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1. Scope

This is a general test description for cast-resin and dry-type transformers. Special costumer standards or values are not included. If not indicated, the description is for a two-winding transformer. Auxiliary parts of the transformer are also not included, except as indicated e.g. temperature sensors.

The scope of this chapter describes “routine” tests, this means the standard requires these tests on each transformer.
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 60076-16:2011 Transformers for wind turbine application
IEC 60076-19:2013 Determination of uncertainties in the measurements of losses
IEC 60270:2000 High voltage test techniques – Partial discharge measurements
EN 50588-1:2015 Medium power transformers 50 Hz, with highest voltage for equipment not exceeding 36 kV – General requirements
EN 50629:2015 Energy performance of large power transformers (Um > 36 kV or Sr ≥ 40 MVA)

Others:
Regulation EC No. 548/2014 of 21 May 2014 to implement the EC Directive 2009/125/EC
3. Separate-source AC withstand voltage test

3.1. Standard
IEC 60076-11:2018 clause 14.2.5 // part 3 clause 10

3.2. Aim
This insulation test ensures that the quality of the insulation between the windings and the earthed parts, core, core clamping, etc. is correct. Furthermore, the constructive coordination is checked.

3.3. Test
The test is applied using AC voltage and is to be carried out with a single phase-AC voltage supply that is as much as possible sinusoidal and does not fall below 80% of the rated frequency. The full test voltage has to be applied for 60s between all connected windings and auxiliary wirings. All other terminals and the core of the transformer, including the temperature sensors, will be shorted and grounded.

The test level complies with IEC 60076-11:2018 (clause 11.1, table 3). If the transformer has an installation altitude higher than 1000m, the test level shall be corrected according to IEC 60076-11:2018 (clause 11.2, table 4). For auxiliary wiring the test level is 2 kV.

3.3.1. Tapping position for test
During the test, all windings are shorted. Therefore, the tapping position is of no consequence. Usually it is the tapping position with the highest turns (tap 1).

3.3.2. Test setup

![Diagram](picture 1: test setup for separate-source AC withstand voltage test)

- **S**: electricity supply
- **T1**: high voltage transformer
- **T2**: transformer to be tested
- **E**: voltage divider
- **P1**: peak volt meter
- **P2**: ampere meter (measurement shunt)
3.3.3. Commonly used measuring devices for testing

<table>
<thead>
<tr>
<th>measuring devices</th>
<th>manufacturer</th>
<th>type</th>
<th>range / accuracy</th>
<th>frequency</th>
<th>class</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Voltage Tester</td>
<td>ETL Prüftechnik</td>
<td>UH28C</td>
<td>5 kV/100 mA</td>
<td>50-60 Hz</td>
<td>n.a.</td>
</tr>
<tr>
<td>Hygro-/Thermometer</td>
<td>Greisinger electronic</td>
<td>GFTH95</td>
<td>0-70 °C 10-95% r.F.</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td>Peak voltage meter</td>
<td>MPS</td>
<td>SMG CM80</td>
<td>100 kV 80 kV</td>
<td>50/60 Hz</td>
<td>n.a.</td>
</tr>
<tr>
<td>Measuring capacitor</td>
<td>MPS</td>
<td>SMG MK200</td>
<td>200 kV 200 kV</td>
<td>50/60 Hz</td>
<td>n.a.</td>
</tr>
</tbody>
</table>

*table 1: Commonly used measuring devices*

3.4. Recorded values for the test

The test voltage, test frequency and test duration are documented in the test certificate.

3.4. Test criteria

The test is passed if no break down of the test voltage occurs.
4. Measurement of voltage ratio and check of phase displacement

4.1. Standard

IEC 60076-11:2018 clause 14.2.2 // part 1 clause 11.3

4.2. Aim

- Checking voltage ratio “ü” from HV to LV
- Determining deviations from the measured data to the desired values and documenting them
- Proving polarity as well as vector group

4.3. Theoretical principal

Firstly, the desired value for the single-phase translation is determined. Additionally, the voltage is being converted phase to phase in the phase voltage and the HV phase voltage is being divided by the LV phase voltage.

On a Dyn (10kV/400 V) circuit e.g.

\[ \bar{U} = \frac{U_1}{U_2/\sqrt{3}} = \frac{10\text{kV}}{400/\sqrt{3}} = 43.30 \]

\[ \bar{U} = \frac{N_1}{N_2} = \frac{U_1}{U_2} = \frac{I_2}{I_1} \]

\[ N_1 = \text{number of windings primary side}, \quad N_2 = \text{number of windings secondary side} \]

*formula 1: Voltage ratio formula for transformers*

Afterwards the connections for the single-phase measurement will have to be determined. This is mandatory to prove the accuracy of the polarity and the vector group. To do that the phase angle will be determined via the characteristic number of the group vector.

On a Dyn5 e.g.

\[ \varphi = 5 \times 30^\circ = 150^\circ \]

This means that each phase of the LV winding is shifted 150° clockwise from the phase of the HV.

If you now draw a vector diagram with the circuits, it is possible to find two parallel vectors. In this case 1U-1V to 2N-2U. So, if it is measured in single phase, the phase deviation has to be 0°. If this applies the correct vector group is proven.

On certain circuits an additional theoretic, artificial neutral point has to be created.
4.4. Measurement

The measurement of the voltage ratio in proportion to “ü” and of the phase angle \( \phi \) is conducted via a voltage ratio measurement bridge.

Via a measurement program the direct aberration is shown from the desired values of the voltage ratio and of the vector group, respectively the phase angles.

The measurement is conducted with a voltage between 10V - 230V AC (depending on the bridge), in single phase. In the process, the HV winding is fed, which leads to the induction of voltage in the LV winding. This voltage is measured and is compared with the fed voltage. The result is compared with the desired values and the difference in percentage is displayed. Through measuring between phase to phase or between a phase and the neutral point, the phase angle will be also controlled.

4.4.1. Tapping position for measurement

Between the measurements, all HV taps are to be measured during this test.

➢ In case of an LV tap, it is necessary to measure the HV nominal tap to the LV tap.

4.4.2. Test setup

![Test setup for the measurement of the voltage ratio](image)

U1: supply voltage of the bridge   U2: secondary voltage transformer being tested
4.4.3. Commonly used measuring devices for measurement

<table>
<thead>
<tr>
<th>measuring devices</th>
<th>manufacturer</th>
<th>type</th>
<th>range / accuracy</th>
<th>frequency</th>
<th>class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transformer Turns Ratio Meter</td>
<td>HAEFELY / Tettex</td>
<td>TTR 2796</td>
<td>Ratio 0.8 - 100 101 - 1.000 1.001 - 1.500 1.501 - 2.000 2.001 - 4.000 4.001 - 13.000 13.001 - 20.000 Phase ± 180° -&gt; ± 0,03% ± 0,05% ± 0,05% ± 0,05% ± 0,15% ± 0,20% ± 0,05° -&gt; ± 0,05°</td>
<td>50/60 Hz</td>
<td>n.a.</td>
</tr>
<tr>
<td>Winding Analyser</td>
<td>HAEFELY / Tettex</td>
<td>WA 2293</td>
<td>Ratio 1.0 - 100 100 - 2.000 20.000 - 100.000 1.0 - 500 500 - 10.000 1.0 - 500 Phase (Ratio) ± 0,25 ° ± 1,00 ° ± 0,05 °</td>
<td>50/60 Hz</td>
<td>n.a.</td>
</tr>
<tr>
<td>universal measuring instrument</td>
<td>Omicron</td>
<td>CPC 100 CP TD1 CP SB1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Table 2: Commonly used measuring devices*

4.4.4. Recorded values for the measurement

All tap settings of the transformer are measured and the results are documented and given in percentage from “ü”.

4.5. Test criteria / Maximum values

The test is not seen as passed if the voltage ratio deviates more than ± 0.5% (or 10% of the short circuit impedance if lower) in principal tapping, from the guaranteed values according to Standard IEC 60076-1 (clause 10 limiting deviation, table 1, section 2).

The customer specified vector group has to be proven.
5. Measurement of the resistance of the windings

5.1. Standard
IEC 60076-11:2018 clause 14.2.1 // part 1 clause 11.2

5.2. Aim
➢ Recognizing poor / faulty contacts
➢ Determining issues / damage in the windings
➢ Resistance data is needed for the calculation of the short-circuit losses at the reference temperature

5.3. Measurement
Before measurement the external cooling medium temperature shall not have change more than 3°C in 3 hours previous to testing.

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

The measurement is conducted either with a resistance measurement bridge 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.

\[ R = \frac{U}{I} \]

R= ohmic resistance  
\( U= \) voltage  
\( I= \) current

*formula 2: ohmic law*

The fed current is about \( \frac{1}{15} \) of the rated current. If the amperage would be too high or would flow for too long, the windings would heat up and falsify the measurements.

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

After the resistance measurement, the induced AC withstand voltage test is carried out. Due to the fact that the core has become saturated because of the use of DC current. The induced AC withstand voltage test counters the saturation and the core is demagnetized (degaussing).
5.3.1. Tapping position for measurement

If the HV tapping range is between ±5% of rated voltage, only the principal tap shall be measured. Otherwise as a typetest, the taps with the highest and lowest number of turns will also measured.

➢ In the case of an LV tap, it is necessary measure the tap.

5.3.2. Test setup

During this measurement, the ohmic resistance (real resistance R) of all windings is measured. It is always measured phase to phase e.g. U–V, U-W, V-W.

The connection for the measurement is usually as close as possible to the winding.
5.3.3. Commonly used measuring devices for measurement

<table>
<thead>
<tr>
<th>measuring devices</th>
<th>manufacturer</th>
<th>type</th>
<th>range / accuracy</th>
<th>frequency</th>
<th>class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micro Ohmmeter</td>
<td>TINSLEY</td>
<td>5895</td>
<td>0,1µΩ - 10µΩ -&gt; 0,2%</td>
<td>DC</td>
<td>n.a.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>10µΩ - 100Ω -&gt; 0,1%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0,1 A - 10 A DC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winding Analyser</td>
<td>HAEFELY / Tettex</td>
<td>WA 2293</td>
<td>0,1µΩ - 300µΩ -&gt; 0,1%±</td>
<td>DC</td>
<td>n.a.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0,5µΩ</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>300,1µΩ - 30kΩ -&gt; 0,1%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>30,01kΩ - 300Ω -&gt; 1%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Micro Ohmmeter</td>
<td>IBEKO Power AB - DV Power</td>
<td>RMO40T</td>
<td>0,1 µΩ - 2kΩ -&gt; ±(0,1% rgd + 0,1% FS)</td>
<td>DC</td>
<td>n.a.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2kΩ - 10kΩ -&gt; ±(0,2% rgd + 0,1% FS)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5mA - 40A DC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Micro Ohmmeter</td>
<td>IBEKO Power AB - DV Power</td>
<td>RMO60T</td>
<td>0,1 µΩ - 2kΩ</td>
<td>DC</td>
<td>n.a.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5mA - 60A DC</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>±(0,2% rgd + 0,2% FS)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>universal measuring instrument</td>
<td>Omicron</td>
<td>CPC 100 CP TD1 CP SB1</td>
<td></td>
<td>DC</td>
<td>n.a.</td>
</tr>
<tr>
<td>Hygro-/Thermometer</td>
<td>Greisinger electronic</td>
<td>GFTH95</td>
<td>0-70 °C</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>10-95% r.F.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Commonly used measuring devices

5.3.4. Recorded values for the measurement

The measured resistance values are documented in Ω.

The actual temperature $\theta_{\text{meas}}$ is written into the protocol to give a relation to the reference temperature for the short-circuit measurement.

Measurement uncertainty in %.

5.4. Test criteria / Maximum values

Not applicable
6. Induced AC withstand voltage test

6.1. Standard
IEC 60076-11:2018 clause 14.2.6 // part 3 clause 11.2 (IVW)

6.2. Aim
Checking of the inner insulation of the windings, insulation between the single windings and layers and between the windings of single phases.

6.3. Test
The test is conducted with double the rated voltage (2xUn), the duration of the test is calculated after formula 3, but not less than 15 sec.
The test voltage is usually fed at the winding with the lowest rated voltage, via the induction of the transformer it is ensured that double the rated voltage can be found on all windings.

The test frequency has to be at least double the rated frequency fR to prohibit saturation of the core. If the core would be brought into saturation, the magnetizing current will rise disproportionally (see picture below picture 5).

\[
\text{test duration [s]} = 120 \cdot \frac{\text{rated frequency}}{\text{test frequency}}
\]

The test at the SGB-test facility is made with a test frequency of 200 Hz for 2 min. (during the initial testing), to assure a higher level of security.
6.3.1. Tapping position for testing

It is only necessary to reach the rated turn voltage. Therefore, the tapping position is of no significance. Usually it is the principal tapping position.

6.3.2. Test setup

![Test setup diagram]

**picture 6: Test setup for induced AC withstand voltage test**

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

6.3.3. Commonly used measuring devices for testing

<table>
<thead>
<tr>
<th>measuring devices</th>
<th>manufacturer</th>
<th>type</th>
<th>range / accuracy</th>
<th>frequency</th>
<th>class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precision Power Analyzer</td>
<td>ZIMMER</td>
<td>LMG 500</td>
<td>U_{rms} 1000 V / I_{rms} 32 A</td>
<td>DC - 10 MHz</td>
<td>0,01-0,03</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>U_{pk} 3200 V / I_{pk} 120 A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LV-current-transf.</td>
<td>H&amp;B</td>
<td>Ti 48</td>
<td>2,5-500 A/5 A</td>
<td>50/60 Hz</td>
<td>0,1</td>
</tr>
<tr>
<td>HV-voltage-transf.</td>
<td>epro</td>
<td>NVRD 40</td>
<td>2-40 kV/100 V</td>
<td>50/60 Hz</td>
<td>0,02</td>
</tr>
<tr>
<td>HV-current-transf.</td>
<td>epro</td>
<td>NCO 60</td>
<td>1-600 A/5 A</td>
<td>50/60 Hz</td>
<td>0,01</td>
</tr>
</tbody>
</table>

*table 4: Commonly used measuring devices*

6.3.4. Recorded values for the test

The test voltage, test frequency and test duration are documented in the test certificate.

6.4. Test criteria

The test is passed if no break down of the test voltage occurs.
7. Measurement of the no-load losses and current

7.1. Standard

IEC 60076-11:2018 clause 14.2.4 // part 1 clause 11.5

7.2. Aim

Measurement and documentation of the no-load current I₀ and the no-load losses P₀

7.3. Theoretical principal

The following losses arise during no-load measurements
- Iron losses Pₑ in the core and other constructive parts
- Dielectric losses in the insulation

As the iron losses Pₑ account for a much larger percent of total losses than the dielectric losses, the dielectric losses can be omitted from the formula, so the following formula applies:

\[ P₀ = Pₑ \]

Iron losses are caused by hysteresis losses in the magnetization.

Eddy currents do not have as much of an influence in modern transformers using individually insulated core iron sheets.

7.4. Measurement

The measurement of no-load losses and of the no-load current are made using the same test setup as for the induced over voltage test (clause 6). It is carried out with the rated voltage Ur and the rated frequency fr. The measurement voltage is applied as close to Ur as possible.

The measured losses are corrected after IEC 60076-1 clause 11.5

\[
P₀(C) = Pₘ * (1 + d)
\]

\[
d = \frac{U' - U}{U}
\]

\[
P₀ = \text{iron losses}
\]

\[
Pₘ = \text{measured losses}
\]

\[
U' = \text{rectified value}
\]

\[
U = \text{arithmetic average of}
\]

*formula 4: Calculation of the corrected iron losses*

The no-load losses do not have to be named at a reference temperature, because with rising temperature the losses will accordingly decrease.

This is due to the fact that the core in a warm state, is slightly easier to magnetize and because of this, less losses will occur.

7.4.1. Tapping position for measurement

It is only necessary to reach the rated turn voltage.

Therefore, the tapping position is of no significance. Usually it is the principal tapping position.
7.4.2. Equivalent circuit diagram for a transformer in no-load

7.4.3. Test setup

S: electricity supply  P1: wattmeter
T2: transformer to be tested  P2: amperemeter (I_{RMS})
T3: current transformer  P3: voltmeter (U_{RMS})
T4: voltage transformer
7.4.4. Commonly used measuring devices for measurement

<table>
<thead>
<tr>
<th>measuring devices</th>
<th>manufacturer</th>
<th>type</th>
<th>range / accuracy</th>
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<tbody>
<tr>
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<td>ZIMMER</td>
<td>LMG 500</td>
<td>U rms 1000 V / I rms 32 A</td>
<td>DC - 10 MHz</td>
<td>0,01-0,03</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>U pk 3200 V / I pk 120 A</td>
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<td></td>
</tr>
<tr>
<td>LV-current-transf.</td>
<td>H&amp;B</td>
<td>Ti 48</td>
<td>2,5-500 A/5 A</td>
<td>50/60 Hz</td>
<td>0,1</td>
</tr>
<tr>
<td>HV-voltage-transf.</td>
<td>epro</td>
<td>NVRD 40</td>
<td>2-40 kV/100 V</td>
<td>50/60 Hz</td>
<td>0,02</td>
</tr>
<tr>
<td>HV-current-transf.</td>
<td>epro</td>
<td>NCO 60</td>
<td>1-600 A/5 A</td>
<td>50/60 Hz</td>
<td>0,01</td>
</tr>
</tbody>
</table>

*Table 5: Commonly used measuring devices*

7.4.5. Recorded values for the measurement

Voltage [V], amperage [A] and corrected losses [W] for all phases (in R.M.S.) are recorded. The no-load current is given in a percentage of the rated current.

Measurement uncertainty in %.

7.5. Test criteria / Maximum values

➢ Following Standard IEC 60076-1 (clause 10 limiting deviation, table 1, section 1).

The total losses are only allowed to differ a max. of 10% and the no-load respectively short-circuit losses only a max. of 15% from the guaranteed value.

If the no-load current is bindingly given, it is allowed to differ a max. of +30% of the values (section 5 in table 1).

Or

➢ Agreement between supplier and purchaser

Or if the transformer is for the European market

➢ The maximum Value for the no-load losses P₀ must be made in accordance with Standard EN 50588-1 table 4 (if applicable table 5 and 6) or table 8 or

Standard EN 50629 table A.1

8.1. Standard

EN 60076-11:2018 clause 14.2.3 // part 1 clause 11.4

8.2. Aim

➢ Determination of the short-circuit voltage / impedance in percent (Uₓ or ez) at a reference temperature.
➢ Determination of the short-circuit losses (Pₓ) at a reference temperature.

**Short-circuit voltage** = The voltage, at which primary and secondary rated current Iᵣ flows, if one of the sides of the transformer is shorted.

8.3. Measurement

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

A current between 50% and 100% of the rated current of the connected windings is fed. In our testing facility, we prefer to use 60% of the rated current when possible as through years of experience we have found this to be an optimum percent at which to take the measurement due to the ability to reach the measuring current faster, thus preventing the warming of the transformer and it also brings the measurement adequately over the IEC minimum of 50%.

It is imperative that the measurement be carried out as swiftly as possible, because the windings will heat up due to the current and the measured data is then falsified.

Due to the fact that during operation the short-circuit losses will increase through heating of the windings, Pₓ and ez are given at the reference temperature.

The connection for the measurement is usually as close as possible to the winding (similar connection as in chapter 5 Measurement of the resistance of the windings.

The reference temperature is calculated using the average winding-temperature rise limits from all windings, as given in IEC 60076-11 (clause 10.1, table 2) + 20 or if the winding-temperature rise is different from table 2 then average winding-temperature rise limits from all windings + yearly average temperature of the external cooling medium.

\[ \theta_{ref} = \Delta \theta_w + 20{\textdegree}C \]

\[ \text{e.g. class of insulation } F \leftrightarrow 100 \text{ Kelvin} \quad \text{reference temperature} = 100{\textdegree}K + 20{\textdegree}C = 120{\textdegree}C \]

8.3.1. Tapping position for measurement

If the HV tapping range is between ±5% of rated voltage, only the principal tap shall be measured. Otherwise as a typetest, the taps with the highest and lowest number of turns will also measured.

➢ In case of an LV tap, it is necessary measure the tap.
8.3.2. Equivalent circuit diagram for transformer in load

![Equivalent circuit diagram for transformer in load]

**picture 9: transformer in short-circuit**

8.3.3. Test setup

![Test setup of the short-circuit measurement]

**picture 10: test setup of the short-circuit measurement**

S: electricity supply
T2: transformer to be tested
T3: current transformer
T4: voltage transformer

C1: capacitor bank
P1: wattmeter
P2: amperemeter (I_RMS)
P3: voltmeter (U_RMS)

8.3.4. Commonly used measuring devices for measurement

<table>
<thead>
<tr>
<th>measuring devices</th>
<th>manufacturer</th>
<th>type</th>
<th>range / accuracy</th>
<th>frequency</th>
<th>class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precision Power Analyzer</td>
<td>ZIMMER</td>
<td>LMG 500</td>
<td>U rms 1000 V / I rms 32 A</td>
<td>DC - 10 MHz</td>
<td>0,01-0,03</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>U pk 3200 V / I pk 120 A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LV-current-transf.</td>
<td>H&amp;B</td>
<td>Ti 48</td>
<td>2,5-500 A/5 A</td>
<td>50/60 Hz</td>
<td>0,1</td>
</tr>
<tr>
<td>HV-voltage-transf.</td>
<td>epro</td>
<td>NVRD 40</td>
<td>2-40 kV/100 V</td>
<td>50/60 Hz</td>
<td>0,02</td>
</tr>
<tr>
<td>HV-current-transf.</td>
<td>epro</td>
<td>NCO 60</td>
<td>1-600 A/5 A</td>
<td>50/60 Hz</td>
<td>0,01</td>
</tr>
</tbody>
</table>

**table 6: Commonly used measuring devices**

8.3.5. Recorded values for the measurement

All voltages [V], amperages [A] and losses [W] (in R.M.S.) are then recorded. Measurement uncertainty in %.
8.4. Calculations to determine $P_L$ and $ez$ at the reference temperature

Because the measurement is carried out at between 50% and 100% of the rated current, the measured values have to be calculated first. This is possible as losses increase quadratically with the current.

$$P_{L\,\text{cold}}(\text{at } I_R) = P_{\text{meas}} \times \left(\frac{I_{R\,HV}}{I_{\text{meas}}}\right)^2$$

*formula 5: calculation of short-circuit losses at measured temperature*

To calculate the losses in relation to the temperature, the ohmic part of the losses ($I^2R$) and the additional losses ($P_Z$) are determined (reactance in picture 9: transformer in ).

With the previous data, a calculation for the additional losses can be accomplished, so foremost, the ohmic part of the losses are calculated.

This is calculated via the ohmic law through conversion.

$${\{P = U \times I\}} \quad \& \quad {\{U = R \times I\}} \quad \triangleq \quad P = I^2 \times R$$

*formula 6: conversion of the ohmic law*

To do that, the average of the three measurements are taken (clause 5 Measurement of the resistance of the windings) and are multiplied by the appropriate rated squared current.

Additionally, the factor 1.5 is necessary, because the resistance values and the current are related in phase to phase. Through calculation to phase values the factor 1.5 results. Finally, only the ohmic losses of HV and LV have to be added.

$$\sum I^2 R_{\text{cold}} = (I_{R\,HV}^2 \times \text{average } R_{HV} \times 1.5) + (I_{R\,LV}^2 \times \text{average } R_{LV} \times 1.5)$$

*formula 7: calculation of the ohmic losses at measured temperature*

Because now the losses in general, as well as the ohmic losses are known, the difference between both, forms the additional losses ($P_Z$)

$$P_{Z\,\text{cold}} = P_{L\,\text{cold}} - \sum I^2 R_{\text{cold}}$$

*formula 8: calculation of additional losses at measured temperature*

So the ohmic losses and the additional losses are now known. For the next step both losses are calculated to the reference temperature.

To put that into a formula only the material constant is needed.

$$\theta_K = \text{by } Al = 225 \quad \theta_K = \text{by } Cu = 235$$

*picture 11: material constant of Al and Cu*

With the constant, the losses will either be calculated up or down.

The ohmic parts ($I^2R$) are caused by the winding itself.

Due to that fact, they are calculated upwards.

$$\sum I^2 R_{\text{hot}} = \sum I^2 R_{\text{cold}} \times \frac{\theta_K + \theta_{\text{ref}}}{\theta_K + \theta_{\text{meas}}}$$

*formula 9: calculation of the ohmic losses at a reference temperature*
The additional losses \((P_Z)\) are caused by all non-ohmic losses. E.g. core magnetization, eddy currents, etc.

\[
P_{Z\ hot} = P_{Z\ cold} \ast \frac{\theta_K + \theta_{meas}}{\theta_K + \theta_{ref}}
\]

*Formula 10: calculation of additional losses at a reference temperature*

The sum of both tests, results in the total short-circuit losses \((P_L)\) at the reference temperature.

\[
P_{L\ hot} = \sum R_{hot} + P_{Z\ hot}
\]

*Formula 11: calculation of short-circuit losses at reference temperature*

Now that the losses are known, the calculation of the short-circuit voltage, respectively the short-circuit impedance, can be carried out in percent.

For that, the measurement voltage for the short-circuit test again has to be related to the rated current, because of the linear behavior of current and voltage this is very easy. Afterwards using the same formula, the voltage in percent of the rated voltage is stated.

\[
e_{Z\ cold} = \frac{I_{R\ HV}}{I_{meas}} \ast U_{meas} \ast \frac{100\%}{U_{R\ HV}}
\]

*Formula 12: calculation of short-circuit voltage at measured temperature*

To give the \((e_z)\) at the reference temperature this value is divided again into the ohmic part \((e_r)\) and an imaginary part \((e_x)\) (similar to \((P_Z)\)).

To do that, the proportion of the rated apparent power of the transformer and the short-circuit losses at measured temperature are used.

\[
e_{r\ cold} = \frac{P_{L\ cold} \ast 100\%}{S_r}
\]

*Formula 13: calculation of the ohmic parts of short-circuit voltage at measured temperature*

The imaginary part \((e_x)\) is derived from the Kappic triangle, but is seen as being independent of the temperature.

\[
e_x = \sqrt{e_{Z\ cold}^2 - e_{r\ cold}^2}
\]

*Formula 14: calculation of the imaginary part \(e_x\)*

*Picture 12: Kappic triangle*
To now determine the ohmic part \((er)\) of the short-circuit voltage, the same calculation as for \((er_{cold})\) will be used, but now the losses are at the reference temperature.

\[
er_{hot} = \frac{P_{L,hot} \times 100\%}{S_R}
\]

\textit{formula 15: calculation of the ohmic parts of the short-circuit voltage at a reference temperature}

To now finally determine the short-circuit voltage at the reference temperature, the ohmic parts \((er)\) and the imaginary parts \((ex)\) are being summed up using the Kappic triangle.

\[
ez_{hot} = \sqrt{ex^2 + er_{hot}^2}
\]

\textit{formula 16: calculation of the short-circuit voltage at a reference temperature}

In the test protocol these calculated values are given in the section “Measurement of short-circuit impedance and load loss “:

- Load losses at rated current \(P_L\) at Iₖ [W]
- Additional losses \(P_x\) [W] *
- Ohmic losses \(I^2R\) [W] *
- Load losses \(P_L\) [W] *
- Imaginary impedance \(ex\) [%] *
- Ohmic impedance \(er\) [%] *
- Short-circuit impedance \(ez\) [%] *

* (calculated to the reference temperature)

8.5. Test criteria / Maximum values

- Following Standard IEC 60076-1 (clause 10 limiting deviation, table 1, section 1).
  The total losses are only allowed to differ a max. of 10% and the no-load respectively short-circuit losses only a max. of 15% from the guaranteed value.
  If the no-load current is bindingly given, it is allowed to differ a max. of +30% of the values (section 5 in table 1).

Or

- Agreement between supplier and purchaser

Or if the transformer is for the European market

- The maximum Value for the load losses \(P_L\) must be made in accordance with Standard EN 50588-1 table 4 (if applicable table 5 and 6) or table 8 or Standard EN 50629 table A.1
9. Control of the temperature sensors

To ensure that all temperature sensors that are installed in the transformer function faultlessly, their resistances are measured after the routine test with an ohmmeter and documented (in $\Omega$) in the test protocol.

![Diagram of temperature sensor connections]

*picture 13: connection of temperature sensors*

9.1. Commonly used measuring devices for measurement

<table>
<thead>
<tr>
<th>measuring devices</th>
<th>manufacturer</th>
<th>type</th>
<th>range / accuracy</th>
<th>frequency</th>
<th>class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multimeter</td>
<td>FLUKE</td>
<td>Fluke-87-V</td>
<td>1000V/10A/50M$\Omega$</td>
<td>DC</td>
<td>0,1-1,0</td>
</tr>
</tbody>
</table>

*table 7: Commonly used measuring devices*
10. Partial discharge measurement

10.1. Standard

10.2. Aim
➢ Proof of quality of the insulation (cast)
➢ Detection of defects (e.g. missing contact washers, constructive parts that are not grounded)

10.3. Theoretical principal
Partial discharge (also Pre-discharge) is a term in the electrotechnical field. It is primarily about the form and characteristics of classes of insulation. If in high voltage insulations or alongside air distances highly inhomogeneous field profiles occur, it can lead to a transgression of dielectric strength levels relating to the type of material. In this state of an incomplete electric break down in the insulation between the electrodes, discharges are identified. Such partial discharges (abbreviated also referred to as “PD”) mostly occur in insulation with ac voltage being applied.

picture 14: Lichtenberg-figure in an ashlar of acryl.
Actual size: 76mm × 76mm × 51mm

picture 15: schematic display of the development of partial discharge in a sharp point-plate arrangement generated through incoming radiation
**Consequences of PD:** These discharges can cause a complete break down of insulation over time. Looking at the safety of a company and the life span of a transformer, a transformer is not allowed to show any elevated PD-values (max. 10 pC).

![Picture 16: the sliding discharge on a board out of polycarbonate leading to the destruction of the insulator](image)

**10.3.1. Possible reasons for PD**
- electric free floating constructive parts in the transformer (e.g. bad grounding connection)
- material or constructive mistakes (e.g. bad contact, missing contact washers)
- dimensioning faults
- casting
- spikes on HV or grounded parts within the electrical field
- there are many various reasons that a transformer can have elevated levels of PD, from insignificant to serious

**10.3.2. Outer partial discharges (corona)**
Outer partial discharges are discharges from the surfaces of free electrodes of metal into the surrounding air space. They generally originate at sharp edged parts, at which the power of the field is highly increased. This phenomenon is commonly seen on high voltage wires with an audible and sometimes visible corona discharge. Also St. Elmo’s fire is placed into this category. Outer pre-discharges can be prohibited through a rounded design of all edges, as well as field controlling rings (e.g. at high voltage cascades).

![Picture 17: corona PD pattern](image)

In the PD-Measuring Software, corona has a special form. (PD-pattern)
In most cases, corona changes the PD value linear with the voltage
10.3.3. Inner partial discharges

In general, all partial discharges that are not audible or visible are considered to be inner partial discharges. Insulating mediums can be a solid, liquid or gaseous. Discharges occur, where homogeneities of the medium lie under strong field influence, for example in the case of gas bubbles, which are located in an insulating fluid, for example oil, or in cast resin. These gas bubbles, consisting of air, carbon dioxide (e.g. in case of influence of humidity at the hardening of polyurethane resin) or oil decomposition gases, has an inferior dielectric constant compared to the surrounding oil, which leads to an increase of field power. The insulating characteristics of the gas bubble are disturbed by the locally lower electrical strength, which results in partial discharges. As well as not correctly connected built-in parts in building elements, which have been produced through cast resin or treatment (switching power supply transformers, high tension cascades) leading to partial discharges. Other examples include transformer windings which are not sealed, made of enameled copper wire, used in switching power supply transmissioners and flimsily winded membrane capacitors for applications of ac voltage. Inner partial discharges, because of ultraviolet radiation and ionization can, in the long run, cause damage the surrounding insulating material and therefore have to be avoided.

![Picture 18: Inner PD pattern](image)

In the PD-Measuring Software, internal PD has a special form.

(PD-pattern)

In most cases, in a small voltage range the PD value doesn’t change dramatically while the voltage is changing. The PD inception voltage is higher than the PD extinction voltage.

10.3.4. PD classification:

On a transformer, you can have a mixed form of PD sources.

![Picture 19: PD classification](image)
10.4. Measurement

All windings with an $U_m \geq 3.6$ kV are to be tested.

10.4.1. Measurement chamber

The measurement is carried out in a faraday cage, shielding the transformer from incoming electromagnetic fields. Furthermore, the test bay has to be of an adequate size, to ensure enough distance from the transformer to coupling-capacitors, the voltage source, walls, etc., prohibiting disturbances of the electric field during the execution of the measurement.

10.4.2. Connection

The voltage supply is applied in the same way as the induced over voltage test (clause 6).

Three coupling-capacitors (voltage divider) $C_k$ are connected to the HV-windings. PD- and voltage signals are separated via a quadripole/measuring impedance under the coupling-capacitor. The quadripole is connected via a fiber optic cable to the measurement PC.

10.4.3. Tapping position for measurement

The test shall be performed in the principal tap.
10.4.4. Measurement Frequency band

According IEC 60270, we measure in a wide-band

\[ f_{\text{center}} = 250 \text{ kHz} \quad f \Delta = 300 \text{ kHz} \]

This means we measure discharges (apparent charge) with a Bandwidth between 100kHz and 400kHz. For this, the pulse resolution time \( T_r \) is 5\( \mu \text{s} \) – 20\( \mu \text{s} \) or with active integrator \( T_r < 1\mu \text{s} \).

Note: Narrow band can also used (Bandwidth 9kHz – 30kHz Frequency range between 50kHz – 1MHz)

10.4.5. Calibration

Before the actual measurement can take place, a calibration of the measurement circle is necessary. Therefore a defined PD-impulse with a PD charge calibrator is fed between each conducted phase of the transformer and the earth. This value then has to be divided through the value received on the measurement device. The result of this calculation is called a "calibration factor". With this factor, all measurement results are multiplied incl. the base interference level (performed by the software).

The charge calibrator we use has a pulse repetition frequency of 300 Hz and a pulse rise time from < 4 ns

10.4.6. Measuring duration and voltage levels

The measurement is carried out over a time of 210 seconds, where in the first 30 seconds it is tested with a voltage \( U_{\text{meas}} \) of 1,8 \( x \) \( U_{\text{rated}} \). For the other 180 seconds \( U_{\text{meas}} = 1,3 \times U_{\text{rated}} \) (picture).

![picture 22: voltage-time diagram for PD-measurement](image)
10.4.7. Test setup

10.4.8. for supplying

![Diagram showing test setup for measurement of partial discharge]

*picture 23: Test setup for measurement of partial discharge*

- **S**: electricity supply
- **T2**: transformer to be tested
- **T3**: current transformer
- **T4**: voltage transformer

10.4.9. for measuring

![Diagram showing test setup for PD measurement]

*picture 24: Test setup of the PD-measurement*

- **Ck**: couple-capacitors
- **Zm**: measurement impedance
- **pC**: measurement device with reading of pC
- **q0**: PD charge calibrator (only to be used previous to testing)

10.4.10. Commonly used measuring devices for measurement

<table>
<thead>
<tr>
<th>Measuring devices</th>
<th>Manufacturer</th>
<th>Type</th>
<th>Range / Accuracy</th>
<th>Frequency</th>
<th>Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>PD-measurement system</td>
<td>Omicron</td>
<td>MCU502 4xMPD600 3xMPP600</td>
<td>500 fC - 3nC</td>
<td>0 - 32 MHz</td>
<td>0,01-0,03</td>
</tr>
</tbody>
</table>

*Table 8: Commonly used measuring devices*
10.4.11. 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.

10.5. Test criteria / Maximum values

➢ The Background level should not exceed the half of the value of the maximum PD level.
➢ The partial discharge level is allowed a maximum of 10pC with correction factor.
11. Appendix

11.1. Example test certificate

Test certificate for 3 Phase dry-type transformer

<table>
<thead>
<tr>
<th>Customer:</th>
<th>XY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer order nr.:</td>
<td>1234</td>
</tr>
<tr>
<td>Date of order:</td>
<td>xx,xx,xxxx</td>
</tr>
<tr>
<td>Customer item no.:</td>
<td>123456</td>
</tr>
<tr>
<td>SGB order number:</td>
<td>123456789/10</td>
</tr>
<tr>
<td>Type:</td>
<td>DTTH1NG 3150/30</td>
</tr>
<tr>
<td>Serial-number:</td>
<td>123456</td>
</tr>
<tr>
<td>Wd. number:</td>
<td>123456</td>
</tr>
<tr>
<td>page:</td>
<td>1 of 11</td>
</tr>
</tbody>
</table>

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

2. Technical data
3. Routine testing
10. Appendix / Test results

Approved by: Regensburg

Remarks:
SGB Stahlstrom - Gerätebau GmbH
Chemnitzer Str. 10, DE-91055 Regensburg
Test Lab Cast Resin Transformers
www.sgb-smit.com
### Technical data

#### 3 Phase dry-type transformer according to Standard IEC 60076-11:2018

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SGB order number</td>
<td>1234567/89/10</td>
</tr>
<tr>
<td>Serial number</td>
<td>123456</td>
</tr>
<tr>
<td>Type</td>
<td>DTH1MSG 3150/30</td>
</tr>
<tr>
<td>Wid. number</td>
<td>123456</td>
</tr>
<tr>
<td>Protection // Mass dry-type transformer</td>
<td>IP00 / indoor // 6831 kg</td>
</tr>
<tr>
<td>Maximum altitude [m]</td>
<td>1000</td>
</tr>
<tr>
<td>Max. temp. of cooling medium [°C]</td>
<td>55</td>
</tr>
<tr>
<td>Kind. PT</td>
<td>Service: Continuous</td>
</tr>
<tr>
<td>Environment class</td>
<td>E2</td>
</tr>
<tr>
<td>Climate class</td>
<td>C2</td>
</tr>
<tr>
<td>Fire class</td>
<td>F1</td>
</tr>
<tr>
<td>Max. dur. of short circuit [sec:]</td>
<td>2</td>
</tr>
<tr>
<td>E / I ref. [6.7]</td>
<td>Test [sec]: 0.31</td>
</tr>
<tr>
<td>Magnetic flux density B [T]</td>
<td>1.609</td>
</tr>
<tr>
<td>Core material (grain-oriented electrical steel)</td>
<td>Mass [kg]: 4288.2</td>
</tr>
</tbody>
</table>

#### Rated power [kVA]

<table>
<thead>
<tr>
<th>HV</th>
<th>LV</th>
</tr>
</thead>
<tbody>
<tr>
<td>8000</td>
<td>3900</td>
</tr>
</tbody>
</table>

#### Rated voltage [V]

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>+2 x 750V (2.5 %)</td>
<td></td>
</tr>
<tr>
<td>30000</td>
<td>55</td>
</tr>
<tr>
<td>-2 x 750V (2.5 %)</td>
<td></td>
</tr>
</tbody>
</table>

#### Rated current [A]

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>79.06</td>
<td>3203.3</td>
</tr>
</tbody>
</table>

#### Um/ULAC [kV]

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>150 / 190 / 70</td>
<td>11.6 / 3</td>
</tr>
</tbody>
</table>

#### Insulation class

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>F</td>
</tr>
</tbody>
</table>

#### Max. temperature rise [K]

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>85</td>
<td>85</td>
</tr>
</tbody>
</table>

#### Conductor material / Mass [kg]

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Al / 481</td>
<td>Al / 490</td>
</tr>
</tbody>
</table>

#### Continuous short-circuit current [kA]

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0.64</td>
<td>28.88</td>
</tr>
</tbody>
</table>
Routine testing
(according to Standard IEC 60076-11:2018)

SGB order number: 123456/789/10
Serial number: 123456
Type: OTTHING 3150/30
Wd. number: 123456

Dielectric tests

Separate-source AC withstand voltage test HV:
Separate-source AC withstand voltage test LV:
Separate-source AC withstand voltage test of auxiliary wiring:

\[
\begin{array}{|c|c|c|}
\hline
\text{[kV]} & \text{[Hz]} & \text{[sec.]} \\
\hline
70.0 & 50 & 60 \\
3.0 & 50 & 60 \\
2.0 & 50 & 60 \\
\hline
\end{array}
\]

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

Induced AC withstand voltage test LV:

\[
\begin{array}{|c|c|c|}
\hline
\text{[kV]} & \text{[Hz]} & \text{[sec.]} \\
\hline
1.3 & 200 & 30 \\
\hline
\end{array}
\]

Example pictures and schematics refer to a standard transformer. Deviations from the actual product may be possible.
**Routine testing**
(according to Standard IEC 60076-11:2018)

<table>
<thead>
<tr>
<th>SGB order number:</th>
<th>123456789/12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serial number:</td>
<td>123456</td>
</tr>
</tbody>
</table>

**Measurement of voltage ratio and check of phase displacement**

<table>
<thead>
<tr>
<th>Connector HV / LV:</th>
<th>3000/300</th>
<th>3075/300</th>
<th>3000/300</th>
<th>2075/200</th>
<th>2000/200</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deviation [%]:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase U</td>
<td>-0.03</td>
<td>-0.03</td>
<td>-0.03</td>
<td>-0.03</td>
<td>0.01</td>
</tr>
<tr>
<td>Phase V</td>
<td>-0.01</td>
<td>-0.01</td>
<td>-0.02</td>
<td>-0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Phase W</td>
<td>-0.01</td>
<td>-0.02</td>
<td>-0.02</td>
<td>-0.02</td>
<td>-0.01</td>
</tr>
</tbody>
</table>

| Deviation Phase displacement [°]: |          |          |          |          |          |
| Phase U            | 0.02     | 0.02     | 0.02     | 0.02     | -0.03    |
| Phase V            | -0.01    | -0.01    | -0.01    | -0.01    | -0.03    |
| Phase W            | -0.03    | -0.03    | -0.03    | -0.03    | -0.04    |

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

According to Standard (IEC 0076-11:2018)

SGS order number: 123456789/10
Serial number: 123456

Type: OTH/ENG 350/30
Wd. number: 123456

Measurement of winding resistance

connection: HV 30,000 LV
1U - 1V 1,74758

Measured values in [Ω]:
1U - 1W 1,74032
1V - 1W 1,74758

connection: 1U 0,690 kV
2U - 2V 0,0003740

Measured values in [Ω]:
2U - 2W 0,0001952
2V - 2W 0,0003753

Temperature 22,0°C

Used measuring instruments:
Winding Analyzer 2293 Nr. 297742

Example pictures and schematics refer to a standard transformer. Deviations from the actual product may be possible.
Routine testing
(according to Standard IEC 60076-13:2018)

| SGB order number: | 123456789/10 | Serial number: | 123456 
| Type: | OTTH1NG 1510/10 | Wd. number: | 123456 |

Measurement of no-load loss and current

<table>
<thead>
<tr>
<th>Voltage [V]</th>
<th>Currents [A]</th>
<th>Losses [W]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ua 489,0</td>
<td>Ia 5,867</td>
<td>Pa 1499</td>
</tr>
<tr>
<td>Ua 690,7</td>
<td>Ia 3,994</td>
<td>Pa 1366</td>
</tr>
<tr>
<td>Ua 689,3</td>
<td>Ia 5,580</td>
<td>Pa 1882</td>
</tr>
<tr>
<td>0 690,0</td>
<td>Ta 5,950</td>
<td>Σ 4567</td>
</tr>
</tbody>
</table>

The measurement uncertainty is max. ± 0,31% | Used measuring instruments:
Precision Power Analyzer: Zimmer IMG 500 Nr. 12891605
Current transformer: H&B T48 Nr. 81 K 163 | H&B T48 Nr. 81 K 164 | H&B T48 Nr. 81 K 165

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

SGB Stäckstrans - Gewirkbau GmbH
Ohmstraße 10, 0693165 Regensburg
Test Lab Cast Recis Transformers
www.sgb-smit.com
Routine testing
(according to Standard IEC 60076-11:2018)

SGB order number: 123456789/10
Serial number: 123456789

Measurement of short-circuit impedance and load loss

connection HV 30 kV & Frequency 50 Hz; LV 690 V short-circuit at 3900 kVA

<table>
<thead>
<tr>
<th>Voltage (V)</th>
<th>Currents (A)</th>
<th>Losses [W]</th>
<th>P at 21 °C &amp; 22,0 °C (W)</th>
<th>39846</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ua 1754</td>
<td>I: 38,79</td>
<td>P: 4421</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ua 1756</td>
<td>I: 35,14</td>
<td>P: 3574</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ua 1749</td>
<td>I: 38,55</td>
<td>P: 1002</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G 1753</td>
<td>I: 38,86</td>
<td>P: 6011</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The measurement uncertainty is max. ± 0.22% | Used measuring instruments:

Precision Power Analyzer: Zimmer LMG 500 W 123981926
Voltage-transformer: EPRO NW 60 Nr. 2/O8/5845 | EPRO NW 60 Nr. 2/O8/5856 | EPRO NW 60 Nr. 2/O8/5857
Current-transformer: EPRO NCO 60 Nr. 2/O8/5847 | EPRO NCO 60 Nr. 2/O8/5848 | EPRO NCO 60 Nr. 2/O8/5850

Example pictures and schematics refer to a standard transformer. Deviations from the actual product may be possible.
Routine testing
(according to Standard IEC 60076-31, 2018)

SGB order number: 12496/639/10
Serial number: 124958
Type: OTTHINS 3150/30
Wid. number: 12458

Measurement of partial discharge

Testing voltage
Frequency 200 Hz

<table>
<thead>
<tr>
<th>Voltage</th>
<th>80 sec</th>
<th>180 sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2 * UHV</td>
<td>54.00</td>
<td>39.00</td>
</tr>
<tr>
<td>2.0 * UHV</td>
<td>1.242</td>
<td>1.3 * UHV</td>
</tr>
</tbody>
</table>

Test results in pC:

<table>
<thead>
<tr>
<th>Testing voltage</th>
<th>2U</th>
<th>1V</th>
<th>1W</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2 * UHV</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Background level</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Measuring circuit

Measurement in tap: 3/30 kV

Calibration factor K
(append):

2.9

Measurement device bandwidth [kHz]:

100 - 400 kHz

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

According to Standard (IEC 60076-11:2018)

<table>
<thead>
<tr>
<th>SGB order number</th>
<th>123456789/10</th>
<th>Serial number:</th>
<th>123456</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>DITHING 3150/30</td>
<td>Wd. number:</td>
<td>123456</td>
</tr>
</tbody>
</table>

Temperature sensor resistance measurement (at 22.0°C):

1-2-3 PT 100/Ω LV Phase U 109/109 Ω
4-5-6 PT 100/Ω LV Phase V 109/109 Ω
7-8-9 PT 100/Ω LV Phase W 109/109 Ω
21-12-13 PT 100/Ω LV Phase U reserve 109/109 Ω
24-15-16 PT 100/Ω LV Phase V reserve 109/109 Ω
27-18-19 PT 100/Ω LV Phase W reserve 109/109 Ω
21-22-23 PT 100/Ω Core Phase V 109/109 Ω
26-25-26 PT 100/Ω Core Phase V reserve 109/109 Ω

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

Remarks

Measurement carried out in Protection IP00
# Appendix

**Test results / 3.1 Acceptance test certificate according to DIN EN 10204:2004**

## Routine testing

### Dielectric tests

- Separate-source AC withstand voltage test / HV / LV / of auxiliary wiring:
  - U0 / U / U (kV): 50 [HV]; 40 [LV]
- Induced AC withstand voltage test (UV):
  - 2.38 [kV]: 318 [HV]; 30 [LV]

### Measurement of voltage ratio and check of phase displacement

<table>
<thead>
<tr>
<th>Guarantee value</th>
<th>Test result</th>
</tr>
</thead>
<tbody>
<tr>
<td>10000/5000</td>
<td>1.01</td>
</tr>
</tbody>
</table>

### Measurement of winding resistance at 22.0 °C

Measurement of winding resistance HV/LV: √

### Measurement of no-load loss and current at 50 Hz

| N: | 4.750 | ±0.0% | 4.077 | -5.32% | √ |
| A: | 0.055 | 0.1% | 0.055 | 0.1% | √ |

### Measurement of short-circuit impedance and load loss at 120 °C

| P: | 34031 | ±0.0% | 32543 | -4.67% | √ |
| Q: | 10.05 | ±18.0% | 13.39 | 7.39% | √ |

### Measurement of partial discharge

| PD max. HV at 1.3 x rated voltage (pC): | √ |
| (Background level 1) (pC): | 1 |

---

Approved by: [Signature]

---

SGB Stativstrom - Switzerland GmbH
Openstrasse 10, D-93055 Regensburg
Test Lab Cost Neon Transformers
www.sgb-smit.com

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Appendix

SGB order number: 126436789/10
Serial number: 123456
Type: DITTHING 1150/30
Wld. number: 123456

EU-Declaration of Conformity

Hereby we declare that the product designated above (serial number), in regards to its design and build and the model placed into circulation by us, corresponds to the designated EU Directive below. In the case of a modification to the product that is not coordinated with us, this Declaration shall become invalid.

The conformity with the following directives / regulations is declared:


Applied harmonized standards are especially:

Other standards applied are:

- EN 60076-11 2018

Head of Engineering
Cast Resin Transformers
Starkstrom - Gerätebau GmbH

Teamleader Test Lab
Cast Resin Transformers
Starkstrom - Gerätebau GmbH

Regensburg,
11.2. Example rating plate

<table>
<thead>
<tr>
<th>Type: DTH1NO 310/38</th>
<th>Serial number: 123456</th>
<th>Customer item no.: 123456</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer specification: XV</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rated power [kVA]</th>
<th>2000</th>
<th>3000</th>
</tr>
</thead>
<tbody>
<tr>
<td>+2x 750V (2.5 %)</td>
<td>000</td>
<td>000</td>
</tr>
<tr>
<td>-2x 750V (2.5 %)</td>
<td>000</td>
<td>000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rated current [A]</th>
<th>75.1</th>
<th>320.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use: LI / AC [A7]</td>
<td>58 / 170 / 70</td>
<td>1,978 / 1,978</td>
</tr>
<tr>
<td>Insulation class / Max. temperature rise [°C]</td>
<td>F / 85</td>
<td>F / 85</td>
</tr>
<tr>
<td>Conductor material / Mass [kg]</td>
<td>AL / AL</td>
<td>AL / 600</td>
</tr>
<tr>
<td>Continuous short-circuit current [A]</td>
<td>0.00</td>
<td>26.50</td>
</tr>
</tbody>
</table>

Protection / Mass dry-type transformer: IP20 Indoor / 65/51 kg | Maximum altitude: 1000 m

Environment class: E5 | Climate class: C2 | Fire class: F1 | Humid: FT | Service: Continue

Max. dur. of short circuit (sec): 2 | IE/N: 6.7 / T2 (h); 0.3 |

Rated at 5000 kVA, HV/LV [%]: 11.50 | Frequency [16]: 50 |

Rated at 5000 kVA, HV/LV [%]: 11.50 | at 120°C |

Winding group: Dyn11 | Cooling: AH |

Manufacturing year: 2020 |

3 Phase dry-type transformer

STARKSTROM-GERÄTEBAU GmbH
Cristmasstr. 10
DE-93005 Regensburg

3 Phase dry-type transformer

CE
### 11.3. Example calibration list

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Measurement</th>
<th>Quantity</th>
<th>Method</th>
<th>Error</th>
<th>Result</th>
<th>Date</th>
<th>Measurement Date</th>
<th>Calibration Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example 1</td>
<td>Calibration 1</td>
<td>1 unit</td>
<td>Method 1</td>
<td>Error A</td>
<td>Result A</td>
<td>Date 1</td>
<td>Measurement Date 1</td>
<td>Calibration Date 1</td>
</tr>
<tr>
<td>Example 2</td>
<td>Calibration 2</td>
<td>2 units</td>
<td>Method 2</td>
<td>Error B</td>
<td>Result B</td>
<td>Date 2</td>
<td>Measurement Date 2</td>
<td>Calibration Date 2</td>
</tr>
</tbody>
</table>
11.4. Test lab layout

picture 25: test lab layout

picture 26: routine and heat rise bays

picture 27: PD and sound chamber
11.5. List of pictures, formulas, tables and sources

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TABLE 7: COMMONLY USED MEASURING DEVICES 24
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list of sources:
➢ D.J. Kraaij - Die Prüfung von Leistungstransformatoren
➢ Wikipedia
➢ IEC
➢ Omicron