frequency f_R. The measurement voltage is applied as close to U_R as possible.

The transformer will always be measured at IP00 AN, if applicable also in AF and with the FAN´s alone.
Sound level measurement in an enclosure (e.g. IP21) is a special test and must be ordered separately.

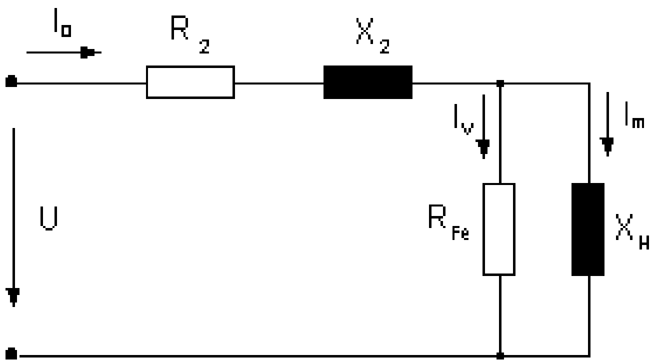
4.4.1.Measurement chamber

The measurement is carried out in a soundproofed chamber (-31 dB(A)).

4.4.2.Tapping position for measurement

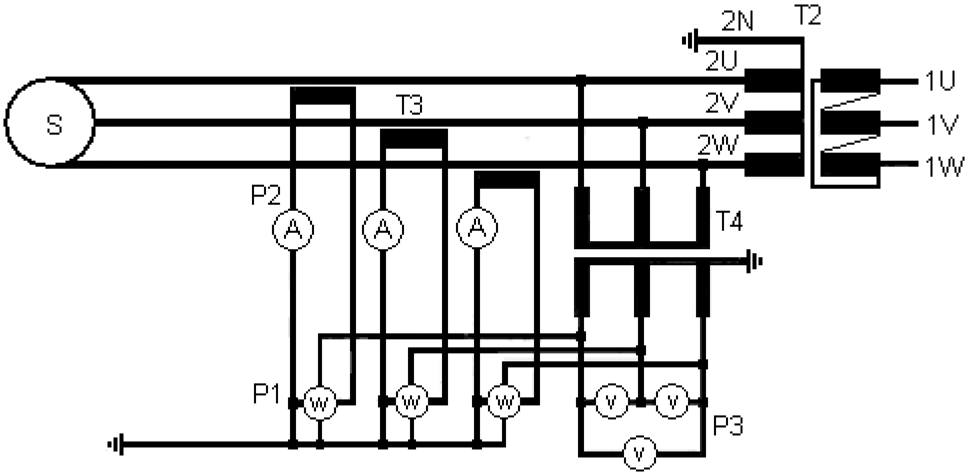
It is only necessary to reach the rated turn voltage.
Therefore, the tapping position does not matter. Usually it is the principal tapping position.

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



picture 2: transformer in no-load

4.4.4.Test setup for supplying



S: electricity supply

T2: transformer to be tested

T3: current transformer

T4: voltage transformer

P1: wattmeter

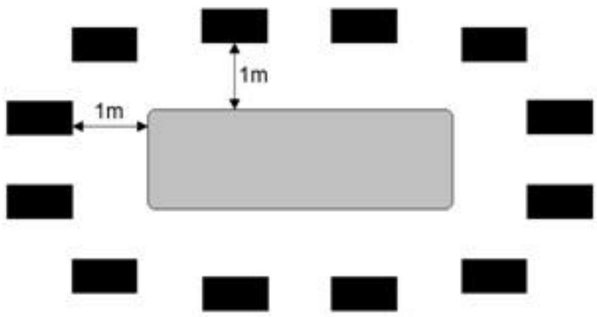
P2: amperemeter (I_{RMS})

P3: voltmeter (U_{RMS})

picture 3: test setup for measurement of sound level

4.4.5.Test setup for measuring

Surrounding the transformer, there are 12 microphones at a distance of one meter from the transformer and located at the middle height of the coils.



picture 4: microphones surrounding the transformer

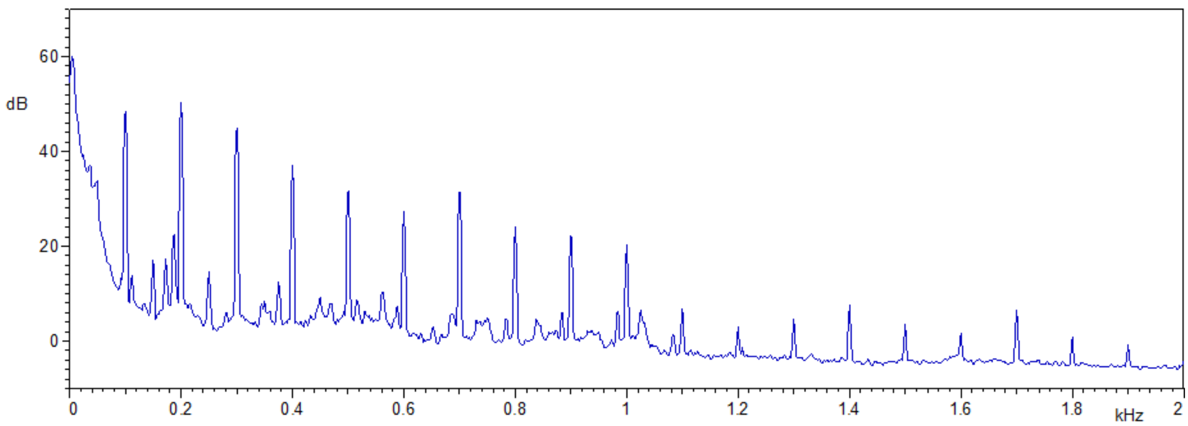
4.4.6.Commonly used measuring devices for measurement

measuring devices	manufacturer	type	range / accuracy	frequency	class
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
LV-current-transf.	H&B	Ti 48	2.5-500 A/5 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
12 microphones	G.R.A.S	1/2" freefild microphone 46AE CCP-preamplifier 26CA	3.15 Hz - 20 kHz -> ± 2.0 dB 5 Hz - 10 kHz -> ± 1.0 dB	n.a.	n.a.
12 datalogging modules	Heim Systems GmbH	DATaRec 4	Bandwidth max. 20 kHz <0.2 ° ±0.1 % or ±1 mV	n.a.	n.a.

table 1: Commonly used measuring devices

4.4.7.Recorded values for the measurement

For each of the 12 microphones the A-weighted sound pressure level $L_{P(A)}$ and a sound spectrum from 0-2 kHz is given (see picture below).



picture 5: sound pressure level sepctrum

If AF and FAN sound is applicable than we will note the A-weighted sound pressure level $L_{P(A)}$ for this also.

4.5. Calculations to determine sound level values

The first step is that the average A-weighted sound pressure level $L_{P(A)}$ will be calculated.

$$L_{P(A)}[average\ uncorrected] = 10\ \log\left[\frac{1}{N}\sum_{i=1}^{N} 10^{0,1 L_{P(A)}\ i}\right]$$

formula 3: calculation of the average A-weighted sound pressure level $L_{P(A)}$

N = number of microphones

$L_{P(A)}\ i$ = A-weighted sound pressure level $L_{P(A)}$ of microphone no. i

If the measured distance or the guaranteed distance is not 1m, then the A-weighted sound pressure level shall be $L_{P(A)}$ corrected according the formula from IEC 60076-10:2016.

$$L_{P(A) at\ rated\ distance} = L_{P(A) at\ measured\ distance} - 10\ \log\frac{S_{at\ rated\ distance}}{S_{at\ measured\ distance}}$$

formula 4: correction for distance

S = measurement surface

Finally, the calculation of the sound power level $L_{W(A)}$

$$L_{W(A)} = L_{P(A)} + 10\ \log\frac{S}{S_0}$$

formula 5: calculation of the sound power level LW(A)

S = measurement surface

S_0 = is equal to the reference area (1 m²)

4.6. Test criteria / Maximum values

The guarantee sound level values must be held.

5. Measurement of excitation

5.1. Standard

None

5.2. Aim

Determination of the point of core saturation

5.3. Measurement

The measurement of the excitation is made using the same test setup as for the no-load measurement (chapter for routine tests, clause 6). It is carried out with rated frequency f_R and multiple voltages (see below).

percent of rated voltage

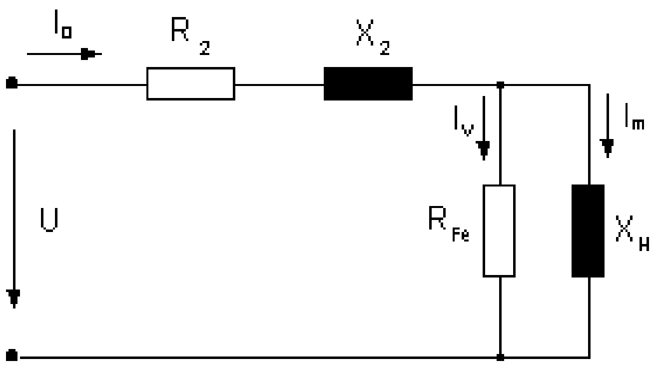
10%	
20%	
30%	
40%	
50%	
60%	
70%	
75%	
80%	
83%	
85%	
88%	
90%	
93%	
95%	
98%	
100%	
103%	
105%	
108%	
110%	
113%	
115%	
118%	
120%	
123%	(if applicable, due to high core saturation)
125%	(if applicable, due to high core saturation)
130%	(if applicable, due to high core saturation)

table 2: usual voltages for excitation curve

5.3.1. Tapping position for measurement

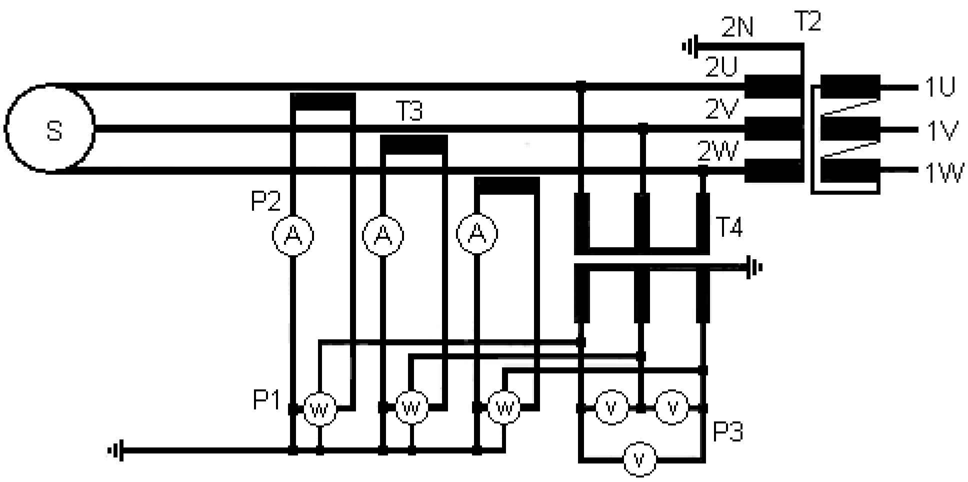
It is only necessary to reach the rated turn voltage.
Therefore, the tapping position does not matter. Usually it is the principal tapping position.

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



picture 6: transformer in no-load

5.3.3. Test setup



picture 7: test setup for measurement of excitation

S: electricity supply

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

5.3.4.Commonly used measuring devices for measurement

measuring devices	manufacturer	type	range / accuracy	frequency	class
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
LV-current-transf.	H&B	Ti 48	2.5-500 A/5 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

table 3: Commonly used measuring devices

5.3.5.Recorded values for the measurement

Voltage [V], amperage [A] and losses [W] for all phases (in R.M.S.) are recorded.
The Magnetic flux density [T] is indicated based on the individual test voltages.

5.4. Test criteria / Maximum values

none

6. Determination of the capacity of the windings against earth and between the windings as well as loss factors (tan δ)

6.1. Standard

IEC 60076-1:2011 clause 11.1.2.2 a

6.2. Aim

The purpose of the measurement is to determine the value of the capacity of the windings against earth and between the windings as well as loss factors (tan δ).

This value can be compared with the measured value after x years or between the factory and installation site.

A difference between the values can occur e.g.: due to changing of the coil position, humidity on the transformers or aging of the insolating material.

Note: Any change in the climatic conditions will change the measured readings.

6.3. Measurement

The determination of capacity windings-to-earth and between windings shall be made according to IEC 60076-1:2011 (chapter 11.1.2.2 a) as a routine test for transformers with an Um > 72.5 kV.

For transformers with Um <72.5 kV, the test will only be done at the explicit request of the customer.

The measurement of dissipation factor (tan δ) of the insulation system capacitance is described as special test according IEC 60076-1:2011 (chapter 11.1.4 c & d).

In the current IEC standard, there is nothing mentioned about this measurement except for its existence. In the last version of the standard (IEC 60076-1:2000), the following comment was made (see picture below).

60076-1 © IEC:1993+A1:1999 – 61 –

10.1.3 Special tests

a) Dielectric special tests (IEC 60076-3).
b) Determination of capacitances windings-to-earth, and between windings.
c) Determination of transient voltage transfer characteristics.
d) Measurement of zero-sequence impedance(s) on three-phase transformers (10.7).
e) Short-circuit withstand test (IEC 60076-5).
f) Determination of sound levels (IEC 60551).
g) Measurement of the harmonics of the no-load current (10.6).
h) Measurement of the power taken by the fan and oil pump motors.
i) Measurement of insulation resistance to earth of the windings, and/or measurement of dissipation factor (tan δ) of the insulation system capacitances. (These are reference values for comparison with later measurement in the field. No limitations for the values are given here.)

If test methods are not prescribed in this standard, or if tests other than those listed above are specified in the contract, such test methods are subject to agreement.

picture 8: excerpt from the standard

6.3.1.Preparing the transformer for the measurement

- For the measurement, all windings have to be shorted.
- The mean earth terminal of the transformer has to be connected with the earth of the measurement device (e.g. frame of CPC 100 + CP TD1).
- For three-winding transformers with two LV windings, the two LV terminals should be connected together. The connection setup shall be used from a two-winding transformer.
- If at all possible, the measurement shall be made in the enclosure.

6.3.2.Test voltage

The test voltage should not exceed 80 % of the value of the separate-source AC withstand voltage test for the connected winding.

6.3.3.Test frequency

The test frequency should be the rated transformer frequency.

6.3.4.Climate conditions

The climate conditions shall be noted as accurately as possible

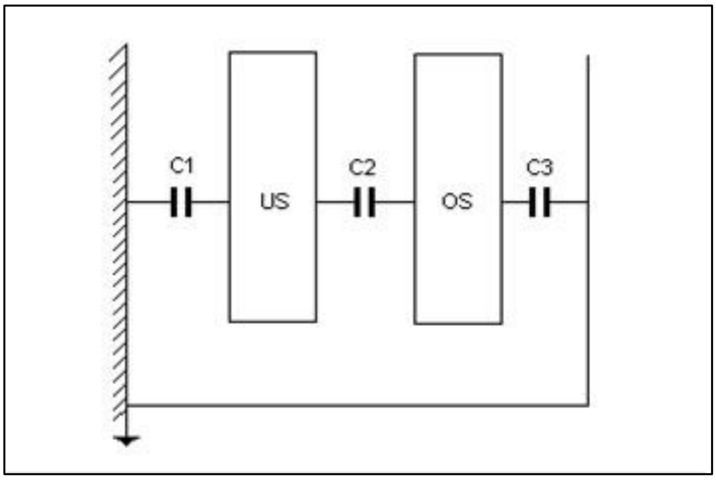
- Temperature in °C
- Humidity in %
- Air-pressure in hPa

6.3.5.Test circuits

6.3.5.1. For two-winding transformers

no.:	circ.:	High voltage connection	red lead (A)	blue lead (B)
C3	GSTg-A	HV (OS)	LV (US)	n.c.
C2	UST-A	HV (OS)	LV (US)	n.c.
C1	GSTg-A	LV (US)	HV (OS)	n.c.

table 4: circuits for two-winding transformers



picture 9: test setup for capacity measurement at two-winding transformers

For transformers with a shield winding between HV and LV an extra measurement must be made, this is necessary because the measurement between the windings isn´t possible. The circuit designated C2 will determine the value of the HV to the shield. The extra circuit C2 is for the value LV to shield.

no.:	circ.:	High voltage connection	red lead (A)	blue lead (B)
C2 extra	UST-A	LV (US)	HV (OS)	n.c.

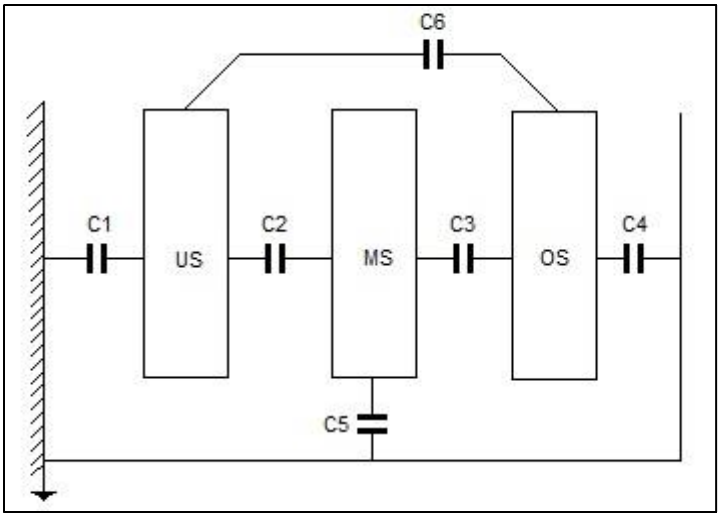
table 5: additional circuits for two-winding transformers

SGB
Your dedicated partner of the SGB-SMIT Group

6.3.5.2. For three-winding transformers

no.:	circ.:	High voltage connection	red lead (A)	blue lead (B)
C3	UST-A	HV (OS)	MV (MS)	LV (US)
C4	GSTg-A+B	HV (OS)	MV (MS)	LV (US)
C2	UST-B	MV (MS)	HV (OS)	LV (US)
C5	GSTg-A+B	MV (MS)	HV (OS)	LV (US)
C1	GSTg-A+B	LV (US)	HV (OS)	MV (MS)
C6	UST-A	LV (US)	HV (OS)	MV (MS)

table 6: circuits for three-winding transformers



picture 10: test setup for capacity measurement at three-winding transformers

6.3.6.Commonly used measuring devices for measurement

measuring devices	manufacturer	type	range / accuracy	frequency	class
universal measuring instrument	Omicron	CPC 100 CP TD1 CP SB1		0-400 Hz	n.a.

table 7: Commonly used measuring devices

6.3.7.Recorded values for the measurement

The following measured values should be noted:

Circuit
Voltage in kV
Currentsin mA
Losses in W (not necessary)
Tan delta in % (at reference from 10 kV or at testing voltage)
Capacity Cx in pF (at reference from 10 kV or at testing voltage)

6.4. Test criteria / Maximum values

none

7. Insulation resistance

7.1. Standard

- None for dry-type-transformers

other but not applicable standards would be:

- IEC 60204-11:2018 - Safety of machinery - Electrical equipment of machines
  (rated voltage > test voltage < 5kV DC; insulation resistance value ≥ 1MΩ)
- IEC 60364-6:2016 (DIN VDE 0100-600-06:2017) - Low-voltage electrical installations
  (acc. protection class: test voltage 0.25-1kV DC; insulation resistance value ≥ 0.5-1MΩ)
- IEC 60076-1:2011 clause 11.1.2.2 (only for transformers ≥72.5kV) no notes to execution included

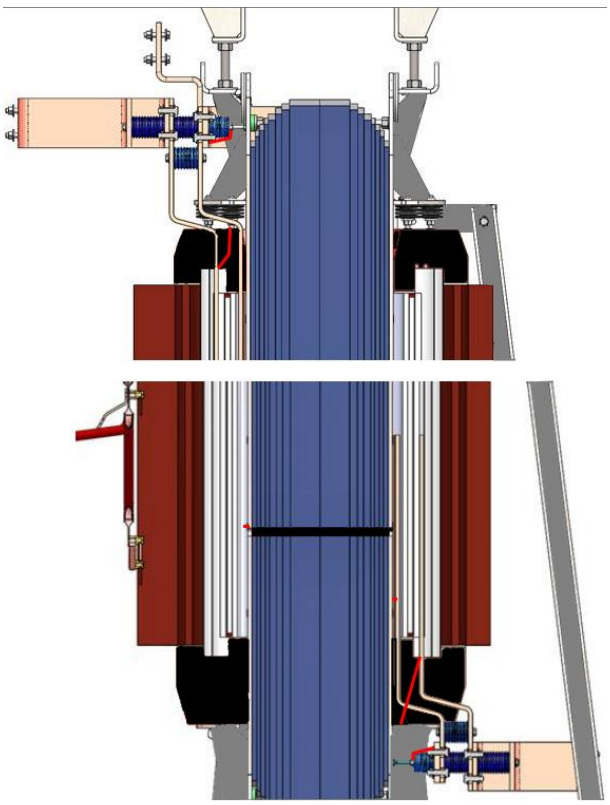
7.2. Aim

The purpose of the measurement is to determine the value of the DC resistance of the windings against earth and between the windings.

For liquid immersed transformers, the insulation value can be compared with the measured value after x years or between the factory and installation site.

7.3. Theoretical principal

The insulation resistance is the ohmic resistance which results between two condutive parts with an insulation in-between e.g. winding to winding or winding to earth.
The current measured is caused by polarization of the insulating material (mainly on the surface of the insulation material).

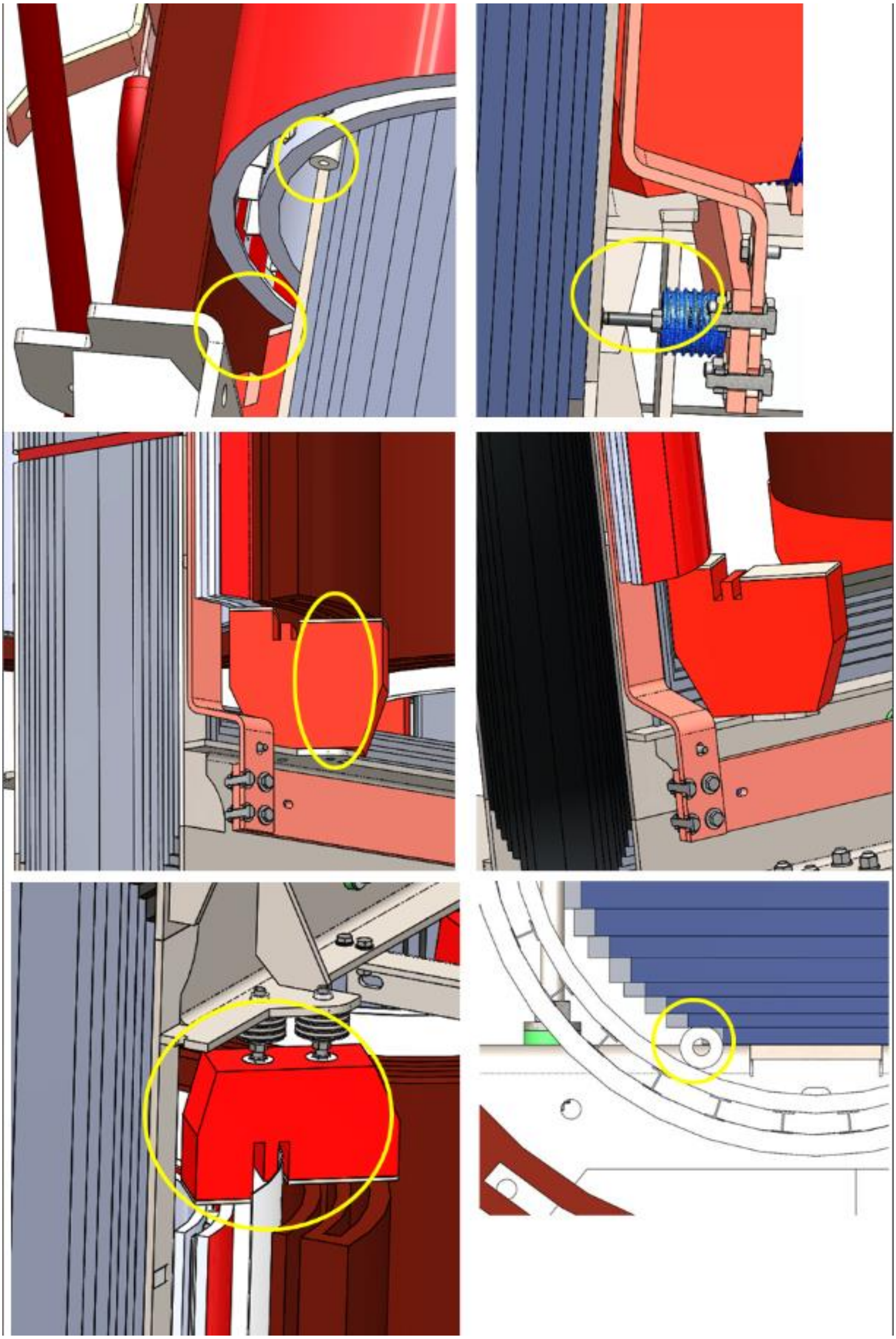


picture 11: transformer active-part cross-section

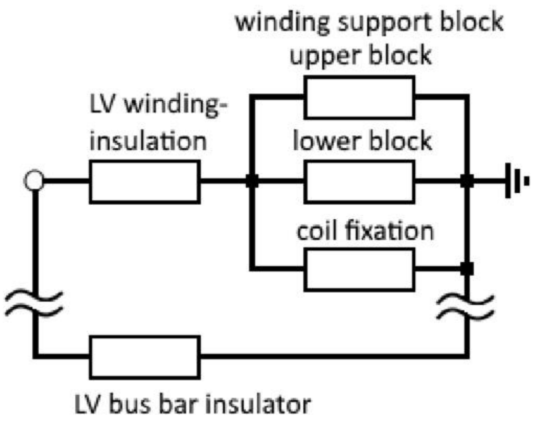
Through the fact that the main insulation of a dry-type-transformer is the air between windings or other conductive parts, only a few parts remain that have direct contact with the winding (e.g. coil-support, insulators, ...).

Therfore the climatic conditions will have a significant influence on the value of the insulation resistance, e.g. by condensation on the surface of an insulator.

As can be seen in the picture below (picture 11: transformer active-part cross-section & picture 12: close up transformer active-part cross-section), the insulation consists of many different parts, which together result in a parallel connection of the induvidual insulation resistances in series (e.g. winding to support block to bolts of the support blocks, winding bus bar to insulator to the core-press-construction.



picture 12: close up transformer active-part cross-section



picture 13: equivalent circuit diagram of the main insulation parts

Therfore it could happen that e.g. the isolator of the LV busbar (if existing) creates a parallel circuit (picture 13: equivalent circuit diagram of the main insulation parts) with winding support and LV insulation. In this case the winding support and the winding insulation (with e.g. cast resin) could be irrelevant (depending on conditions).

7.4. Measurement

During the measurement of the insulation resistance as well as the capacitance measurement, ambient conditions (ambient temperature, air pressure and relative humidity) have a huge significance.

Consideration should be taken that no condensation has formed on/in the transformer.

Note: Any change of climatic conditions, coil position or insulation aging will change the measured readings.

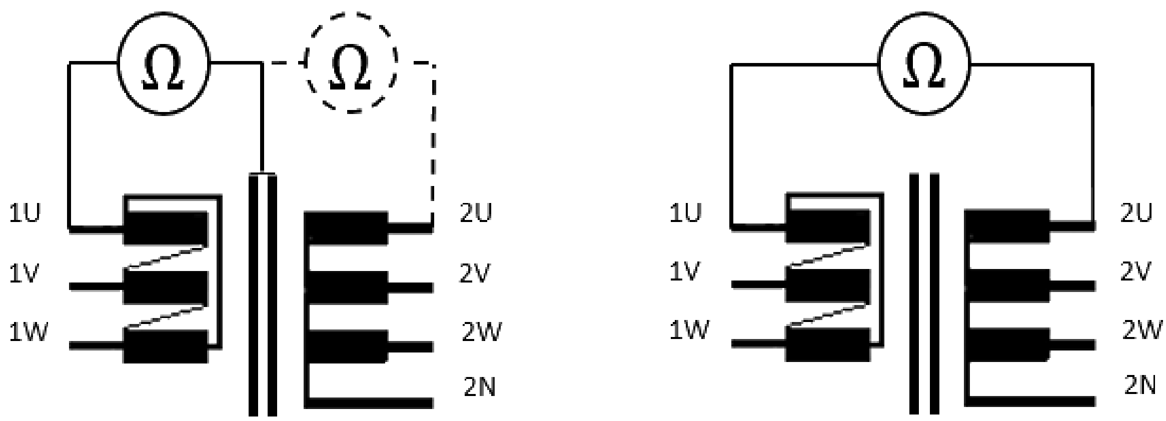
7.4.1.Test voltage

For windings, the test voltage should be 2.5 kV DC, for insulated core bolts 500 V DC.

7.4.2.Test setup

For this test, the windings shall be tested against earth as well as winding system against winding system (within the three-phase connection).
e.g. HV to LV // HV to ground // LV to ground

Also, the core bolts will be tested (if applicable). e.g. bolts to ground



picture 14: test setup for insulation resistance

7.4.3.Commonly used measuring devices for measurement

measuring devices	manufacturer	type	range / accuracy	frequency	class
Ins. resist. - meter	GOSSEN	Metriso 5000	0-4GΩ	DC	1.5

table 8: Commonly used measuring devices

7.4.4.Recorded values for the measurement

The following measured values should be noted:

- Connection
- Voltage in kV DC
- Resistance in MΩ or GΩ

7.5. Test criteria / Maximum values

In the standard for dry-type-transformers this test is not required, listed or provided with minimum values.

The minimum insulation resistance can be determined by a rule of thumb. This was valid until 1985 (per volt a 1kOhm).

When tested at the factory, we expect as a minimum value (Un [V] / 1000 + 1) MΩ.

e.g. HV with 15 kV and LV with 690 V
HV = 15 kV corresponds 16 MΩ
LV = 690 V corresponds 1.69 MΩ
Bolts = 0 V corresponds 1 MΩ

8. Sweep Frequency Response Analysis (SFRA)

8.1. Standard

IEC 60076-16:2011 Appendix A.4

8.2. Aim

The purpose of the measurement is to be a non-intrusive tool for verifying the geometric integrity of the transformer.

This graph can be compared with the original graph after x years or between the factory and installation site.

A difference between the values can occur e.g.: due to changing of the coil position, humidity or a turn-to-turn short on the transformer.

This measurement has more relevance when measuring oil-type transformers, as a dry type transformer can be physically measured when referencing possible shifting of coils due to transport issues and when assessing a possible transformer failure such as a winding failure or other damage to the windings themselves, the failure is generally either possible to diagnose visually or by basic testing procedures.

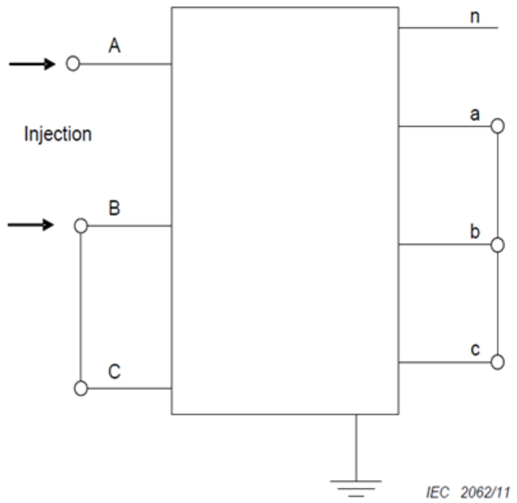
8.3. Measurement

When performing this measurement, it is crucial that the variables are controlled as much as possible as any deviation from the original measurement will create a deviation on the new performed results. Variables include, but are not limited to, temperature, humidity, air pressure, the location of the test contacts and the tightness of the testing contacts. Especially at higher frequencies, the type of grounding is significant for the results.

8.3.1.Testing voltage and frequency

The testing output voltage is 2.83 Volts and uses a varying frequency, starting at 10 Hz and measures until 20 MHz (possible).

8.3.2.Excerpt from the standard IEC 60076-16



Key

A,B,C	High voltage terminals
a,b,c	Low voltage terminals
n	Is neutral terminal

picture 15: HV Injection test figure

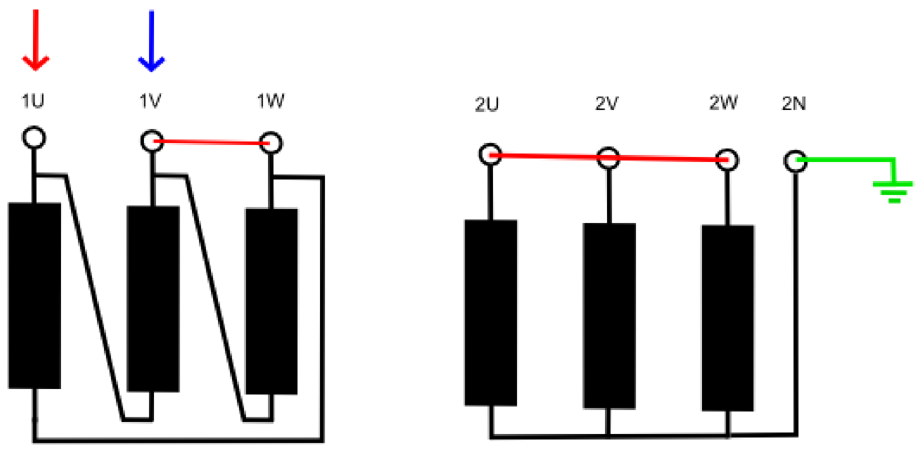
With the 3 LV phases short circuited, 3 different ways of HV injection should be considered:

- HV phases B and C connected together and LV neutral connected to the ground of transformer. This case shall be used when the LV neutral is earthed during operation and gives the value of phase A.
- HV phases B and C connected together and connected to ground and LV neutral connected to the ground of transformer. This case is valid to see the difference in case of high voltage system ground fault and gives the value of phase A.
- HV phases B and C connected together and LV neutral not connected. This case shall be used when the LV neutral is not earthed during operation, Figure A.4 shows this kind of measurement configuration and gives the value of phase A.

For measurement of the other phases, rotation of the same sequences should be applied.

The following connection diagrams show the above explained case 1

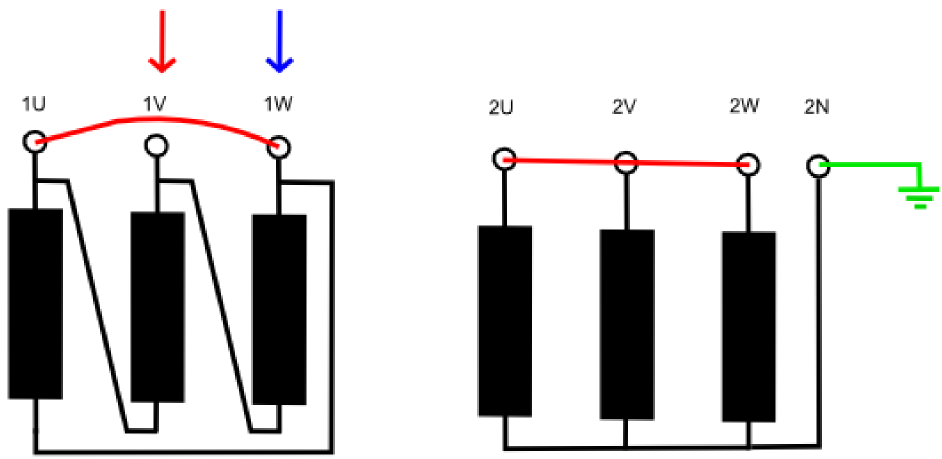
8.3.3.Measurement between phase 1 and phase 2



picture 16: Measurement between phase 1 and phase 2

Red & Yellow cable:	*1U*		
Blue cable:	*1V*	*(1V and 1W are shorted)*	
LV:		*2U, 2V, 2W are shorted*	*(2N is grounded)*
Key			
1U, 1V, 1W	*High voltage terminals*		
2U, 2V, 2W	*Low voltage terminals*		
2N	*is neutral terminal*		

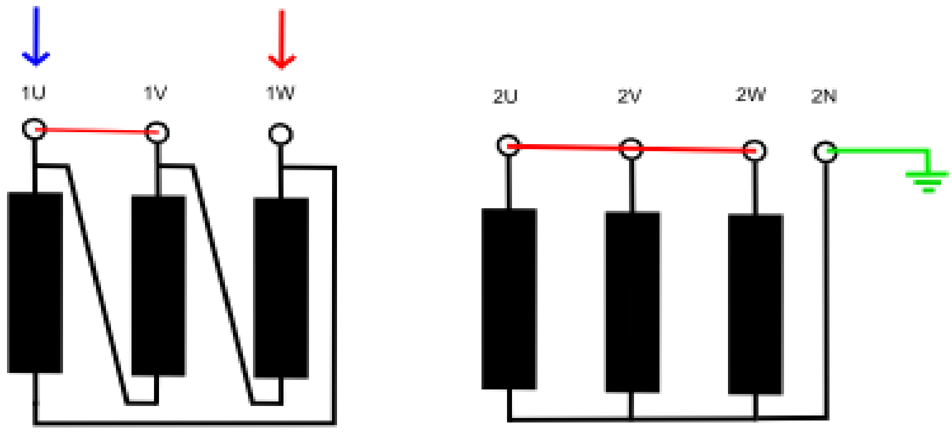
8.3.4.Measurement between phase 2 and phase 3



picture 17: Measurement between phase 2 and phase 3

Red & Yellow cable:	*1V*		
Blue cable:	*1W*	*(1W and 1U are shorted)*	
LV:		*2U, 2V, 2W are shorted*	*(2N is grounded)*
Key			
1U, 1V, 1W	*High voltage terminals*		
2U, 2V, 2W	*Low voltage terminals*		
2N	*is neutral terminal*		

8.3.5.Measurement between phase 3 and phase 1



picture 18: Measurement between phase 3 and phase 1

Red & Yellow cable:	*1W*		
Blue cable:	*1U*	*(1U and 1V are shorted)*	
LV:		*2U, 2V, 2W are shorted*	*(2N is grounded)*
Key			
1U, 1V, 1W	*High voltage terminals*		
2U, 2V, 2W	*Low voltage terminals*		
2N	*is neutral terminal*		

8.3.6.Commonly used measuring devices for measurement

measuring devices	manufacturer	type	range / accuracy	frequency	class
SFRA Analyzer	Omicron	FRAnalyzer	20Hz-20MHz	AC	--

Table 9: Commonly used measuring devices

8.3.7.Recorded values for the measurement

A spectrum from 20Hz-20MHz will be given in the test sheet for Magnitude and Phaseangle. Additional if the customer wishes, we can supply a “tfra”-file from Omicron with all raw measument data.

8.4. Test criteria / Maximum values

none

9. Measurement of zero sequence impedance

9.1. Standard

IEC 60076-1:2011 clause 11.6

9.2. Aim

The purpose of the measurement is to give the impedance based upon the transformer for informative purposes when designing earth-fault protection and earth-fault current calculations.

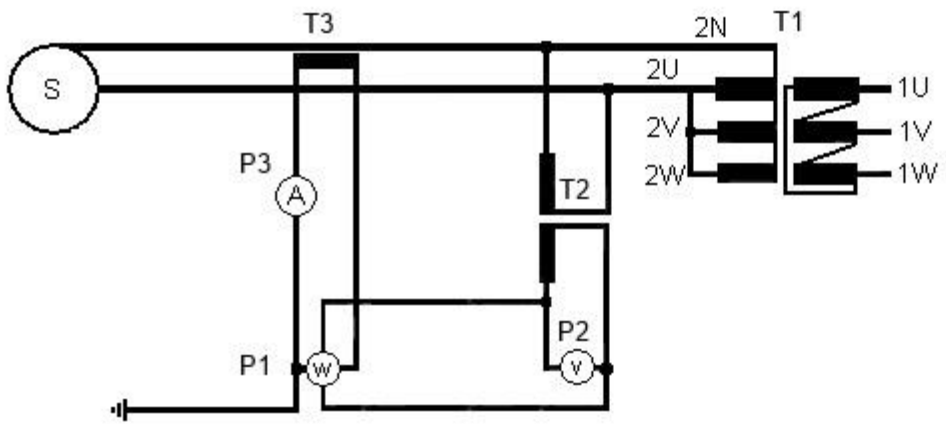
9.3. Measurement

The measurement is possible on star or zigzag connected windings. The measurement is carried out by supplying a current at rated frequency between the three parallel connected phase systems and the neutral terminal.

9.3.1. Testing current and frequency

The appropriate current shall either be 30 % of the nominal current or the maximal available current available through testing facilities. According to the IEC, the current on the neutral and the duration of application should be limited to avoid excessive temperatures of metallic constructive parts. The test shall always be carried out at nominal frequency in nominal tapping position.

9.3.2. Test setup



picture 19: test setup for zero sequence impedance

9.3.3. Commonly used measuring devices for measurement

measuring devices	manufacturer	type	range / accuracy	frequency	class
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
LV-current-transf.	H&B	Ti 48	2.5-500 A/5 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

Table 10: Commonly used measuring devices

9.3.4. Recorded values for the measurement

The voltage, current and losses per phase are measured and documented.

9.4. Test criteria / Maximum values

none

10. Measurement of harmonics of the no-load current in % of fundamental components

10.1. Standard

IEC 60076-1:2000 clause 10.6

10.2. Aim

The purpose of the measurement is to give the harmonics of the no-load current in the three phases.

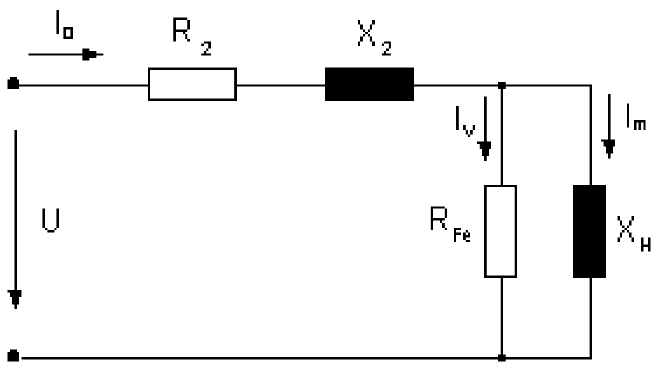
10.3. Measurement

The measurement of the excitation is made using the same test setup as for the no-load measurement (chapter for routine tests, clause 6). It is carried out with the rated voltage U_R and the rated frequency f_R.

10.3.1. Tapping position for measurement

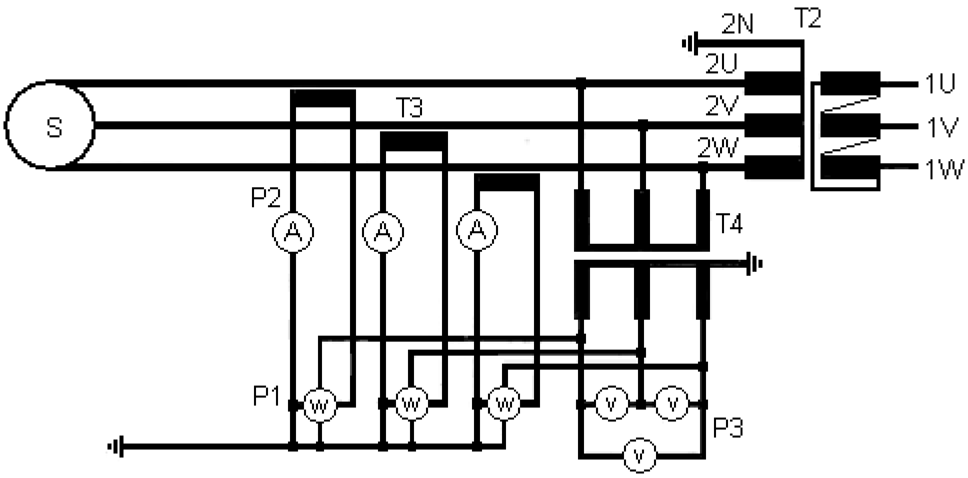
It is only necessary to reach the rated turn voltage.
Therefore, the tapping position does not matter. Usually it is the principal tapping position.

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



picture 20 transformer in no-load

10.3.2. Test setup



picture 21: test setup for measurement of harmonics of the no-load current in % of fundamental components

S: electricity supply

T2: transformer to be tested

T3: current transformer

T4: voltage transformer

P1: wattmeter

P2: amperemeter (I_{RMS})

P3: voltmeter (U_{RMS})

10.3.3. Commonly used measuring devices for measurement

measuring devices	manufacturer	type	range / accuracy	frequency	class
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
LV-current-transf.	H&B	Ti 48	2.5-500 A/5 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

Table 11: Commonly used measuring devices

10.3.4. Recorded values for the measurement

The harmonics of the no-load current in the three phases are measured and the magnitude of the harmonics is expressed as a percentage of the fundamental component.

10.4. Test criteria / Maximum values

none

11.Measurement of partial discharge with earth

11.1. Standard

IEC 60076-11:2018 clause 14.4.1

11.2. Aim

Partial discharge measurement of single-phase line-to-earth fault condition.

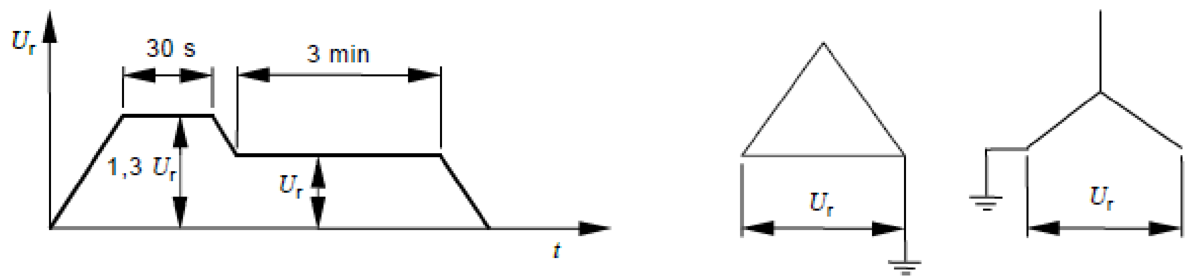
This special test is for transformers connected to systems which are isolated or earthed through a high value impedance and which can continue to be operated under a single phase line-to-earth fault condition.

11.3. Measurement

For detailed information on the partical discarge measurement and the measurement environment, please see (chapter for routine tests, clause 10).

11.3.1. Differences to the routine partical discarge measurement

A phase-to-phase voltage of 1.3 Ur shall be induced for 30 s, with one line terminal earthed, followed without interruption by a phase-to-phase voltage of Ur 1.0 for 3 min during which the partial discharge shall be measured. This test shall be repeated with another line terminal earthed.



picture 22: measurement of partial discharge with earth

All other criteria refer to routine partical discarge measurement.

11.3.2. Commonly used measuring devices for measurement

measuring devices	manufacturer	type	range / accuracy	frequency	class
PD-measurement system	Omicron	MCU502 4xMPD600 3xMPP600	500 fC - 3nC	0 - 32 MHz	0.01-0.03

Table 12: Commonly used measuring devices

11.3.3. Recorded values for the measurement

The background level and the maximum PD values within the 180 sec. for all phases in [pC], are then recorded in the test protocol.

11.4. Test criteria / Maximum values

The partial discharge level is allowed a maximum of 10pC with correction factor.

12.Appendix

12.1. Example test certificate Sound level measurement

special tests

(based on Standard: IEC 60076-11:2018)

SGB
Your dedicated partner of the SGB-SMIT Group

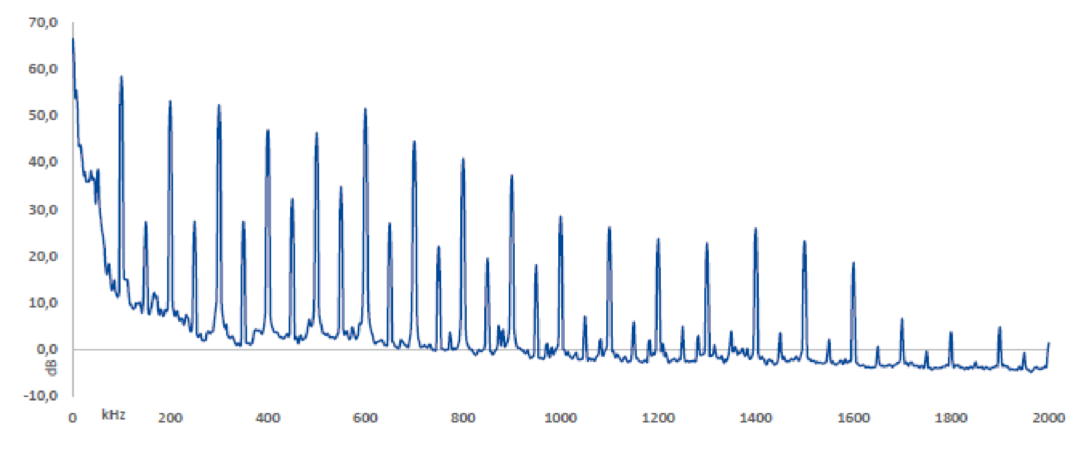
SGB order number:	123456789/10	Serial-number:	123456
Type:	DTTH1NG 3150/30	Wd. number:	123456

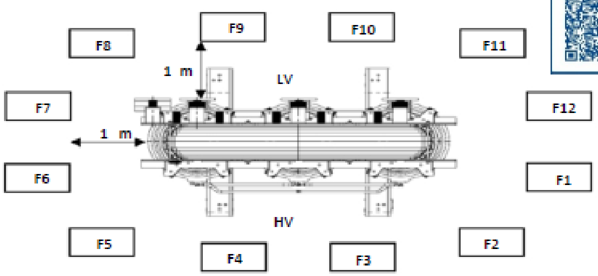
Measurement of A-weighted sound level by sound pressure method at no load

	AN	AF	Fan
F1	57,2	61,8	60,3
F2	54,9	64,9	64,6
F3	55,1	66,0	65,7
F4	56,2	64,9	64,3
F5	55,8	63,4	62,8
F6	52,4	62,0	61,6
F7	51,8	61,3	61,0
F8	56,2	63,7	62,9
F9	56,8	64,7	64,0
F10	53,3	65,7	65,6
F11	54,9	64,9	64,5
F12	52,0	62,3	61,9
Average	55,1	64,1	63,6

Test results in dB[A] at 1 m
connection LV 690 V
Frequency 50 Hz
Measurement carried out in Protection IP00

	AN	AF
Lp 1m :	55,1	64,1
Lw:	71,0	79,9





more information?
see general test description

Example pictures and schematics refer to a standard transformer. Deviations from the actual product may be possible.

Remarks:

Tested by, Date of test

4 / 13
page

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

12.2. Example test certificate measurement of excitation

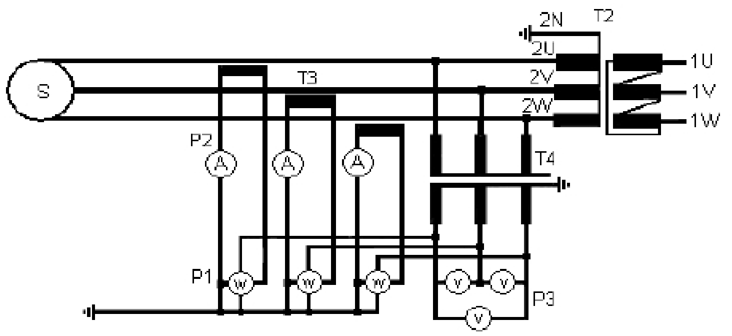
special tests

SGB order number:	123456789/10	Serial-number:	123456
Type:	DTTH1NG 3150/30	Wd. number:	123456

Measurement of excitation

connection LV 690 V & Frequency 50,0 Hz / Protection IP00 Magnetic flux density B = 1,649 [T]

Rated voltage [V]:		B [T]:	Voltage [V]: Average	Currents [A]:				Losses [W]:
				U	V	W	Average	Σ
10%	69,0	0,17	69,8	0,754	0,541	0,767	0,688	55
20%	138,0	0,33	138,0	1,234	0,876	1,267	1,126	196
30%	207,0	0,50	207,5	1,626	1,149	1,684	1,487	415
40%	276,0	0,66	275,1	1,959	1,382	2,040	1,794	696
50%	345,0	0,82	344,4	2,276	1,607	2,384	2,089	1055
60%	414,0	0,99	414,3	2,593	1,838	2,727	2,386	1497
70%	483,0	1,16	484,0	2,937	2,085	3,093	2,705	2022
75%	517,5	1,24	517,1	3,122	2,215	3,281	2,873	2306
80%	552,0	1,32	551,5	3,338	2,367	3,495	3,067	2629
83%	572,7	1,37	572,3	3,489	2,474	3,640	3,201	2841
85%	586,5	1,40	587,3	3,603	2,554	3,747	3,302	3001
88%	607,2	1,45	606,2	3,785	2,679	3,914	3,459	3219
90%	621,0	1,48	620,4	3,950	2,791	4,064	3,602	3397
93%	641,7	1,53	641,3	4,235	2,989	4,323	3,849	3678
95%	655,5	1,57	655,0	4,484	3,168	4,556	4,069	3886
98%	676,2	1,62	676,3	5,040	3,574	5,078	4,564	4248
100%	690,0	1,65	689,7	5,583	3,986	5,592	5,054	4514
103%	710,7	1,70	709,8	6,906	5,041	6,938	6,295	4979
105%	724,5	1,73	725,4	8,728	6,536	8,781	8,015	5401
108%	745,2	1,78	744,5	12,977	9,991	13,023	11,997	6019
110%	759,0	1,82	759,8	18,982	14,930	18,928	17,613	6582
113%	779,7	1,86	779,2	31,711	25,680	31,511	29,634	7379
115%	793,5	1,90	794,4	47,683	39,811	47,269	44,921	8137
118%	814,2	1,94	813,7	76,666	67,399	75,976	73,347	9204
120%	828,0	1,98	828,1	105,514	95,116	104,185	101,605	10172
123%	848,7	2,03	848,1	153,195	142,488	151,780	149,154	11852
125%	862,5	2,06	862,0	193,760	183,342	192,116	189,739	13354
128%	883,2	2,11	882,2	262,814	254,436	261,524	259,591	16098



Example pictures and schematics refer to a standard transformer. Deviations from the actual product may be possible.

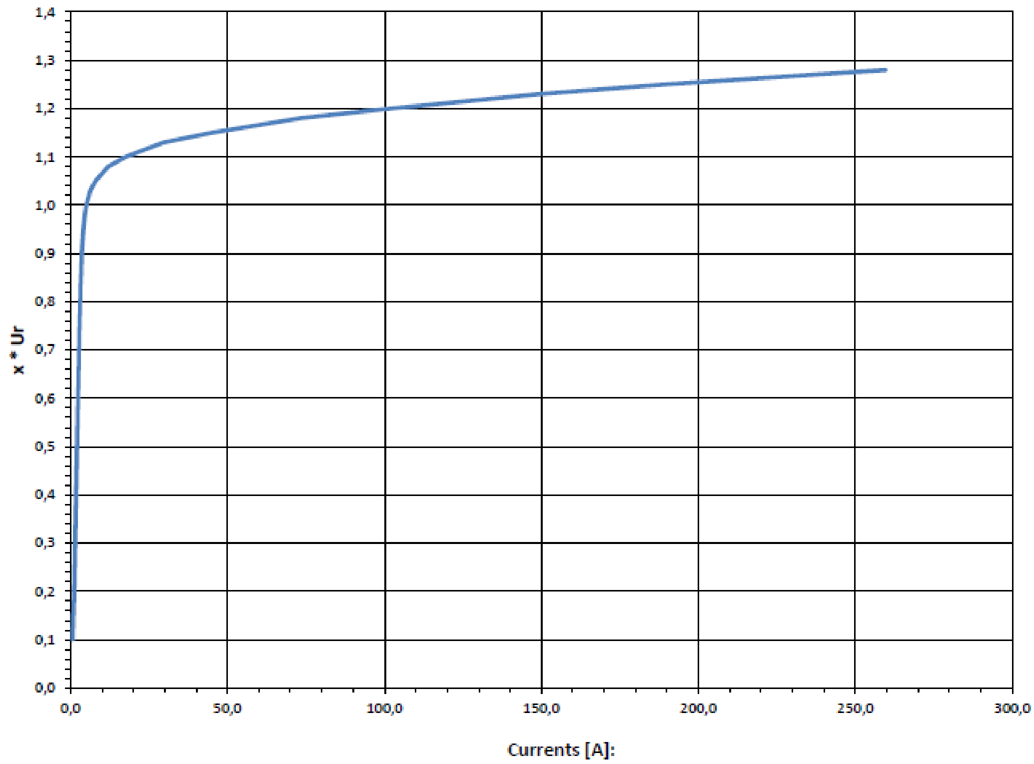
Tested by, Date of test

5 / 13
page

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

special tests

SGB order number:	123456789/10	Serial-number:	123456
Type:	DTTH1NG 3150/30	Wd. number:	123456



more information?
see general test description

Remarks:

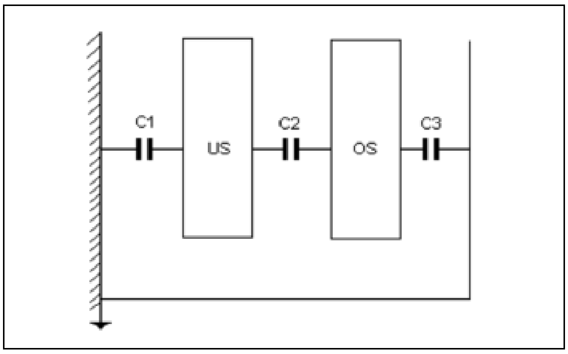
12.3. Example test certificate determination of the capacity of the windings against earth and between the windings as well as loss factors (tan δ)

special tests

(according to Standard: IEC 60076-1:2011)

SGB order number:	123456789/10	Serial-number:	123456
Type:	DTTH1NG 3150/30	Wd. number:	123456

Determination of the capacity of the windings against earth and between the windings as well as loss factors (tan δ)



Temperature [°C]:	22,8
Humidity [%]:	33,9
Air-pressure [hPa]:	970,2
Frequency [Hz]:	50,0

Measurement carried out in Protection IP00

Example pictures and schematics refer to a standard transformer. Deviations from the actual product may be possible.

	at Testing voltage				
	Voltage [kV]:	Currents [mA]:	Losses [W]:	tg d. [%]:	Cx [pF]:
C3	10,0	3,520		0,018	1119,8
C2	10,0	0,758		0,212	234,0
C1	2,4	1,464		0,075	1935,3

more information?
see general test description

Remarks:

,
Tested by, Date of test

10 / 13
page

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

12.4. Example test certificate Insulation resistance

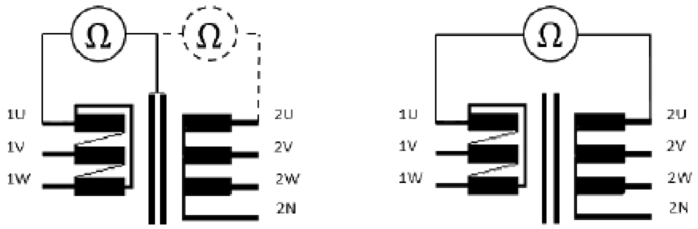
Routine testing

(according to Standard IEC 60076-11:2018)

SGB order number:	123456789/10	Serial-number:	123456
Type:	DTTH1NG 3150/30	Wd. number:	123456

Insulation resistance

		min:	Test passed
bolts / earth || Testing voltage 0,5kV DC	> 2 GΩ	≥ 1 MΩ	✓
HV / earth || Testing voltage 2,5kV DC	5 GΩ	≥ 31,0 MΩ	✓
LV / earth || Testing voltage 2,5kV DC	5 GΩ	≥ 1,7 MΩ	✓



Example pictures and schematics refer to a standard transformer. Deviations from the actual product may be possible.

Remarks

Measurement carried out in Protection IP00

,
Tested by, Date of test

3 / 13
page

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

12.5. Example test certificate SFRA

special tests

(according to Standard: IEC 60076-16:2011)

SGB order number:	123456789/10	Serial-number:	123456
Type:	DTTH1NG 3150/30	Wd. number:	123456

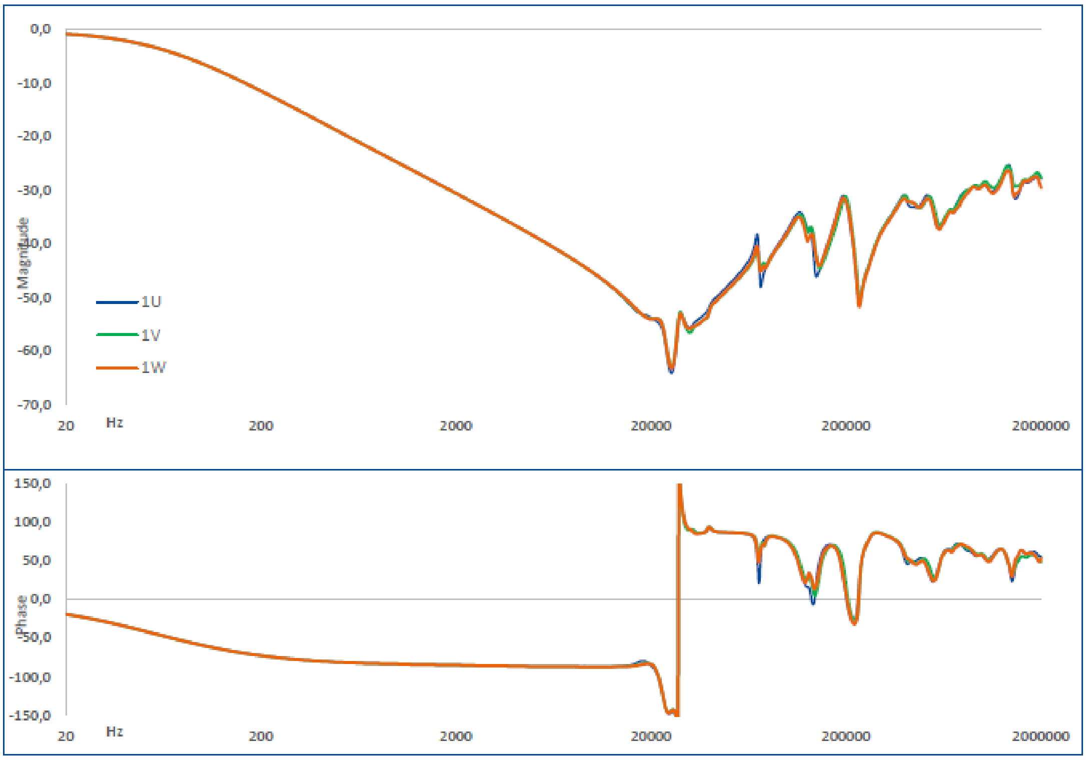
Sweep Frequency Response Analysis (SFRA)

Measurement carried out in Protection IP00   Measurement in tap:3

Measurement device bandwidth 20Hz - 2MHz | Points / Sweep: 1000 | Input Imedance 50Ω

Measuring circuit

	red/yellow-cable	blue-cable	short-circuit	earth	highest resonance [Hz]
connection	1U	1V-1W	2U-2V-2W	2N	227.585
	1V	1U-1W	2U-2V-2W	2N	230.094
	1W	1U-1V	2U-2V-2W	2N	230.094



Remarks:

more information?
see general test description

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

,
Tested by, Date of test

11 / 13
page

Note: Omicron FRAnalyzer software (freeware) is required to open the raw data file.

12.6. Example test certificate zero sequence impedance

special tests

(according to Standard: IEC 60076-1:2011)

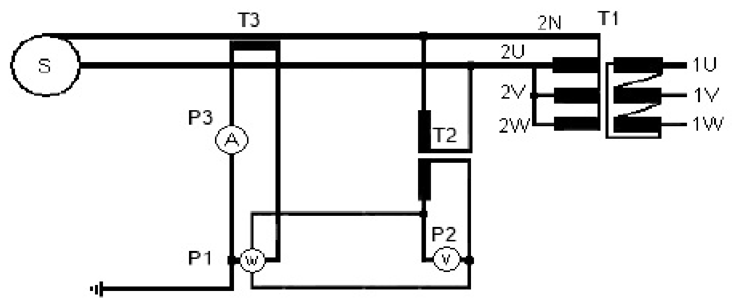
SGB order number:	123456789/10	Serial-number:	123456
Type:	DTTH1NG 3150/30	Wd. number:	123456

Measurement of zero sequence impedance

Measurement carried out in Protection IP00

Measurement of zero sequence impedance LV

Voltage [V]:	1,982
Currents [A]:	441,9
Losses [W]:	58,30
Zo [Ω/ Phase]:	**0,01345546**



Example pictures and schematics refer to a standard transformer. Deviations from the actual product may be possible.

more information?
see general test description

Remarks:

12.7. Example test certificate Measurement of harmonics of the no-load current in % of fundamental components

special tests

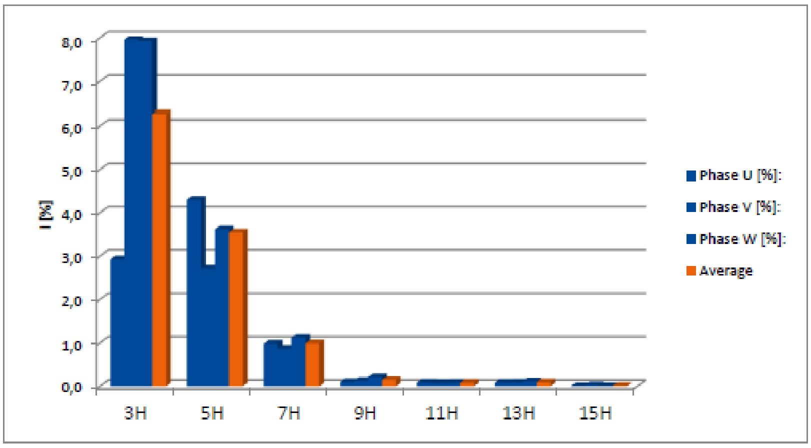
(according to Standard: IEC 60076-1:2000)

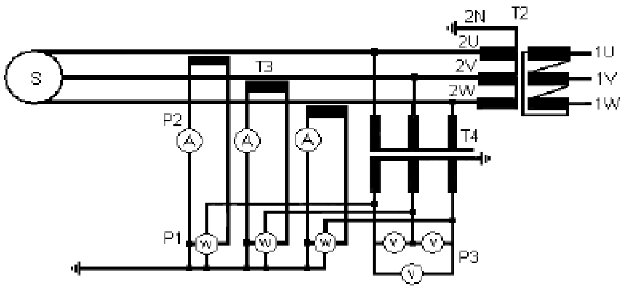
SGB order number:	123456789/10	Serial-number:	123456
Type:	DTTH1NG 3150/30	Wd. number:	123456

Measurement of harmonics of the no-load current in % of fundamental components

connection LV 1009,16 V & Frequency 50,0 Hz / Protection IP00

	Phase U [%]:	Phase V [%]:	Phase W [%]:	Average
3H	2,9	8,0	7,9	6,3
5H	4,3	2,7	3,6	3,5
7H	1,0	0,9	1,1	1,0
9H	0,1	0,1	0,2	0,1
11H	0,1	0,1	0,1	0,1
13H	0,1	0,1	0,1	0,1
15H	0,0	0,0	0,0	0,0





Example pictures and schematics refer to a standard transformer. Deviations from the actual product may be possible.

more information?
see general test description

Remarks:

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

12.8. Example test certificate Measurement of partial discharge with earth

special tests

(according to Standard: IEC 60076-11:2018)

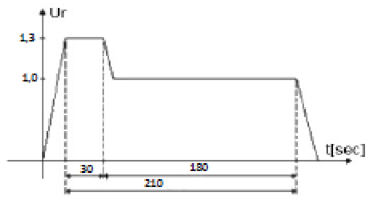
SGB order number:	123456789/10	Serial-number:	123456
Type:	DTTH1NG 3150/30	Wd. number:	123456

Measurement of partial discharge with earth

Testing voltage

Frequency 200 Hz

30 sec.	[kV]	180 sec.	[kV]
1,3 * UrHV	39,00	1,0 * UrHV	30,00
1,3 * UrLV	0,897	1,0 * UrLV	0,690

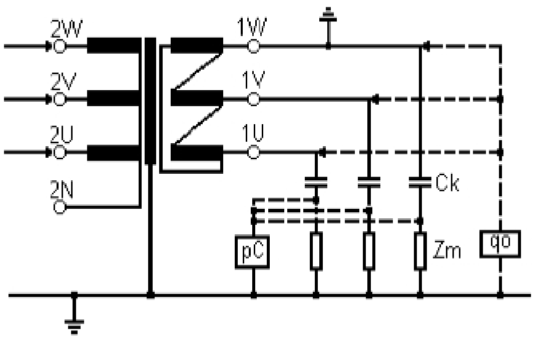


Test results in pC:

Testing voltage	1U / earth		1V / earth		1W / earth	
	1V	1W	1U	1W	1U	1V
1 * Ur	3	2	2	2	2	2
Background level	1	1	1	1	1	1

Measuring circuit

Measurement in tap:	3 | 30 kV
Calibration factor Kü (qo/q):	3,12
Measurement device bandwidth [kHz]:	100-400



Example pictures and schematics refer to a standard transformer. Deviations from the actual product may be possible.

more information?
see general test description

Remarks:

PD max. 10 pC at 1 x Rated voltage

12.9. Example calibration list

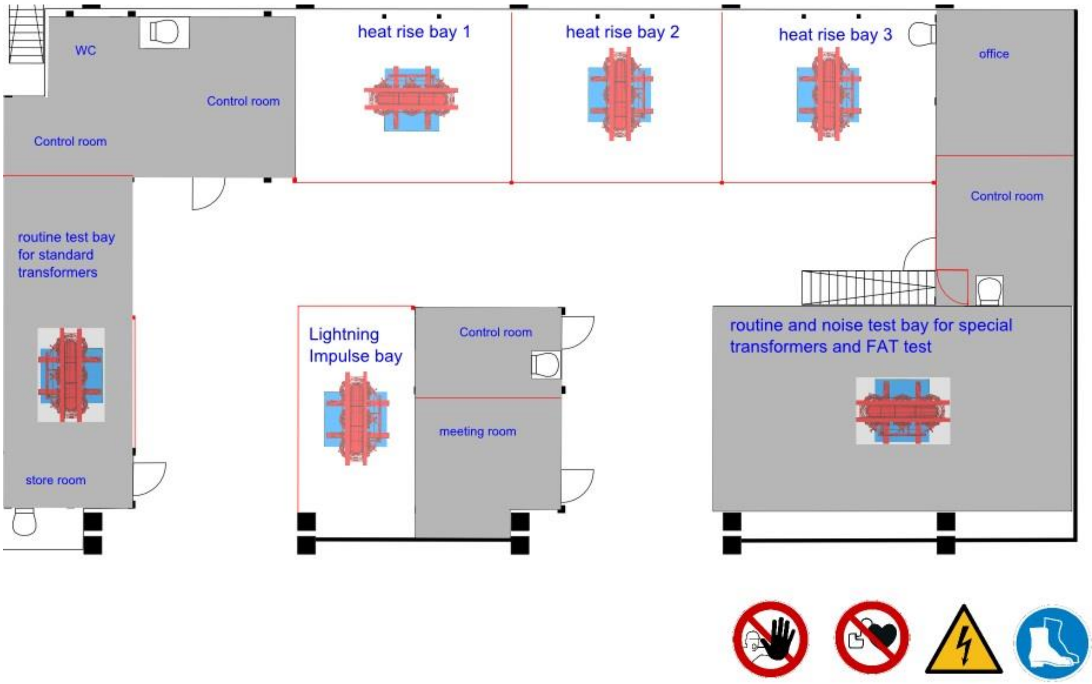
Kalibrierung von Meßgeräten im GTP
Calibration of measuring equipment in test field distr. transformer

Meßgeräte	Measuring devices	Hersteller Manufactur	Typ type	F.-Nr.: Ser.-No.:	Meßbereich Range	Frequenz frequency	Klasse class	Standort location	Letzte Kalibrierung Calibration	Nächste Kal. Next cal.	STATUS	Kalibrierungsart
HS-Span.-Wandler	HV-voltage-transf.	epro	NVRD 40	2/06/5855	2-40 kV/100V	50/60 Hz	0,02	Routine	23.12.2013	Dez 2016	In Ordnung	ÖKD
HS-Span.-Wandler	HV-voltage-transf.	epro	NVRD 40	2/06/5856	2-40 kV/100V	50/60 Hz	0,02	Routine	23.12.2013	Dez 2016	In Ordnung	ÖKD
HS-Span.-Wandler	HV-voltage-transf.	epro	NVRD 40	2/06/5857	2-40 kV/100V	50/60 Hz	0,02	Routine	23.12.2013	Dez 2016	In Ordnung	ÖKD
HS-Strom-Wandler	HV-current-transf.	epro	NCO 60	2/06/5847	5-600 A/5 A	50/60 Hz	0,01	Routine	27.12.2013	Dez 2016	In Ordnung	ÖKD
HS-Strom-Wandler	HV-current-transf.	epro	NCO 60	2/06/5848	5-600 A/5 A	50/60 Hz	0,01	Routine	27.12.2013	Dez 2016	In Ordnung	ÖKD
HS-Strom-Wandler	HV-current-transf.	epro	NCO 60	2/06/5850	5-600 A/5 A	50/60 Hz	0,01	Routine	27.12.2013	Dez 2016	In Ordnung	ÖKD
NS-Strom-Wandler	LV-current-transf.	H&B	TI 48	B1 K 163	2,5-500 A/5 A	50/60 Hz	0,1	Routine	23.12.2013	Dez 2016	In Ordnung	ÖKD
NS-Strom-Wandler	LV-current-transf.	H&B	TI 48	B1 K 164	2,5-500 A/5 A	50/60 Hz	0,1	Routine	23.12.2013	Dez 2016	In Ordnung	ÖKD
NS-Strom-Wandler	LV-current-transf.	H&B	TI 48	B1 K 165	2,5-500 A/5 A	50/60 Hz	0,1	Routine	23.12.2013	Dez 2016	In Ordnung	ÖKD
HS-Span.-Wandler	HV-voltage-transf.	epro	NVOS 30	2/06/5343	2-20 kV/100V	50/60 Hz	0,02	Schallmessraum,Noise & PD	23.12.2013	Dez 2016	In Ordnung	ÖKD
HS-Span.-Wandler	HV-voltage-transf.	epro	NVOS 30	2/06/5345	2-20 kV/100V	50/60 Hz	0,02	Schallmessraum,Noise & PD	23.12.2013	Dez 2016	In Ordnung	ÖKD
HS-Span.-Wandler	HV-voltage-transf.	epro	NVOS 30	2/06/5346	2-20 kV/100V	50/60 Hz	0,02	Schallmessraum,Noise & PD	23.12.2013	Dez 2016	In Ordnung	ÖKD
HS-Strom-Wandler	HV-current-transf.	epro	NCO 30	2/06/5339	5-50 A/5 A	50/60 Hz	0,01	Schallmessraum,Noise & PD	27.12.2013	Dez 2016	In Ordnung	ÖKD
HS-Strom-Wandler	HV-current-transf.	epro	NCO 30	2/06/5340	5-50 A/5 A	50/60 Hz	0,01	Schallmessraum,Noise & PD	27.12.2013	Dez 2016	In Ordnung	ÖKD
HS-Strom-Wandler	HV-current-transf.	epro	NCO 30	2/06/5341	5-50 A/5 A	50/60 Hz	0,01	Schallmessraum,Noise & PD	27.12.2013	Dez 2016	In Ordnung	ÖKD
HS-Span.-Wandler	HV-voltage-transf.	MWB	NUZG 35	73/485997	3-35 kV/100V	50/60 Hz	0,005	Wärmelauf, Heat Rise 1+2	09.10.2013	Okt 2016	In Ordnung	ÖKD
HS-Span.-Wandler	HV-voltage-transf.	MWB	NUZG 35	73/485998	3-35 kV/100V	50/60 Hz	0,005	Wärmelauf, Heat Rise 1+2	09.10.2013	Okt 2016	In Ordnung	ÖKD
HS-Span.-Wandler	HV-voltage-transf.	MWB	NUZG 35	73/485999	3-35 kV/100V	50/60 Hz	0,005	Wärmelauf, Heat Rise 1+2	14.10.2013	Okt 2016	In Ordnung	ÖKD
HS-Strom-Wandler	HV-current-transf.	MWB	VJO 60	04/220564	5-600 A/5 A	50/60 Hz	0,05	Wärmelauf, Heat Rise 1+2	07.10.2013	Okt 2016	In Ordnung	ÖKD
HS-Strom-Wandler	HV-current-transf.	MWB	VJO 60	04/220563	5-600 A/5 A	50/60 Hz	0,05	Wärmelauf, Heat Rise 1+2	07.10.2013	Okt 2016	In Ordnung	ÖKD
HS-Strom-Wandler	HV-current-transf.	RITZ	NOSW 60 M	806006	5-600 A/5 A	50/60 Hz	0,05	Wärmelauf, Heat Rise 1+2	07.10.2013	Okt 2016	In Ordnung	ÖKD
NS-Strom-Wandler	LV-current-transf.	H&B	TI 48aS	6003181	2,5-250 A/5 A	50/60 Hz	0,1	Wärmelauf, Heat Rise 1+2	17.09.2013	Sep 2016	In Ordnung	ÖKD
NS-Strom-Wandler	LV-current-transf.	H&B	TI 48	6712115	2,5-250 A/5 A	50/60 Hz	0,1	Wärmelauf, Heat Rise 1+2	17.09.2013	Sep 2016	In Ordnung	ÖKD
NS-Strom-Wandler	LV-current-transf.	H&B	TI 48aS	6003182	2,5-250 A/5 A	50/60 Hz	0,1	Wärmelauf, Heat Rise 1+2	17.09.2013	Sep 2016	In Ordnung	ÖKD
NS-Strom-Wandler	LV-current-transf.	RITZ	KSW 73	50943038	100A/5A	50/60 Hz	0,2	Wärmelauf, Heat Rise 1+2	29.01.2015	Jan 2018	In Ordnung	Werkskalibrierung
NS-Strom-Wandler	LV-current-transf.	RITZ	KSW 73	50943039	100A/5A	50/60 Hz	0,2	Wärmelauf, Heat Rise 1+2	29.01.2015	Jan 2018	In Ordnung	Werkskalibrierung
NS-Strom-Wandler	LV-current-transf.	RITZ	KSW 73	50943040	100A/5A	50/60 Hz	0,2	Wärmelauf, Heat Rise 1+2	29.01.2015	Jan 2018	In Ordnung	Werkskalibrierung
HS-Span.-Wandler	HV-voltage-transf.	epro	NVRD 40	2/06/5858	2-40 kV/100V	50/60 Hz	0,02	Wärmelauf, Heat Rise 3+4	23.12.2013	Dez 2016	In Ordnung	ÖKD
HS-Span.-Wandler	HV-voltage-transf.	epro	NVRD 40	2/06/5853	2-40 kV/100V	50/60 Hz	0,02	Wärmelauf, Heat Rise 3+4	23.12.2013	Dez 2016	In Ordnung	ÖKD
HS-Span.-Wandler	HV-voltage-transf.	epro	NVRD 40	2/06/5854	2-40 kV/100V	50/60 Hz	0,02	Wärmelauf, Heat Rise 3+4	23.12.2013	Dez 2016	In Ordnung	ÖKD
HS-Strom-Wandler	HV-current-transf.	epro	NCO 60	2/06/5852	5-600 A/5 A	50/60 Hz	0,01	Wärmelauf, Heat Rise 3+4	27.12.2013	Dez 2016	In Ordnung	ÖKD
HS-Strom-Wandler	HV-current-transf.	epro	NCO 60	2/06/5849	5-600 A/5 A	50/60 Hz	0,01	Wärmelauf, Heat Rise 3+4	27.12.2013	Dez 2016	In Ordnung	ÖKD
HS-Strom-Wandler	HV-current-transf.	epro	NCO 60	2/06/5851	5-600 A/5 A	50/60 Hz	0,01	Wärmelauf, Heat Rise 3+4	27.12.2013	Dez 2016	In Ordnung	ÖKD
NS-Strom-Wandler	LV-current-transf.	epro	NCD 3000d	2/01/2152	10 - 3000 A	50/60 Hz	0,1	Wärmelauf, Heat Rise 3+4	01.10.2013	Okt 2016	In Ordnung	ÖKD
NS-Strom-Wandler	LV-current-transf.	epro	NCD 3000d	2/01/2153	10 - 3000 A	50/60 Hz	0,1	Wärmelauf, Heat Rise 3+4	01.10.2013	Okt 2016	In Ordnung	ÖKD
NS-Strom-Wandler	LV-current-transf.	epro	NCD 3000d	2/01/2154	10 - 3000 A	50/60 Hz	0,1	Wärmelauf, Heat Rise 3+4	01.10.2013	Okt 2016	In Ordnung	ÖKD
NS-Strom-Wandler	LV-current-transf.	RITZ	KSW 73	50943041	150A/5A	50/60 Hz	0,2	Wärmelauf, Heat Rise 3+4	29.01.2015	Jan 2018	In Ordnung	Werkskalibrierung
NS-Strom-Wandler	LV-current-transf.	RITZ	KSW 73	50943042	150A/5A	50/60 Hz	0,2	Wärmelauf, Heat Rise 3+4	29.01.2015	Jan 2018	In Ordnung	Werkskalibrierung
NS-Strom-Wandler	LV-current-transf.	RITZ	KSW 73	50943043	150A/5A	50/60 Hz	0,2	Wärmelauf, Heat Rise 3+4	29.01.2015	Jan 2018	In Ordnung	Werkskalibrierung
NS-Strom-Wandler	LV-current-transf.	H&B	TI 48a	6201965	2-2500 A/5 A	50/60 Hz	0,1	Messgerätschrank	05.09.2013	Sep 2016	In Ordnung	ÖKD
NS-Strom-Wandler	LV-current-transf.	H&B	TI 48a	6200551	2-2500 A/5 A	50/60 Hz	0,1	Messgerätschrank	05.09.2013	Sep 2016	In Ordnung	ÖKD
NS-Strom-Wandler	LV-current-transf.	H&B	TI 48a	5710365	2-2500 A/5 A	50/60 Hz	0,1	Messgerätschrank	06.09.2013	Sep 2016	In Ordnung	ÖKD
NS-Strom-Wandler	LV-current-transf.	GOSSEN	StW2	PT 26	5-800 A/5 A	50 Hz	0,2	Messgerätschrank	16.09.2013	Sep 2016	In Ordnung	DKD
NS-Strom-Wandler	LV-current-transf.	GOSSEN	StW2	PT 212	5-800 A/5 A	50 Hz	0,2	Messgerätschrank	16.09.2013	Sep 2016	In Ordnung	DKD
NS-Strom-Wandler	LV-current-transf.	GOSSEN	StW2	PT 258	5-800 A/5 A	50 Hz	0,2	Messgerätschrank	16.09.2013	Sep 2016	In Ordnung	DKD
Schallpegelkalibrator	Acoustical Calibrator	B&K	4231	2229872	94,0 dB	1000 Hz	1	Schallmessraum,Noise & PD	03.11.2015	Nov 2016	In Ordnung	DKD
Schwingungskalibrator	Calibrator	B&K	4294	2481776	10ms-2/10mms/10um	159,2 Hz	–	Messgerätschrank	15.04.2016	Apr 2017	In Ordnung	DKD
Isolationsmeßgerät	Ins. resist. - meter	GOSSEN	Metriso 5000	PT 1104	0-20000 MOhm	DC	1,5	Routine	08.01.2016	Jan 2017	In Ordnung	DKD
Isolationsmeßgerät	Ins. resist. - meter	GOSSEN	Metriso 5000 A	UP831	10 k Ohm - 1 TOhm	DC	2	Messgerätschrank	08.03.2016	Mrz 2017	In Ordnung	DKD
Hochspannungsprüfer	High Voltage Tester	ETL Prüftechnik	UH28A	0002001SP500143	5 kV/100 mA	50 Hz	1,5	Wagen für Vorprüfungen	15.02.2016	Feb 2017	In Ordnung	DKD
Hochspannungsprüfer	High Voltage Tester	ETL Prüftechnik	UH28C	2.000698E+13	5 kV/100 mA	50-60 Hz	1,5	Routine	08.01.2016	Jan 2017	In Ordnung	DKD
Multimeter	Multimeter	FLUKE	Fluke-87-V	92650143	1000V/10A	50-60 Hz	0,1-1,0	Routine	07.01.2016	Jan 2017	In Ordnung	DKD
Multimeter	Multimeter	FLUKE	Fluke-87-V	28150413	1000V/10A	50-60 Hz	0,1-1,0	Wärmelauf, Heat Rise, allgemein	09.02.2016	Feb 2017	In Ordnung	DKD
Multimeter	Multimeter	FLUKE	Fluke-87-V	20070206	1000V/10A	50-60 Hz	0,1-1,0	Wagen für Vorprüfungen	07.11.2015	Nov 2016	In Ordnung	DKD
Multimeter	Multimeter	GOSSEN	Metrahit18S	M439110	1000 V/10 A	50-60 Hz	0,05-0,5	Endkontrolle	20.03.2014	Mrz 2017	In Ordnung	DKD
Druck/Termo/Barometer	Hygro-/Thermo-/Barometer	Greisinger electronic	GFTB 200	34907549	-50-100°C 0% - 100% Rel. Luftfeuchte 10,0 - 1100,0 hPa			Stosspannungsplatz	25.01.2016	Jan 2017	In Ordnung	Werkskalibrierung
Feuchtemessgerät	Hygro-/Thermometer	Greisinger electronic	GFTH95	000355-01	0-70 °C 10-95% r. F.			Routine	07.01.2016	Jan 2017	In Ordnung	DKD
Digitalthermometer	Digitalthermometer	Greisinger electronic	GTH175	GT-P-123	-199,9 - 199,9°C	–	0,1	Wagen für Vorprüfungen	15.02.2016	Feb 2017	In Ordnung	DKD
Übersetzungsmessgerät	Transfomer Turns Ratio Meter	HAEFELY / Tettex	TTR 2796	176930	0,8 - 20000 ±0,08% - ±0,15%	50/60 Hz	0,05	Wärmelauf, Heat Rise 3+4	17.03.2016	Mrz 2017	In Ordnung	KEMA
Übersetzungsmessgerät	Transfomer Turns Ratio Meter	HAEFELY / Tettex	TTR 2796	177496	0,8 - 20000 ±0,08% - ±0,15%	50/60 Hz	0,05	Wärmelauf, Heat Rise 1+2	11.05.2016	Mai 2017	In Ordnung	KEMA
Wicklungsanalysator	Winding Analyser	HAEFELY / Tettex	WA 2293	179742	siehe Zertifikat	50/60 Hz	siehe Zertifikat	Routine	24.09.2015	Sep 2016	In Ordnung	KEMA
Wicklungsanalysator	Winding Analyser	HAEFELY / Tettex	WA 2293	182721	siehe Zertifikat	50/60 Hz	siehe Zertifikat	Wagen für Vorprüfungen	14.01.2016	Jan 2017	In Ordnung	Werkskalibrierung
Wicklungsohmmeter	Micro Ohmmeter	IBEKO Power AB - DV Power	RMO40T	15RP418		DC	0,2	Wärmelauf, Heat Rise 1+2	29.03.2016	Mrz 2017	In Ordnung	DKD
Wicklungsohmmeter	Micro Ohmmeter	IBEKO Power AB - DV Power	RMO40T	15RP428		DC	0,2	Wärmelauf, Heat Rise 1+2	28.10.2015	Okt 2016	In Ordnung	Werkskalibrierung
Wicklungsohmmeter	Micro Ohmmeter	IBEKO Power AB - DV Power	RMO40T	15RP438		DC	0,2	Wärmelauf, Heat Rise 1+2	04.03.2016	Mrz 2017	In Ordnung	DKD
Wicklungsohmmeter	Micro Ohmmeter	IBEKO Power AB - DV Power	RMO60T	2985778	0,1 µOhm - 2000 Ohm	DC	0,2	Wärmelauf, Heat Rise 3+4	12.01.2016	Jan 2017	In Ordnung	DKD
Wicklungsohmmeter	Micro Ohmmeter	IBEKO Power AB - DV Power	RMO60T	2985748	0,1 µOhm - 2000 Ohm	DC	0,2	Wärmelauf, Heat Rise 3+4	01.02.2016	Feb 2017	In Ordnung	DKD
Wicklungsohmmeter	Micro Ohmmeter	IBEKO Power AB - DV Power	RMO60T	2985758	0,1 µOhm - 2000 Ohm	DC	0,2	Wärmelauf, Heat Rise 3+4	12.01.2016	Jan 2017	In Ordnung	DKD
Wicklungsohmmeter	Micro Ohmmeter	IBEKO Power AB - DV Power	RMO60T	1281058	0,1 µOhm - 2000 Ohm	DC	0,2	Wagen für Vorprüfungen	28.05.2015	Mai 2016	In Ordnung	DKD
Wicklungsohmmeter	Micro Ohmmeter	TINSLEY	5895	275981	0,1µOhm-180 Ohm	DC	0,1	Testarbeitsplatz fahrbar	22.05.2015	Mai 2016	In Ordnung	DKD
Wicklungsohmmeter	Micro Ohmmeter	TINSLEY	5895	275904	0,1µOhm-180 Ohm	DC	0,1	Routine	11.12.2015	Dez 2016	In Ordnung	DKD
Universalmeßgerät	universal measuring instrument	Omicron	CPC 100 CP TD1 CP SB1	ID015Y NF216V HG812W	siehe Zertifikat	siehe Zertifikat	siehe Zertifikat	Messgerätschrank	25.08.2015	Aug 2016	In Ordnung	Werkskalibrierung
TE-Kalibrator	PD-Calibrator	Omicron	CAL 542 Version B	HH529D	1 - 100 pC	300 Hz	–	Schallmessraum,Noise & PD	31.07.2015	Jul 2016	In Ordnung	Werkskalibrierung
TE-Kalibrator	PD-Calibrator	MPS	TPK	200095	5-500 pC	100 Hz	–	Schallmessraum,Noise & PD	07.09.2015	Sep 2016	In Ordnung	Werkskalibrierung
TE-Kalibrator	PD-Calibrator	MPS	TPK	215116	5-50 0pC	100 Hz	–	Schallmessraum,Noise & PD	07.09.2015	Sep 2016	In Ordnung	Werkskalibrierung
Scheitelspannungsmessgerät Messkondensator	Peak voltage meter Measuring capacitor	MPS MPS	SMG MC200	211117 211165	200 kV 200 kV	50/60 Hz 50/60 Hz	2,0	Wärmelauf, Heat Rise 3+4	26.10.2015	Okt 2016	In Ordnung	Vor Ort Kalibrierung
Scheitelspannungsmessgerät Messkondensator	Peak voltage meter Measuring capacitor	MPS MWB	SMG CM80	211158 88 336426	100 kV 80 kV	50/60 Hz 50/60 Hz	2,0	Routine	26.10.2015	Okt 2016	In Ordnung	Vor Ort Kalibrierung
Datenerfassungssystem	Data Acquisition Unit	YOKOGAWA	DA100-13-1F 2x DU100-12 DT300-11	91L818637 91L537210 / 91L537214 91MC19216	0-250°C		0,1K	Wärmelauf, Heat Rise 1	11.01.2016	Jan 2017	In Ordnung	DKD
Datenerfassungssystem	Data Acquisition Unit	YOKOGAWA	DA100-13-1F 2x DU100-12 DT300-11	91L818638 91L339418 / 91L339417 91L339413	0-250°C		0,1K	Wärmelauf, Heat Rise 2	11.01.2016	Jan 2017	In Ordnung	DKD
Datenerfassungssystem	Data Acquisition Unit	YOKOGAWA	DA100-13-1F 2x DU100-12 DT300-11	12A526584 12A418884 / 12A418881 12A424348	0-250°C		0,1K	Wärmelauf, Heat Rise 3	14.01.2015	Jan 2016	In Ordnung	DKD
Datenerfassungssystem	Data Acquisition Unit	YOKOGAWA	DA100-13-1F 2x DU100-12 DT300-11	91L339416 91L537213 / 91L537212 91MC19217	0-250°C		0,1K	Wärmelauf, Heat Rise 4	07.01.2016	Jan 2017	In Ordnung	DKD
Bildschirmschreiber	Temperature recorder	JUMO	Logoscreen nt	10230002				Wärmelauf, Heat Rise, allgemein	07.12.2015	Dez 2016	In Ordnung	DKD
Präzisions-Leistungs-Messgerät	Digital-powermeter	ZIMMER	LMG 500	02910810	U rms 1000 V / I rms 32 A U pk 3200 V / I pk 120 A	DC - 10 MHz	0,05-0,03	Wärmelauf, Heat Rise 4	05.01.2016	Jan 2017	In Ordnung	DKD
Präzisions-Leistungs-Messgerät	Precision Power Analyzer	ZIMMER	LMG 500	12471508	U rms 1000 V / I rms 32 A U pk 3200 V / I pk 120 A	DC - 10 MHz	0,05-0,03	Schallmessraum,Noise & PD	06.08.2015	Aug 2016	In Ordnung	Werkskalibrierung
Präzisions-Leistungs-Messgerät	Precision Power Analyzer	ZIMMER	LMG 500	12881605	U rms 1000 V / I rms 32 A U pk 3200 V / I pk 120 A	DC - 10 MHz	0,05-0,03	Routine	19.05.2016	Mai 2017	In Ordnung	Werkskalibrierung
Präzisions-Leistungs-Messgerät	Precision Power Analyzer	ZIMMER	LMG 500	12891605	U rms 1000 V / I rms 32 A U pk 3200 V / I pk 120 A	DC - 10 MHz	0,05-0,03	Wärmelauf, Heat Rise 1	18.05.2016	Mai 2017	In Ordnung	Werkskalibrierung
Präzisions-Leistungs-Messgerät	Precision Power Analyzer	ZIMMER	LMG 500	02920810	U rms 1000 V / I rms 32 A U pk 3200 V / I pk 120 A	DC - 10 MHz	0,05-0,03	Wärmelauf, Heat Rise 3	07.01.2016	Jan 2017	In Ordnung	DKD
Präzisions-Leistungs-Messgerät	Precision Power Analyzer	ZIMMER	LMG 500	02920806	U rms 1000 V / I rms 32 A U pk 3200 V / I pk 120 A	DC - 10 MHz	0,05-0,03	Messgerätschrank	05.05.2015	Mai 2016	In Ordnung	DKD
Präzisions-Leistungs-Messgerät	Precision Power Analyzer	ZIMMER	LMG 310	80703497	U rms 1000 V / I rms 30 A U pk 2000 V / I pk 60 A	DC - 1 MHz	0,05	Messgerätschrank	05.03.2015	Mrz 2016	In Ordnung	DKD
Präzisions-Leistungs-Messgerät	Precision Power Analyzer	ZIMMER	LMG 310	80104401	U rms 1000 V / I rms 30 A U pk 2000 V / I pk 60 A	DC - 1 MHz	0,05	Wärmelauf, Heat Rise 2	16.02.2016	Feb 2017	In Ordnung	DKD
Stoßspannungsmesssystem	Imp. voltage test system	High Volt	SMC 2000-400 MIAS 100-14-2B	924761 906223 905843	10 - 400 kV 20 kJ			Stosspannungsplatz	27.10.2015	Okt 2016	In Ordnung	Vor Ort Kalibrierung
Frequenzanalysator	FRANALYZER	OMICRON	FRANALYZER	JK914L	5Hz-2MHz	5Hz-2MHz		Messgerätschrank	17.07.2015	Jul 2016	In Ordnung	DKD

calibration list SGB cast resin Regensburg 15.07.2016

page 1

12.10. Test lab layout



picture 23: test lab layout

picture 24: routine and heat rise bays

picture 25: PD and sound chamber

12.11. List of pictures, formulas, tables and sources

LIST OF PICTURES:

LIST OF FORMULAS:

LIST OF TABLES:

list of sources:

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