

Recommendation 6A

*Technical requirements for
10-15-20 kV/0.4-0.69 kV oil-immersed dis-
tribution transformers*

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1. SCOPE

This recommendation applies to three-phase, oil-immersed distribution transformers with normal accessories.

The transformers are used to transmit power from arc-suppression-coil-earthed or isolated 10-20 kV networks to solidly earthed low voltage networks.

This recommendation consists of a Danish and an English version. In case of any discrepancies between the two versions, the Danish version is legally valid.

2. GENERAL REQUIREMENTS

The transformer must comply with applicable Danish legislation.

The general requirements and testing requirements which are in force at the time of the invitation to tender and which are contained in CENELEC, CEN and IEC standards must be met.

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.

2.1 Temperature

The transformer is designed for installation at ambient temperatures in the range:

$$-25^{\circ}\text{C} \dots +40^{\circ}\text{C}$$

Furthermore, the monthly average temperature must not exceed 30°C, and the annual average temperature must not exceed 20°C.

3. PRINCIPAL ELECTRICAL DATA

3.1 Rated frequency

50 Hz.

3.2 Rated power

Recommended rated power values:

100 – 200 – 250 – 400 – 500 – 630 – 800 – 1000 – 1250 – 1600 – 2000 – 2500 kVA.

3.2.1 For a load current, the total harmonic content¹ and the even harmonic content, see DS/EN 60076-1, must be limited to 5% and 1% respectively. If these limits are exceeded, the harmonic content in the load current must be taken into account by using a transformer with a higher rated power or derate to a lower rated power.

If applicable, see DEFU report RA 532 "Transformers exposed to harmonic currents" [in Danish: *Transformere udsat for harmoniske strømme*] for a detailed description of the load limit of the transformers when they are exposed to harmonic currents.

3.3 Dimensioning of neutral point

The neutral point and neutral conductor on the secondary side (low voltage side) must be dimensioned for rated current of the secondary winding.

3.4 Overload capacity

The overload capacity of the transformer must be in accordance with the values stated in DS/EN 60076-7 for normal transformers (ONAN). Bushings on the primary and secondary

¹ The harmonic content is determined with:
$$H[\%] = 100 \cdot \left[\sum_{h=2}^{h=H} \left(\frac{I_h}{I_1} \right) \right]^{\frac{1}{2}}$$

side, tap changers, accessories etc. must not limit the overload capacity of the transformer as set out above.

For hermetically sealed transformers, a maximum permissible oil temperature lower than the value of 115°C indicated in DS/EN 60076-7 must be indicated in tenders and on the rating plate.

3.5 Rated voltages

| Nominal voltage | Primary [kV] | | | Secondary [V] | |
|----------------------|--------------------|-------|----|---------------|------------------|
| | 10 | 15 | 20 | 400 | 690 |
| Rated voltage, U_r | 10,50 ² | 15.75 | 21 | 420 | 690 ³ |

3.6 Tappings

The high voltage winding must have five tappings corresponding to its rated voltage $\pm 2.2,5\%$. It must be possible to switch between the tappings by means of the tap changer, see 4.1. It must be possible to load the transformer as described in 3.4 in all tap-changer positions.

3.7 Vector group

Dyn 5 or Dyn 11. If the rated power is less than or equal to 200 kVA, the vector group may be Yzn 5 or Yzn 11.

3.8 Short circuit voltage

Unless otherwise specified in the invitation to tender, the short circuit voltage must be as shown below, see DS/EN 50588-1.

| Rated power [kVA] | ≤ 630 | > 630 |
|----------------------------------|------------|---------|
| Short circuit voltage, e_k [%] | 4 | 6 |

A higher short circuit voltage may be specified in special situations to limit the short circuit level.

3.9 Ability to withstand short circuit

In all tap changer positions, the transformer and all equipment and accessories must be able to withstand the thermal and mechanical influences in the event of external short circuits and earth faults.

The invitation to tender must indicate the short circuit power of the network. It is presupposed that the short circuit power of the 10-15-20 kV network is 500 MVA (standard practice in Europe according to DS/EN 60076-5) if the short circuit power is not known.

3.10 Insulation level

The transformer must have uniform insulation and be dimensioned for the following voltages:

| Rated voltage, U_r [kV] | Highest voltage for the equipment, U_m [kV] | 1 min. alternating voltage [kV] | Impulse voltage 1,2/50 μ s [kV] |
|---------------------------|---|---------------------------------|-------------------------------------|
| 0,42 | 1,1 | 3 | 6 |
| 0,69 | 1,1 | 3 | 6 |
| 10,5 | 12 | 28 | 75 |
| 15,75 | 17,5 | 38 | 95 |
| 21 | 24 | 50 | 125 |

3.11 Losses and sound power level

The maximum load loss, no-load loss and sound power level of the transformer must be specified in the invitation to tender.

3.11.1 The load losses and no-load losses must comply with the maximum loss requirements in phase 2 in EU Regulation No 548/2014 of 21 May 2014 and No 2019/1783 of 1 October 2019. The requirements are reproduced in the table below for load loss in column A_0 and for no-load loss in column AA_0 .

² 10,75 kV with a fixed transformation ratio.

³ Unless otherwise agreed.

For losses lower than those set out in the above EU Regulations, the tenders submitted must be based on the capitalisation factors for no-load loss and load loss indicated in the invitation to tender.

If the no-load and load losses exceed the agreed values, the purchaser reserves the right to reject the transformer. No price adjustment will be made for no-load or load losses below the values stated in the tender submitted.

If the purchase concerns a batch of transformers, the losses of each individual transformer will be considered.

3.11.2 Unless otherwise specified in invitation to tender, the maximum sound power level of the transformer must be as specified in DS/EN 50588-1. The following table reproduces the sound power levels from DS/EN 50588-1.

| Nominal power [kVA] | A _k | AA ₀ | Sound power |
|------------------------|----------------|--------------------|----------------------|
| | P [W] | P ₀ [W] | L _{WA} [dB] |
| 100 | 1250 | 130 | 40 |
| 200* | 2017 | 225 | 44 |
| 250 | 2350 | 270 | 46 |
| 400 | 3250 | 387 | 49 |
| 500 | 3900 | 459 | 50 |
| 630 | 4600 | 540 | 51 |
| 800 | 6000 | 585 | 52 |
| 1000 | 7600 | 693 | 54 |
| 1250 | 9500 | 855 | 55 |
| 1600 | 12000 | 1080 | 57 |
| 2000 | 15000 | 1305 | 59 |
| 2500 | 18500 | 1575 | 62 |

*Values are calculated by linear interpolation based on values in EU Regulations No 548/2014 of 21 May 2014 and No 2019/1783 of 1 October 2019 and DS/EN 50588-1 for a 160 kVA and a 250 kVA transformer.

For transformers intended for noise-sensitive locations, it may be necessary to prescribe lower values for the sound power level than specified in the table.

The sound power level is documented as described in DS/EN 60076-10. If the sound power level exceeds the agreed value, the purchaser reserves the right to reject the transformer.

4. CONSTRUCTIONS

4.1 Tap-changers

The transformer must have a tap changer for switching in the de-energised state between the tapplings described in 3.6. The tap changer must be built into the transformer tank. Clockwise turning of the tap-changer must increase the voltage on the low voltage side.

The tap changer must be easily accessible for operation and reading of the step position even if high voltage and low voltage cables are installed on the transformer. The steps must be clearly marked with the numbers 1, 2, 3, 4 and 5, where 1 indicates connection of the maximum number of primary windings. Step 3 must correspond to the rated voltage transformation ratio. The tap-changer must not limit the overload capacity of the transformer.

4.2 Cooling equipment

The cooling system of the transformer must be designed for natural oil and air circulation (ONAN).

Note: A transformer with ester oils must be designed for a natural insulating fluid with a fire point above 300°C and air circulation (KNAN).

4.3 Bushings

Bushings may be realised as open type bushings or as plug-in type bushings. Unless otherwise specified in the invitation to tender, bushings must be 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 must be wrapped in plastic for delivery.

The bushings on the high voltage and low voltage side must be designed and placed according to the following guidelines.

4.3.1. Open type bushings on the high voltage side must be made in accordance with DS/EN 50180-1.

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

The minimum creepage distance to earth must be as follows:

| Rated voltage, U_r [kV] | Creepage distance [mm] |
|---------------------------|------------------------|
| 10,5 | 280 |
| 15,75 | 400 |
| 21 | 580 |

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

4.3.2. Plug-in type bushings must be made in accordance with DS/EN 50180-1 and be of type A, unless otherwise specified in the invitation to tender.

4.3.3. Low voltage bushings must be made in accordance with DS/EN 50386.

Connecting bolts and nuts etc. must be made in accordance with DS/EN 50386. Connecting flanges must be provided for transformers with a rated power greater than or equal to 500 kVA.

4.3.4. The bushings must be placed and marked as shown in the figure in annex B2. 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] | Rated power [kVA] | Centre distance [mm] |
|---------------------------|-------------------|----------------------|
| 0,42 | ≤ 200 | 70 |
| 0,42 | $> 200, < 1600$ | 150 |
| 0,42 | ≥ 1600 | 165 |
| 0,69 | ≤ 200 | 70 |
| 0,69 | $> 200, < 1600$ | 150 |
| 0,69 | ≥ 1600 | 165 |
| 10,5 | 50...2500 | 265 |
| 15,75 | 50...2500 | 265 |
| 21 | 50...2500 | 265 |

4.4 Transformer tank etc.

The transformer tank, gaskets etc. must be dimensioned to remain oil-tight and without permanent deformation at loads within the limits indicated in DS/EN 60076-7 (ONAN).

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.

The transformer must have three connection points for earth conductors. One must be placed on the cover next to the neutral terminal on the low voltage side. The other two must be placed at the bottom of the transformer tank at opposite ends. The earth terminals must be of type B1 in DS/EN 50216-4 and must be realised in accordance with this standard. Bolts etc. must be made of stainless steel.

4.5 Surface treatment

The transformer must be designed, and surface treated as described in annex B1.

4.6 Dimensions

The invitation to tender must state the following:

Maximum height of the transformer (including any mounted rollers), (h in the figure in annex B2)

Maximum width of the transformer, (b in the figure in annex B2)

Maximum length of the transformer, (l in the figure in annex B2)

All dimensions apply to the transformer including bushings and all equipment and accessories mounted (apart from the contribution from mounted rollers).

5. ACCESSORIES

The transformer must be equipped with the accessories listed below.

Accessories must be in accordance with the relevant part of DS/EN 50216.

5.1 Valves

The transformer tank must be equipped with an oil drain device 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 in the case of transformers below 1000 kVA. In the case of transformers with a rated power greater than or equal to 1000 kVA there must be two valves with a 31 Ø mm bore placed at diagonally opposite corners.

5.2 Thermometers and thermometer pockets

The transformer cover must have a thermometer pocket made according to DS/EN 50216-4. Transformers with a rated power greater than or equal to 500 kVA must have two thermometer pockets. 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 etc.

The transformer must be prepared for mounting of rollers for transport forward and back. If the rated power is greater than or equal to 500 kVA, it must be possible to turn the rollers for transport side to side. The invitation to tender must indicate whether rollers are to be included in the delivery.

The rollers which can be mounted on the transformer must be made in accordance with DS/EN 50216-4, must be of type W1 and must be selected from the following table:

| Roller diameter (d in the figure in annex B2) [mm] | Roller width [mm] | Maximum carrying capacity per roller [t] |
|--|----------------------|--|
| 125 | 40 or 50 | 2,5 |
| 160 | 50 | 3,6 |
| 200 | 70 | 6,3 |

The distance between rollers must be in accordance with DS/EN 50216-4 and must be determined on the basis of the following table:

| Rated power [kVA] | Distance between rollers (e in the figure in annex B2) [mm] |
|-------------------------|---|
| $S \leq 250$ | 520 |
| $250 \leq S \leq 1250$ | 670 |
| $1250 \leq S \leq 1600$ | 820 |
| $1600 \leq S \leq 2500$ | 820 or 1070 |

The frame of transformers with a rated power greater than or equal to 1000 kVA must be prepared for mounting of towing lugs necessary for transport.

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, mineral oil meeting the requirements of DS/EN 60296 must be used.

The oil must have been tested as “non-corrosive” in accordance with DS/EN 62535.

Note: If a transformer is to be delivered with an ester oil instead of mineral oil, the requirements concerning the oil are contained in DS/EN 62770 for natural ester oils and in DS/EN 63012 for synthetic ester oils.

5.5 Rating plate

On the low voltage side, a rating plate of a weatherproof and oil-resistant type must be affixed with the minimum information specified in EN 60076-1, the voltage transformation ratios at no-load, and the type of oil. It must be possible to move the rating plate between all sides of the transformer.

The following information must be contained on the rating plate:

- Transformer type
- Reference to standard
- Manufactures name
- Product serial number
- Year of manufacture
- Number of phases
- Rated power
- Rated frequency
- Rated voltage and tapping voltage for the individual tapings
- Rated current
- Vector group
- Short circuit voltage
- Cooling
- Total weight
- Weight of insulation oil
- Insulation level (with reference to EN 60073-3)
- Maximum short circuit current used to determine the ability of the transformer to withstand short circuit.

In particular:

- Type of insulation oil
- Barcode with serial number (if there is space on the rating plate).

6. TESTS

Before a delivery is approved, the following tests must have been carried out with a satisfactory result. Tests must be carried out in accordance with relevant parts of the DS/EN 50885 series and the DS/EN 60076 series.

Routine tests must be carried out on all transformers in the delivery. Type tests must be carried out on a unit which is representative for the type. Special tests must be carried out as specified either as routine tests or type tests.

6.1 Routine tests

- Measurement of the resistance of windings, see DS/EN 60076-1
- Measurement of voltage transformation ratio and vector group, see DS/EN 60076-1
- Measurement of short circuit voltage and load losses, see DS/EN 60076-1
- Measurement of no-load losses and no-load current, see DS/EN 60076-1
- Applied voltage test, see DS/EN 60076-3
- Induced voltage withstand test, see DS/EN 60076-3.

6.2 Type tests

- Temperature rise test, see DS/EN 60076-2
- Full wave lightning impulse voltage test (high voltage winding), see DS/EN 60076-3.

6.3 Special tests

- Measurement of sound level (performed as a routine test), see DS/EN 60076-10
- Test of ability to withstand short circuit (performed as a type test), see DS/EN 60076-5
- Test of corrugated transformer tank (performed as a type test), see DS/EN 50588-1
- Endurance test
- Leak test.

7. DATA TO BE PROVIDED IN INVITATION TO TENDER

The following data and information must be provided in invitation to tender:

- Cooling, see 4.2.
- Rated power, see 3.2.
- Rated frequency, see 3.1.
- Rated voltages (primary and secondary), see 3.5.
- Maximum load losses, see 3.11.1.
- Maximum no-load losses, see 3.11.1.
- Capitalisation factor for no-load and load losses, see 3.11.1.
- Maximum sound power level, see 3.11.2.
- Highest voltage for windings (primary and secondary), see 3.10.
- Insulation level, see 3.10.
- Tappings, see 3.6.
- Tap changer for switching in the de-energised state, see 4.1.
- Vector group, see 3.7.
- System earthing for windings (primary and secondary), see 1.
- Special conditions in connection with installation, mounting, transport and handling.
- Any special restrictions for dimensions and weight.
- Indication of where various accessories are to be placed.

- **In particular:**
 - Short circuit voltage, see 3.8.
 - Short circuit power of the network, see 3.9.
 - Special conditions regarding ambient temperature and any restrictions in connection with cooling.
 - Whether the transformer is to have a fixed voltage transformation ratio or whether there are deviating requirements concerning tappings, see 3.6.
 - Whether bushings are to be plug-in type bushings, and which type, see 4.3.
 - If applicable, surface treatment requirements, see B1, e.g. whether hot dip galvanising is preferred.
 - Requirements concerning dimensions etc. (maximum height, width and length), see 4.6.
 - Whether the transformer is to have a lower sound power level than specified in DS/EN 50588-1, see 3.11.2.
 - Special requirements for oil type, see 5.4.
 - Whether the transformer is to be delivered with valves, see 5.1.
 - Whether thermometer pocket(s), see 5.2, can be omitted.
 - Whether a thermometer is to be included in the delivery. Whether it is to have contacts which can transmit an alarm, see 5.2.
 - Whether transport rollers are to be included in the delivery, see 5.3.
 - Special requirements concerning transport rollers, see 5.3.

- **Commercial:**
 - Delivery time and unloading conditions
 - Delivery address
 - Earliest and last delivery time
 - If applicable, the delivery terms; unless otherwise indicated Carriage Paid To place of delivery, see Incoterms 2020.
 - Deadline for submission of tender, final dimension drawings etc.
 - Possible requirements concerning insurance, warranty period, deposits, period of validity of the tender etc.

Furthermore, the commercial terms should be specified in detail.

8. DATA TO BE PROVIDED IN TENDERS SUBMITTED

The following information must be provided in the tenders submitted:

- Price for complete delivery
- Possible price adjustments
- Information about customs duties, VAT and exchange rate adjustments
- Terms of payment
- Guaranteed values for no-load loss and no-load current at rated voltage
- Guaranteed values for load loss and short circuit voltage at rated transformation ratio and 75°C reference temperature
- Guaranteed sound power level
- Data for bushings, creepage distance and rated current
- Oil type and, if applicable, inhibitor, in which case data for the base oil
- Safety data sheet for the oil.
- Oil content in kg and volume
- Total weight of the transformer
- For hermetically sealed transformers, tenders must state by how much the volume of the transformer tank can change (minimum 10%) without permanent changes in shape. Where necessary, the maximum oil temperature is stated
- Surface treatment
- Final dimension drawings
- Delivery time
- Warranty period

In addition, the supplier must confirm that the requirements stated in the invitation to tender have been met. Possible deviations must be specified in detail.

ANNEX:

B1. PROTECTION AGAINST CORROSION

Note: Updating corrosion protection requirements is under consideration.

B1.1

Efforts must be made to obtain a lifetime of 20 years or more.

B1.2

An environmental impact equivalent to heavy pollution is presupposed (heavy pollution, see DS/EN 60071-2).

B1.3

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 deposit and protruding surface defects must be completely removed.

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

B1.4 Outside surface treatment

The supplier may choose between the following protective systems:

B1.4.1. Painting

The pre-treatment must be blast-cleaning, minimum grade of cleanliness Sa 2 1/2 according to DS/EN ISO 8501-1.

The surface treatment must be realised as follows:

Application of base coat: two-component zinc-rich epoxy or metallisation with zinc
min. 50 μm

Application of intermediate coat: Middle coat: two-component epoxy
min. 140 μm

or vinyl or chlorinated rubber min. 160 μm

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

Finish coat, on thermoplastic intermediate coat: must thermoplastic finish coat.

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 find no more than the following number of pinholes:

- Edge length 3 pores/m edge length
- Surface 3 pores/ m^2 surface

B1.4.2 Hot dip galvanising according to DS/EN 1461 class B.

B1.4.3 If as a result of the metal thickness or the construction neither hot dip galvanising in class B nor treatment with paint as described in 4.1 is possible, hot dip galvanising according to DS/EN 1461 class C is preferred to treatment with paint. Any such deviation must be indicated and explained in the tender.

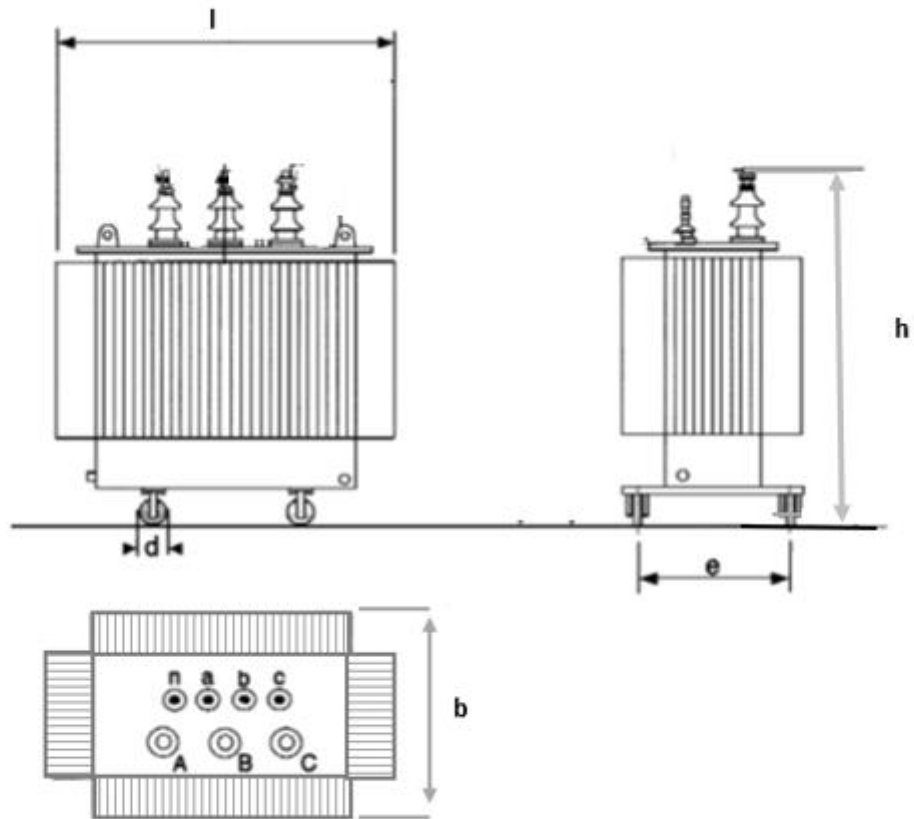
B1.5 Screws, nuts, washers etc. must be made of acid proof stainless steel (AISI 1316)., Screw threads must be rolled. Threads etc. must be greased.

B1.6 If the supplier offers alternative treatments, the described treatment suggestions are quality references. In general, larger layer thicknesses of the alternatives are required, especially when they do not include a zinc-rich base coat, whereas the pinhole and adhesion requirements remain unchanged.

B1.7 Inside treatment The transformer tank must be cleared of rust, slag and welding beads, vacuumed and cleaned. If the inside of the transformer tank is at risk of rusting during production, it must be painted on the inside with an oil-resistant paint.

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

ANNEX B2: DIMENSIONS



NOTE: Height h is indicated with the high voltage bushing as the highest point. The low voltage winding can also be the highest point, in which case it is this point that must be used.