

Recommendation 7

*Technical terms and conditions etc. for
10-15-20 kV earthing transformers*

3rd edition 2021

Danish Energy
Vodroffsvej 59
1900 Frederiksberg C

Tel.: +45 35 300 400

E-mail: [de@danske-
energi.dk](mailto:de@danske-
energi.dk)

www.danskeenergi.dk



CONTENTS

1. SCOPE

2. REFERENCES

3. PRINCIPAL ELECTRICAL DATA

- 3.1 Rated frequency
- 3.2 Rated voltages
- 3.3 Vector group
- 3.4 Rated current of the primary neutral point
- 3.5 Rated power of secondary winding
- 3.6 Dimensioning of secondary neutral point
- 3.7 Overload capacity
- 3.8 Short circuit voltage
- 3.9 Zero-sequence impedance
- 3.10 Ability to withstand short circuit
- 3.11 Insulation level
- 3.12 Losses

4. CONSTRUCTIONAL DETAILS

- 4.1 Cooling equipment
- 4.2 Bushings
- 4.3 Transformer tank etc.
- 4.4 Surface treatment

5. ACCESSORIES

- 5.1 Valves
- 5.2 Thermometers and thermometer pockets
- 5.3 Transport arrangements
- 5.4 Oil
- 5.5. Marking

6. TESTS

- 6.1 Routine tests
- 6.2 Type tests
- 6.3 Special tests

7. DATA TO BE PROVIDED IN INVITATION TO TENDER

8. DATA TO BE PROVIDED IN TENDERS SUBMITTED

ANNEX 1: LOCATION GUIDE

ANNEX 2: NOTE ABOUT SHORT CIRCUIT PROTECTION OF NEUTRAL POINT TRANSFORMERS

ANNEX 3: SURFACE TREATMENT

1. SCOPE

This recommendation applies to three-phase, oil-immersed earthing transformers for the supply of solidly earthed, low voltage power in primary substations in 10-15-20 kV networks.

The primary side neutral point constitutes the point of connection for 10-15-20 kV arc-suppression-coils, see DEFU Recommendation 3.

The transformers must be designed for air temperatures in the range of -25...+40°C. However, the average temperature will not exceed 30°C in 24 hours and 20°C in a year.

The recommendation is published in Danish and English. In case of discrepancy between the two versions the Danish version shall prevail.

2. REFERENCES

The transformer must comply with applicable Danish legislation.

The general requirements and test requirements in DS/EN 60076-6 and relevant standard issued by CENELEC, CEN and IEC standards at the time of the invitation to tender must be fulfilled.

It is the responsibility of the user of this recommendation to ensure that the current version and any applicable amendments to legislation, regulations and standards are used when preparing invitations to tender. Information about the applicable version of a standard and any amendments is available from Danish Standards, CENELEC or IEC.

The terminology used in this recommendation is in accordance with the definitions given in the mentioned standards.

3. ELECTRICAL MAIN DATA

3.1. Rated frequency 50 Hz

3.2. Rated voltages

	Primary [kV]			Secondary [V]
Nominal network voltage	10	15	20	400
Rated voltage, U_r	11	16	22	420

If the specific circumstances so warrant, other values may be indicated in the invitation to tender.

Fixed transformation ratios are used.

3.3 Vector group ZNyn5.

3.4. Rated current of the

Rated voltage [kV]	Rated current in the primary neutral point [A]
--------------------	------------------------------------------------

**primary
neutral
point**

11	31,5	63	100	160	200	250	315	400				
16	22	43	68	108	135	173	217					
22	16	31,5	50	80	100	125	160	200	250	315	400	500

**3.5. Rated
power of
secondary
winding**

Typical values used in Denmark are:

100 kVA, 160 kVA and 200 kVA

Unless otherwise specified in the invitation to tender, the following values are used:

With a rated current of the primary neutral point of less than 160 A: 100 kVA.
160 A and above: 200 kVA.

**3.6. Load-
ing of the
secondary
neutral
point**

The neutral point of the secondary winding of the transformer must be dimensioned for persistent load at 10% of the rated current of the secondary side plus the rated current in all secondary phases without exceeding the temperature rise limits in DS/EN 60076-2.

**3. 7. Over-
load ca-
pacity**

The overload capacity must be in accordance with the values stated in DS/EN 60076-7 for normal transformers (ONAN).

With simultaneous loading with rated power of the secondary winding, full current in the secondary neutral point, see section 3.6, and rated current in the primary neutral point, see section 3.4, the permitted temperature rise is 10°C greater than stated in DS/EN 60076-2.

**3.8. Short
circuit
voltage**

Unless specific values are indicated in the invitation to tender, the following minimum values must be respected:

Rated power, [kVA]	Short circuit voltage, % min.
100	1,2
160	1,9
200	2,4

**3.9. Zero-
sequence
imped-
ance**

The zero-sequence impedance of the transformer must be specified in the invitation to tender. In arc-suppression coil tuning, the influence of the zero-sequence impedance of the earthing transformer is taken into account such that the arc-suppression coil current is reduced.

The maximum zero-sequence impedance should be 10-15% of the short circuit impedance of the earthing transformer in order to reduce the influence of the latter.

**3.10. Abil-
ity to with-
stand**

The transformer must be able to withstand the thermal and dynamic effects in the event of external short circuits and earth faults.

short circuit The invitation to tender must indicate the short circuit power of the network. Here, it is presupposed that the short circuit power of the 10-15-20 kV network is 500 MVA (standard practice in Europe according to CENELEC EN 60076-5) if the short circuit power is not known. The duration of the fault current, see EN 60076-5, is assumed to be 2 seconds unless otherwise stated in the invitation to tender. See also annex 3 about the ability to withstand short circuit currents and short circuit protection.

3.11. Insulation level The transformer windings must be made with uniform insulation and must have the following insulation level:

Rated voltage [kV]	Highest voltage for equipment [kV]	Short-time withstand voltage [kV]	Impulse voltage 1.2/50 μ s [kV]
0,42	1,1	3	-
11	12	28	75
16	17,5	38	95
22	24	50	125

3.12. Losses Tenders must state guaranteed values for no-load loss and for load losses at the rated current in the secondary winding. If so required in the invitation to tender, tenders must also state a guaranteed value for load loss at the rated current in the primary neutral point.

If a partial loss differs by more than + 0% from the value stated in the tender, the purchaser reserves the right to reject the transformer.

4. CONSTRUCTION

4.1. Cooling equipment The cooling system of the transformer must be made for natural oil and air circulation (ONAN).

4.2. Bushings Bushings must be made as open type bushings or as plug-in type bushings. Unless otherwise specified in the invitation to tender, bushings must be made as open type bushings. Bushings must not limit the overload capacity of the transformer.

Bushings must be mounted on the cover of the transformer.

The bushings on the primary and secondary side are made and placed according to the following guidelines.

4.2.1. Open type bushings on the primary side must be made in accordance with DS/EN 50180-1.

The insulators must be made of brown-glazed porcelain which is suitable for use in an environment with heavy pollution (SPS¹ class d), see DS/IEC TS 60815-1.

The minimum creepage distance to earth is as follows:

¹ Site pollution severity class.

Rated voltage, U_r [kV]	Creepage distance [mm]
11	280
16	400
22	580

Connecting bolts and nuts etc. must be made in accordance with DS/EN 50180.

4.2.2. Plug-in type bushings on the primary side must be made in accordance with DS/EN 50180-1.

4.2.3. Secondary side bushings must be made in accordance with DS/EN 50386.

Connecting bolts and nuts etc. must be made in accordance with DS/EN 50386.

4.2.4. The bushings must be placed and marked as shown in the figure in annex B1. The markings must be weatherproof and oil-resistant.

The minimum distance between the centre lines of the bushings must be as follows:

Rated voltage, U_r [kV]	Centre distance [mm]
0,42	150
11	265
16	265
22	265

For 22 kV transformers, the clearance between live metal parts on the high voltage side must be at least 225 mm, see DS/EN 60076-3, which may require a greater centre distance depending on the type of bushing.

4.3. Transformer tank etc.

4.3.1. The transformer tank, gaskets etc. must be dimensioned to remain oil-tight and without permanent deformation at loads within the limits indicated in section 3.7.

4.3.2. Cooling ribs made of corrugated sheet metal must be braced to each other at the top and bottom if the ribs are more than 100 mm deep.

4.3.3. The transformer must have three connection points for earth conductors, one of which is placed on the cover next to the neutral point. The other two are placed at the bottom of the tank at opposite ends. The earth terminals must be of type B1 in DS/EN 50216-4 and must be made in accordance with this standard.

They must both be an M12 earthing screw with two nuts. The screws etc. must be made of stainless steel.

4.4 Surface treatment

The surface treatment must be made as described in annex 4, and the invitation to tender will specify either corrosion class 1 for indoor installation or corrosion class 3 for outdoor installation.

5. ACCESSORIES

The transformer must be equipped with corrosion-resistant versions of the accessories listed below. However, if the oil system of the transformer is hermetically sealed from the ambient air, sections 5.1, 5.2 and 5.3 are not applicable.

- 5.1. Valves** The transformer tank must be equipped with an oil draining plug made in accordance with DS/EN 50216-4 and placed on the side as far down as possible. Draining must take place through a valve with a 22 mm Ø bore.
- 5.2. Thermometers pockets and thermometers** The transformer cover must have a thermometer pocket made according to DS/EN 50216-4. In the case of transformers with a gas cushion, the pocket must be long enough to be certain that it reaches the oil. The pocket must be filled with oil and closed with a pipe plug.
- If a thermometer is included in the delivery, it must have a maximum pointer. If it is specified in the invitation to tender that the thermometer is to be able to transmit a signal for alarms, it must have two contacts.
- 5.3. Transport arrangements** The transformer must be prepared for mounting of rollers for transport forward and back. The invitation to tender must indicate whether rollers are to be included in the delivery.
- The transformer must have loops or hooks for lifting of both the complete oil-filled transformer and the core with cover.
- 5.4. Oil** Unless otherwise specified in the invitation to tender, the oil must be mineral oil and must meet the requirements of DS/EN 60296 for transformer oil type A or type B.
- The invitation to tender must indicate whether the transformer oil is to be inhibited.
- To minimise the risk of copper sulphides forming in the oil, the oil must be tested as “non-corrosive” in tests prescribed in DS/EN 62535.
- 5.5. Marking** On the low voltage side, a rating plate must be affixed of a weatherproof and oil-resistant type with the following information, see DS/EN 60076-6:
- Type of transformer (neutral point transformer)
 - Reference to EN 60076-6
 - Manufacturer
 - Serial no.
 - Year of manufacture
 - Insulation level
 - Rated frequency
 - Rated voltage
 - Rated neutral point current and duration
 - Type of cooling (ONAN)
 - Temperature rise for top oil and average rise for winding
 - Total weight
 - Weight of insulation oil

- Type of insulation oil
- Vector group and diagram
- Zero-sequence impedance

For the secondary winding, the following information must appear on the rating plate:

- No-load voltage of secondary winding
- Short circuit voltage (measured value)
- Rated power of secondary winding

6. TESTS

Before a delivery is approved, the tests for earthing transformers stated in DS/EN 60076-6 must have been carried out with a satisfactory result.

Routine tests are carried out on all transformers in the delivery. Type tests are carried out on a unit which is representative for the type.

In addition, special tests must have been carried out to document the ability of the delivered transformer type to withstand short circuit, see DS/EN 60076-5, and its sound level and sound power level if so required in the invitation to tender, see DS/EN 60076-10.

For hermetically sealed transformers, a special test must be carried out to demonstrate a high probability that there will be no fatigue fractures in the transformer tank.

Protocols with the results of all the tests carried out must be submitted to the purchaser in duplicate no later than the time of invoicing.

6.1 Routine tests

- Measurement of winding resistance, see DS/EN 60076-1
- Measurement of no-load losses and no-load current, see DS/EN 60076-1
- Measurement of zero-sequence impedance, see DS/EN 60076-6
- Test with overvoltage from separate voltage source, see DS/EN 60076-3
- Induced voltage withstand test, see DS/EN 60076-3
- Measurement of voltage transformation ratio and check of vector group, see DS/EN 60076-1
- Measurement of short circuit voltage and load losses, see DS/EN 60076-1
- Direct voltage test of the secondary winding, see DS/EN 60076-3
- Verification of paint layer thickness

6.2 Type tests

- Temperature rise test, see DS/EN 60076-6
- Lightning impulse voltage test, see DS/EN 60076-3

6.3 Special tests

- Short circuit test with the secondary winding short circuited, see DS/EN 60076-5 (performed as a type test)
- Measurement of sound level, see DS/EN 60076-10

7. DATA TO BE PROVIDED IN INVITATION TO TENDER

The following data and information must be provided when tenders are invited:

- The rated power of the secondary winding and rated current of the primary neutral point, see section 3.4 and 3.5
- Rated voltages, see section 3.2
- Possible requirements exceeding the minimum requirements concerning oil in the recommendation, see section 5.4
- Corrosion class, see annex 3
- Place of delivery and unloading conditions
- Time of delivery
- Deadline for submission of tender, final dimension drawings etc.
- If applicable, requirements concerning insurance, warranty period and deposits.

In particular:

- If applicable, deviations from the standard rated voltage, see section 3.2
- If applicable, short circuit voltage requirements, see section 3.8
- Requirements concerning zero-sequence impedance, see section 3.9
- Whether the ability to withstand short circuit is required, see section 3.10
- Whether a guaranteed value is required for load loss at rated current in the primary neutral point, see section 3.12
- Whether bushings other than open type bushings are required, see section 4.2
- Whether the cover is to be bolted or welded to the tank
- Whether the transformer is to be delivered with valves, see section 5.1
- Whether the transformer is to have a thermometer pocket, see section 5.2
- Whether a thermometer is to be included in the delivery and the type of thermometer, see section 5.2
- Whether rollers are to be included in the delivery, see section 5.3
- If applicable, restrictions relating to external dimensions
- If applicable, colour requirements for painted transformers
- Which test protocols with results of type tests and special tests, see section 6, are to be submitted with tenders.

Details of the commercial terms and conditions should also be provided*

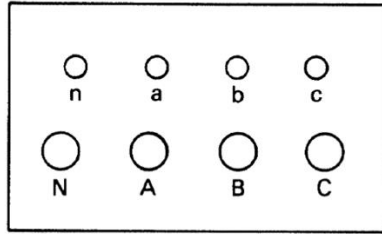
8. DATA TO BE PROVIDED IN TENDERS SUBMITTED

The following information must be provided in the tenders submitted:

- Price for complete transformer carriage paid to place of delivery
- Price of spare parts and warranty period
- Possible price adjustments
- Information about customs duties, exchange rates and VAT
- Terms of payment
- Guaranteed values at 75°C reference temperature for each of the following:
 - o No-load current and no-load losses at rated voltage
 - o Short circuit voltage and load losses at rated current in secondary winding
 - o If so required in the invitation to tender: load losses at rated current in primary neutral point
- Protocol of required type tests and special tests
- Data for bushings: creepage distance and rated current
- Oil type and, if applicable, inhibitor, in which case data for the base oil
- Total weight of the transformer
- For hermetically sealed transformers, whether or not they have a gas cushion
- For hermetically sealed transformers without a gas cushion, tenders must state by how much the oil volume of the tank can change (minimum 10%) without causing permanent changes in shape
- Surface treatment
- Final dimension drawings
- Delivery time
- Warranty period.

In addition, the manufacturer must confirm in the tender that the transformer meets the requirements stated in the terms and conditions of the invitation to tender. Possible deviations from the requirements must be specified in detail.

ANNEX 1: LOCATION GUIDE



ANNEX 2: NOTE ABOUT SHORT CIRCUIT PROTECTION OF EARTHING TRANSFORMERS

An earthing transformer differs from a normal transformer in that the high voltage winding is designed for a much greater load in terms of the neutral point current than the secondary winding. For this reason, the synchronous short circuit impedance tends to be low.

The short circuit currents in the event of a short circuit faults at the low voltage terminals are high, making it difficult to achieve dynamic short circuit protection.

Another difference compared to a normal transformer is that there is no balancing of the zero-sequence flux when the neutral point of the low voltage winding is placed under load. The zero-sequence impedance in the low voltage winding is high. It can be expected to be in the order of 10-20 times higher than the synchronous short circuit impedance.

The current on the high voltage side in the event of a phase-earth fault on the low voltage side is low, see the following formula:

$$I_f = \frac{2}{3} \cdot \frac{3 \cdot U_f}{(2 \cdot Z_k + Z_0) \cdot \frac{U_n^2}{S_n}}$$

Example: 11 kV, 100 kVA, $Z_k = 2\%$, $Z_0 = 15 \cdot Z_k$ results in:

$$I_f = \frac{2}{3} \cdot \frac{3 \cdot 11/\sqrt{3}}{(2 \cdot 2\% + 30\%) \cdot \frac{11^2}{0,1}} = 30A$$

The overcurrent protection on the primary side will allow 1/3 of the arc-suppression coil current to pass, but superimposed with a certain part of the load. Consequently it will often be difficult or impossible to achieve full protection of the low voltage side, regardless of whether high voltage fuses or overcurrent relays and switches are used.

It is therefore recommended that the transformer be installed and operated in such a way that faults between the low voltage fuses and the transformer are effectively ruled out. It will not be necessary to require the transformer to be short circuit proof because of the low voltage fuses, which limit both the thermal and the dynamic impact of faults in the low voltage network.

The rated current of the low voltage fuses is selected to be as close as possible to the rated current of the transformer so that phase-neutral faults are disconnected.

If the functional unit of the switchgear, where the earthing transformer is connected, is protected with high voltage fuses, their rated current is selected to be the next closest standard value above 1/3 of the neutral point current multiplied by a safety factor of at least 1.2, i.e.:

11 kV:									
Neutral point	A	31,5	63	100	160	200	250	315	400
Fuse	A	16	25	40	63	80	100	125	160
16 kV:									
Neutral point	A	22	43	68	108	135	172	217	
Fuse	A	10	20	30	50	63	80	100	
22 kV:									
Neutral point	A	16	31,5	50	80	100	125	160	200

Fuse	A	10	16	20	40	40	50	63	80
------	---	----	----	----	----	----	----	----	----

Concerning the inrush current in a transformer and/or arc suppression coil, it should be verified that the 10 ms and 100 ms fusing currents of the fuses are not less than 4 and 2 times the rated current of the primary neutral point respectively.

ANNEX 3: RESISTANCE TO CORROSION

Note: Updating corrosion protection requirements are under consideration.

1. Efforts must be made to obtain a lifetime of 20 years or more.
2. An environmental pollution corresponding to heavy pollution (pollution level III (heavy), see EN 60071-2) must be assumed.
3. All construction parts must be well drained. Profile and plate edges must be rounded off, $r \geq 2$ mm or equal to half the metal thickness. Welding beads and protruding surface defects must be completely removed.

All welds must be fully welded and all welding cinder must be removed prior surface treatment. After welding with coated electrodes, the construction must be carefully washed off with water if the subsequent cleaning is blast-cleaning.

4. Outside surface treatment.
Supplier may choose between following system procedures:

- 4.1 Paint.

The pre-treatment must be sand blast-cleaning, minimum purity degree Sa 2 1/2 according to ISO 8501-1.

The surface treatment must be carried out as follows:

Basic treatment: two-component zinc-rich epoxy or metallisation with zinc
min. 50 μm

Intermediate paint: two-component epoxy
or vinyl or chlorinated rubber
min. 140 μm
min. 160 μm

Paint finish: on epoxy two-component polyurethane or vinyl/acrylic enamel
min. 30 μm

A thermoplastic intermediate paint must be covered with thermoplastic paint finish. Alternative paint treatments can be offered for evaluation and possible approval by the purchaser.

Adhesion testing according to DS/EN ISO 2409 must result in values Gt 0, Gt 1 or Gt 2. The test requirement must be met both at the time of delivery and at the end of the warranty period.

Pinhole testing with low voltage pinhole detector (9 V, wet sponge, see e.g. DS/R 454) must show max. following number of pinholes:

3 pinholes/m edge length

3 pinholes/m² surface

- 4.2. Hot dip galvanising (of smaller items).

Hot dip galvanising according to DS/ISO 1459 and 1461 class B.

- 4.3 Where metal thickness or the construction cause, that neither hot dip galvanising in class B or treatment with paint as described in 4.1 is possible, hot dip galvanising according to DS/ISO 1459 and 1461 class C is preferred to treatment with paint. Any such deviation must be indicated and explained in the tender.

5. The requirements on screws, nuts, washers etc. are stainless steel (AISI 316), screw threads to be rolled. Threads etc. to be greased.

6. Inside treatment.

Rust, cinder and welding pearls in the transformer tank and oil conservator, if any, must be vacuumed and removed. The oil conservator must be painted on the inside with an oil-resistant paint; the same applies to the transformer tank.

Cooling elements must be treated on the inside so that they are clean and free of rust and welding cinder etc.

7. If the supplier offers alternative treatments, the described treatment suggestions must be quality references. In general, larger layer thicknesses of the alternatives are required, especially when they do not include a zinc-rich basic treatment, Requirements to pinhole occurrence and adhesion remain unchanged.