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NTS, Ställverk och primärapparater

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VF Eldistribution

TEKNISK RIKTLINJE

UTGÅVA  
10

FASTSTÄLLD  
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*Anders*

# POWER TRANSFORMERS 2 MVA AND ABOVE

## Introduction

These guidelines are mainly based on Standard SS-EN 60076. The guidelines specify alternative in the case of more possibilities and also include additions and elucidations to the standard. The guidelines can be made binding by the client and will then specify the requirements which together with the applicable standard are valid for the design and testing.

## Revision

| Revision | Revision note                                                                                                                                   | Date       |
|----------|-------------------------------------------------------------------------------------------------------------------------------------------------|------------|
| 10       | Section 2, Valid standards to be related to time of published RFQ (Request For Quotation)                                                       | 2022-01-01 |
| 10       | Section 3.3, Table 3.2 updated according to SS-EN 60076-5 for Um=245 kV and Um=420 kV.                                                          | 2022-01-01 |
| 10       | Section 4.4.1, Insulation levels for Um 123 kV updated.                                                                                         | 2022-01-01 |
| 10       | Section 4.4.2, Table 4.3 updated.                                                                                                               | 2022-01-01 |
| 10       | Section 4.7.2, With the fans out of operation transformers with cooling type ONAF must be capable of loading with 70 % of the ONAF rated power. | 2022-01-01 |
| 10       | Section 4.13, Combination of paper and oil shall be chosen to avoid stray gassing and to maximize life span.                                    | 2022-01-01 |
| 10       | Section 4.14.1, Design of stabilising winding clarified.                                                                                        | 2022-01-01 |
| 10       | Section 4.14.2, Table 4.8 updated                                                                                                               | 2022-01-01 |
| 10       | Section 7, Mechanically linked indicating device not required.                                                                                  | 2022-01-01 |
| 10       | Section 8, Requirements updated.                                                                                                                | 2022-01-01 |
| 10       | Section 9.1, Device for gas sampling at service level shall always be included and be connected by means of a flexible tube.                    | 2022-01-01 |
| 10       | Section 9.1, For the gas and oil actuated relay, it must be clearly indicated if a valve is open or closed.                                     | 2022-01-01 |
| 10       | Section 9.2, Location of oil level indicators located on the conservator clarified.                                                             | 2022-01-01 |
| 10       | Section 9.3, Temperature ranges for top oil temperature gauge and winding temperature gauge suggested.                                          | 2022-01-01 |
| 10       | Section 9.3, Doubled top oil temperature gauges for inter-bus transformers only for cooling type OF.. and OD...                                 | 2022-01-01 |
| 10       | Section 9.3, All two winding transformers shall be provided with one temperature gauge in the low voltage winding.                              | 2022-01-01 |

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| 10 | Section 9.3, Two winding transformers 63 MVA and above shall be provided with one temperature gauge in each winding.                                                                      | 2022-01-01 |
| 10 | Section 9.3, Transformers with three windings or more shall be provided with one temperature gauge in each winding.                                                                       | 2022-01-01 |
| 10 | Section 9.4, Contact adjustable only for the manufacturer.                                                                                                                                | 2022-01-01 |
| 10 | Section 9.7, Selected fibre locations must be documented on a drawing, included in the final documentation.                                                                               | 2022-01-01 |
| 10 | Section 10.1, For the cooling equipment, valve requirements are clarified.                                                                                                                | 2022-01-01 |
| 10 | Section 11.1, Component markings clarified.                                                                                                                                               | 2022-01-01 |
| 10 | Section 11.1, Cubicle doors shall be equipped with an espagnolette lock.                                                                                                                  | 2022-01-01 |
| 10 | Section 11.2, Requirements regarding cubicle lightning clarified.                                                                                                                         | 2022-01-01 |
| 10 | Section 11.2, Non-corrosive metallic ventilation nets.                                                                                                                                    | 2022-01-01 |
| 10 | Section 11.3.1, Equipment in boxes and cubicles for auxiliary power, current transformers and bushing capacitive taps shall be selected in such a way that no extra heating is necessary. | 2022-01-01 |
| 10 | Section 11.3.1, Thermal insulation shall be halogen free.                                                                                                                                 | 2022-01-01 |
| 10 | Section 11.3.2, A plate with recommended temperature settings to be placed inside the cubicle in vicinity of the thermostat.                                                              | 2022-01-01 |
| 10 | Section 11.3.2, Design of heating clarified.                                                                                                                                              | 2022-01-01 |
| 10 | Section 11.3.3, Design of heating supervision clarified.                                                                                                                                  | 2022-01-01 |
| 10 | Section 12, Each core shall be connected to the terminal box by a separate cable.                                                                                                         | 2022-01-01 |
| 10 | Section 13.1, Fire resistant cable glands.                                                                                                                                                | 2022-01-01 |
| 10 | Section 13.2, Short circuit capability for auxiliary power supply clarified.                                                                                                              | 2022-01-01 |
| 10 | Section 13.4, Winding temperature rise for matching transformers clarified.                                                                                                               | 2022-01-01 |

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| 10 | Section 13.5, Normally the cooling equipment power supply shall be taken from the local power supply.                                         | 2022-01-01 |
| 10 | Section 13.5, Requirements regarding one extra group for auxiliary power updated.                                                             | 2022-01-01 |
| 10 | Section 14, Cable channels must not contain halogen.                                                                                          | 2022-01-01 |
| 10 | Section 14, Requirements regarding insulation of peeled part of a cable sheath clarified.                                                     | 2022-01-01 |
| 10 | Section 15.3, One eyelet shall be located in the vicinity of the slip protection.                                                             | 2022-01-01 |
| 10 | Section 15.3, Requirements regarding slip protection and handrails clarified.                                                                 | 2022-01-01 |
| 10 | Section 15.5, Requirements regarding designation plates clarified.                                                                            | 2022-01-01 |
| 10 | Section 15.8, Cable dimensions updated.                                                                                                       | 2022-01-01 |
| 10 | Section 15.8, For $U_m < 72.5$ kV, the arresters shall be separately earthed to the cover, using shortest possible cables.                    | 2022-01-01 |
| 10 | Section 15.8, Location of surge arresters clarified.                                                                                          | 2022-01-01 |
| 10 | Section 15.8, An external bracket for surge arresters must be easy to dismantle.                                                              | 2022-01-01 |
| 10 | Section 15.10, Jacks must be dimensioned with respect to the total transformer weight, including oil.                                         | 2022-01-01 |
| 10 | Section 15.10, Dimensioning of oak beams clarified.                                                                                           | 2022-01-01 |
| 10 | Section 15.10, Maximum allowed stresses during transport clarified.                                                                           | 2022-01-01 |
| 10 | Section 15.11, Requirements regarding platform for inspection of gas and oil actuated rely, including permanently assembled ladders, updated. | 2022-01-01 |
| 10 | Section 15.11, Platform for inspection of gas and oil actuated rely to be provided only if specified.                                         | 2022-01-01 |
| 10 | Section 16.4, Minimum allowed coating thickness clarified.                                                                                    | 2022-01-01 |
| 10 | Section 18.1, The oil must contain at least 0.2% (kg/kg) of an oxidation inhibitor.                                                           | 2022-01-01 |
| 10 | Section 18.1, Two new biodegradable oils approved.                                                                                            | 2022-01-01 |

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| 10 | Section 18.3, Requirement regarding separately mounted conservators clarified.                                                                                                                | 2022-01-01 |
| 10 | Section 19.1.1, Separate rating plate for matching transformer.                                                                                                                               | 2022-01-01 |
| 10 | Section 19.1.1, Additional information on the rating plate.                                                                                                                                   | 2022-01-01 |
| 10 | Section 19.1.6.2, Current transformer rating plate data updated.                                                                                                                              | 2022-01-01 |
| 10 | Section 19.1.8, Oil level and oil volume must be shown at oil level diagram.                                                                                                                  | 2022-01-01 |
| 10 | Section 19.1.9, Visible labels showing the direction of rotation of fans shall be provided.                                                                                                   | 2022-01-01 |
| 10 | Section 23.7.4, Zero sequence measurement requirements updated.                                                                                                                               | 2022-01-01 |
| 10 | Section 23.7.5.3, Maximum allowed PD-level when $U=1.58 \times U_r / \sqrt{3}$ is 200 pC.                                                                                                     | 2022-01-01 |
| 10 | Section 23.7.7, Over pressure test according to SS-EN 60076-1.                                                                                                                                | 2022-01-01 |
| 10 | Section 23.7.11, Winding insulation resistance measurement clarified.                                                                                                                         | 2022-01-01 |
| 10 | Section 23.7.15, For inter-bus transformers 500 MVA and above and generator step up transformers 75 MVA and above, the sound power level in load operation shall be measured for information. | 2022-01-01 |
| 10 | Section 23.8.4, Duration of thermal overload temperature rise test clarified.                                                                                                                 | 2022-01-01 |
| 10 | Section 23.8.4, If optical fibres are used, the overload temperature rise test shall include readings, which shall be recorded at least every hour and be presented in the test report.       | 2022-01-01 |
| 10 | Section 24.1, Impact recorder maximum registered values during transport, including maximum allowed values shall be included in the SAT report.                                               | 2022-01-01 |
| 10 | Section 24.1.1, FDS test substituted by DFR test.                                                                                                                                             | 2022-01-01 |
| 10 | Section 26.3, Table 26.1 updated.                                                                                                                                                             | 2022-01-01 |
| 10 | Section 26.3, Immediately after approval, circuit diagrams and transformer outline drawings including accessories, shall be supplied in AutoCAD dwg format.                                   | 2022-01-01 |
| 10 | Section 26.4, Plate drawings included in the                                                                                                                                                  | 2022-01-01 |

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|    | instruction manual.                                                                            |            |
| 10 | Section 26.4, Data compilation omitted from instruction manual.                                | 2022-01-01 |
| 10 | Section 26.4, Bushing drawings to be included in the instruction manual.                       | 2022-01-01 |
| 10 | Section 26.4, A safety data sheet for the oil shall be provided in the instruction manual.     | 2022-01-01 |
| 10 | Section 27, In part 14, "circulating current" is added as an alternative.                      | 2022-01-01 |
| 10 | Section 27, Verification of cooling capacity at installation not in open air may be requested. | 2022-01-01 |

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# 1 SCOPE

These guidelines cover three phase and single-phase 50 Hz oil immersed power transformers rated 2 MVA and above.

Four categories are dealt with:

- |   |                                                                                                                                   |
|---|-----------------------------------------------------------------------------------------------------------------------------------|
| A | Distribution system power transformers - rated 2 - 100 MVA and highest voltage for equipment 12 - 170 kV with recommended ratings |
| B | Inter-bus transformers - interconnecting voltage systems 72.5 kV and above                                                        |
| C | Generator step up (GSU) transformers including wind farm transformers (wind)                                                      |
| D | High Voltage DC (HVDC) transformers                                                                                               |

# 2 STANDARDS

If standards referred to have been revised, the ones in force at the time of published RFQ (Request For Quotation) shall be considered as valid, unless otherwise is agreed upon. SS-EN documents are the ruling requirements, thereafter CENELEC (EN, HD or TS documents) and thereafter IEC or ISO.

|                    |                                                                                                                   |
|--------------------|-------------------------------------------------------------------------------------------------------------------|
| SS-EN/EN/IEC 60076 | Power transformers                                                                                                |
| SS-EN 60076-1      | Part 1: General                                                                                                   |
| SS-EN 60076-1/A1   | Part 1: Amendment No. A1                                                                                          |
| SS-EN 60076-1/A12  | Part 1: Amendment No. A12                                                                                         |
| SS-EN 60076-2      | Part 2: Temperature rise                                                                                          |
| SS-EN 60076-3      | Part 3: Insulation levels and dielectric tests                                                                    |
| SS-EN 60076-4      | Part 4: Guide to the lightning impulse and switching impulse testing –Power transformers and reactors             |
| SS-EN 60076-5      | Part 5: Ability to withstand short circuit                                                                        |
| IEC 60076-7        | Part 7: Loading guide for oil-immersed power transformers                                                         |
| IEC 60076-8        | Part 8: Application Guide                                                                                         |
| SS-EN 60076-10     | Part 10: Determination of sound levels                                                                            |
| IEC 60076-10-1     | Part 10-1: Determination of sound levels. - Application guide                                                     |
| SS-EN 60076-11     | Part 11: Dry-type transformers                                                                                    |
| SS-IEC 60076-12    | Part 12: Loading guide for dry-type power transformers                                                            |
| SS-EN 60076-14     | Part 14: Design and application of liquid-immersed power transformers using high-temperature insulation materials |
| IEC 61378-2        | Converter transformers – Part 2: Transformers for HVDC applications                                               |

|                  |                                                                                                                                                                                      |
|------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| SS-EN 50216      | Power transformer and reactor fittings                                                                                                                                               |
| SS-EN 50216-1    | Part 1: General                                                                                                                                                                      |
| SS-EN 50216-2    | Part 2: Gas and oil actuated relay for liquid immersed transformers and reactors with conservator                                                                                    |
| SS-EN 50216-2/A1 | Part 2: Amendment No. A1                                                                                                                                                             |
| SS-EN 50216-3    | Part 3: Protective relay for hermetically sealed-liquid immersed transformers and reactors without gaseous cushion                                                                   |
| SS-EN 50216-3/A2 | Part 3: Amendment No. A2                                                                                                                                                             |
| SS-EN 50216-4    | Part 4: Basic accessories                                                                                                                                                            |
| SS-EN 50216-5    | Part 5: Liquid level, pressure devices and flow meters                                                                                                                               |
| SS-EN 50216-5/A2 | Part 5: Amendment No. A2                                                                                                                                                             |
| SS-EN 50216-5/A3 | Part 5: Amendment No. A3                                                                                                                                                             |
| SS-EN 50216-6    | Part 6: Cooling equipment – Removable radiators for oil-immersed transformers                                                                                                        |
| SS-EN 50216-7    | Part 7: Electric pumps for transformer oil                                                                                                                                           |
| SS-EN 50216-8    | Butterfly valves for insulating liquids                                                                                                                                              |
| SS-EN 50216-8/A1 | Part 8: Amendment No. A1                                                                                                                                                             |
| SS-EN 50216-9    | Oil-to-water heat exchangers                                                                                                                                                         |
| SS-EN 50216-10   | Oil-to air heat exchangers                                                                                                                                                           |
| SS-EN 50216-11   | Oil and winding temperature indicators                                                                                                                                               |
| SS-EN 50216-12   | Fans                                                                                                                                                                                 |
| SS-EN 10088-3    | Stainless steel – Part 3: Technical delivery conditions for semi-finished products, bars, rods, wire, sections and bright products of corrosion resisting steels for general purpose |
| SS-EN 50110-1    | Operation of electrical installations – Part 1: General requirements                                                                                                                 |
| SS-EN 50180      | Bushings above 1 kV up to 36 kV and from 250 A to 3,15 kA for liquid filled transformers                                                                                             |
| SS-EN 50243      | Outdoor bushings for 24 kV and 36 kV and for 5 kA and 8 kA for liquid filled transformers                                                                                            |
| SS-EN 50299      | Oil-immersed cable connection assemblies for transformers and reactors having highest voltage for equipment Um from 72.5 to 550 kV                                                   |
| SS-EN 50386      | Bushings up to 1 kV and from 250 A to 5 kA, for liquid filled transformers                                                                                                           |
| SS-EN 50629      | Energy performance of large power transformers (Um > 36 kV or Sr ≥ 40 MVA)                                                                                                           |
| CLC TS 50458     | Capacitance graded outdoor bushings 52 kV up to 420 kV for oil immersed transformers (not published)                                                                                 |
| SS-EN 60038      | IEC standard voltages                                                                                                                                                                |
| SS-EN 61869-1    | Instrument transformers-Part 1: General requirements                                                                                                                                 |
| SS-EN 61869-2    | Instrument transformers-Part 2: Additional requirements for current transformers                                                                                                     |
| SS-EN 60071      | Insulation co-ordination; Part 1, 2 and 5                                                                                                                                            |
| SS-EN 60137      | Insulating bushings for alternating voltages above 1000 V                                                                                                                            |
| SS-EN 60214-1    | On-load tap-changers                                                                                                                                                                 |
| IEC 60214-2      | Application guide for on-load tap-changers                                                                                                                                           |
| SS-EN 60296      | Fluids for electro technical applications - Unused mineral insulating oils for transformers and switchgear                                                                           |
| SS-EN 60507      | Artificial pollution tests on high-voltage insulators to be used on a.c. systems                                                                                                     |
| SS-EN 60529      | Degrees of protection by enclosures (IP code)                                                                                                                                        |
| IEC TR 60616     | Terminal and tapping markings for power transformers                                                                                                                                 |

|                         |                                                                                                                                                                                                                            |
|-------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| SS-EN 60664-1           | Insulation co-ordination for equipment within low-voltage systems                                                                                                                                                          |
| IEC/TS 60815            | Guide for the selection of insulators in respect of polluted conditions                                                                                                                                                    |
| SS-EN 61000             | Electromagnetic compatibility; Part 1 - 6 (IEC or EN shall apply if no SS-EN standards are published)                                                                                                                      |
| SS-EN 61140             | Protection against electric shock – Common aspects for installation and equipment                                                                                                                                          |
| SS-EN 61936-1           | Power installations exceeding 1 kV a.c. - Part 1: Common rules                                                                                                                                                             |
| SS-EN 61462             | Composite hollow insulators - Pressurized and unpressurized insulators for use in electrical equipment with rated voltage greater than 1 000 V - Definitions, test methods, acceptance criteria and design recommendations |
| IEC/IEEE 65700-19-03    | Bushings for d.c. application                                                                                                                                                                                              |
| SS-EN 62155             | Hollow pressurized and unpressurized ceramic and glass insulators for use in electrical equipment with rated voltages greater than 1000 V                                                                                  |
| SS-EN ISO 1461          | Hot dip galvanized coatings on fabricated iron and steel articles – Specifications and test methods                                                                                                                        |
| SS-EN ISO 9001          | Quality systems – Requirements                                                                                                                                                                                             |
| SS-EN ISO 10684         | Fasteners – Hot dip galvanized coatings                                                                                                                                                                                    |
| SS-EN ISO 12944         | Paints and varnishes – Corrosion protection of steel structures by protective paint systems; Part 1 - 8                                                                                                                    |
| SS-EN ISO 14001         | Environmental systems – Requirements with guidance for use                                                                                                                                                                 |
| SS-ISO 6708             | Pipe work components – Definition and selection of DN (nominal size)                                                                                                                                                       |
| SS 14 2324              | Stainless steel – SS steel 23 24                                                                                                                                                                                           |
| SS-EN 61936-1           | Power installations exceeding 1 kV AC-General                                                                                                                                                                              |
| SS-EN 50522             | Power installations exceeding 1 kV AC-Earthling                                                                                                                                                                            |
| SS-EN 1092-1            | Flanges and their joints – Circular flanges for pipes, valves, fittings and accessories, PN-designated-Part 1                                                                                                              |
| SS-EN 12560-1           | Flanges and their joints – Gaskets for Class-designated flanges-Part 1                                                                                                                                                     |
| SS-EN 1514-1            | Flanges and their joints – Dimensions of gaskets for PN-designated flanges-Part 1                                                                                                                                          |
| Cigré Report 204        | Guidelines for conducting design reviews for transformers 100 MVA and 123 kV and above                                                                                                                                     |
| Cigré Report 209        | The short circuit performance of power transformers                                                                                                                                                                        |
| Cigré Report 673        | Guide on transformer transportation                                                                                                                                                                                        |
| ELSÄK-FS 2008:1         | Elsäkerhetsverkets föreskrifter (New Swedish Safety Code)                                                                                                                                                                  |
| AFS 2008:03             | Swedish Work Environment Authority Regulations                                                                                                                                                                             |
| ISO 14122-3             | Maskinsäkerhet - Fasta konstruktioner för tillträde till maskiner - Del 3: Trappor, trappstegar och skyddsräcken                                                                                                           |
| ISO 14122-4             | Maskinsäkerhet - Fasta konstruktioner för tillträde till maskiner - Del 4: Fasta stegar                                                                                                                                    |
| ISO 3601-1              | Fluid power systems -- O-rings -- Part 1                                                                                                                                                                                   |
| ISO 3601-2              | Fluid power systems -- O-rings -- Part 2                                                                                                                                                                                   |
| ISO 3601-3              | Fluid power systems -- O-rings -- Part 3                                                                                                                                                                                   |
| IEEE Std C57.163TM-2015 | IEEE Guide for Establishing Power Transformer Capability while under Geomagnetic Disturbances                                                                                                                              |
| Incl. Cor 1-2016        | Flänsöppningar (Flange openings)                                                                                                                                                                                           |
| SEN 280901              |                                                                                                                                                                                                                            |

|                  |                                                                                                                                                                                                                                         |
|------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| SS-EN 61558-2-1  | Safety of power transformers, power supplies, reactors and similar products – Part 2-1: Particular requirements and tests for separating transformers and power supplies incorporating separating transformers for general applications |
| SS-EN 61558-2-13 | Part 2-13: Particular requirements and tests for auto transformers and power supply units incorporating auto transformers                                                                                                               |
| SS-EN 62271-211  | Kopplingsapparater för spänning över 1 kV – Del 211: Direkt anslutning av krafttransformatorer till Gasisolerade metallkapslade ställverk med märkspänning högre än 52 kV                                                               |

## 3 OPERATING CONDITIONS

### 3.1 Mode of operation

The transformers shall if not otherwise specified be designed for outdoor erection and continuous operation and be capable of bi-directional power flow (category C transformers included).

### 3.2 Ambient temperature

As a lower limit of ambient air temperature  $-40^{\circ}\text{C}$  shall apply. (***Deviation from SS-EN 60076-1, Cl 4.2***)

For all equipment due consideration shall be taken to the increased maximum ambient temperature caused by the temperature of the transformer tank which is assumed to reach  $105^{\circ}\text{C}$  on the cover. The lower limit ambient temperature  $-40^{\circ}\text{C}$  shall be accounted for as well.

For built in bushing current transformers the following shall apply (if not otherwise verified by the supplier):

- maximum ambient temperature  $115^{\circ}\text{C}$
- maximum daily average temperature  $105^{\circ}\text{C}$

### 3.3 Network data

If not otherwise stated the system earthing conditions are given in Table 3.1 and the maximum network short circuit power levels are given in Table 3.2. If not otherwise stated the given range of the ratio between the zero sequence impedance and the positive sequence impedance shall be valid. (Note that all conceivable combinations of lower levels may be at hand.) The given values apply also for multi winding transformers.

| Highest voltage<br>for equipment, $U_m$<br>(kV) | System earthing         | $X_0/X_+$<br>( - ) |
|-------------------------------------------------|-------------------------|--------------------|
| 1.1                                             | Effectively earthed     | -                  |
| 3.6                                             | Not effectively earthed | -                  |
| 7.2                                             | -"-                     | -                  |
| 12                                              | -"-                     | -                  |
| 24                                              | -"-                     | -                  |
| 36                                              | -"-                     | -                  |
| 52                                              | -"-                     | -                  |
| 72.5 – 82.5                                     | -"-                     | -                  |
| 123                                             | -"-                     | -                  |
| 145 – 170                                       | Effectively earthed     | 1 – 3 (IEC)        |
| 245                                             | -"-                     | 1 – 3 (IEC)        |
| 420                                             | -"-                     | 1 – 3 (IEC)        |

Table 3.1 System earthing

| Highest voltage<br>for equipment, $U_m$<br>(kV) | Network short circuit power<br>(MVA, ref $U_m$ ) |
|-------------------------------------------------|--------------------------------------------------|
| 1.1                                             |                                                  |
| 3.6                                             | 250                                              |
| 7.2                                             | 500                                              |
| 12                                              | 500                                              |
| 24                                              | 1000                                             |
| 36                                              | 2000                                             |
| 52                                              | 3000                                             |
| 72.5 – 82.5                                     | 4000                                             |
| 123                                             | 8000                                             |
| 145 – 170                                       | 10000                                            |
| 245                                             | 20000                                            |
| 420                                             | 40000                                            |

Table 3.2 Network short circuit power

### 3.4 Specific site conditions

The supplier shall claim detailed information of how the transformer would be installed at site. If the client in Compilation of technical data requires a site installation other than “in open air”, the supplier shall, dependent on kind of site installation, give information about minimum distances around the transformer. A drawing with a proposal of the transformer arrangement shall be enclosed to the tender. The transformer shall be constructed in such a way that the allowed temperature rises shall not exceed the stated requirements in SS-EN 60076-2 on site. Protective walls shall allow the cooling equipment to be located inside. Protective walls for the purpose of sabotage protection shall, if built by Svenska kraftnät, alternatively financed by Svenska kraftnät funds aimed for emergency management, fulfil the requirements stated in TR09-15.

## 4 ELECTRICAL DATA AND OTHER MAIN CHARACTERISTICS

### 4.1 Ratings

For transformers category A and wind farm transformers the ratings shall be selected from Table 4.1.

| Rated power (MVA)  |                        |         |      |      | 4                                                      | 6.3 | 10 | 16 | 25 | 40  | 63  | 100 |
|--------------------|------------------------|---------|------|------|--------------------------------------------------------|-----|----|----|----|-----|-----|-----|
| Rated voltage (kV) |                        |         |      |      | Approximate impedance voltage in principal tapping (%) |     |    |    |    |     |     |     |
| HV side            |                        | LV side |      |      |                                                        |     |    |    |    |     |     |     |
| 22.5               | $\pm 8 \times 1.67\%$  |         |      | 11.5 | 7                                                      | 7   | 8  | 9  |    |     |     |     |
| 45                 | $\pm 8 \times 1.67\%$  |         | 23   | 11.5 | 7                                                      | 7   | 8  | 9  |    |     |     |     |
| 55                 | $\pm 8 \times 1.67\%$  |         | 23   | 11.5 | 7                                                      | 7   | 8  | 9  | 10 |     |     |     |
| 70                 | $\pm 16 \times 1.67\%$ | 34.5    | 23   | 11.5 |                                                        |     | 8  | 9  | 10 | 10  |     |     |
| 72.5               | $\pm 16 \times 1.67\%$ | 34.5    | 23   | 11.5 |                                                        |     | 8  | 9  | 10 | 10* | 12* |     |
| 75                 | $\pm 8 \times 1.67\%$  | 34.5    | 23   | 11.5 |                                                        |     | 8  | 9  | 10 | 10* | 12* |     |
| 123                | $\pm 8 \times 1.67\%$  | 34.5    | 23   | 11.5 |                                                        |     | 8  | 9  | 10 | 10* | 12* |     |
| 140                | $\pm 8 \times 1.67\%$  | 46      | 34.5 | 23   | 11.5                                                   |     |    | 9  | 10 | 10* | 12* | 12* |
| 145                | $\pm 8 \times 1.67\%$  | 46      | 34.5 | 23   | 11.5                                                   |     |    | 9  | 10 | 10* | 12* | 12* |
| 150                | $\pm 8 \times 1.67\%$  | 46      | 34.5 | 23   | 11.5                                                   |     |    | 9  | 10 | 10* | 12* | 12* |

Table 4.1 Recommended standard ratings. \* Higher impedance values are acceptable for transformers feeding distribution systems, especially at 10 kV, or special applications.

Rated voltages 70-72.5 kV are used for transformers which are re connectable to rated voltages 140-145 kV respectively. For rated voltages 70 and 72.5 kV, the limit for constant power shall be minus 10%, if not otherwise stated.

For transformers connected to decentralized production, e.g. wind farm transformers, 33, 22 and 11 kV may be specified on LV side.

Rated voltage 140 kV is used in the southern half of Sweden and 150 kV in the northern half. In some cases 145 kV is chosen for full flexibility.

For other transformers the ratings will be specified in every single case.  
In some cases a "high-load" case will be specified for inter-bus transformers together with maximum allowable winding hotspot temperature for given ambient conditions.

For two winding transformers operating at rated power and 20 °C ambient temperature the ageing rate must not exceed 1 p.u. For transformers with three windings or more, proper loading cases must be stated in clause 27. Loading cases for inter-bus transformers and loading cases for generator step up transformers must be stated as well.

## 4.2 Connection symbol

Transformers of category A/C shall normally have the connection symbol YNyn0/YNd11. For other transformers the connection symbol is specified in every single case.

## 4.3 Tapping range

The tapping range for transformers of category A shall be selected from Table 4.1. The tapping range for other transformers is specified in every single case.

## 4.4 Insulation levels, creepage distances and air clearances

### 4.4.1 Insulation levels

Insulation levels shall fulfil the requirements in Table 4.2.

| Highest voltage for equipment, Um (kV) | Insulation level according to SS-EN 60076-3 |       |
|----------------------------------------|---------------------------------------------|-------|
| 1.1                                    | LI40                                        | AC3   |
| 3.6                                    | LI60                                        | AC10  |
| 7.2                                    | LI75                                        | AC20  |
| 12                                     | LI125                                       | AC28  |
| 24                                     | LI170                                       | AC50  |
| 36                                     | LI250                                       | AC70  |
| 52                                     | LI325                                       | AC95  |
| 72.5 – 82.5                            | LI550 AC230 – LI250 AC95                    | AC140 |
| 123                                    | LI550 AC230 – LI250 AC95                    |       |
| 145 – 170                              | SI750 LI850 – LI325 AC140                   |       |
| 245                                    | SI1050 LI1300 – LI125 AC50                  |       |
| 420                                    |                                             |       |

Table 4.2 Highest voltage for equipment and insulation levels

- Note 1 For phase to phase insulation the following addition shall apply  
145 - 170 kV LI550 AC 275  
245 kV SI750 LI850  
420 kV SI1050 LI1300
- Note 2 For the neutral point of autotransformers the following shall apply:  
420/145 kV LI250 AC95  
420/170 kV LI250 AC95  
420/245 kV LI250 AC95  
In some cases LI550 AC230 may be specified

Note 3 Type C wind farm transformers, connected to direct earthed systems and equipped with a  $\Delta$ -connected secondary winding, should be able to be operated with the Y-connected winding neutral point isolated or grounded through a high impedance resistor/reactor/UT transformer. For the neutral point the following shall apply:

|              |                |
|--------------|----------------|
| 145 - 170 kV | LI325 AC140 kV |
| 245 kV       | LI550 AC230 kV |
| 420 kV       | LI650 AC325 kV |

#### 4.4.2 Air clearances

The requirements on minimum air clearances are summarised in Table 4.3.

| Highest voltage<br>for equipment, Um<br>(kV) | Minimum free air clearance |                       |
|----------------------------------------------|----------------------------|-----------------------|
|                                              | phase - earth<br>(mm)      | phase - phase<br>(mm) |
| 3.6                                          | 320                        | 320                   |
| 7.2                                          | 320                        | 320                   |
| 12                                           | 320                        | 320                   |
| 24                                           | 320                        | 320                   |
| 36                                           | 320                        | 320                   |
| 52                                           | 480                        | 480                   |
| 72.5 – 82.5                                  | 630                        | 630                   |
| 123                                          | 1100                       | 1100                  |
| 145 – 170                                    | 1300                       | 1300                  |
| 245                                          | 1700                       | 2300                  |
| 420                                          | 2600                       | 3600                  |

Table 4.3 Minimum air clearances

Notes to Table 4.3:

- Air clearances for 245 and 420 are based upon SS-EN 60076-3
- The air clearance is assumed to be measured from bushing live parts
- In some cases the clearances have to be increased to account for the size of connectors

#### 4.4.3 Creepage distances

The creepage distance requirements for ceramic and polymeric insulators in clean and polluted environment are summarised in Table 4.4.

| Highest voltage<br>for equipment, Um<br>(kV) | Minimum creepage distance                            |                                                     |                                                           |
|----------------------------------------------|------------------------------------------------------|-----------------------------------------------------|-----------------------------------------------------------|
|                                              | Ceramic type<br>Clean environment<br>Class I<br>(mm) | Polluted<br>environment<br>Class II and III<br>(mm) | Polymeric type<br>Clean<br>environment<br>Class I<br>(mm) |
| 3.6                                          | 60                                                   | 90                                                  | -                                                         |
| 7.2                                          | 120                                                  | 185                                                 | -                                                         |
| 12                                           | 200                                                  | 300                                                 | 150                                                       |
| 24                                           | 400                                                  | 600                                                 | 300                                                       |
| 36                                           | 600                                                  | 900                                                 | 450                                                       |
| 52                                           | 850                                                  | 1300                                                | 650                                                       |
| 72.5 – 82.5                                  | 1350                                                 | 2100                                                | 1000                                                      |

|                  |               |              |              |
|------------------|---------------|--------------|--------------|
| 123<br>145 – 170 | 1950<br>2750  | 3050<br>4300 | 1450<br>2050 |
| 245<br>420       | 6000<br>10000 |              |              |

Table 4.4 Creepage distances

Notes to Table 4.4:

- Pollution classes according to IEC 60815
- For an alternative method of ceramic type insulator performance in polluted environment refer to Clause 23.8.7.1.
- For polymeric insulators the creepage distance is not a relevant parameter for the performance in polluted environment. For the performance verification, refer to Clause 23.8.7.2.
- For transformers having highest voltage for equipment 245 and 420 kV environment Class II shall apply for all windings.
- The ratio (creepage distance) / (insulator length) must not exceed 3.5 for ceramic type insulators.
- In case of environment Class II or III the insulator shall be designed with alternating short and long sheds, i.e. of the self-cleaning type.
- Creepage distances are given as minimum length.

#### 4.4.4 Safety distances for inspection platform

For the design of the inspection platform and its ladder minimum safety distances equal to the earth air clearance above increased by 6 % shall apply.

When applying this the distance from the neck to the fingertip is assumed to be 900 mm and the distance from the neck to the sole of the foot to be 1600 mm.

#### 4.4.5 Internal arresters

Internal arresters shall normally not be used. However, in some special cases they may be used, but only after written approval by the client.

### 4.5 Short circuit impedances (Impedance voltage)

For standardised (A) transformers the impedances are chosen from Table 4.1 if not otherwise stated (NOTE: Typical values). For other transformers the impedances are specified in every single case. For inter-bus transformers larger than or equal to 500 MVA, the deviation between measured and guaranteed short circuit impedance (principal tap position) must not exceed 5% (**Deviation from SS-EN 60076-1**). Limitations on zero sequence impedances could be set depending on size of neutral reactor or for the performance of the network system.

### 4.6 Short circuit withstand capability

The transformers shall withstand external short circuits on any voltage level. For a transformer set comprising a main unit and a regulating unit the short circuit withstand requirement also applies to faults at the connections between the two units. The ability to withstand the dynamic effects of short circuits shall be verified through theoretical evaluation and successful full-scale tests on a reference transformer at a Short-Circuit Testing laboratory.

In the theoretical evaluation of the ability to withstand the dynamic effects of short circuit, the following shall be accounted for:

- Currents at three phase and two phase short circuits and earth faults
- The transformer operating at 105% of rated voltage
- The from the network incoming short circuit power to each bus is assumed to vary linearly with the voltage
- The system earthing and the most unfavourable ratio between the zero sequence and positive sequence network impedances
- The short circuit impedances being 0.95 times the guaranteed values
- Generator step-up transformers shall also be capable of withstanding switching in at 180° phase opposition
- For windings with non-effectively earthed neutral point it shall be assumed that earth fault can occur between the line and neutral on the transformer itself.
- Manufacturing tolerances shall be considered, i.e. differences between drawings and measurements in the workshop.

Built-in current limiting reactors shall normally not be used. However, in some special cases they may be used, but only after written approval by the client.

## 4.7 Loading capability

### 4.7.1 General

If not otherwise stated all transformers, even multi winding transformers, shall be capable of continuous operation with rated current in all windings without exceeding the allowable standardised temperature rises, including winding hot spot temperature rises. The client states the rated power.

In addition the transformers shall, if specified, fulfil the loading requirements in data compilation, section 27, Loading cases for inter-bus transformers and data compilation, section 27, Loading cases for generator step up transformers. Further requirements are specified in Clause 4.7.2.

### 4.7.2 Additional loading requirements

The transformers shall also fulfil the requirements in IEC 60076-7.

With the fans out of operation transformers with cooling type ONAF must be capable of loading with 70 % of the ONAF rated power.

Cooling type ONAN transformers shall be prepared for future assembly of fans for additional cooling. This additional cooling must allow a loading with 130 % of rated ONAN current without exceeding the temperature rise limits of SS-EN 60076-2. The transformer rated power is not changed and is still referring to ONAN cooling conditions.

The loading of three winding transformers (except generator step up units) shall be limited by the winding having the highest rated power. Each of the other two windings shall be capable of carrying its rated power and the other the rest up to the maximum winding rated power. E.g. 63/38/25 MVA or 63/63/0 MVA for a 63/63/25 MVA transformer.

For generator step up transformers the rated voltage of windings connecting to the generator(s) shall normally be equal to the generator rated voltage(s).

Generator step up transformers without OLTC shall in addition be capable of operation at a voltage above 105 % of the rated voltage but not greater than 110 %. At a current  $K$  ( $0 \leq K \leq 1$ ) times the transformer rated current the voltage shall be limited in accordance with the following formula:

$$U(\%) = 110 - 5 \times K^2$$

Bushings, on-load tap-changers and other accessories shall be selected in such way that they can carry currents above the corresponding winding rated current of at least the same amplitude and for the same duration as the transformer itself can withstand. Worst tap changer position to be considered. Bushing rated currents must, however, exceed the winding rated current by 20 % (30 % for cooling type ONAN). On-load tap-changer rated through-currents must, however, exceed the winding rated current by 10% for cooling type ONAN.

For built in current transformers refer to Clause 12.

The transformer neutral and its bushing as well as built in bushing current transformers shall have the same loading capability as the corresponding line terminals (for auto connection the line terminals of the high voltage side). HVDC converter transformer loadings will be derived from the over all plant requirements.

If not otherwise explicitly stated, it shall be possible to operate the transformer with rated power at 105% of rated voltage, irrespective of highest voltage for equipment (**Deviation from SS-EN 60076-1, Cl 5.4.3**).

For OLTC, the rated through-current ( $I_r$ ), valid for the rated step voltage ( $U_{ir}$ ), must exceed the transformer rated current in its worst tapping position.

## 4.8 Neutral point loading

### 4.8.1 Transformers of categories B and C

The neutral points of three limbed, three phase units with  $U_m \geq 245$  kV, shall be capable of carrying a DC current in accordance with the standard GIC signature in IEEE Std C57.163TM-2015 IEEE Guide for Establishing Power Transformer Capability while under Geomagnetic Disturbances, Chapter 9.1, Figure 24. ( $I_{base} = 10$  A/phase,  $I_{peak} = 90$  A/phase,  $t_{b1} = 60$  min,  $t_{b2} = 20$  min and  $t_p = 2$  min. Total number of cycles equal to four.)

In case of single phase units or five limbed three phase units the supplier shall state the maximum allowed continuous neutral point DC current.

### 4.8.2 Transformers of category D

If not otherwise stated the AC side neutral of an HVDC transformer shall be capable of continuously carrying a DC current of 10 A (if applicable per single phase unit) the transformer operating at its worst loading at maximum ambient temperature.

### 4.8.3 Non effectively earthed transformers

If not otherwise stated none effectively earthed neutral points shall be capable of

- Continuously carrying an AC current amounting to 10% of the rated phase current and the transformer operating at its worst loading at maximum ambient temperature
- Starting from steady state with continuously current of 10 % of rated phase current the neutral shall be designed for carrying at least 30 % of rated phase current for 15 min and the transformer operating at its worst loading at maximum ambient temperature

### 4.9 Type of cooling

Cooling type ONAN is the normal case for transformers rated 25 MVA and below. For higher ratings cooling type ONAN, ONAF or OFAF is to be optimised considering the loss evaluation and the available space. Type OFWF is used only if specified. For type OD.. cooling the same maximum allowable temperature rise as for type OF.. shall apply (***Deviation from SS-EN 60076-2, Cl 6.2***). Furthermore when disconnecting a fully loaded transformer at max ambient temperature it shall not be required to pump oil through the windings, i.e. no post tripping cooling.

### 4.10 Sound levels

If not otherwise specified the no-load sound **power** levels in Table 4.5 shall apply:

| Max allowable sound level            |                                       |
|--------------------------------------|---------------------------------------|
| Equivalent two-winding rating<br>MVA | Sound power level – $L_{WA}$<br>dB(A) |
| 6,3                                  | 65                                    |
| 10                                   | 68                                    |
| 16                                   | 72                                    |
| 25                                   | 77                                    |
| 40                                   | 82                                    |
| 63                                   | 85                                    |
| 100                                  | 86                                    |
| 150                                  | 87                                    |
| 200                                  | 89                                    |
| 300                                  | 91                                    |
| 500                                  | 93                                    |
| 750                                  | 95                                    |

Table 4.5 Maximum allowed sound power levels

A positive tolerance of +0 dB(A) shall be valid.

The sound power level  $L_{WA}$  shall be measured in accordance with SS-EN 60076-10 and shall apply both with and without cooling equipment in operation.

For transformers with variable flux voltage regulation sound level measurement shall be performed at the tapping giving the highest core flux density.

In case of separately erected cooling equipment maximum allowable sound level will be specified in every single case.

The transformer size is equivalent to the high voltage winding rated power.

For intermediate sizes linear interpolation shall be used.

Factory measured sound power level shall be rounded off to the closest integer value before comparison with the guarantee level.

For transformers 200 MVA and above a measurement of the load sound **power** level shall be performed.

#### 4.11 Core design

If not otherwise specified the transformer core shall be of three limbed core type. Five limbed core or shell type may be used in special cases if explicitly specified in the inquiry.

#### 4.12 Inrush current

The manufacturer shall state a guarantee level of the maximum amplitude of the inrush current. In addition the manufacturer shall state calculated r.m.s. value and time to half value of the line and neutral point currents when switching in the transformer in the most unfavorable phase position and at the highest overexcitation according to Clause 4.7. It is then assumed that all breaker poles close at the same instant and the network having data according to Clause 3.3 Network Data.

#### 4.13 Winding design

The manufacturer shall in the tender state the depolymerisation number (DP) of the insulation paper used in the windings:

- New paper from the paper sub-supplier (actual value)
- Processed and tested transformer ready for shipping (calculated value)

Thermally upgraded paper is to be used.

Foil windings are normally not accepted.

The transformer shall be designed in such a way that copper sulphide deposition will be prevented. Copper winding wires shall always be equipped with a high temperature varnish layer. The varnish layer shall be designed for hot spot temperatures according to IEC 60076-7.

Combination of paper and oil shall be chosen to avoid stray gassing and to maximize life span.

#### 4.14 Alternative designs

##### 4.14.1 Stabilising winding

If not otherwise stated or there are special limits on zero sequence impedances no stabilising winding shall be furnished. If requested its insulation level shall be chosen according to its highest voltage for equipment.

If a stabilising winding is provided the delta shall be normally closed and earthed externally to the tank cover. However, it shall be possible to operate the transformer with the stabilising winding not closed.

A stabilising winding shall be thermally and mechanically dimensioned by the supplier. The design shall be approved by the client.

#### 4.14.2 Auxiliary winding

An auxiliary low voltage winding with  $U_m=1.1$  kV (one or a few turns around each core leg, connected in yn) feeding a small matching transformer with vector group either Yyn or Ynauto, shall be furnished on standardised transformers, for other transformers only if specified. For more details, see chapter 13. The matching transformer transforms the voltage to  $0.42 \pm 5\%$  to be used for local power supply.

For transformers having voltage regulation of type VFVV (variable core flux) tapplings  $0.42 \pm 2 \times 3.75\%$  may be specified.

If an auto connected matching transformer is provided this must be designed for a highest input voltage of maximum 420 V.

For standardised transformers the rated power shall be chosen from Table 4.6.

| Power transformer | Auxiliary transformer |
|-------------------|-----------------------|
| (MVA)             | (kVA)                 |
| 4-8               | 40                    |
| 10-20             | 63                    |
| 25-50             | 100                   |
| 63-100            | 160                   |

Table 4.6 Auxiliary winding rated power

For other transformers the auxiliary power rating is specified in every single case, normally 250, 315 or 400 kVA.

#### 4.14.3 Off-circuit tap changing and change over between system voltages

Off-circuit tap changing and change over between system voltages will be specified if required, see chapter 6. For three winding transformers, an off-circuit tap changer will normally be located in the intermediate winding.

### 4.15 Other data

#### 4.15.1 Supply voltages for motors, control equipment etc.:

Maximum voltage variation -15% to +10% shall apply at the connection point of apparatuses.

##### 4.15.1.1. On-load tap-changer motor operation

Normally 110 V dc (in some cases 220 V dc) or 400/230 V ac (three-phase motor).

##### 4.15.1.2. On-load tap-changer motor drive control and indication

110 V ac from an interposing transformer or 110 V dc (in some cases 220 V dc).

4.15.1.3. Cooling equipment motors  
400/230 V ac

4.15.1.4. Cooling equipment control

- Operation voltage: 230 V ac, single phase
- Signalling voltage: 110 V or 220 V dc

4.15.1.5. Other control equipment

- Operation voltage 110 or 220 V dc
- Signalling voltage 110 or 220 V dc

4.15.1.6. Lighting and heater  
230 V ac, single phase

#### 4.15.2 Contact breaking capacity

Contacts for external use shall at least have the following breaking capacity if not otherwise specified in the relevant transformer fitting standard (SS-EN 50216):

- 0.15 A at 220 V dc and L/R = 40 ms
- 0.30 A at 110 V dc and L/R = 40 ms

#### 4.15.3 Enclosure class and degree of protection

Apparatuses and connection boxes shall at least fulfil enclosure class IP45 according to SS-EN 60529 and degree of protection Class I according to SS-EN 61140. However, a box intended for a possible matching transformer, may have a lower enclosure class in order not to prevent necessary heat dissipation.

#### 4.15.4 Control equipment insulation levels etc.

The following insulation categories in accordance with SS-EN 60664-1 shall apply:

| Equipment                    | Over voltage category | Material group | Pollution degree |
|------------------------------|-----------------------|----------------|------------------|
| Terminal blocks              | III                   | I              | 2                |
| Current transformer circuits | IV                    | I              | 2                |
| Motors                       | IV                    | I              | 2                |
| Other parts                  | IV                    | I              | 2                |

Table 4.7 Insulation categories

#### 4.15.5 Disturbance requirements

Control equipment, cooling equipment and on-load tap-changer motor drive equipment shall fulfil the requirements set up in SS-EN 61000

## 5 BUSHINGS

### 5.1 General

If not otherwise specified, for highest voltage for equipment  $U_m \geq 52$  kV, capacitance graded bushings shall be used. Applicable standard is SS-EN 60137. For  $U_m \geq 145$  kV, the bushings shall be of either resin impregnated paper (RIP) or resin impregnated synthetics (RIS) type.

If not otherwise stated, for  $U_m > 1.1$  kV, the bushing external insulation material shall be made from silicone rubber. Other solutions may be accepted, but first after written approval.

Ceramic type bushing shall fulfil SS-EN 50180, SS-EN 50243 or SS-EN 50386. Deviations may be made for the connection details on the oil side but first after written approval from the client.

For each combination of highest voltage for equipment and insulation level only one type of bushing is allowed.

Extended bushing turrets may be specified to facilitate future installation of a sound level reduction enclosure. The height ( $d$ ) of an extended bushing turret shall comply with Figure 5.1 below.

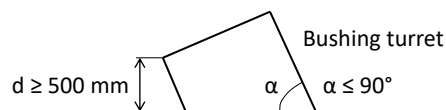


Figure 5.1 Extended bushing turret.

### 5.2 Marking

Each bushing shall have a rating plate showing the identification, e.g. type and catalogue No. On smaller bushings this can be stamped into the top bolt or the flange or on a separate plate on the transformer.

### 5.3 Measuring taps

Phase bushings for highest voltage for equipment  $U_m \geq 72.5$  kV shall be equipped with measuring taps. The taps shall normally be short circuited. If required the measuring taps shall be connected to a separate common connection box at service level where they normally shall be short circuited.

### 5.4 Oil level indication

Oil filled bushings for highest voltage for equipment  $U_m \geq 245$  kV shall be provided with oil level indication.

## 5.5 Special requirements for oil-SF<sub>6</sub> connection assemblies.

Requirements given in SS-EN 62271-211 shall apply.

The transformer supplier shall provide a detailed description of the oil level and pressure supervision system for the bushings.

It is the transformer supplier's responsibility to make such arrangements that short circuit bridges have no harmful impact on the transformer.

The over all responsibility of the interface lies on the transformer supplier.

Other requirements such as pressure supervision, expansion chambers, level indication etc. are specified in every single case.

## 5.6 Special requirements for cable connection assemblies.

For highest voltage for equipment 72.5 kV and above the requirements given in SS-EN 50299 and SS-EN 50299C1 shall apply.

The over all responsibility of the interface lies on the transformer supplier.

Other requirements such as cable box with SF<sub>6</sub>, oil or air etc. are specified in every single case.

## 5.7 Special requirements for encapsulated buses.

It is the transformer supplier's responsibility to make such arrangements that short circuit bridges have no harmful impact on the transformer.

The over all responsibility of the interface lies on the transformer supplier.

Other requirements such as interface, short circuit bridges etc. are specified in every single case.

## 5.8 Special requirements for polymeric insulators.

The sheds shall be of a polymeric material, formed from silicone. The final polymer compound after the addition of functional fillers shall contain at least one-third pure silicone rubber, but shall not contain any ethyl vinyl acetate (EVA), ethyl propylene rubber (EPR), ethylene propylene diene monomer (EPDM) or other UV-sensitive material. Only high temperature vulcanized silicone rubber (HTV) or liquid silicone rubber (LSR) shall be used. Room temperature vulcanized silicone rubber (RTV) shall not be used in high voltage applications.

Tracking resistance 4.5 kV in class 1A per IEC 60587

Recovery of hydrophobicity: WC 1-3 (IEC TS 62073) 48 hours after hydrophobicity weakening by 96 h immersion in distilled water at room temperature.

All hollow silicone composite insulators shall comply with the requirements of the SS-EN publication SS-EN 61462 and the relevant parts of SS-EN 62217. The design of the composite insulators shall be tested and verified according to SS-EN 61462 (design test and type test). Each composite insulator shall undergo routine tests according to SS-EN 61462.

## 5.9 Terminals

### 5.9.1 General

Current carrying connections including screws, nuts and washers necessary for the connection of external conductors are to be provided by the client in case of capacitance graded bushings.

The terminals shall primarily be provided with flat terminals (flags).

Cylindrical terminals are accepted in those cases where the terminal is a natural termination of the internal conductor arrangement.

### 5.9.2 Flat terminals

The flat terminal shall fulfil the dimension requirements below. To admit the assembly of the current carrying connection there must be a free space of minimum 5 mm between the flat terminal and the apparatus to be connected.

The size of the flat terminal shall be selected from Table 5.1 below:

| Size     | Rated apparatus current |
|----------|-------------------------|
| 2 - 40   | 400 A                   |
| 4 - 75   | 630 - 1250 A            |
| 9 - 125  | 1600 - 3150 A           |
| 12 - 165 | 4000 A                  |

Table 5.1 Flat terminals

### 5.9.3 Cylindrical terminals

The cylindrical terminal shall fulfil the dimension requirements below. The terminal shall be secured against rotation.

The size of the cylindrical terminal shall be selected from Table 5.2 below:

| Size | Rated apparatus current |                 |
|------|-------------------------|-----------------|
|      | Aluminium terminal      | Copper terminal |
| 30   | 630 - 1250 A            | 630 - 1600 A    |
| 40   | 1600 A                  | 2000 - 2500 A   |
| 60   | 2000 - 2500 A           | 3150 - 4000 A   |

Table 5.2 Cylindrical terminals

### 5.9.4 Material

Terminals of copper or a copper alloy must not exceed a temperature of 105 °C (high current bushings, >10 kA, excluded) and shall be tin coated to layer thickness of at least 10 µm. Copper alloy sensitive to stress corrosion must not be used.

Terminals of aluminium or an aluminium alloy must not be surface treated. In case of an alloy this shall have the same corrosion resistance as pure aluminium. Aluminium alloy sensitive to stress corrosion, layer corrosion or grain boundary erosion must not be used.

Flat terminal of aluminium or an aluminium alloy shall have a hardness of at least HB min 75.

5.9.5 Flat terminal dimensions

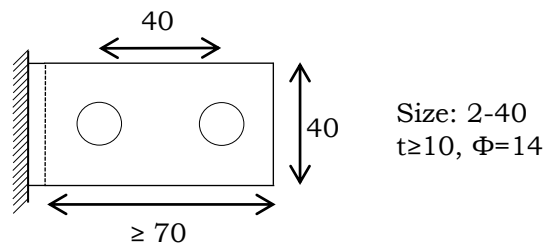


Figure 5.2 Flat terminal size 2-40

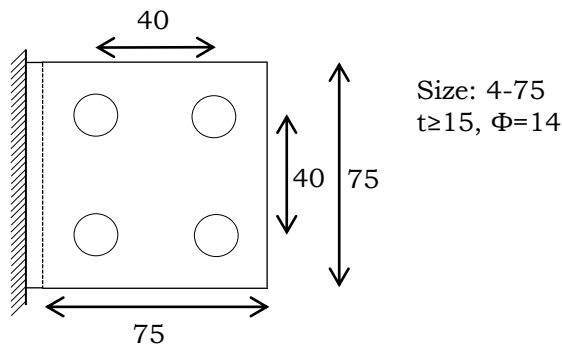


Figure 5.3 Flat terminal size 4-75

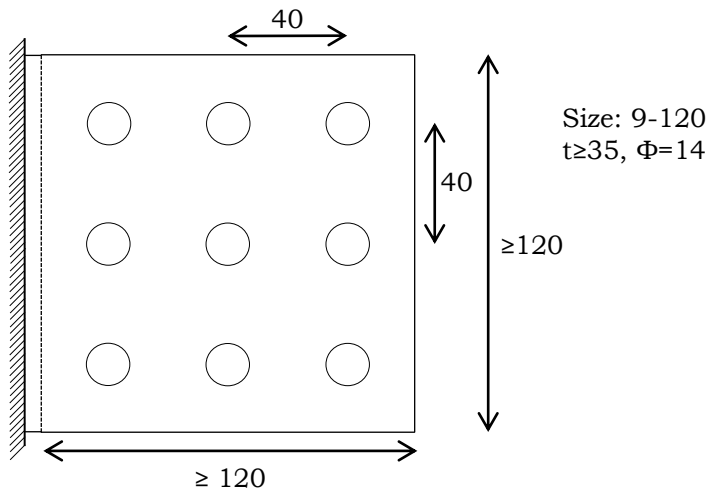


Figure 5.4 Flat terminal size 9-120

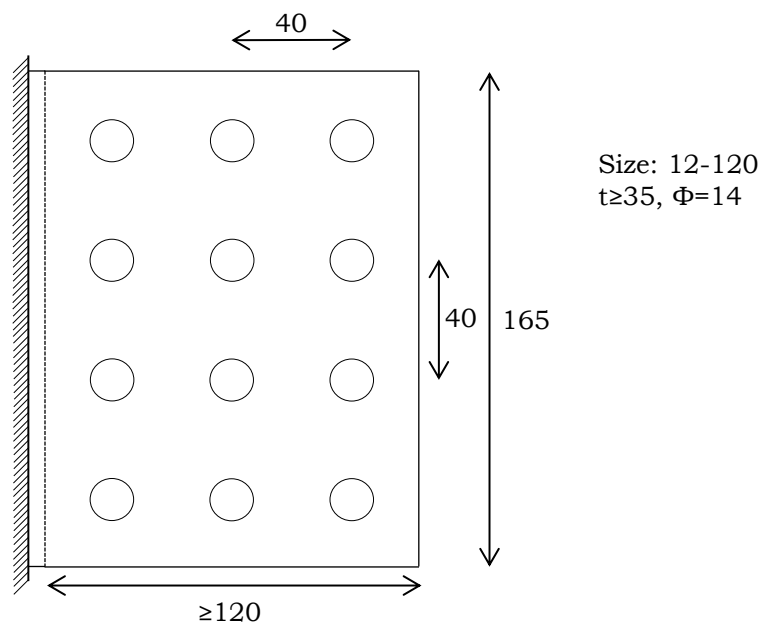


Figure 5.5 Flat terminal size 12-120

#### 5.9.6 Cylindrical terminal dimensions

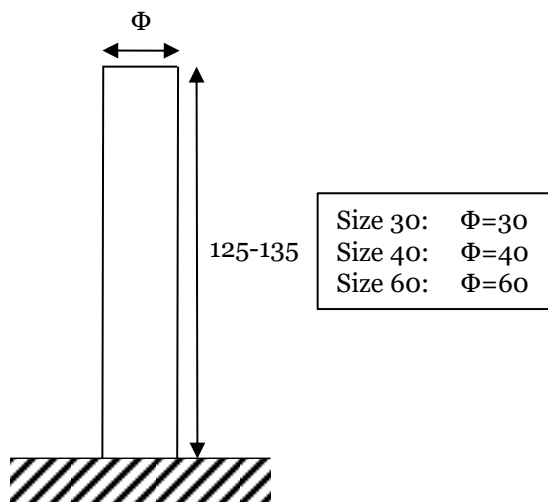


Figure 5.6 Cylindrical terminal

#### 5.10 Spare bushings

In the inquiry preferred bushings may be stated based upon the available spares. If quoted bushings do not comply with the preferred ones spare bushings shall be included in the tender.

## 6 OFF-CIRCUIT TAP-CHANGING AND SYSTEM VOLTAGE RECONNECTION

Change of ratio (+x%, 0, -x%) and reconnection between system voltages (series-parallel, Y-D) shall be made with the transformer not energized. The reconnection shall be made by means of bolted connections accessible through hatches in the cover.

The design shall prevent connection pieces, screws and nuts from falling into the tank.

## 7 ON-LOAD TAP-CHANGERS

Change of ratio in operation shall be made by high speed on-load tap-changers for remote and local operation. The tap-changers shall fulfil the requirements in SS-EN 60214-1 and IEC 60214-2.

The diverter switch shall whenever suitable use vacuum switching technology in order to minimise the maintenance requirements.

Special attention shall be paid to reduce recovery voltage transients on the 0.42 kV auxiliary system emerging from on-load tap-changer operations. Such transients may occur in case of free floating regulating windings when operating the coarse or change-over selectors. These transients may have adverse effect on equipment connected to the 0.42 kV system and consequently the supplier is obliged to take measures for their reduction to non-harmful levels.

If applicable diverter switch oil compartments shall be provided with pressure or oil flow gauges.

## 8 ON-LOAD TAP-CHANGER MOTOR DRIVE

### 8.1 General

The operating mechanism shall be constructed for local and remote motor operation.

The drive shall be located for an easy operation in service.  
All operation handles shall be located inside the motor drive cubicle.

Contacts for raise and lower shall be electrically blocked.

One complete operation must not take more than 35 turns at hand operation. The required number of turns shall be indicated on a plate on the drive. The operation time at motor operation must normally not exceed 8 s.

As soon as the drive is in progress this must be indicated and labelled.

The drive shall be provided with legible and weather proof labels with arrows for the hand operation and also labelled "ÖKA" (raise) and "MINSKA" (lower) at the arrow points.

Raising the voltage means that a higher tapping number is connected when making an electrical raise operation or a clockwise operation.

The drive shall be provided with a legible position indicator, readable from the outside. The indicator shall be mechanically controlled by the tap changer. The tap positions shall be numbered from one and upwards. The highest ratio shall correspond to position No. 1, i.e. in the normal case this will give a higher voltage on the low voltage side at a higher tap position.

If applicable, the mechanical and electrical limiting devices shall be easily movable to any tap position. In addition each limiting device shall have a blocking function to prevent harmful operation.

For electrically operated single phase tap-changers a zero-voltage in any motor circuit shall be signalled and operation of the other phases shall be prevented.

## 8.2 Functional requirements

A change of the drive motor polarity must not imply a reversal of the rotation. When at stand still all phase conductors shall be disconnected.

The motors shall be protected against overload by motor protective switches.

It must be possible to operate the motor protective switches by hand.

The motor protective switches shall be provided with an auxiliary contact which is closed when the switch is open. This contact will be used for signalling at protective switch tripping.

Circuits for motor, control, position indication and heating shall be electrically completely separated. The circuit for the motor shall not be protected by fuses.

A started cycle of operation shall be completed even if the operation pulse length is shorter than the time required for one step.

When an over current is passing through the tap-changer the drive motor shall stop. This shall be accomplished by means of external breaking contacts in series with the drive operating circuit. When these external contacts are closed the operation cycle shall be completed.

The drive shall be easily re-connectable so that independent of the operation pulse length only a single step operation will be carried out, so called step-by-step operation. For another step to be performed the operation pulse must be disconnected and a new pulse must be given after completion of the first step.

When the drive reaches either end limit the contacts for electrical stop shall open both in motor and control circuits for the actual operating direction. The limit switches shall have forced mechanical operation and also be independent of any spring force for its operation.

The following auxiliary contacts shall be provided:

- One making contact which closes as soon as the drive is leaving its rest position and which remains closed until the operation cycle is completed.
- This contact will indicate that a switching is immediately at hand or already under way.
- Contacts for potentiometer transmitter tap position indication.

The potentiometer transmitter shall have as many positions (N) as the number of tapplings and N-1 sub resistors. Each resistor shall be of about 10 or 50  $\Omega$  with an individual spread of maximum 1%.

If requested, for remote indication of the tap changer position, a measuring amplifier (transducer) 4 – 20 mA shall be provided, supplied by 110 V DC if not otherwise is stated. The transmitter shall be of programmable type. If needed, programming cable and program software must be included.

For plus/minus and for coarse/fine tap-changing so called "run through" contacts must not indicate separate tap positions.

The contacts shall be used for tap position indication.

For parallel operation, circulation current method will normally be used. If specified, contacts for simultaneous or master follow parallel control shall be provided. If such contacts not are specified, future addition of such contacts shall be possible.

## 9 SUPERVISORY EQUIPMENT

The transformers shall normally be provided with the following gauges. These shall have a prompt making and breaking function.

In order not to prevent the development of new technologies other configurations may be accepted, however, only after written approval.

### 9.1 Gas and oil actuated relay

The gas and oil actuated relay shall be provided with two electrically separate contacts:

- One closing for slow gas formation to be used for alarm.
- One closing for heavy gas formation, heavy oil flow and low oil level to be used for tripping.

The relay shall be provided with shut off valves as well as a by-pass with a shut off possibility in order to facilitate relay exchange. It must be clearly indicated if a valve is open or closed.

A device for gas sampling at service level shall be included, connected by means of a flexible tube. Gas sampling shall be possible to carry out when the transformer is in service.

The relay shall be located in such a way that a person executing testing or replacement work standing on a ladder or on the platform according to Clause 15.11 can not reach within the safety distance according to Clause 4.4.4.

### 9.2 Oil level indicator

The oil level indicator shall have making contacts closing at too high and too low oil level. If specified, one extra contact shall be provided for the main volume indicator, closing at a level 5% (north Sweden) or 15% (south Sweden) above the “too low” oil level. The contacts will be used for signalling.

For transformers having a high voltage side highest voltage for equipment  $U_m \geq 72.5$  kV the oil level indicators shall be located at service level (not on the conservator) and, if specified, be provided with remote indication possibility (potentiometer). Several indications are required between the minimum and maximum level. Oil level indicators located on the conservator must be readable from service level close to the transformer (~1 m).

To prevent water from dripping into oil level indicators a drip protection or a protruded roof shall be provided.

### 9.3 Temperature gauges (thermometers)

The temperature gauges shall at least have four (two for cooling type ONAN) independently adjustable contacts closing when the temperature reaches the adjusted value. For control of the cooling equipment, more contacts might be needed.

The contacts shall be electrically separated. One contact of each of the gauges shall be used for signalling/tripping the others will be used optionally e.g. for control of cooling.

The temperature gauges shall be provided with a legible maximum pointer resettable from the outside.

Inter-bus transformers 500 MVA and above (cooling type OF.. or OD..) and generator step up transformers 75 MVA and above shall be provided with two temperature gauges for the top oil temperature. Other transformers shall be provided with one top oil temperature gauge. The location of the thermometer pocket shall allow the outgoing top oil to the cooling equipment to be measured.

Transformers of cooling type OF, shall if specified, be provided with one bottom oil temperature gauge.

If not otherwise specified, the ranges should cover -20 °C to 120 °C and 0 °C to 150 °C for the top oil temperature gauge and winding temperature gauge respectively.

Winding temperature gauges (showing the true winding hot spot temperature, i.e. calibrated by means of the true hot spot factor) shall be provided as follows (not applicable to stabilizing and auxiliary windings):

- Two winding transformers smaller than 63 MVA shall be provided with one temperature gauge in the LV winding.
- Two winding transformers 63 MVA and above shall be provided with one temperature gauge in each winding.
- Transformers with three windings or more shall be provided with one temperature gauge in each winding.
- Generator step up transformers 75 MVA and above shall be provided one additional winding temperature gauge based upon bottom oil and winding average oil.
- All temperature gauges shall be provided with Pt100 resistors for remote temperature indication (4 – 20 mA signals). For inter-bus transformers 500 MVA and above and generator step up transformers 75 MVA and above transducers shall be included.

In addition to thermometer pockets for the above gauges there shall be one extra thermometer pocket.

To prevent water from dripping into the thermometers a drip protection or a protruded roof shall be provided.

## 9.4 On-load tap-changer overpressure relay

The diverter switch oil compartment shall be provided with an overpressure relay (alternatively an oil-flow relay) equipped with a contact, adjusted by the manufacturer, closing when reaching a specified pressure (an oil flow). In case of more than one oil space individual relays for each space shall be provided.

It shall be possible to perform a function test of the overpressure relay (oil flow relay) without disassembly.

## 9.5 Cooling equipment gauges and transmitters

In case of OF/OD.. cooling oil flow gauges having contacts closing, in case the oil pump is in operation, at too low oil flow shall be provided. Contact closing shall occur also in case of wrong oil flow direction.

In case of cooling type ..WF the following is required for each cooler:

- Oil flow gauge and meter with one contact closing for a flow above and below settings specified by the manufacturer.
- Water flow gauge and meter with one contact closing for a flow above and below settings specified by the manufacturer
- Pressure gauge (manometer) for minimum pressure of the oil out of the cooler with one contact closing at a minimum pressure specified by the manufacturer
- Pressure gauge (manometer) for maximum pressure of incoming water with one contact closing at a maximum pressure specified by the manufacturer
- The pressure gauges (manometers) may be replaced by differential pressure gauges (differential manometer) with one contact closing when the pressure difference between oil and water is falling below a value specified by the manufacturer
- The pressure gauge contacts are intended for signalling/tripping
- For each cooler Pt100 transmitters with transducers (4 – 20 mA signals) shall be provided for
  - oil into each cooler
  - oil out of each cooler
  - water into each cooler
  - water out of each cooler

## 9.6 On-line dissolved gas monitor

If specified, transformers 63 MVA and above, generator step up transformers (category C transformers) and transformers for HVDC (category D) shall be equipped with an on-line dissolved gas monitor.

The monitoring system performance will be specified in every single case and could range from a relatively simple system (a) to a relatively advanced system (b).

a. A system, indicating a weighted sum of some of the combustible gases and the moisture-in-the-oil.

b. A system supplied with a data management and analysis tool with the capability to automatically collect data from online DGA monitors to a central database. The system should be capable to correlate all 9 fault gases, moisture-in-oil, oil temperature, and ambient temperature to the transformer load. The online DGA monitor should have an embedded server to allow remote access, using any smart device (such as a smart phone or tablet), based on the user providing access via Ethernet or SIM.

There shall be at least 4 – 20 mA signals for remote indication of gases and moisture.

The power supply to the monitors shall be 110 V dc, alternatively 220 V dc or 230 V ac.

## 9.7 Optical fibres for direct winding temperature measurements

Inter-bus transformers 500 MVA and above and generator step up transformers 75 MVA and above shall be equipped with optical fibres for direct winding temperature measurements, that allow for monitoring of the winding hottest-spot directly. For inter-bus transformers 100 MVA and above, the same equipment shall be offered as an option. The utilisation of the option shall be decided not later than one month after the design review is completed. The total number of optical fibres shall be at least sixteen (16) and they shall be distributed to windings, normally on the centre leg. Fibres shall be located to places where the hottest-spot of particular winding is expected and where no oil flow exists. Selected locations shall be motivated by the manufacturer and approved by the customer at the design review meeting. Selected locations must be documented on a drawing, included in the final documentation. Fibres shall be brought out from the transformer and they shall be ended into a separate connection box. If specified, fibres shall be connected to optic signal conditioner for winding monitoring, e.g. Neoptix T/Guard or equivalent. The entire measurement uncertainty of the system ( $\approx \pm 2$  K), shall be included in the maximum allowed hotspot temperature.

# 10 COOLING EQUIPMENT

Normally the cooling equipment shall be designed in accordance with requirements stated in chapter 10.1 and 10.2. However, in order not to prevent the development of new technologies other configurations may be accepted, however, only after written approval.

## 10.1 General

System (inter bus) transformers  $\geq 500$  MVA with cooling by means of pumps and generator step up transformers  $\geq 75$  MVA, shall have the cooling equipment divided in at least two groups. The groups shall be electrically separate, have its own protection, measurement and control and be supplied through separate cables. Preferred supplying cable shall be managed by means of a switch.

In case oil pumps is used, the number of cooling groups, each with one or more pumps, must be at least two.

Each cooling group must have the same cooling capacity.

For cooling type OD.. or OF.., each pump shall be provided with shut off valves in order to facilitate pump exchange.

For cooling type ON.., each radiator shall be provided with shut off valves.

Pipes between tank and separately mounted coolers shall be provided with shut off valves.

It must be clearly indicated if a valve is open or closed.

For cooling by means of oil pumps, all components having circulating oil must withstand an internal overpressure of 0.3 MPa(e) without any leakage the oil having a temperature of 90 °C. If combined with radiators, pumps allowing self circulation shall be used.

Water cooler tubes etc. (cooling type ..WF) shall withstand an internal overpressure of 0.5 MPa(e).

Water coolers shall be of double wall/tube design with leakage detection.

The manufacturer shall if requested take part in the design of the site as to cooler location and thereby also guarantee that the necessary cooling air will be supplied according to Clause 3.2.

In case of separately mounted coolers the necessary cabling and piping as well as assembly shall be included in the supply.

## 10.2 Cooler control equipment

In the normal case the top oil thermometer will control the coolers. Switch on temperatures and switch off temperatures shall by the manufacturer be selected in such a way that the total transformer losses are minimized. Selected temperatures shall by the manufacturer be motivated and justified at the design review meeting. As benchmarks, the last cooling group shall be switched on-off at 50-40 °C or 60-50 °C, depending on number of groups. The previous cooling group shall be switched approximately 10 K lower compared to next group. Spare terminal blocks for connection of another type of cooling control such as a current relay for current control or a breaker auxiliary contact shall be provided.

It shall be possible to control the oil pumps by an auxiliary contact of the transformer breaker.

Normally the cooling equipment power supply shall be taken from the local power supply. However, if specified, the power supply might be taken from an auxiliary winding. In case of supply from an auxiliary winding, necessary cabling shall be included.

The ac power supply shall be arranged in accordance AFS 2008:03, Cl 1.6.3 "Frånkoppling av kraftkällor" ("Disconnection of power sources"). Each fan group shall be equipped with a visible lockable disconnecting switch.

Over time, each cooling group shall be equally utilized. An automatic interchange relay to select the leading cooling group stage shall be provided. The automatic interchange relay may be excluded, however, only after written approval.

In case the automatic interchange relay is excluded, the control shall have a number of switches, equal to the number of cooling groups, with a handle for operation mode selection.

The switches shall then be labelled:

|                                 |         |                             |
|---------------------------------|---------|-----------------------------|
| Switches                        | FRÅN    | (off)                       |
|                                 | TILL    | (on)                        |
|                                 | VAKT t1 | (gauge t1)                  |
|                                 | VAKT t2 | (gauge t2)                  |
|                                 | HK      | (breaker auxiliary contact) |
| temperature setting $t_1 < t_2$ |         |                             |

Table 10.1 Cooling selector

The number of cooling groups (n) may exceed two shall be equal to the number of gauges (tn), where  $t_1 < t_2 < \dots < t_n$ .

For cooling types including pumps, each cooling group must contain the same number of pumps and fans. For cooling type OD.. without radiators, the first cooling group must be switched on when the transformer is energized. For remaining cooling types, including pumps, the first cooling group is governed by gauge t1.

If specified, fans shall be automatically operated in case of risk for freezing.

Each motor shall have its own motor protective switch having both manual and automatic operation.

The motor protective switch shall have at least one auxiliary contact which is closed when the switch is open. This contact will be used for signalling at protective switch tripping.

The motor protective switches must not be provided with under-voltage protection.

Motor protections and contactors (auxiliary relays) in each cooling group shall at least be provided with one miniature circuit breaker (MCB).

The complete control circuit shall be protected by a circuit breaker and be provided with voltage supervision. Provisions for disconnection in case of fire or risk of fire shall be provided.

Staggered switching may become necessary if found advantageous from the dimensioning point of view.

For transformers with an auxiliary winding feeding the cooling equipment the manufacturer shall dimension main and group circuit breakers as well as feeder cables taking into consideration that these can not cause any undesired trippings at a simultaneous start of all pump and fan motors. This might be the case after an outage when the motors have stopped and the voltage returns and all the temperature gauges have their contacts closed.

For transformers without an auxiliary winding or in case of coolers fed from the client's local power supply the manufacturer shall state the maximum value and duration of the total starting current at simultaneous start of all motors as above. Taking the selectivity into account information shall also be given on which size and type is applicable for the main circuit breaker through which the complete cooling equipment is fed.

The principal cooling equipment circuit is given in the principal cooling circuit diagram below.

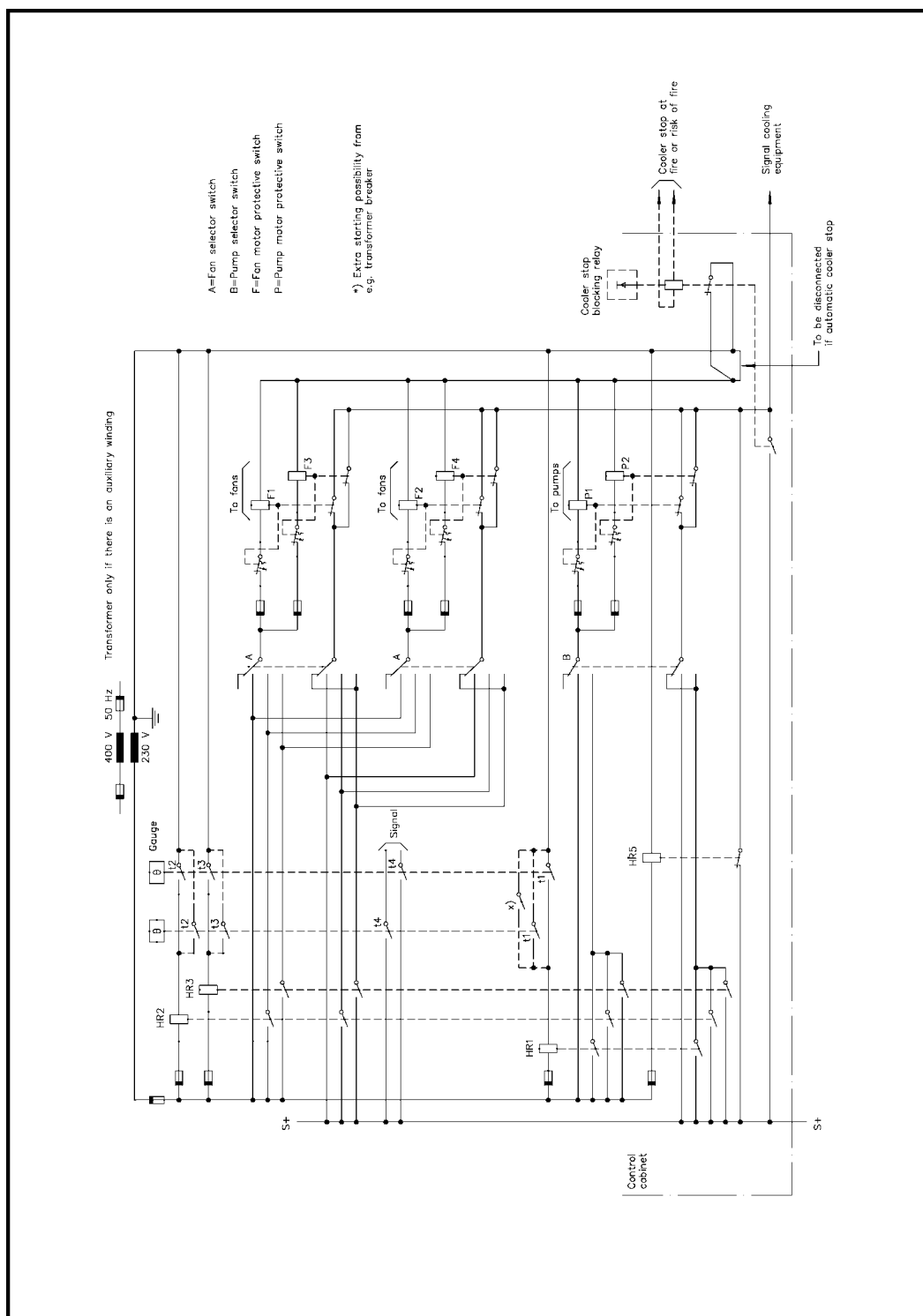


Figure 10.1 Principal cooling circuit diagram

### 10.3 Variable speed control

If specified, fans shall be equipped with variable rotation speed control. It shall be one control/ supply unit for all fans.

Selection of steering for cooling shall be made by one handle (On, Off, Speed control, Temperature control). (PÅ, AVSTÄLLD, VARVTALSTYRNING, TEMPERATURSTYRNING).

Temperature control will be with hysteresis, normally  $\pm 5$  K. In case variable speed control not is able to function, cooling shall automatically switch over to temperature control mode controlled by the top oil temperature and winding temperature gauges. In case of malfunction, equipment for speed control shall generate a local alarm for maintenance purpose. Alarm to be connected to terminals for possible remote indication.

Speed control shall operate to keep the temperature within  $\pm 10$  K, for instance by droop control. For transformers 200 MVA and above, it shall be possible to switch between at least two different set values. These setting values shall be changed automatically, either by season control (summer/winter) or by load (high/low). The Speed control unit shall also handle the risk for freezing of fans but only if speed control not is in operation. For instance, operation periodically with low speed at ambient temperature interval  $-7$  °C to  $+3$  °C. Setting values/interval for “anti-freeze” shall always be possible to adjust. In temperature control mode “anti-freeze” exercise of fans is not needed.

Typical setting values for cooling control:

Speed control normal operation interval: Top oil  $15$  °C (min speed) -  $35$  °C (max speed)

Speed control winter (November-Mars) or at high load for units  $\geq 200$  MVA: Top-oil  $10$ - $25$  °C.

Speed control summer (April-October) or at low load for units  $\geq 200$  MVA: Top oil  $25$ - $40$  °C.

Temperature control: Start/stop of fans Top oil,  $35$ °C and winding hotspot  $40$  °C. Working in parallel.

If needed, frequency converter (or similar) shall be mounted on anti-vibration plate. If risk of overheating inside cubicle for frequency converter or other, it shall by thermostat automatically switch over cooling to temperature control mode.

## 11 CONTROL EQUIPMENT DESIGN

### 11.1 General design

The control equipment shall be assembled functionally and be subdivided as follows:

- Supervisory equipment
- On-load tap-changer motor drive
- Cooling equipment
- Current transformers

Current transformer terminals shall always be located in a separate cubicle.

It shall be possible to arrange separate cubicles for connections to the bushing capacitive taps.

In case of small scale control equipment supervisory equipment may be connected in the on load tap changer motor drive.

The control equipment shall be designed and assembled to withstand occurring transformer vibrations.

Boxes and cubicles shall be lockable by means of a padlock ( $\varnothing_{\text{padlock}}=5-6$  mm,  $\varnothing_{\text{hole}}\approx 8-10$  mm) and located for easy access. Doors shall be equipped with doorstops and be lockable by means of an espagnolette lock without any detachable tools. For small doors, and cubicles not located at service level, other solutions may be accepted, however only after written approval. The cubicles shall always be mounted on the transformer tank so that it is readily and safely accessible from ground level with the transformer in service. Cables shall normally be connected from below why the underside shall be at least 600 mm above the erection plane, including oak planks, supports, wheels or skids. The bottom of all boxes and cubicles shall be equipped with blind flanges for connection of external cables. Flange sizes shall be selected in accordance with standard SEN 280901, for instance FL21.

All components shall be provided with individual markings for easy identification in the circuit diagram. The markings shall be permanent, visible and located in the vicinity of the component.

### 11.2 Ventilation and lighting

Boxes and cubicles shall have draining and self-ventilation. As protection for insects openings shall be provided with non-corrosive metallic nets having a mesh size of about 1 mm.

To prevent water dripping into the boxes or the cubicles, a dripping protection or a protruded roof shall be provided.

Boxes and cubicles for the on-load tap-changer drive and for the control equipment shall be provided with lighting (LED light bulb type with socket E14 or E27) and an earthed 230 V socket with a residual current circuit breaker.

It shall be provided a possibility to feed the lighting in the on load tap changer motor drive and control cabinet from the station local power supply.

## 11.3 Heating

### 11.3.1 General

Boxes and cubicles containing electronic device, MCB:s or device containing moving parts, for instance relays, need extra heating. All such equipment must be able to operate correct in a cubicle temperature exceeding +0 °C.

Equipment in boxes and cubicles for auxiliary power, current transformers and bushing capacitive taps shall be selected in such a way that no extra heating is necessary.

It shall be provided a possibility to feed the heating in on load tap changer motor drive and control cabinet from the station local power supply.

Cubicles containing heaters shall always be provided with thermal insulation. Thermal insulation shall be halogen free and of incombustible material.

Heaters shall be protected against unintentional contact.

### 11.3.2 Design

The heating shall in general consist of two parts:

- Part 1, constantly connected, which secures avoidance of moisture
- Part 2, controlled by a thermostat, which gets connected when the temperature in the cubicle falls below a certain level (maximum +5 °C)

In case only moisture is an issue, Part 2 might be excluded.

The size of the heaters in Part 1 and Part 2 must be optimised with respect of a low energy consumption in combination of avoidance of moisture (Part 1) and ensuring sufficiently high temperature to guarantee correct functionality at – 40 °C ambient temperature (Part 2).

A plate with a recommended switch on temperature setting (maximum +5 °C) to be placed inside the cubicle in vicinity of the thermostat.

To obtain a uniform temperature in a cubicle, it might be necessary to divide a heater in several parts.

### 11.3.3 Supervision

Supervision of the heating in Part 1 and Part 2 shall be individual and be of type current monitoring relays.

For Part 1 the supervision shall be constantly connected and for Part 2, the supervision shall be controlled by the thermostat, which controls the heater.

Alarm from Part 2 must be blocked when the corresponding heater is disconnected.

In case of subdivided heaters, each heater shall be supervised individually.

An extra thermostat shall be provided to give an alarm before the temperature drops below the limit of safe equipment function.

## 11.4 Terminal blocks

### 11.4.1 General

Connection blocks shall be of disconnecting type, Phoenix URTK/S or Weidmüller WTL6/1 EN STB. Other types may be accepted after written agreement.

Terminals shall preferably be placed horizontally and opened down. In case of vertical location, terminals shall be opened to the left. Connection blocks for 230 and 400 VAC shall have labels, indicating their purpose. These terminals must be touch protected and separated from other terminals blocks. If more than one conductor is connected to a terminal same cross section must be used.

All cubicles shall have 8 mm wide slide link type disconnect terminal blocks.

Terminal blocks shall be suitable for the connection of conductors having a cross section of 1 - 10 mm<sup>2</sup> (single stranded) and 1 - 6 mm<sup>2</sup> (multi stranded).

Terminal blocks for the motor power supply shall have a size governed by its purpose.

All cables coming from the outside shall be connected to the one side of the terminal groups and all the internal cables to the other one. Maximum two conductors may be connected to one terminal.

The terminal blocks shall be located for easy access. For the connection of incoming conductors minimum 100 mm free space along the complete terminal row shall be provided.

The terminal block labelling shall begin on 1 within each group.

### 11.4.2 Disposition of terminal groups in the control cabinet

The main cabinet terminal blocks should be functionally grouped like the following sample disposition

| Terminal group  | Use                                                                 | Notes                                                                                                          |
|-----------------|---------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------|
| X1<br> <br>X10  | Power supply and<br>Auxiliary supply                                | Power supply to have lower numbers than auxiliary power<br>Incoming feeder to have lower number than outgoing. |
| X11<br> <br>X50 | Pumps, fans<br>Flow indicators, manometers<br>Cooler circuit faults | Pumps to have lower numbers than fans. Signalling and indication in group X50                                  |
| X51<br> <br>X53 | OLTC gauges                                                         |                                                                                                                |
| X54             | Gas and oil actuated relay                                          |                                                                                                                |
| X55<br>X56      | Oil level indicator                                                 |                                                                                                                |
| X57             | Remote cooler control                                               | E.g. transformer breaker                                                                                       |
| X61<br> <br>X70 | Temperature transmitter                                             | If supply from current transformer this shall be connected to this group                                       |

|                 |                             |  |
|-----------------|-----------------------------|--|
| X91<br> <br>X99 | Gauges for oil-SF6 bushings |  |
|-----------------|-----------------------------|--|

Table 11.1 Control cabinet terminal blocks

### 11.4.3 Disposition of terminal groups in the OLTC motor drive

The OLTC cabinet terminal blocks should be functionally grouped like the following sample disposition

| Terminal group  | Use                                       | Notes                                                |
|-----------------|-------------------------------------------|------------------------------------------------------|
| X1              | Power supply                              |                                                      |
| X2              | Auxiliary power supply                    | Heating, lighting, excluding tap position indication |
| X3              | Operating circuits                        | Including operating voltage                          |
| X4              | Signalling circuits                       |                                                      |
| X5<br>X6        | Position indicator, potentiometer         |                                                      |
| X7              | Position indication                       |                                                      |
| X8<br> <br>X11  | Position switch of type break before Make |                                                      |
| X12<br> <br>X15 | Position switch of type make before Break |                                                      |
| X16             | Follower switch, for parallel control     |                                                      |
| X17             | Follower contact                          |                                                      |
| X20<br>X21      | End limit switches                        |                                                      |
| X22             | Gauges in main control cabinet            |                                                      |
| X26<br> <br>X30 | Spare                                     |                                                      |
| X51<br> <br>X53 | OLTC gauges                               |                                                      |

Table 11.2 OLTC motor drive terminal blocks

#### 11.4.4 Disposition of terminal groups in the current transformer cubicle

##### 11.4.4.1. Disposition

The terminal blocks shall be grouped as follows:

| Terminal group | Use                                                          |
|----------------|--------------------------------------------------------------|
| X11            | Core No. 1 for all three phases for the highest voltage      |
| X12            | Core No. 2 for all three phases for the highest voltage      |
| X13            | Core No. 3 ...                                               |
| X14            | Core No. 4 ...                                               |
| X15            | Core No. 5 ...                                               |
| X21            | Core No. 1 for all three phases for the next highest voltage |
| X22            | Core No. 2 ...                                               |
| X23            | Core No. 3 ...                                               |
| X24            | Core No. 4 ...                                               |
| X25            | Core No. 5 ...                                               |
| X31            | Core No. 1 ...                                               |
| ...            |                                                              |
| ...            |                                                              |
| X101           | Core No. 1 in the neutral for the highest voltage            |
| X102           | Core No. 2 "-                                                |
| X201           | Core No. 1 in the neutral for the next highest voltage       |
| X202           | Core No. 2 ...                                               |
| X301           | Core No. 1 ...                                               |
| ...            |                                                              |
| ...            |                                                              |

Table 11.3 CT cubicle terminal blocks

11.4.4.2. Terminal numbering for current transformers around phase bushings

Example: Core No. 2 of the highest voltage winding

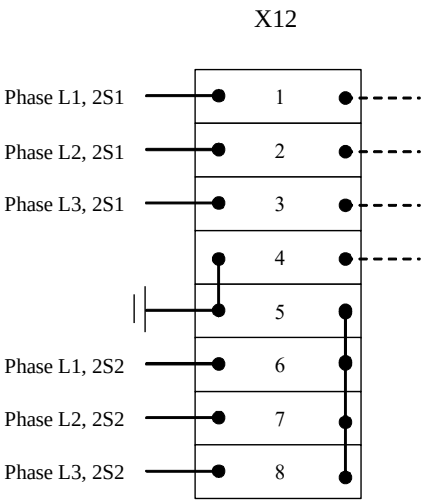


Figure 11.1 Phase CT terminal block numbering

11.4.4.3. Terminal numbering for current transformers around neutral bushings

Example: Core No. 1 for the neutral of the next highest voltage winding

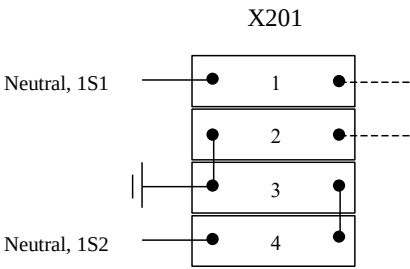


Figure 11.2 Neutral CT terminal block numbering

## 12 BUSHING CURRENT TRANSFORMERS

### 12.1 General

Current transformers will normally only be required around phase and neutral bushings for  $U_m \geq 72.5$  kV.

Current transformers for temperature indication shall fulfil these requirements, however, ratio, accuracy and marking are chosen by the transformer manufacturer.

Each core shall be connected to the terminal box by a separate cable.

The bushing current transformer shall be mounted with P2 closest to the transformer. The test conductor terminal marking, M, shall correspond to P1.

The metering core(s) shall be located closest to the bushing and be labelled No. 1(-2).

### 12.2 Electrical data

#### 12.2.1 Rated primary currents

The current transformers shall be designed for a rated primary current according to Table 12.1. The highest rated current should be the value closest above 1.0 times the power transformer rated current.

| Phase bushing (A) | Neutral bushing (A) |
|-------------------|---------------------|
| 150               | 150                 |
| 300               | 300                 |
| 500               | 500                 |
| 1000              | 1000                |
| 1500              | 1000 to 1500        |
| 2000              | 1000 to 2000        |
| 3000              | 1000 to 3000        |
| 4000              | 1000 to 4000        |

Table 12.1 Rated bushing CT currents

Transformers fulfilling conditions described in chapter 6, may require bushing current transformers with a re-connectable rated primary current.

#### 12.2.2 Rated secondary currents

Rated secondary current shall be 1 A. In some cases 2 A will be specified in line with the old company standard.

### 12.2.3 Rated continuous thermal current

For generator step up transformers the rated continuous thermal current shall be 1.05 times rated current of the power transformer.

For other transformers the rated continuous thermal current shall be 1.8 times rated current for transformers 100 MVA and below and 1.5 for larger ones.

### 12.2.4 Rated short time currents

The current transformers shall be capable of withstanding a primary rated short-time current for 1 sec of at least 15 times the rated primary current, however, not higher than 50 kArms.

### 12.2.5 Insulation levels

The current transformers shall fulfil the requirements in SS-EN 61869-2.

### 12.2.6 Cores and windings

#### 12.2.6.1. Phase bushings

##### 12.2.6.1.1. General

The current transformers shall be designed with three, four or five cores:

- Maximum four relay cores
- Maximum two metering cores

Each core shall have its own secondary winding which shall be electrically completely separated from the other windings.

##### 12.2.6.1.2. Accuracy classes

Relay cores shall fulfil the following requirements:

| Rated current<br>(A) | Rated output<br>(VA) | Accuracy<br>class |
|----------------------|----------------------|-------------------|
| <500                 | 10                   | 5P20              |
| ≥500                 | 15                   | 5P20              |

Table 12.2 Relay accuracy requirements for line terminal CT:s

Metering cores shall fulfil the following requirements:

| Rated output<br>(VA) | Accuracy<br>class |
|----------------------|-------------------|
| 7.5                  | 0.2SFS10          |

Table 12.3 Metering accuracy requirements for line terminal CT:s

Accuracy class shall range from 1 VA to 7.5 VA.

#### 12.2.6.2. Neutral bushings

##### 12.2.6.2.1. General

The current transformers shall be designed with two cores. Each core shall have its own secondary winding, which shall be electrically completely separated from the other winding.

#### 12.2.6.2.2. Accuracy classes

The cores shall fulfil the following requirements:

| Rated output<br>(VA) | Accuracy<br>class |
|----------------------|-------------------|
| 15                   | 5P20              |

Table 12.4 Relay accuracy requirements for neutral terminal CT:s

#### 12.2.6.3. Accuracy limit factor and instrument security factor

As a common designation to the accuracy limit factor (ALF) and the instrument security factor (Fs) the concept "over current number (n)" will be used in these guidelines.

#### 12.2.6.4. Secondary winding resistance for relay cores

The secondary winding resistance, at 75 °C winding temperature, must not exceed the values in Table 12.5 below.

| Ir (A)  | ≤500 | 1000 | 2000 | 3000 | 4000 |
|---------|------|------|------|------|------|
| Rct (Ω) | 5    | 5    | 9    | 12   | 18   |

Table 12.5 Maximal secondary winding resistance for relay cores

#### 12.2.6.5. Test conductor

The cores shall be provided with a common test conductor (~35 mm<sup>2</sup>), by means of which current transformer testing can be carried out without magnetizing and loading of the power transformer.

#### 12.2.6.6. Superposed magnetization

Superposed magnetization may not be used, but turns correction without any significant superposed magnetizing effects can be accepted.

## 12.3 Design

### 12.3.1 General

The current transformers shall fulfil the requirements of the SS-EN 61869-2.

### 12.3.2 Test terminals

One end of the test conductor shall be connected to an additional terminal clamp, marked M, in the terminal box on the transformer top and the other end to the transformer tank.

### 12.3.3 Secondary terminals

Earthing of the secondary terminals (S2) shall be made at the CT-earth in the common connection cubicle, illustrated in Figure 17.1.

## 13 AUXILIARY POWER SUPPLY

A principle outline, showing auxiliary low voltage winding (i.e. few turns around each core leg, connected in yn) feeding a small matching transformer with vector group either YNyn or YNauto, is illustrated in Figure 13.1. The matching transformer transforms the voltage to  $0,42 \pm 5\%$  to be used for auxiliary local power supply.

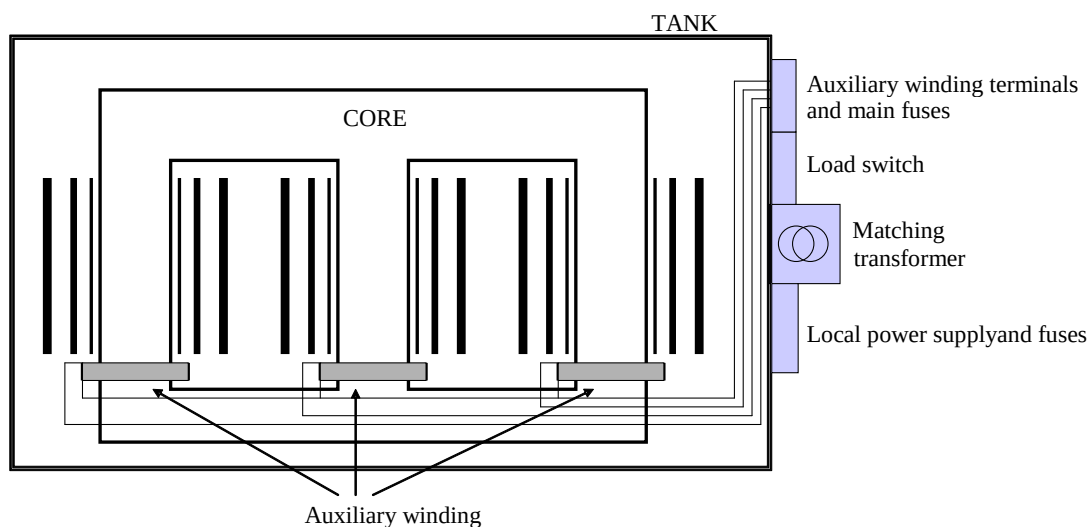


Figure 13.1 Auxiliary power circuit, principle outline

### 13.1 General

Each compartment shall be classified to withstand actual short circuit power and there should be a fire protection in between them, including fire resistant cable glands. All conductors and the auxiliary winding shall be designed to withstand forces caused by a short circuit between main fuses and matching transformer. All live parts shall be touch protected (IP2) and be protected against arcing. Cables, terminals shall not imply any restriction in loading capacity. The auxiliary power circuit on the outside of the main transformer tank (ref. Figure 13.1) is subdivided into:

- a. Auxiliary winding terminals and main fuses
- b. Load switch
- c. Auxiliary transformer (matching transformer)
- d. Local power supply and fuses

## 13.2 Auxiliary winding terminals and main fuses.

The auxiliary winding terminals shall be fused outside the transformer tank in immediate vicinity of the terminals. The neutral terminal shall be earthed through an accessible and removable connection to a flat terminal, welded to the transformer tank.

Winding terminals and main fuses shall be designed for avoidance of short circuits and earth faults. Main fuses shall be provided with a single phase insulating protection. The equipment shall be enclosed in a cubicle with a hinged front cover, bolted or lockable by means of a padlock.

The terminal/fuse cubicle shall be provided with a legible plate reading "**Får endast öppnas i spänningslöst tillstånd**" (Only to be opened when off circuit).

The main fuses are a short circuit protection for the transformer and are considered as a part of it.

## 13.3 Load switch

At service level there shall be an encapsulated load switch having the breaking capacity 1.25 times the auxiliary winding rated current at  $\cos(\varphi)=0.7$  (ind.).

The load switch cubicle shall be provided with a hinged front cover, bolted or lockable by means of a padlock.

## 13.4 Matching transformer

A dry type matching transformer shall be provided in an enclosure with a hinged front cover, bolted or lockable by means of a padlock. The matching transformer shall be covered by plexiglass withstanding arcing.

The cooling type of the matching transformer shall be AN.

The average winding temperature rise shall not exceed the rated values specified in Table 2 of SS-EN 60076-11. When the matching transformer is located inside a cubicle, a correction should be made to the rated average winding temperature rise to account for the enclosure. Verification shall be performed by means of measurements or calculations in accordance with clause 5.2.4 in SS-EN 60076-11.

Note that if an auto connected matching transformer is provided, its primary voltage must not exceed 420 V.

### 13.5 Local power supply and fuses

The auxiliary winding voltage shall be tapped from a separate distribution board assembled on the tank in close vicinity to the auxiliary transformer and be provided with two or three groups. All groups shall be fused by knife (blade) type fuses and be of covered type, disconnect able 3-phase by hand.

Selectivity between fuses at both sides of the matching transformer shall be performed. The fuses in the group for local power supply shall be dimensioned for a current one step below the auxiliary transformer nominal current (For example 50 A for 40 kVA matching transformer). For transformers 500 MVA and above one spare group shall be included. The spare group shall normally be dimensioned as the group for local power supply. For other transformers, there shall be space for future addition of one extra group. If a third group for transformer cooling is specified, these fuses shall be dimensioned for at least the total cooling power consumption. The fuse holders shall allow changing of fuse size, at least one step up and down.

Terminals for cable protective earthing shall be furnished for each fuse group.

There shall be a free space for the client's cables and cable boxes.

A touch proof terminal for cable neutrals and a terminal for cable protective earthings shall be furnished.

### 13.6 Neutral conductor

The auxiliary equipment shall be provided with a through-running, blue coloured neutral conductor. In case of a full wound matching transformer, its two neutrals shall be connected to each other.

### 13.7 Protective earth conductor and protective earthing.

A through-running and unbroken protective, yellow/green coloured, earthing conductor shall be furnished. In the main fuse box this conductor shall be connected to the tank.

Protective earthing of each enclosure or cubicle to the earthing conductor shall be made. Dimensions shall be chosen in accordance to existing fault currents. Serial earthing is not allowed.

13.8 Auxiliary power circuit connection diagram

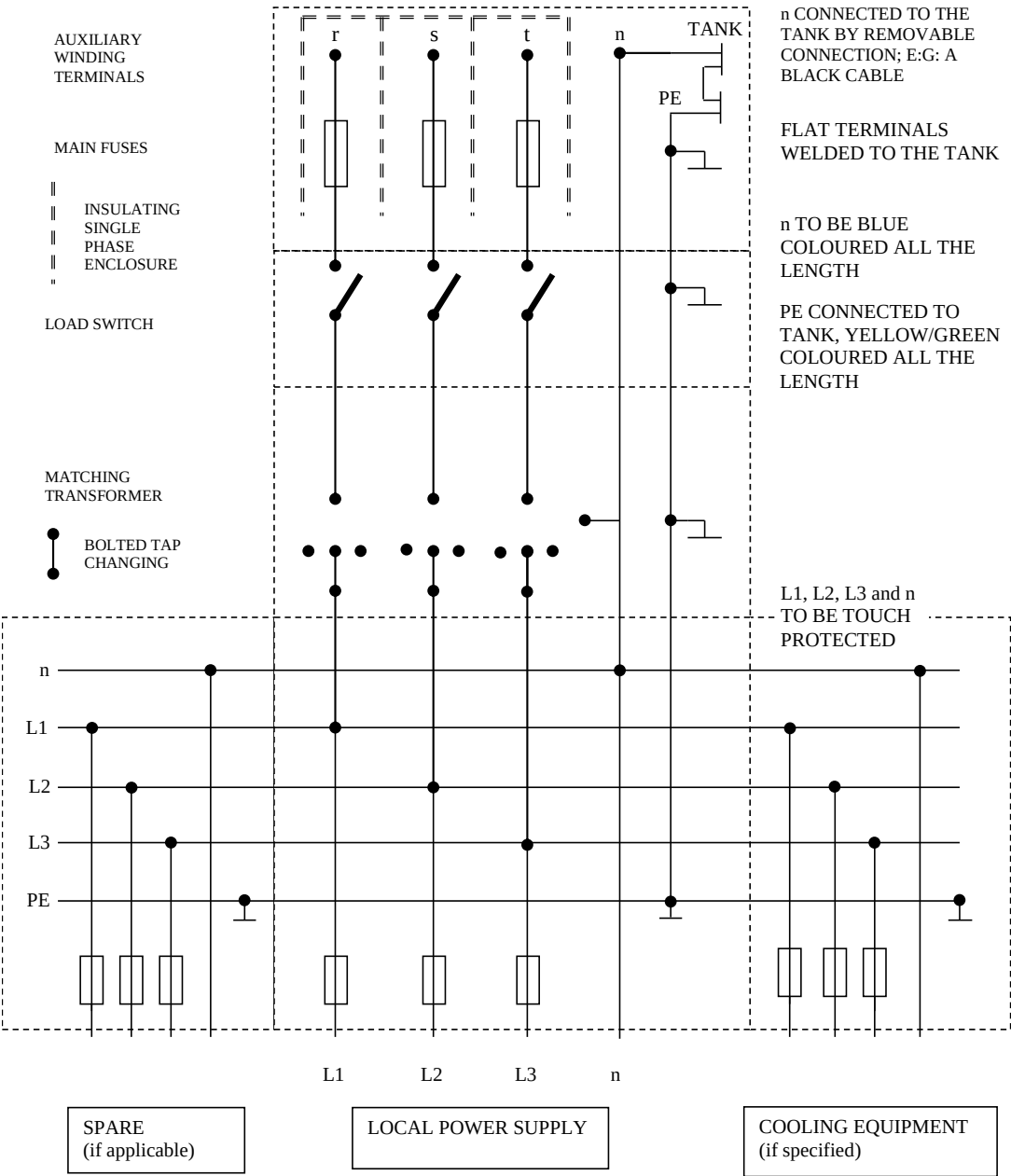


Figure 13.2 Auxiliary power circuit diagram

## 14 POWER AND CONTROL CABLES

Permanently installed cables shall be of screened type and possibly wire armoured cable.

To prevent excessive heating the cables must not come into contact with the transformer cover and they shall be installed in such a way that they do not become an obstacle for water drainage.

Outer cables must not be located inside pipes.

Cables on the cover and other horizontally installed cables shall be protected against treading, however, this is not required when using steel wire armouring.

Clips and cable straps shall be of stainless steel.

Cable sheath and possible protective earthing conductor shall be earthed in both ends of the cable. Peeled part of a cable sheath shall be insulated. Insulation shall be green/yellow if it serves as PE, otherwise it shall be transparent or grey.

The cable bending radius of any cable must not be below ten times its own diameter.

Power cables must have black insulation and control cables, inside cubicles, must have grey insulation. Protective earthing by means of an insulated cable shall have green/yellow insulation.

Cable insulation and cable channels must not contain halogen.

All cables and cable cores shall be provided with individual markings at both ends for the identification in the circuit diagram. The cables markings outside boxes and cubicles shall be of stainless steel.

Cable glands must be of metallic type.

## 15 TRANSFORMER TANK

### 15.1 General

Welders must be qualified in accordance with applicable ISO standards. Welding shall be performed in accordance with applicable ISO standards. Preparation grade P3 shall apply. The tank bottom shall be self-supported, implying a possibility to locate the tank on beams with variable width and internal distance.

Bell type tanks are generally not permitted.

### 15.2 Vacuum safety

For transformers with the high voltage winding highest voltage for equipment  $U_m \geq 72.5$  kV the tank must withstand a full internal vacuum. A vacuum proof tank shall have a marking indicating this.

### 15.3 Cover

Transformers with highest voltage for equipment  $U_m \geq 72.5$  kV shall have the cover welded to the tank. For  $U_m < 72.5$  kV the cover may be bolted, however only after written approval. The edge of the cover shall be equipped with a slip protection according to SS 831342, for separate ladders. If cover height, including oak beams, wheels, supports etc., exceeds 4 m, handrail according to SS 831340, must be provided. If specified, preferable for large transformers, a fixed ladder according to SS 831340, might be included. On the cover there should be a necessary number of fasten eyelets, located on the cover or on each bushing turret. One eyelet shall be located in the vicinity of the slip protection. For smaller transformers, without bushing turrets, at least two symmetrically located eyelets should exist. Tank and cover shall be designed for opening and sealing.

### 15.4 Hand holes

Hand holes shall be provided to facilitate the exchange of any bushing without dismantling of the cover. If a bushing exchange not is facilitated by means of hand holes, these can be excluded, however, only after written approval.

### 15.5 Designation plates

In the middle, approximately at  $\frac{3}{4}$  height, of each long side of the tank, it shall be possible to assemble designation plates (height 270 mm, width 270 mm) by means of screws (four holes  $\varnothing \approx 5$  mm, centered symmetrically 10 mm from the edge in each corner).

For each winding (middle phase) and each neutral, it shall for the current transformers be possible to assemble a designation plate in the vicinity of each component (height 80 mm, width 200 mm) by means of screws (two holes  $\varnothing \approx 5$  mm, centered symmetrically 10 mm from the edge on each short side).

If applicable, for each winding (middle phase) and each neutral, it shall for surge arresters be possible to assemble a designation plate in the vicinity of each component (height 80 mm, width 200 mm) by means of screws (two holes  $\varnothing 5$  mm, centered symmetrically 10 mm from the edge on each short side).

All designation plates shall be easily readable from service level.

## 15.6 Valves

### 15.6.1 General

Butterfly valves and ball valves are preferred.

### 15.6.2 Sampling valves

One to three oil sampling valves shall be provided:

- One for sampling at cover level
- One for sampling at half the tank height
- One for sampling at the tank bottom (as low as possible)

The number of sampling levels are chosen as follows:

| Highest voltage for equipment<br>(kV) | Sampling level |
|---------------------------------------|----------------|
| 145 – 420                             | A, B, C        |
| 72.5 – 82.5                           | A, C           |
| $\leq 52$                             | C              |

Table 15.1 Oil sampling valves

All valves shall be located at the tank bottom level. For the valves A and B a pipe connection from the sampling level shall be furnished. The valve dimension shall be Connection No. 20 with an internal thread R 3/4".

### 15.6.3 Valves for extra heat exchanger

If specified, transformers 100 MVA and above and all generator step up transformers shall be provided with two extra valves, Connection No. 100 or 200, intended for the connection of heat exchangers for heat recovery.

The heat exchanger system will normally be designed and assembled by the client, but the external oil circuit design and the selection of material will be handed over to the manufacturer for approval.

At site the external oil circuit shall be approved by the manufacturer. The transformer guarantee shall be valid without any limitations due to the external heat exchanger system.

## 15.7 Pressure relief valve

The transformer tank may be equipped with a pressure relief valve. Location and design to be proposed by the supplier. The device shall be equipped with enclosure and necessary pipe arrangement, to lead any oil down to the transformer oil pit.

## 15.8 Surge arresters

An external bracket on the tank, easy to dismantle, may be specified to facilitate installation of surge arresters close to the bushing terminals to obtain best possible protection. The bracket shall be painted in the same way as the transformer. The delivery may include:

- Attachments
- Attachments and bracket (including cabling)
- Attachments, bracket and surge arresters (including cabling)

The surge arresters shall fulfil requirements stated in TR01-12E and shall be earthed on the tank by means of black insulated cables (minimum 35 mm<sup>2</sup> Cu Um<72.5 kV, minimum 50 mm<sup>2</sup> Cu Um≥72.5 kV) with low wave impedance, mounted on cable ladders or equivalent. The earthing cables must not be assembled together with other cables. For Um≥72.5 kV, the arresters shall be mounted on insulated base and it shall be possible to use surge counters and perform measuring of leakage current from each arrester at service level with the unit energized. All cables shall be connected to a common busbar, welded to the tank and provided with five holes, three holes for the surge arrester cables and two holes for connection to ground.

For Um<72.5 kV, the arresters shall be separately earthed to the cover, using shortest possible cables.

On the bracket, it shall be possible to assemble designation plates for each surge arrester (height 80 mm, width 200 mm) by means of screws.

In case attachments and bracket will be chosen, the following dimensions can be used, if not otherwise is specified:

- Um≤36 kV. Ø<sub>plate</sub> ≈100 mm, one centralized hole with Ø<sub>hole</sub> =14 mm.
- 36<Um≤72.5 kV. Ø<sub>plate</sub> ≈280 mm, three holes 120 degree in between, Ø<sub>hole</sub> =14 mm, holes located at radius 111 mm. (might be oval for flexibility in radius)
- 72.5<Um≤170 kV. Ø<sub>plate</sub> ≈320 mm. Holes might be drilled at a later stage.
- Um>170 kV. To be designed by the supplier.

## 15.9 Gaskets and seals

Any person who is responsible for the design, manufacture and installation/assembly, respectively, of items concerning sealing solutions for transformers shall possess necessary competence within seals and sealing technology. Seals and gaskets must be resistant to transformer oil. Regardless of the type of sealing solution this must be recorded and documented in the technical file and reference made to these guidelines.

The sealing must be vacuum proof to a pressure of 20 Pa (0,2 mbar) and oil tight to a pressure of 0,2 MPa. Furthermore, nominal long term working temperature for distribution and inter-bus transformers can be assumed to be maximum +55 °C for up to 99 % of the service life. For generator step up transformers, transformers for HVDC and wind farm transformers the maximum long term working temperature is assumed to be +70 °C. For the remaining 1% of the service life +80 to +90 °C can be considered. Short term maximum working temperature is assumed to be +105 to +115 °C, appearing very occasionally during the whole service life. Other temperature ranges might be specified in single cases. Required service life for sealing devices is 60 years.

Suitable sealing devices are mainly divided into Gaskets and Seals.

Gaskets: Detailed information regarding gasket type and dimension, housing and material selection is found in international standards e.g. SS-EN 1092-1, SS-EN 12560 part 1 and SS-EN 1514 Part-1. The gaskets must not contain asbestos. It is strongly recommended that selection of the type of gasket and suitable material is made in close cooperation with the gasket manufacturer. Gaskets should be changed into new ones each time a flange is opened.

Seals: Detailed descriptions, including standardized sizes and groove design and quality acceptance criteria is given in national and international standards, preferably: ISO 3601-1, ISO 3601-2, ISO 3601-3. The largest standardized O-ring cross section size shall be used whenever possible to provide for best function and service life. It is important that material selection is made in close cooperation with the O-ring manufacturer. O-rings below lid level should not be re-used.

O-rings shall be used in general, but a rectangular cross section shape may be accepted. In some special application it might not be possible. If so it shall be declared and agreed between supplier and client.

Solid silicon seals are generally not permitted. To secure functionality at low service temperatures, i.e. none energized transformer, they may for deliveries in north Sweden, be chosen in agreement with the client.

Flat gaskets solid silicon rubber is never permitted.

Due to the high complexity, corporation with supplier with high competence is requested. For example: Trelleborg, James walker, Parker and Eriks.

At beginning of project (Design review stage) the supplier shall present a complete solution for the sealing system.

## 15.10 Erection, Lifting devices, Transport

On the transformer tank there shall be a durable marking of the centre of gravity during transport.

Transformers shall be designed for dragging and will normally be placed on oak beams.

Oak beams must be dimensioned with respect to the weight and pressure, however with a minimum thickness of 50 mm.

Erection of larger transformers can be made by means of supports. For moving on rails, wheels may be used and shall, if specified, be included in the supply. If wheels are specified, wheel holders shall be included in the supply.

If anti-vibration plates are specified, these must be dimensioned with respect to the weight and pressure.

Wheel holders or bogies shall be designed for longitudinal and lateral movement. As to track gauges, refer to Clause 15.12 Track gauges.

The transformer tank shall be provided with clearly marked attaching plates for jacks minimum 300 mm above the rail or the erection plane. Jacks must be dimensioned with respect to the total transformer weight, including oil.

When placed on supports in addition to the jacking plates there shall be sufficient number of jacking positions on the tank bottom. These shall be so located that the wheels, wheel holders or bogies do not interfere with the handling of jacks.

Transformers having a transport mass 80 tons and above shall be possible to transport by wagons with home location in Sweden and fulfilling Swedish railway transport profiles, hanging on brackets between the beams. If possible the choice of two different transport wagons is preferred.

Transport profiles, weight limits and the procedure to get transports permits, are described in the Network Statement with amendments, which will be updated and published at the website of the Swedish Transport Administration.

For transformers with maximal transport dimensions (L×W×H) 10000×3400×4700 mm and maximal transport weight 240 ton, most railways can be used. For larger transformers, a more accurate investigation must be performed.

If applicable, transport brackets shall be provided by the manufacturer.

Transformers must not be transported hanging in yokes (loops) between the transport wagon side members.

For the transport two independent impact recorders shall be provided. There shall be one external, tank mounted, and one internal, active-part mounted, impact-recorder. The external is used to indicate if a high impact has occurred and if further check of the internal impact-recorder is necessary. For transformers 200 MVA and below, or if the transformer is transported oil filled, only one recorder outside the tank is required.

The minimum availability for registration must be at least 6 months. The manufacturer shall before the start of the transport state the maximum allowed stresses. However the stated limits in Cigré TB 529 must not be exceeded.

The setting of the detection limits shall be agreed upon between the manufacturer and the client.

The operation of the impact recorders shall regularly be checked during the transport.

## 15.11 Gas and oil actuated relay inspection

If specified, transformers shall be provided with a platform for inspection of the gas and oil actuated relay. The platform and the permanently assembled ladder shall fulfil the requirements of the Swedish Work Environment Authority, as well as ISO 14122-3 and ISO 14122-4. The location of the gas and oil actuated relay, is dealt with in Clause 9.1.

The platform shall be constructed with a floor of lattice type and have raised borders (slip protection).

The platform and the ladder shall be provided with protections against falling down in accordance with AFS 2020:1, 46§, 149§.

Permanently assembled ladders shall always have lockable protection for unintentional entrance.

## 15.12 Track gauges

### 15.12.1 General

The track gauges shall also apply in case of transformer erection on steel or concrete beams or oak planks.

### 15.12.2 Longitudinal movement

Track gauge 1435 mm

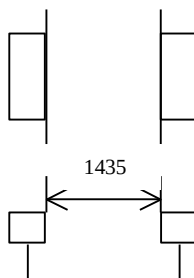


Figure 15.1 Longitudinal track gauge

### 15.12.3 Lateral movement

Alternative A – track gauge 1435 mm<sup>1</sup>

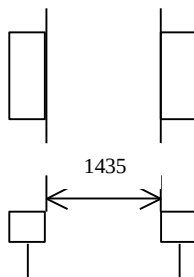


Figure 15.2 Lateral track gauge A

Alternative B – Track gauge 2940 mm, possibly a centrally located support wheels<sup>1</sup>

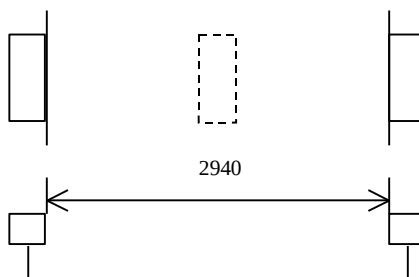


Figure 15.3 Lateral track gauge B

<sup>1</sup> For 70 and 130 kV transformers the track gauge 1435 mm shall be chosen if possible.

Alternative C – Track gauge 4000 mm with a centrally located support wheel

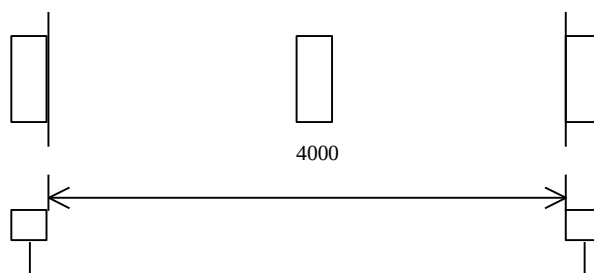


Figure 15.4 Lateral track gauge C

Alternative D – Track gauge 2×1435 or 2×2500 mm with 4000 or 5000 mm centre distance between track pairs.

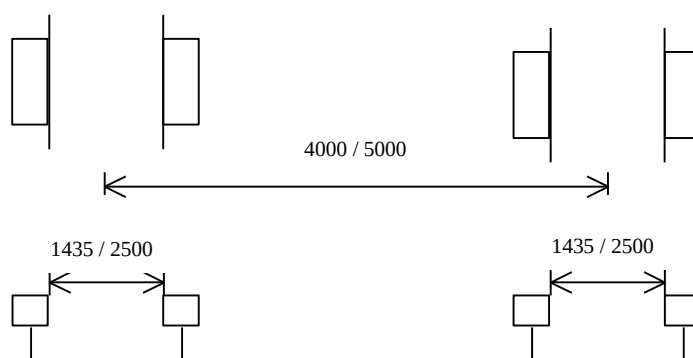


Figure 15.5 Lateral track gauge D

### 15.13 Sound proofing

External sound panels, as well as double walled tanks, are normally not allowed and may be applied only after written approval.

## 16 CORROSION PROTECTION AND SURFACE TREATMENT

### 16.1 Transformer tank, OLTC tank

Type of paints in the system for corrosion protection must be of a type that keeps down the airborne emissions of volatile organic compounds (VOC) to a minimum. This can preferably be obtained by use of water borne paints or high solid paints if not the painting facility is suitable for water borne paints.

The external painting system shall comply with the requirements based on SS-EN ISO 12944 Corrosivity category C4 H (high atmospheric corrosivity with a protection durability of more than 15 years).

Accelerated laboratory test according to SS-EN ISO 12944-6 shall only be used as guidance for qualification of the paint system but to qualify the paint system it must be tested through field test. The outdoor test site for qualification of the paint system must comply with SS-EN ISO 8565. The field test requirement and assessment must be according with section 8.726 in BSK 07. A pre-qualification test can be made according to SS-ISO 11474 (SCAB-test) with requirement and assessment according to section 8.726 in BSK 07.

## 16.2 Connection boxes, cubicles and OLTC motor drive

The external painting system shall comply with the requirements based on SS-EN ISO 12944 corrosivity category C4 H (high durability). Same colour as for the tank shall apply.

## 16.3 Screws etc.

All screws, washers and nuts shall be of acid proof steel (steel grade A4) in accordance with SS 14 2324 and SS-EN 10088-3 or of another from the corrosion point of view equivalent material.

Screws and nuts shall be waxed in order to prevent seizing. Type of washers shall be selected in order to prevent paint cracking.

## 16.4 Radiators

The radiators shall be hot dip galvanized in accordance with SS-EN ISO 1461. The local minimum coating thickness shall be at least 70 µm. Hot dip galvanized surfaces must not be painted. However, if a corrosivity category higher than C4 H is required, painting may be accepted.

## 16.5 Coolers, fans and pumps

The external painting system shall comply with the requirements based on SS-EN ISO 12944 corrosivity category C4 H. Same colour as for the tank shall apply. For cooling type ..WF the coolers must not have copper in direct contact with the transformer oil.

## 17 EARTHING

### 17.1 Principal earthing diagram

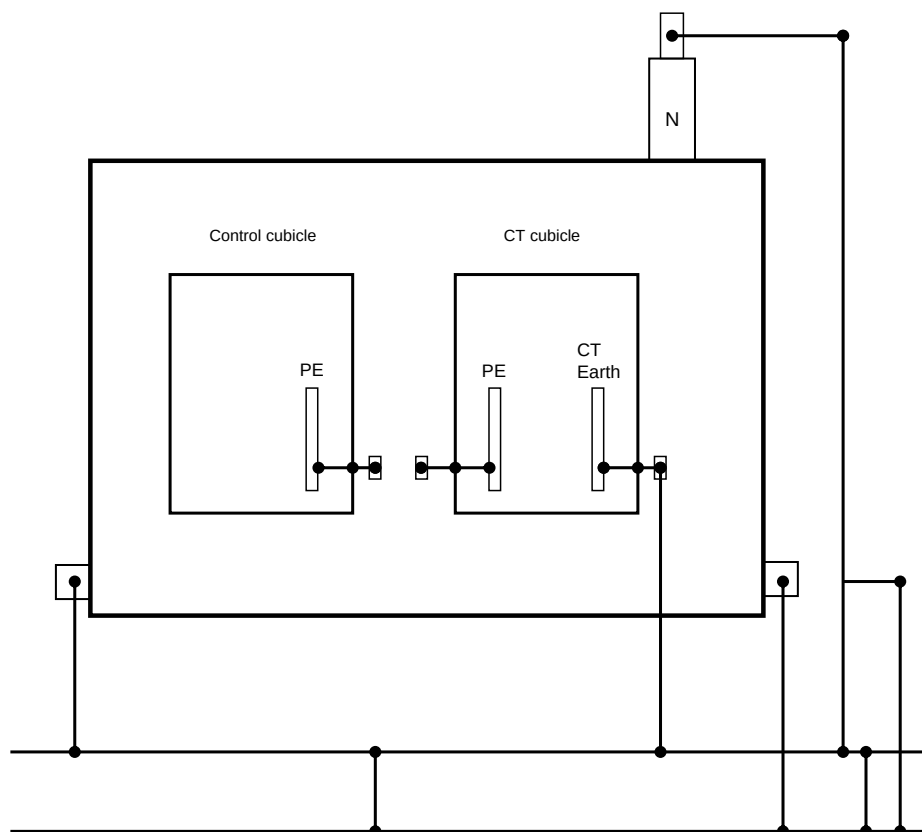


Figure 17.1 Principal earthing diagram

### 17.2 System earthing

#### 17.2.1 Neutral point earthing

For direct earthing of windings having highest voltage for equipment  $U_m \geq 145$  kV the transformer shall, if not otherwise stated, be provided with a neutral bus assembled on the tank. The end of the bus connected to the neutral point (top) shall be disconnect able and the other end (bottom) shall terminate at the same level as other tank earthing points. To avoid tank damages due to fault currents the bus shall be insulated from the tank.

For the connection of earthing cables by cable lugs the neutral bus lower end shall normally be provided with two holes  $\Phi 14$  mm with a vertical c/c 40 mm distance. If specified, four holes shall be provided.

As to fault currents the neutral bus shall be dimensioned in the same way as the transformer.

#### **17.2.2 Earthing of a stabilising winding or an unloaded delta connected winding**

A stabilising winding or an unloaded delta connected winding, shall always have one corner earthed.

#### **17.2.3 Earthing of windings with re connectable connection mode**

Windings with re connectable connection mode Y-D, must be possible to earth in close vicinity to the phase bushings.

### **17.3 Protective earthing**

#### **17.3.1 Transformer tank**

For the protective earthing of the transformer tank two earthing terminals diagonally located close to the tank bottom shall be provided. The earthing cable comprises a few-wire copper conductor, 95 mm<sup>2</sup> for highest voltage for equipment  $U_m \leq 72.5$  kV and 185 or 240 mm<sup>2</sup> for higher voltages.

The terminals shall be flat with four holes,  $\Phi$  14 mm, having a vertical centre distance of 40 mm and a horizontal one of 50 mm. The contact surface shall be protected against corrosion in a way that a good electrical contact will be obtained after assembly.

#### **17.3.2 Connection cubicles and control cabinet**

Connection cubicles and cabinets shall have a protective earthing to the transformer tank through a visible green/yellow earthing connection.

Current transformers shall in their connection cubicle be earthed to a common earthing terminal. This terminal shall also be accessible on the outside of the cubicle and be designed for the connection of an earthing cable of at least 25 mm<sup>2</sup>. A plate "Ansluts till marklinenät" shall be located in the vicinity of the accessing point. The functional earthing of the current transformers (S2) shall be made by a cable with grey insulation.

#### **17.3.3 On-load tap-changer**

The tap-changer cover and/or tank shall have a protective earthing to the transformer tank through a visible green/yellow earthing connection.

#### **17.3.4 Auxiliary power equipment**

Refer to the Clause 13 on auxiliary power equipment.

#### **17.3.5 Separately erected cooling equipment**

Each cooler support shall be provided with one earthing terminal identical with the ones for the transformer tank.

#### **17.3.6 Other equipment**

All metallic pieces not welded to the tank shall be earthed to the tank through visible green/yellow earthing links.

## 17.4 Core earthing

The core and core clamping earthing shall be individually earthed in an external earthing box.

# 18 OIL AND OIL SYSTEM

## 18.1 Oil quality requirements

The oil must be of naphthenic base and be solvent refined and/or severely hydro treated.

The oil must fulfil the requirements for inhibited oil (in accordance with SS-EN 60296) and contain at least 0.2% (kg/kg) of an oxidation inhibitor of type di-tert butyl-parakreosol (DBPC).

The lowest cold start energising temperature (LCSET) shall be -40 °C.

The oil must not be added any pour point depressants.

The oil must not contain any Dibenzyl Disulfide (DBDS).

The oil must not be added any gas absorption additives.

The detection limit to verify the PCB content must be 0 ppm. If an oil sample withdrawn at the delivery contains 2 ppm or more the oil delivery will not be accepted.

The total aromatic content must not be higher than 10% (v/v).

It should be noted that the kinematic viscosity at -30°C must not be higher than 800 mm<sup>2</sup>/s (***Deviation from SS-EN 60296***).

The manufacturer shall present an oil specification for approval. In the specification the type of base, country of origin and refining place shall be clearly stated.

In connection with the factory acceptance tests the manufacturer shall, if specified, withdraw two oil samples from the transformers for among others PCB check (even if the oil will not be shipped with the transformer). Sample containers will be provided by the client.

The following documentation shall accompany each delivery:

- A test certificate indicating country of origin and refining location
- B HPLC "finger print" (HPLC = High Performance Liquid Chromatography)
- C product specification with data according to SS-EN 60296
- D verification proof of a non-corrosive oil with respect to sulphur
- E certificate verifying that the oil used at FAT is compatible with the delivered oil
- F information on:
  - fire fighting precautions
  - decomposition products
  - health hazard
  - first aid
  - personal protection

- environmental hazard
- destruction
- storage and handling
- transport classification

Approved oils are:

- NYNÄS NYTRO 10XN
- SHELL DIALA S4 ZX-I
- NYNÄS NYTRO BIO 300X
- SHELL DIALA S5 BD

Other oils can be accepted, however only after written approval.

## 18.2 Oil system

The main conservator shall be provided with a rubber bag or membrane to prevent humidity to and air access. Other solutions except nitrogen cushion may be accepted for transformers  $\leq 40$  MVA but first after written approval.

On-load tap-changer diverter switches operating in oil shall have an oil compartment completely separated from the transformer oil and provided with a separate expansion space.

After oil filling the leakage of air into the transformer must not exceed 0.3% (by volume). This will normally be fulfilled by using a rubber sack having a diffusion rate of less than 50 l air/m<sup>2</sup> rubber and year at 20 °C. The aging properties of the rubber material shall be presented.

## 18.3 Conservator

At -40°C ambient temperature, off circuited transformer and at steady state condition the oil level must not drop to such a level that the oil level indicator no longer will show any level reading. Furthermore the oil shall not overflow at short-time emergency loading, implying a top oil temperature equal to 115 °C.

Separately mounted conservators is used only if specified and shall have expansion couplings in its connection pipes.

The opening for oil filling shall be provided with a case with an internal thread.

There shall be a shut off valve between the gas operated relay and the conservator.

The conservator must be welded. Necessary hand holes for exchange of rubber bag, inspection and cleaning shall be provided.

## 18.4 Dehydrating breather

The transformer shall be provided with a dehydrating breather with a hydraulic guard.

The air dryer shall be located at service level and the drying substance must be visible along the complete length of the dryer.

The air dryer shall be provided with a label showing the colour change when the drying substance is becoming humid.

The size of the dehydrating breather must be designed for an exchange interval of the drying substance exceeding four years.  
If specified, the dehydrating breather shall be of maintenance-free type.

## 18.5 Oil sampling

Refer to Clause 15.6.2

## 18.6 On-line monitoring

Refer to Clause 9.6

# 19 MARKING

## 19.1 Plates

All plates shall be in Swedish. English language can be accepted for plates belonging to accessories from sub suppliers. Outdoor plates shall be weather resistant.

### 19.1.1 Rating plate

The rating plate shall contain the information according to SS-EN 60076-1, Cl 8 and also:

- IEC/EN/SS-EN-standard
- maximum continuous operating voltage at rated power
- load losses, no-load losses and, if applicable, cooling losses

If applicable, a separate rating plate for a matching transformer shall be provided, with a reference on the main rating plate.

### 19.1.2 Diagram plate

A diagram plate is required for transformers having  $U_m \geq 145$  kV and for all three winding transformers.

### 19.1.3 Accessory plate

For  $U_m \geq 145$  kV, a plate shall be provided (may be combined with the oil circuit diagram plate) showing the following accessory information:

- location
- size or type designation
- purpose

The following accessories shall be included:

- bushings
- gauges
- valves
- venting valves
- hatches for reconnection
- thermometers
- level indicators
- connection cubicles

- tank earthing terminals
- jacking positions

#### 19.1.4 Oil circuit diagram

If specified, an oil circuit diagram shall be provided (may be combined with the accessory plate).

#### 19.1.5 On-load tap-changer and motor drive plate

The rating plate shall contain the information according to SS-EN 60214-1, Cl 9 and also:

- insulation level
- rated through current ( $I_r$ )
- contact length of life
- service interval

#### 19.1.6 Bushing current transformer plate and marking

##### 19.1.6.1. General

The secondary terminals shall be marked according to SS-EN 61869-2 (The alternative 1S1, 1S2 etc. shall be used).

The secondary terminal marking shall correspond to a fictitious primary terminal marking P1 - P2, where P2 is closest to the transformer. The test conductor terminal marking, M, shall correspond to P1.

##### 19.1.6.2. Rating plate

Beside the power transformer rating plate, or as a part of it, or inside the connection cubicle there shall be a permanently fixed, distinct rating plate which shall contain the data in accordance with SS-EN 61869-2. Note here that the current transformer serial No. as well as values of the winding resistance ( $R_{ct}$ ) and the over current factor (FS or ALF) shall be specified.

The rating plate shall in other respects fulfil the requirements in the main document.

##### 19.1.6.3. Diagram plate

Beside the power transformer rating plate, or as a part of it, or inside the connection cubicle there shall be a permanently fixed, distinct diagram plate showing the current transformer connection and terminal marking. The separate main data for the different cores shall be clear from the plate.

The diagram plate shall in other respects fulfil the requirements in the main document.

#### 19.1.7 Off-circuit tap-changer and system voltage re-connection plates

At the location of the off-circuit tap-changer and the system voltage re connection location there shall be a plate showing tapping position and position of connection links etc. The transformer diagram plate shall show the same information.

#### 19.1.8 Oil level diagram

Plates with a diagram showing the oil level and oil volume for energized transformer as a function of top oil temperature and loading conditions (0, 50, 100 %) (0, 100 % for OLTC plate) in steady state condition shall be provided. Even the signalling levels shall be indicated. From readings from the top oil thermometer and the oil level indicator it shall be possible to easily judge if the oil level is normal.

### 19.1.9 Other plates

All cubicles shall have plates showing the purpose.

Each individual accessory, outside cubicles, shall be provided with a plate showing the purpose as well as clear identification. Inside cubicles only clear identification is required.

Pumps shall be provided with plates such as P1, P2 ...

Fans shall be provided with plates such as F1, F2 ...

Visible labels showing the direction of rotation of fans shall also be provided.

## 19.2 Terminal markings

There shall be a sustainable marking of each terminal by means of symbols in relief. It shall be possible to identify each terminal marking from service level. The terminal markings are preferable located at the bushing turrets. Terminal markings to be used are agreed between the supplier and client in every single case.

# 20 INFORMATION IN THE BID

## 20.1 General

In addition to SS-EN 60076-1, Annex A the manufacturer shall in his bid submit all the information asked for as specified below, in the inquiry or elsewhere in this document.

In case of missing information or parts of it the bid will not be taken into consideration.

Catalogues, pamphlets, summaries etc. shall be provided with clear reference to the tendered equipment.

## 20.2 Bid content

In addition to required information, stated in data compilation, the following documents shall be submitted:

- Outline drawing with
  - outer dimensions guaranteed with a tolerance of +200 mm (specified maximum dimensions not to be exceeded)
  - bushing locations and air clearances
  - outer dimensions and tank dimensions

If applicable, Swedish railway coach transport drawing proofing that the transformer will not exceed the Swedish railway transport sections.

- Data compilation as per chapter 27 properly completed. The data compilation shall be updated if design changes are agreed, for instance during tender negotiations or a design review.
- Connection diagram
- If specified a winding diagram showing internal winding locations and type of winding. In case of subdivided windings the percentage turns distribution shall be shown

- If specified, a winding diagram showing dimensioning radial and axial dynamical short-circuits stresses for each winding; the type of stress and fault case shall also be indicated. Manufacturing tolerances must be considered in the short-circuit stress calculations.
- If specified a winding diagram showing size and direction of maximum dynamical mechanical stresses for each winding. The corresponding fault case shall be indicated.
- Test connection diagram for impulse and power frequency tests
- Oil specification in accordance with Clause 18.1
- Spare parts list including unit prices
- List of all deviations from the inquiry, this document and the standards and specifications referred to
- The deviations shall be accompanied with clear references
- If specified a time schedule for drawings, diagrams, control and inspection plans for the manufacturing, tests and assembly
- Type test certificates on units identical in rating and construction.
- List including all tests which will be performed at the Factory Acceptance Test (FAT).

## 21 QUALITY ASSURANCE

### 21.1 Quality and Eco Management Systems

The manufacturer shall in his tender describe his Quality Management System (QMS) and Eco Management System (EMS) to ensure that the transformers in all respects such as design, supply of materials, choice of material, manufacturing, testing, service, maintenance, documentation and environmental impact are fulfilling the requirements set up in the contract documents, standards, specifications and regulations.

The quality management shall be based on and in relevant parts fulfil the requirements in SS-EN ISO 9001 and SS-EN ISO 14001.

The manufacturer is responsible to all his sub suppliers establishing and executing quality management systems on their own.

### 21.2 Quality manuals

Complete quality manuals describing the execution of all the elements of the quality systems shall be available with the manufacturer as a reference for the client or his representative. The manual shall be written in English.

### 21.3 Quality inspection. Inspection plans

The manufacturer shall for each transformer establish a main inspection and test plan (ITP) containing a summary of all the inspections and tests which shall be performed during the manufacturing, factory acceptance testing, final assembly and commissioning.

It shall be clear from the inspection plan where inspection activities shall be performed, the parties to be present and inspection plans in force and distribution of testing and inspection documents.

The main inspection and test plan shall be approved by the client before the beginning of the manufacturing.

The client or his representative shall have the right to take part in any inspection or test and shall also be informed of the result as specified in the inspection documents.

The client or his representative shall also at any moment have the right to, without any advance notice, make a follow-up of an arbitrary inspection, manufacturing step or test at the manufacturer's or the sub supplier's plant and then also be informed of the result.

Inspections and tests performed in the presence of the client or his representative will not imply any limitation of the manufacturer's responsibility.

## 22 DESIGN REVIEW

A design review includes an electrical and a mechanical part. For all category B through D transformers and category A transformers 100 MVA and above design reviews shall be conducted in accordance with the guidelines in Cigré TB 209 and TB 529.

The data compilation sheet shall be reviewed and, if necessary, updated during the design review.

If requested design reviews may be conducted even for other transformers.

The objective of the design review is

- to ensure that there is a clear and mutual understanding of the technical requirements
- to verify the system and project requirements and to indicate areas where special attention may be required
- to verify that the design complies with the technical requirements
- to identify any prototype features and to evaluate their reliability and risks

The review is preferably held after completion of the electrical design but before start of any manufacturing activities affected by the design.

The review shall be held at the manufacturer's plant and it shall be considered as confidential. Its purpose is not to make changes in the design, however if it is evident that the manufacturer not is fulfilling specified requirements, necessary changes in the design may be required.

Special attention shall be paid to the verification of Thermal design (see sections 9.7, 23.8.3, 23.8.4) and Mechanical design (Short circuit capability) (see section 23.8.5). Here the Guide No. 529 and SS-EN/IEC Standards can be used as a support with below chapters as reference.

## 22.1 Thermal design review

The thermal design review shall be performed as per Cigré Guide 529 Chapter 9.3 Thermal design.

A thermal design review shall be done on the complete order design before manufacturing starts. A detailed Thermal Network model shall be used for the calculation of hotspot temperature in oil-guided windings which includes at least the effects of

- Local stray losses
- Extra spacers
- Exact position of oil guides
- Extra insulation on disk edges (“edge collars”)

The following calculations shall be done:

- Rise of top oil temperature,  $\Delta T_{\text{top, oil}}$
- Rise of average oil temperature,  $\Delta T_{\text{avg, oil}}$
- Rise of average winding temperature,  $\Delta T_{\text{avg, wdg}}$
- Rise of hotspot temperature and its position,  $\Delta T_{\text{hotspot}}$
- Determination of the hotspot factor  $H_{\text{test}}$  to be used at the temperature rise test by application of SS-EN 60076-2 procedure from the result of the network model:
- $H_{\text{test}} = (\Delta T_{\text{hotspot}} - \Delta T_{\text{top, oil}}) / g$ , where the gradient  $g = (\Delta T_{\text{avg, wdg}} - \Delta T_{\text{avg, oil}})$

The thermal design review shall also include a verification of the design with respect to GIC requirements, see Clause 4.8.1.

## 22.2 Mechanical design review

The mechanical design review shall be performed as per Cigré Guide 529 Chapter 9.4 and SS-EN 60076-5, Annex A.

The design review related to short circuit is not only a verification of calculations, it should be a process to be sure that there is a clear understanding of the transformers installation and service conditions related to short circuit, to verify that the manufacturing materials and components are suitable for the intended application, that there is a solid and validated design concept, as well as state of the art design tools and calculation and adequate manufacturing processes and qualified personal. Specifically methods of calculations of forces and stressed with allowed criteria shall be shown and agreed upon. SS-EN 60076-5, Annex A is a bench-mark.

## 23 FACTORY ACCEPTANCE TESTS. FINAL INSPECTION.

### 23.1 General

The factory acceptance tests shall be witnessed by the client or his representative and a notice shall be submitted at least two weeks before commencement of the tests.

At the acceptance tests the transformer shall be assembled as for service, i.e. complete with conservator, coolers, auxiliary transformer, supervisory equipment etc. This means that for instance oil-SF6 bushings must not be replaced by corresponding oil-air bushings. Deviations from this requirement may be made, however, only after written approval from the client.

Type tests report on a representative transformer may be referred to if the type test is not older than five years and is submitted together with the bid. If this is not the case type tests shall be made. The meaning of "representative" is explained further in the NOTE to SS-EN 60076-1, Cl 3.11. These requirements apply also to on-load tap-changers, bushings and built in current transformers.

### 23.2 Standards. Testing specifications.

Factory acceptance tests shall be performed in accordance with SS-EN/IEC 60076 if not specified otherwise below.

Transformers for HVDC (Category D) shall in addition to the requirements below also be tested in accordance with IEC 61378-2.

Bushings shall be tested in accordance with SS-EN/IEC if not specified otherwise below.

On-load tap-changers shall be tested in accordance with SS-EN 60076-1, SS-EN 60214-1 and IEC 60214-2 if not specified otherwise below.

Current transformers shall be tested in accordance with SS-EN 61869-2 if not specified otherwise below.

### 23.3 Testing environment

During site tests ambient temperatures down to 0°C are accepted for practical reasons.

### 23.4 Instrumentation

All measuring equipment shall be of at least class 0.2. Analogue watt meters giving a full deflection for a power factor of 0.1 may be of class 0.5. The equipment shall be calibrated at least once a year at a measurement laboratory. The latest calibration curves shall be available at the test location. The equipment shall in addition be provided with visible markings showing the last calibration date.

## 23.5 Tolerances

In the bid, order and contract it may be stated that the guaranteed losses shall apply without tolerances. This refers only to the calculation of bonus and penalty.

For impedances there may be individually specified tolerances.

## 23.6 Test results and test reports

### 23.6.1 General

A preliminary test report including copies of draft test reports shall be handed over to the client's inspector immediately after completion of each test. The inspector shall have the right to receive a draft test result copy as soon as a part test is finished.

Routine test reports for bushings, on-load tap-changers, auxiliary transformer and current transformers shall be presented to the inspector without request. Type test reports for the other equipment shall be available at the test location.

The result from all routine, type and special tests shall be compiled in a document together with the test program as well as a possible non-conformance report. Note that if type tests have been performed on another transformer or its accessories, the corresponding type test reports shall be included.

At the latest three weeks after the factory acceptance tests the test report shall be available at the client's office.

### 23.6.2 Bushing current transformers

Type test certificates referred to shall un-requested be sent to the client without any delay.

Type test certificates more than five years old cannot be accepted without special agreement.

The routine test certificates shall include, in addition to the routine test results, the following information:

- The date and reference No. of the type test certificate
- Current transformer data
- The parameters  $n$  and  $R_{ct}$  (from the type test) for each core for the determination of the over current factor at different burdens.
- The client's reference number
- The current transformer serial No.

## 23.7 Routine tests

### 23.7.1 Measurement of winding resistance (SS-EN 60076-1, Cl 11.2)

Resistance measurement shall, if applicable, be made in the principal, middle (if deviant from the principal) and extreme tapplings. Resistance measurement shall also be made in the lower-limit full power tap when applicable.

In case of winding(s) re-connectable between different system voltages, resistance measurements shall be performed for all connection possibilities.

### 23.7.2 Measurement of impedance voltage, short circuit impedance and load loss (SS-EN 60076-1, Cl 11.4)

Measurements shall, if applicable, be performed in the principal, middle (if deviant from the principal) and extreme tapplings. Loss and impedance measurement shall also be made at the lower limit full power tap when applicable. If an auxiliary winding is furnished, impedance measurements shall be performed from the other windings to the matching transformer primary and secondary side, in the principal tapping if not otherwise specified.

For auto connected transformers the power shall be fed to the higher voltage and the lower shall be short circuited.

In case of auto connected transformers with a third winding the loss allocation shall be made in accordance with IEC 60076-8, Cl 7.7.2.

In case of winding(s) re-connectable between different system voltages loss measurements shall be performed for each voltage level.

Loss and impedance measurements shall be performed at a current not less than 90% of the rated current.

### 23.7.3 Measurement of no-load loss and current (SS-EN 60076-1, Cl 11.5)

In order to avoid unwanted voltage harmonics, measurement of no-load loss and no-load current shall be performed by use of a stiff voltage source, where both the RMS value and the mean value of the voltage are measured.

The measurements shall be made at 70, 80, 90, 100, 105 and 110% of rated voltage for transformers 10 MVA and below. For larger transformers the measurements shall also be made at 115 % of rated voltage.

The measurements shall be performed according to the three watt meter method and correction for voltage wave form shall always be made. When measurements are performed at room temperature no temperature correction shall be made.

The percentage no-load current shall be presented with at least three decimals in the test report.

If an auxiliary transformer is furnished this must be connected during the loss measurement, i.e. its no-load loss shall be included.

As reference for future field tests three single phase no-load current measurements shall be performed feeding one phase at a time with 230 V, with the neutral grounded.

### 23.7.4 Measurement of zero sequence impedance (SS-EN 60076-1, Cl 11.6)

This section applies only to three phase transformers and shall be performed as routine tests for all transformers having  $U_m > 72.5$  kV.

The test shall be performed on all star- and zigzag-connected windings.

For all auto connected transformers and if not otherwise stated for non-auto transformers the zero sequence impedance shall also be measured for a short circuited high or low voltage winding in pairs.

The zero sequence impedance shall, if applicable, be measured in the principal, middle (if deviant from the principal) and extreme tapplings.

For transformers without a D connected winding the measurements in no-load shall be performed from a very low (+0 A) neutral current up to as high current as possible (approximately 30% of rated current), with a number of measurement points (minimum 15 points) in between. The positive curve slope for low currents must be recorded. In cases where a counteracting magnetic flux exists, the neutral point of the transformer can be loaded up to rated current.

At all tests, neutral current, phase to ground voltage and active power consumption shall be measured. From these measurements the impedance and resistance shall be calculated in ohms per phase.

If a stabilising winding is provided, measurements shall be performed both with the stabilising winding closed and open. Same set of measurements shall be performed with the stabilising winding closed and open.

### 23.7.5 Dielectric tests

#### 23.7.5.1. Applied voltage withstand test (SS-EN 60076-3, Cl 10)

In case of auxiliary power equipment an applied voltage test shall be performed on the complete auxiliary power supply system.

23.7.5.2. Tests on transformers with  $72.5 < U_m \leq 170$  kV (SS-EN 60076-3 Cl. 7.3.2) 3-phase Induced voltage withstand test (IVW) is substituted by a 3-phase Induced voltage test with partial discharge measurement (IVPD) with enhancement voltages as follows:  $2 \times U_r$  for  $U_m = 72.5 - 82.5$  kV, 275 kV for  $U_m = 145 - 170$  kV.

#### 23.7.5.3. Induced voltage test with partial discharge measurement (SS-EN 60076-3, Cl 11.3)

For transformers with a high-voltage winding having  $U_m > 72.5$  kV, partial discharge measurement shall be performed during the induced voltage test.

For three phase transformers the test shall always be carried out as a three phase test.

The following PD guarantee levels shall apply:

- 200 pC when  $U = 1.58 \times U_r / \sqrt{3}$  (**Deviation from SS-EN 60076-3, Cl 11.3.5**)  
(For PD-levels  $> 100$  pC an explanation must be presented.)
- 100 pC when  $U = 1.2 \times U_r / \sqrt{3}$

Measured partial discharge levels and the inception voltage,  $U_i$ , as well as the extinction voltage,  $U_e$ , shall be recorded and presented in the final test report. Neither of  $U_i$  or  $U_e$  is allowed to fall below  $U_r / \sqrt{3}$ .

The normal partial discharge detection method shall be of type broad band measurement, but narrow band measurement may be permitted, however only after written approval from the client.

#### 23.7.5.4. Lightning impulse test

For transformers with a high-voltage winding having  $U_m > 72.5$  kV, lightning impulse tests are routine tests for all windings of the transformer. (SS-EN 60076-3, Cl 7.2.1). Subsequently, lightning impulse tests shall be performed as a routine test on all phase terminals as well as neutral terminals. Transformers with re-connectable windings (series-parallel, Y-Δ) shall be tested equally in both configurations (SS-EN 60076-3, Cl 6).

#### 23.7.5.5. Chopped wave lightning impulse test

Chopped wave lightning impulse tests are routine tests for all windings having  $U_m > 170$  kV (SS-EN 60076-3, Cl 7.2.1). The chopped wave lightning impulse test is combined with the full lightning impulse test in a single sequence.

#### 23.7.5.6. Summary of dielectric tests with test voltages for different categories of windings and $U_m$ -levels

| Category of winding                                                                 | Highest voltage for equipment<br>$U_m$ | Lightning<br>impuls<br>test | Chopped wave<br>lightning<br>impuls<br>test | Switching<br>impuls<br>test | Induced AC voltage tests                                            |                                               |                   |                                                           | Applied<br>voltage AC<br>test |
|-------------------------------------------------------------------------------------|----------------------------------------|-----------------------------|---------------------------------------------|-----------------------------|---------------------------------------------------------------------|-----------------------------------------------|-------------------|-----------------------------------------------------------|-------------------------------|
|                                                                                     |                                        |                             |                                             |                             | IVPD                                                                |                                               | IVW               |                                                           |                               |
|                                                                                     |                                        |                             |                                             |                             | 1-phase                                                             | 3-phase                                       | 1-phase           | 3-phase                                                   |                               |
|                                                                                     |                                        |                             |                                             |                             | Phase-earth<br>kV                                                   | Phase-phase<br>kV                             | Phase-earth<br>kV | Phase-phase<br>kV                                         |                               |
| Uniform<br>insulation                                                               | kV                                     | kV                          | kV                                          | kV                          |                                                                     |                                               |                   |                                                           | kV                            |
|                                                                                     | 7.2                                    | 60                          | Not<br>applicable                           | Not<br>applicable           | Not<br>applicable                                                   | Not<br>applicable                             | Not<br>applicable | $U_1=2 \times U_r$                                        | 20                            |
|                                                                                     | 12                                     | 75                          |                                             |                             |                                                                     |                                               |                   |                                                           | 28                            |
|                                                                                     | 24                                     | 125                         |                                             |                             |                                                                     |                                               |                   |                                                           | 50                            |
|                                                                                     | 36                                     | 170                         |                                             |                             |                                                                     |                                               |                   |                                                           | 70                            |
|                                                                                     | 52                                     | 250                         |                                             |                             |                                                                     |                                               |                   |                                                           | 95                            |
|                                                                                     | 72.5 – 82.5                            | 325                         |                                             | Not<br>applicable           | 140                                                                 |                                               |                   |                                                           |                               |
| 123                                                                                 |                                        |                             |                                             |                             |                                                                     |                                               |                   |                                                           |                               |
| Non-uniform<br>insulation                                                           | 145 – 170                              | 550                         |                                             |                             |                                                                     | $U_1=275$<br>$U_2=1,58 \times U_r$            | $U_1=230$         | Dependant<br>on<br>insulation-<br>level of the<br>neutral |                               |
|                                                                                     | 245                                    | 850                         | 1.1×850                                     | 750                         | $U_1=1,8 \times U_r / \sqrt{3}$<br>$U_2=1,58 \times U_r / \sqrt{3}$ | $U_1=1,8 \times U_r$<br>$U_2=1,58 \times U_r$ | Not<br>applicable |                                                           |                               |
|                                                                                     | 420                                    | 1300                        | 1.1×1300                                    | 1050                        | $U_1=1,8 \times U_r / \sqrt{3}$<br>$U_2=1,58 \times U_r / \sqrt{3}$ | $U_1=1,8 \times U_r$<br>$U_2=1,58 \times U_r$ |                   |                                                           |                               |
| Clarification: $U_1$ = Enhancement voltage, $U_2$ = One hour PD-measurement voltage |                                        |                             |                                             |                             |                                                                     |                                               |                   |                                                           |                               |

Table 23.1 Summary of dielectric tests with test voltages for different categories of windings and  $U_m$ -levels

#### 23.7.6 SFRA

Transformers  $U_m \geq 72.5$  kV and all GSU/wind and HVDC transformers shall be subjected to a sweep frequency response analysis (SFRA) fingerprint measurement. The result shall be described in the test report together with a careful description of the performance of the test, making it possible to repeat the measurement at site.

#### 23.7.7 Pressure testing

The transformer tank and the coolers shall be subjected to an over-pressure test according to SS-EN 60076-1.

#### 23.7.8 On-load tap-changer operation test

In addition to the tests in SS-EN 60076-1 the requirements on multi-step operation and end limits according to Clause 8.2 shall be verified by operation tests.

#### 23.7.9 Bushing current transformers

A power frequency test shall be carried out on the test conductor at 3 kVrms, the windings and other current transformer parts being earthed.

### 23.7.10 Core insulation resistance measurement (SS-EN 60076-1 Cl 11.12)

The following insulation resistances shall be measured:

- Core to tank
- Core to yoke clamps
- Yoke clamps to tank

### 23.7.11 Winding insulation resistance measurement

The following insulation resistance ( $R_{60sek}$ ) and dielectric absorption ratio ( $R_{60sek}/R_{15sek}$ ) (DAR) measurements shall be performed:

- between all windings connected together and ground (tank + core)
- between each winding and the other windings connected together and grounded

### 23.7.12 Tests and inspections on accessories

Inspections shall be carried out to assure that the transformer is equipped with all the accessories and equipment stipulated in contract documents and these guidelines and that they operate as intended.

Each complete control equipment shall be voltage tested with 2 kV 50 Hz for 1 min. Motors for the on-load tap-changer motor drive shall be subjected to a test with at least 1.5 kV 50 Hz for 1 min.

The insulation resistance between electrically separated circuits or between conductor and ground must exceed 2 M $\Omega$  measured with 500 V DC.

### 23.7.13 Painting inspection

Examination of the corrosive protection and the surface treatment requirements in Clause 16 shall be performed. On request, the supplier shall present a painting type test report. A painting inspection certificate shall accompany the delivery. This shall be based on logging during the paint work and must not be drawn up afterwards.

### 23.7.14 Capacitance measurement (SS-EN 60076-1, Cl 11.1.4 c, d)

All capacitance values and values of  $\tan(\delta)$ , between all windings and all windings to ground shall be measured.

### 23.7.15 Sound level measurement (SS-EN 60076-10, Cl 8.1.3 d)

To be performed as a routine test on all transformers with  $U_m=420$  kV.

For transformers with variable flux voltage regulation sound level measurement shall be performed at the tapping giving the highest core flux density.

A frequency analysis with a step factor of 1.25 (one third octave band) shall always be made.

For each location of microphones the measured sound power as well as the frequency analysis shall be reported in the test certificate.

A measurement of the sound intensity shall be performed. The sound power shall then be calculated from the sound intensity in accordance with SS-EN 60076-10.

For inter-bus transformers 500 MVA and above and generator step up transformers 75 MVA and above, the sound power level in load operation shall be measured for information.

## 23.8 Type tests

### 23.8.1 Measurement of zero sequence impedance (SS-EN 60076-1, Cl 11.6)

For transformers having  $U_m \leq 72.5$  kV, measurement of zero sequence impedance are type tests. The type tests shall be performed in accordance with section 23.7.4.

### 23.8.2 Lightning impulse test

For transformers with a high-voltage winding having  $U_m \leq 72.5$  kV, lightning impulse tests are type tests. (SS-EN 60076-3, Cl 7.2.1). For transformers with reconnect able rated voltage, each position shall be type tested.

If a failure occurs during this type test or if the test is not approved of other reasons the impulse test shall be carried out as a routine test on all other identical transformers in the same delivery without any extra cost.

Reference to a type test where a failure or another non approval has occurred with subsequent repair or other measures will not be accepted as a type test but a type test must be performed.

### 23.8.3 Temperature rise test

Temperature rise test shall be performed with full total loss and with maximum rated current for each winding (also for multi winding transformers refer to Clause 4.7.2). The assumptions shall be reported in the test certificate. For verification, two different temperature rise tests may be necessary.

The test shall continue until thermal stability is obtained.

In the test certificate required total loss and currents as well as the ones measured during the test shall be stated.

Temperature of outgoing oil to radiators/coolers shall be measured to obtain the top oil temperature. Recorded and calculated temperatures and temperature rises, including hot spot temperature rises, shall be presented with one decimal place in the test report. The hot spot temperature rises shall always be calculated by means of the true hot spot factors which are equal to  $H_{test}$ , determined at the design review. If optical fibres are used, see section 9.7, the readings shall be recorded at least every hour and be presented in the test report. If optical fibres are used, the maximum of the calculated and measured hot spot temperature is considered to be reported hot spot temperature.

Complete curves for oil and winding temperature determination shall be presented in the test report. All measuring points shall be included and it shall also be clear which measurements are deemed to be erroneous and consequently deleted. The extrapolation method shall also be stated.

When switching off from rated current to determine the warm resistance the measurement must have been started within one minute and the first reliable reading must have been obtained within two minutes from current interruption. The resistance measurement must proceed at least 20 min for cooling type OF/OD.. and 10 minutes for cooling type ON..

In case of type OF/OD.. cooling pumps and fans shall be running after the test power disconnection.

For transformers of category B, 500 MVA and above with cooling type ON.., an additional heat run test with cooling type ONAN shall be performed. If specified, the test shall also be performed on transformers with smaller rated power.

Winding thermometers shall in connection with the temperature rise test be calibrated to show the true winding hot spot temperature, i.e. calibrated by means of the true hot spot factor. All necessary parameter settings and description of the hot spot factor calculation methodology shall be presented in the test report.

For generator step up transformers 75 MVA and above the additional winding thermometer shall be calibrated to show winding hot spot based on bottom oil temperature.

Normal gas production is specified in SS-EN 60076-2, edition 3.0-2011. The change of gas concentrations during the test shall not exceed the following values:

|                                                                                |                                                   |
|--------------------------------------------------------------------------------|---------------------------------------------------|
| H <sub>2</sub>                                                                 | <18 ppm/24 h (<25 ppm/24 h for cooling type ON..) |
| ΣCH <sub>4</sub> +C <sub>2</sub> H <sub>4</sub> +C <sub>2</sub> H <sub>6</sub> | <12 ppm/24 h                                      |
| C <sub>2</sub> H <sub>2</sub>                                                  | <0.1 ppm/24 h                                     |
| CO                                                                             | <40 ppm/24 h                                      |
| CO <sub>2</sub>                                                                | <200 ppm/24 h                                     |

For determination of the change of gas concentrations, it is preferred that the first and last oil sample during the temperature rise test is used.

A verification of the temperature raise of the complete matching transformer system shall be performed in accordance with section 13.4.

### 23.8.4 Overload temperature rise test

To verify the load ability at emergency operation the following temperature tests shall be performed in the factory and at room temperature:

The magnitude of the overload temperature test will be determined in every single case. The test shall continue until thermal stability is obtained, however at least 12 hours. If the manufacturer can prove stability in gas production, the test may be interrupted earlier after approval from the client.

During the test thermovision temperature scanning of the tank shall be performed. Documentation by means of photographs shall be made.

Samples for the analysis of gases dissolved in the oil shall be taken every second hour, the first at the beginning of the test.

If the winding hot spot temperature reaches 140 °C the test shall be interrupted.

At room temperatures above 30 °C the duration of the test alternative a may be reduced after written approval from the client. The basic rule is that the test duration will be halved at a room temperature of 36 °C.

In the determination of oil and winding temperatures, the test will be carried out in the same way as for the conventional temperature rise test.

If optical fibres are used, see section 9.7, the readings shall be recorded at least every hour and be presented in the test report.

### 23.8.5 Thermal and dynamic short circuit withstand test (SS-EN 60076-5)

Such a test may be specified on request as a type test. As an option this test shall be offered by the supplier for inter-bus transformers 500 MVA and above and generator step up transformers 75 MVA and above. In some cases this option can be required also for smaller units. The test will be performed randomly at a laboratory with sufficient capacity. The utilisation of the option shall be decided not later than one month after the design review is completed. Even if no short circuit test will be done, the design shall be verified at the Design review by short circuit stress calculations according SS-EN 60076-5, Annex A and Cigré TB 529 Chapter 9.4 (See 22 Design Review).

A new transformer shall be able to withstand minimum three consecutive three phase short circuits at the dimensioning short circuit condition. The dimensioning short circuit current halved a new transformer must be able to withstand nine consecutive short circuits.

### 23.8.6 Thermal no-load test

If specified, inter-bus transformers 500 MVA and above and generator step up transformers 75 MVA and above a thermal no-load test shall be performed. In the test, the transformer shall be supplied with a voltage of 1,1 times the rated voltage until thermal equilibrium. The magnetic circuit shall be equipped with temperature sensors measuring temperatures at different points; their locations shall be approved in advance by the customer. During different phases of the tests, oil gas analyses shall be performed (the oil samples to be taken from circulating oil). The gas relay shall be fitted on during the thermal tests.

### 23.8.7 Bushings creepage distance verification for polluted conditions

#### 23.8.7.1. Ceramic type insulator

As an alternative to creepage distances in Table 4.4 the insulation may be verified by means of a functional test in accordance with SS-EN 60507, salt fog method (section three). The amount of salt shall be 40 g/l which corresponds to the polluted conditions on the Swedish west coast.

#### 23.8.7.2. Polymeric type insulator

To provide good pollution performance, the polymeric insulator profile must comply with certain profile parameters stated in IEC/TS 60815-1. Values for these parameters are specified below:

| Highest voltage for equipment | L1/D1 and L2/D2 | Creepage Distance/FOD | S/P  | C   |
|-------------------------------|-----------------|-----------------------|------|-----|
| Um [kV]                       | max             | max                   | min  | min |
| 36 - 420                      | 5.0             | 4.5                   | 0.75 | 40  |

Table 23.2 Requirements for polymeric insulators in a polluted environment. The geometrical parameters (expressed in mm) L1, D1, L2, D2, S, P and C are defined in IEC/TS 60815-1.

## 23.8.8 Bushing current transformers

### 23.8.8.1. Temperature rise test

The temperature rise test shall be carried out at rated continuous thermal current.

### 23.8.8.2. Verification of no-load impedance instrument security factor and accuracy limit factor

A complete no-load curve shall be plotted to determine the actual over current number (n) and for verification of the no-load impedance.

The secondary winding resistance ( $R_{ct}$ ) shall be measured and corrected to 75°C. In addition to SS-EN 61869-2 the actual instrument security factor shall be calculated as

$$n = F_s = I_{exc} / I_{sn}$$

In addition to SS-EN 61869-2 the actual accuracy limit factor shall be calculated as

$$n = ALF = I_{exc} / I_{sn}$$

## 23.8.9 Inspection and testing of accessories

It shall be possible to continuously operate contactor and relay coils at 110% of rated voltage without damage. On request this shall be verified by the supplier.

The control equipment terminals shall be tested in accordance with SS-EN 61000-4-4 Class 3.

### 23.8.10 Sound level measurement (SS-EN 60076-10, Cl 8.1.3 d)

To be performed as a type test according to Clause 23.7.15 on all transformers.

# 24 SITE TESTS

## 24.1 Tests on transformer ready for operation

Minimum the following site test shall be carried out before taking the transformer in operation

### 24.1.1 Transformers 100 MVA and above and all GSU and HVDC units

- Oil quality test (to be delivered as separate PDF file)
- Dissolved gas analysis (DGA) (to be delivered as separate PDF file)
- Dielectric frequency response fingerprint (DFR)
- Sweep frequency response analysis (SFRA)
- Winding insulation resistance and polarisation index measurement
- Core insulation resistance measurement
- Winding resistance measurement (if bushings has been removed during transport)
- Bushing CT ratio and no-load current characteristic check (if CT:s have been removed during transport)
- 230 V single phase no-load current measurement
- Operational tests on ALL accessories
- Impact recorder maximum registered values during transport, including maximum allowed values.

### 24.1.2 All other transformers

- Oil quality test (to be delivered as separate PDF file)
- Dissolved gas analysis (DGA) (to be delivered as separate PDF file)
- Core insulation resistance measurement
- Winding resistance measurement (if bushings has been removed during transport)
- Bushing CT ratio and no-load current characteristic check (if CT:s have been removed during transport)
- 230 V single phase no-load current measurement
- Operational tests on ALL accessories
- Impact recorder maximum registered values during transport, including maximum allowed values.

## 24.2 Tests in service

The tests specified in sections 24.2.1 and 24.2.2 below, shall be carried out by the supplier or the client, The executor is stated by the client in data compilation. Guarantees shall not be affected by the choice.

### 24.2.1 Transformers 100 MVA and above and all GSU and HVDC units

- Extended oil quality test after 12 and 24 months in operation
- DGA, after 1, 3, 6, 12 and 24 months in operation

### 24.2.2 All other transformers

- Extended oil quality test after 24 months in operation
- DGA after 12 and 24 months in operation

## 24.3 Site test certificates

The result from the site tests as well as the site test program and the service certificate shall be compiled in a document to be added to the instruction manual.

# 25 TIME SCHEDULES

After the transformer has been ordered the manufacturer shall submit a time schedule for the following activities

- 1 Documentation
- 2 Manufacturing and testing
- 3 Transport
- 4 Erection and commissioning

For item 1 the client and the manufacturer will jointly settle the hold points.

Items 2-4 will be decided by the manufacturer considering the date of commercial operation.

## 26 DOCUMENTATION

### 26.1 General

All of the documentation shall be in Swedish to the utmost possible extent. The documentation required for operation and maintenance must be in Swedish. However, test reports, catalogues and pamphlets may be in English provided a written approval from the client.

### 26.2 Tender documents

Refer to Clause 20.2

### 26.3 Documents for approval

The following documents shall be provided for approval:

| Pos | Date                                                                         | Activity                                                                                                                           | Executed by: |
|-----|------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------|--------------|
| 1   | 4-6 weeks after order                                                        | Document A1, C1 to Client.                                                                                                         | Supplier     |
| 2   | 4 weeks after completion of electrical design                                | Document A2, B1 and C2 to Client for comments.                                                                                     | Supplier     |
| 3   | Within two weeks after Pos 2                                                 | Comments on Pos 2 to Supplier.                                                                                                     | Client       |
| 4   | After completion of designs but before start of any manufacturing activities | Document B2-B8 to Client for comments.                                                                                             | Supplier     |
| 5   | Within two weeks after Pos 4                                                 | Comments on Pos 4 to Supplier.                                                                                                     | Client       |
| 6   | Two weeks before design review, if applicable                                | Document C3 to Client, if applicable.                                                                                              | Supplier     |
| 7   | One month before factory acceptance test                                     | Document D (digital), including B9 but not C5, to Client for comments.                                                             | Supplier     |
| 8   | Within two weeks after Pos 7                                                 | Comments on Pos 7 to Supplier.                                                                                                     | Client       |
| 9   | Three weeks before factory acceptance test                                   | Document C4 to Client.                                                                                                             | Supplier     |
| 10  | Within one week after FAT                                                    | Document C5 to Client.                                                                                                             | Supplier     |
| 11  | Within two weeks after Pos 10                                                | Comments on Pos 10 to Supplier.                                                                                                    | Client       |
| 12  | At the delivery of transformer                                               | Document E to Client.                                                                                                              | Supplier     |
| 13  | Within one month after Pos 12                                                | Document D, (complete set (digital) of the final documentation), including documents B9, B10, C3 (if applicable) and C5 to Client. | Supplier     |
| 14  | Within two weeks after Pos 13                                                | Comments on Pos 13 to Supplier.                                                                                                    | Client       |
| 15  | Within four weeks after installation and site acceptance test                | Document D (complete sets (digital and paper) of the final documentation, including SAT report) to Client.                         | Supplier     |

| Doc. | Drawings as to layout, building basis and assembly:                                                                                                                                                                                                                                                                                                                                                                                          |
|------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| A1   | Transformer outline drawing (updated bid drawing) showing: <ul style="list-style-type: none"><li>- principal dimensions with tolerance (tolerance <math>\leq 10\%</math>)</li><li>- weights with tolerance (tolerance <math>\leq 10\%</math>)</li><li>- location of coolers and conservator (without measurement)</li><li>- location of bushings (without measurement)</li><li>- location of control cabinet (without measurement)</li></ul> |

|                                       |                                                                                                                                                                                                                                                      |
|---------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| A2                                    | Verification of main cooling capacity for installations not in open air (if applicable)                                                                                                                                                              |
| <b>Binding drawings and diagrams:</b> |                                                                                                                                                                                                                                                      |
| B1                                    | Rating plate drawing                                                                                                                                                                                                                                 |
| B2                                    | Transformer outline drawing including accessories                                                                                                                                                                                                    |
| B3                                    | Transport drawing                                                                                                                                                                                                                                    |
| B4                                    | Control cabinet:<br>Circuit diagram<br>List of apparatus<br>Dimension drawing of cabinet with placing of apparatuses (5 weeks after acceptance of Circuit diagram and List of apparatus)                                                             |
| B5                                    | Auxiliary equipment cubicles for complete auxiliary system (if applicable):<br>Circuit diagram<br>List of apparatus<br>Dimension drawing of cubicles with placing of apparatuses (5 weeks after acceptance of Circuit diagram and List of apparatus) |
| B6                                    | Current transformer terminal cabinet (if applicable):<br>Circuit diagram<br>List of apparatus<br>Dimension drawing of cabinet with placing of apparatuses (5 weeks after acceptance of Circuit diagram and List of apparatus)                        |
| B7                                    | Bushing capacitive tap terminal cabinet (if applicable):<br>Circuit diagram<br>List of apparatus<br>Dimension drawing of cabinet with placing of apparatuses (5 weeks after acceptance of Circuit diagram and List of apparatus)                     |
| B8                                    | On load tap changer motor drive cubicle (if applicable):<br>Circuit diagram<br>List of apparatus<br>Dimension drawing of cubicle with placing of apparatuses (5 weeks after acceptance of Circuit diagram and List of apparatus)                     |
| B9                                    | Drawings of all other plates                                                                                                                                                                                                                         |
| B10                                   | Wiring table, List of cables                                                                                                                                                                                                                         |
| <b>Quality control documents:</b>     |                                                                                                                                                                                                                                                      |
| C1                                    | Quality control, environmental management plan (if requested)<br>Organization structure, i.e. project organisation<br>Preliminary time schedule for manufacturing, testing and transport                                                             |
| C2                                    | Inspection and Test Plan                                                                                                                                                                                                                             |
| C3                                    | Design review report, if applicable (To be included in the final documentation.)                                                                                                                                                                     |
| C4                                    | Daily program for factory acceptance test                                                                                                                                                                                                            |
| C5                                    | Test reports                                                                                                                                                                                                                                         |
| D                                     | Instruction manual for assembly, maintenance and service including identification of equipment                                                                                                                                                       |
| E                                     | Valid transportation permission from the Swedish authority "Trafikverket"                                                                                                                                                                            |

Table 26.1 Documents for approval

Documents for approval shall be supplied in PDF format preferable at agreed common web places or by electronic mail.

Immediately after approval, circuit diagrams and transformer outline drawings including accessories, shall be supplied in AutoCAD dwg format. The AutoCAD drawings shall comply with version 2004 and later. Each AutoCAD drawing shall be delivered as an individual file.

Examination and approval of the drawings, diagrams and documentation by the client does not lead to any confinements in the supplier's responsibility.

## 26.4 Instruction manual

The instruction manual shall be supplied in two copies one of which shall be available at the client's office at the latest three weeks before the beginning of the factory acceptance tests. The PDF file of the instruction manual shall be created in a similar design as the paper file itself (all documentation in one file). From the table of contents it shall be possible to move to selected chapter. The PDF file shall not be writing protected.

The instruction manual shall in principle be compiled as follows:

- Lead sheet with client's and manufacturer's reference No.
- Insulation system dimension including barrier thickness and spacer width
- Dimension / Outline drawing with equipment / accessory list
- Plate drawings according to chapter 19.1.1 to 19.1.8.
- Circuit diagram with equipment/apparatus list
- Control cabinet
- Current transformers
- Bushings including drawings
- Matching transformer
- Painting inspection certificate
- On load tap changer with motor drive
- Cooling equipment
- Oil circuit diagram
- Supervisory equipment and other accessories
- Transport
- Erection / Assembly
- Oil specification and information in accordance with Clause 18.1
- A safety data sheet for the oil
- Gasket and sealing solution
- Operation and maintenance instructions
- Diagnostic maintenance
- Instructions including settings for all programmable equipment's
- Product and safety information for all included chemical products
- Other information
- Design review report (if applicable)
- Selected fibre locations (if applicable)
- Test reports (type test reports shall always include a reference to the type tested unit)
- Photographs of the active part and complete transformer

In each section there shall be a summary of included drawings (with information of latest revision) and also the main data of included components.

A summary of all included components (list of apparatuses / equipment list) such as thermometers, on load tap changer, motor drive, pumps, fans etc. shall be provided. Type designations, ratings and a clear identification shall also be provided.

For the bushings and current transformers their location shall be stated (serial No. and phase). The same applies to single phase on-load tap-changers.

In submitted catalogues and pamphlets the actual component shall be legibly marked.

For programmable equipment (transducers, programmable instruments etc.), software, manuals, cables etc. shall be provided.

## 27 DATA COMPILATION FOR POWER TRANSFORMERS

If values and information not explicitly is stated by the client in Data compilation, the tenderer is asked to fill in values and information in accordance with TR01-10E. Several, not explicitly stated values and information, are determined by TR01-10E. Remaining values and information in Data compilation, which not are determined by TR01-10E, shall also be filled in, in order to make it possible for the client to review what the supplier intend to deliver.

### Revision

| ID | Date | Description | Author |
|----|------|-------------|--------|
| -  |      |             |        |
| A  |      |             |        |
| B  |      |             |        |
| C  |      |             |        |

### 1 GENERAL

|                                              |                       |                  |
|----------------------------------------------|-----------------------|------------------|
| Inquiry / Order                              | Pos                   | Station          |
| Tenderer / Manufacturer                      | Reference ( Supplier) | Type designation |
| Factories (Main assembly-Core-Windings-Tank) | Version TR1-10E       |                  |

### 2 NETWORK DATA

|                                          |     |                          |                          |                          |                          |                          |
|------------------------------------------|-----|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| Network                                  | kV  |                          |                          |                          |                          |                          |
| Short circuit power from resp. network   | MVA |                          |                          |                          |                          |                          |
| Reference voltage                        | kV  |                          |                          |                          |                          |                          |
| Relation X0/X+                           | -   |                          |                          |                          |                          |                          |
| Parallel connected xfo on sides X-marked | -   | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

### 3 RATINGS

|                                             |                                              |                                              |                                            |
|---------------------------------------------|----------------------------------------------|----------------------------------------------|--------------------------------------------|
| <input type="checkbox"/> Three phase design | <input type="checkbox"/> Single phase design | <input type="checkbox"/> Stabilizing winding | <input type="checkbox"/> Auxiliary winding |
| Winding                                     | I                                            | II                                           | III                                        |
| Rated voltage                               | kV                                           |                                              |                                            |
| Maximum continous operating voltage         | kV                                           |                                              |                                            |
| Rated power                                 | MVA                                          |                                              |                                            |
| Tapping range                               | %                                            |                                              |                                            |
| Connection mode                             | -                                            |                                              |                                            |

#### 4 INSULATION LEVELS

|                                      |    |   |    |     |  |  |
|--------------------------------------|----|---|----|-----|--|--|
| Winding                              |    | I | II | III |  |  |
| Highest voltage for equipment, $U_m$ | kV |   |    |     |  |  |
| Rated withstand voltages             |    |   |    |     |  |  |
| Lightning impulse                    | kV |   |    |     |  |  |
| Switching impulse                    | kV |   |    |     |  |  |
| Power frequency                      | kV |   |    |     |  |  |
| Air clearances                       |    |   |    |     |  |  |
| phase-phase                          | mm |   |    |     |  |  |
| phase-ground                         | mm |   |    |     |  |  |

#### 5 LOAD LOSS

|                                                                                                         |     |      |  |  |  |  |  |  |  |  |
|---------------------------------------------------------------------------------------------------------|-----|------|--|--|--|--|--|--|--|--|
| Windings                                                                                                |     | I/II |  |  |  |  |  |  |  |  |
| Ratio                                                                                                   | kV  |      |  |  |  |  |  |  |  |  |
| Reference power                                                                                         | MVA |      |  |  |  |  |  |  |  |  |
| Load loss                                                                                               | kW  |      |  |  |  |  |  |  |  |  |
| Impedance voltage                                                                                       | %   |      |  |  |  |  |  |  |  |  |
| Windings                                                                                                |     |      |  |  |  |  |  |  |  |  |
| Ratio                                                                                                   | kV  |      |  |  |  |  |  |  |  |  |
| Reference power                                                                                         | MVA |      |  |  |  |  |  |  |  |  |
| Load loss                                                                                               | kW  |      |  |  |  |  |  |  |  |  |
| Impedance voltage                                                                                       | %   |      |  |  |  |  |  |  |  |  |
| <i>Note: The impedance between a stabilising winding and all other windings shall always be stated!</i> |     |      |  |  |  |  |  |  |  |  |

#### 6 NO-LOAD LOSS

|                             |                                                       |                                                    |  |                                               |                 |
|-----------------------------|-------------------------------------------------------|----------------------------------------------------|--|-----------------------------------------------|-----------------|
|                             |                                                       | OLTC in principal tapping and regulated winding at |  | At rated tapping voltage and OLTC in          |                 |
|                             |                                                       | 1,00× $U_r$                                        |  | max voltage pos                               | min voltage pos |
| No-load loss                | kW                                                    |                                                    |  |                                               |                 |
| No-load current             | %                                                     |                                                    |  |                                               |                 |
| Method of voltage variation | <input type="checkbox"/> constant voltage flux (CFVV) |                                                    |  | <input type="checkbox"/> variable flux (VFVV) |                 |

#### 7 CORE DESIGN

|                                                                                                |                                                |                                                 |                                     |
|------------------------------------------------------------------------------------------------|------------------------------------------------|-------------------------------------------------|-------------------------------------|
| <input type="checkbox"/> core type                                                             | <input type="checkbox"/> windings on all limbs | <input type="checkbox"/> limbs without windings | <input type="checkbox"/> shell type |
| Flux density at no load and OLTC in principal position (with two decimals) at $1,0 \times U_r$ |                                                |                                                 |                                     |
| Limb                                                                                           | T, yoke                                        | T, shell / side limb                            | T                                   |

8

## SOUND LEVELS

|                                                                                                                  |  |   |               |
|------------------------------------------------------------------------------------------------------------------|--|---|---------------|
| Guaranteed max sound POWER level measured in accordance with SS-EN/IEC in any OLTC position ( tolerance +0 dB(A) |  |   |               |
| - transformer with /without coolers in operation                                                                 |  | / | dB(A);<br>LWA |
| - cooling equipment including pumps ( if separate)                                                               |  | / | dB(A);<br>LWA |

9

## BUSHINGS

|                                                            |                          |                          |                          |                          |                          |                          |
|------------------------------------------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| Winding / Terminal number                                  |                          |                          |                          |                          |                          |                          |
| Manufacturer                                               |                          |                          |                          |                          |                          |                          |
| Bushing type                                               |                          |                          |                          |                          |                          |                          |
| - OIP = oil impregnated paper                              |                          |                          |                          |                          |                          |                          |
| - RIP = resin impregnated paper                            |                          |                          |                          |                          |                          |                          |
| - RIS = resin impregnated synthetic                        |                          |                          |                          |                          |                          |                          |
| - RM = resin molded                                        |                          |                          |                          |                          |                          |                          |
| - C = ceramic                                              |                          |                          |                          |                          |                          |                          |
| Insulator type                                             |                          |                          |                          |                          |                          |                          |
| - C = ceramic                                              |                          |                          |                          |                          |                          |                          |
| - P = polymeric                                            |                          |                          |                          |                          |                          |                          |
| Rated current                                              | A                        |                          |                          |                          |                          |                          |
| Rated voltage                                              | kV                       |                          |                          |                          |                          |                          |
| Pollution class (I, II, III)                               |                          |                          |                          |                          |                          |                          |
| Nominal creepage distance                                  | mm                       |                          |                          |                          |                          |                          |
| Oil level indicator                                        | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Capacitance tap                                            | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| <input type="checkbox"/> Terminal box for capacitance taps |                          |                          |                          |                          |                          |                          |
| Bushing type designations                                  |                          |                          |                          |                          |                          |                          |
|                                                            | kV terminal              |                          |                          |                          |                          |                          |
|                                                            | kV terminal              |                          |                          |                          |                          |                          |
|                                                            | kV terminal              |                          |                          |                          |                          |                          |
|                                                            | kV terminal              |                          |                          |                          |                          |                          |
|                                                            | kV terminal              |                          |                          |                          |                          |                          |
|                                                            | kV terminal              |                          |                          |                          |                          |                          |

10

## TAP-CHANGER

|                                                                                                                                                                    |         |                                                       |                 |  |   |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|-------------------------------------------------------|-----------------|--|---|
| <input type="checkbox"/> On-Load Tap-changer (OLTC) <input type="checkbox"/> Off-Circuit Tap-Changer (OCTC) <input type="checkbox"/> Bolted connection under cover |         |                                                       |                 |  |   |
| Manufacturer                                                                                                                                                       |         | OLTC Max rated through-current                        | I <sub>rm</sub> |  | A |
| Type designation                                                                                                                                                   |         | OLTC Rated through-current                            | I <sub>r</sub>  |  | A |
| Location                                                                                                                                                           |         | Transformer maximum rated current at end tap position | -               |  | A |
| Insulation level                                                                                                                                                   | LI – AC |                                                       | kV              |  |   |
| <input type="checkbox"/> oil type <input type="checkbox"/> vacuum type                                                                                             |         |                                                       |                 |  |   |
| <input type="checkbox"/> diverter switch <input type="checkbox"/> selector switch                                                                                  |         |                                                       |                 |  |   |

|                                              |  |                                                                                                                                     |  |                                              |                             |                                 |   |
|----------------------------------------------|--|-------------------------------------------------------------------------------------------------------------------------------------|--|----------------------------------------------|-----------------------------|---------------------------------|---|
| Operating mechanism                          |  |                                                                                                                                     |  |                                              |                             |                                 |   |
| Manufacturer                                 |  | Quantity                                                                                                                            |  | pcs                                          |                             |                                 |   |
| Type designation                             |  |                                                                                                                                     |  |                                              |                             |                                 |   |
| <input type="checkbox"/> Parallel operation. |  | Method: <input type="checkbox"/> circulating current, <input type="checkbox"/> simultaneous, <input type="checkbox"/> master-follow |  |                                              |                             |                                 |   |
| Position transmitter                         |  | <input type="checkbox"/> potentiometer                                                                                              |  | ohms per step                                |                             | others <input type="checkbox"/> |   |
|                                              |  | <input type="checkbox"/> Pt100                                                                                                      |  | <input type="checkbox"/> Transducer included |                             |                                 |   |
| Supply voltages                              |  | motor                                                                                                                               |  | V                                            | <input type="checkbox"/> DC | <input type="checkbox"/> AC     |   |
| position indicators, contactors              |  |                                                                                                                                     |  | V                                            | <input type="checkbox"/> DC | <input type="checkbox"/> AC     |   |
| heater                                       |  |                                                                                                                                     |  | V AC                                         |                             |                                 | W |

# 11 CURRENT TRANSFORMERS

| Terminal     | Ratio (A)   | Core | Accuracy class and rated output |  |      |  | n / sec. Resistance<br>n = FS or ALF |                       |
|--------------|-------------|------|---------------------------------|--|------|--|--------------------------------------|-----------------------|
|              | primary/sec | No.  | 0,2S<br>FS                      |  | 5P20 |  | min<br>ratio<br>n/Rct                | max<br>ratio<br>n/Rct |
| kV phase     | /           |      |                                 |  |      |  |                                      |                       |
|              |             |      |                                 |  |      |  |                                      |                       |
|              |             |      |                                 |  |      |  |                                      |                       |
| kV phase     | /           |      |                                 |  |      |  |                                      |                       |
|              |             |      |                                 |  |      |  |                                      |                       |
|              |             |      |                                 |  |      |  |                                      |                       |
| kV phase     | /           |      |                                 |  |      |  |                                      |                       |
|              |             |      |                                 |  |      |  |                                      |                       |
|              |             |      |                                 |  |      |  |                                      |                       |
| kV phase     | /           |      |                                 |  |      |  |                                      |                       |
|              |             |      |                                 |  |      |  |                                      |                       |
|              |             |      |                                 |  |      |  |                                      |                       |
| kV phase     | /           |      |                                 |  |      |  |                                      |                       |
|              |             |      |                                 |  |      |  |                                      |                       |
|              |             |      |                                 |  |      |  |                                      |                       |
| kV neutral   | /           |      |                                 |  |      |  |                                      |                       |
|              |             |      |                                 |  |      |  |                                      |                       |
|              |             |      |                                 |  |      |  |                                      |                       |
| kV neutral   | /           |      |                                 |  |      |  |                                      |                       |
|              |             |      |                                 |  |      |  |                                      |                       |
|              |             |      |                                 |  |      |  |                                      |                       |
| Manufacturer |             |      |                                 |  |      |  |                                      |                       |

12 AUXILIARY TRANSFORMER

|                                                                                                                                                                                                  |   |   |                  |     |                 |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|---|------------------|-----|-----------------|
| Manufacturer                                                                                                                                                                                     |   |   | Type designation |     |                 |
| Rated voltage ratio                                                                                                                                                                              | / | V | Rated power      | kVA | Connection mode |
| <input type="checkbox"/> Air insulated <input type="checkbox"/> Oil insulated <input type="checkbox"/> Oil insulated, sealed tank type <input type="checkbox"/> Integrated with main transformer |   |   |                  |     |                 |

13 COOLING EQUIPMENT

|                                                                                                                                                                                                                     |  |                         |  |                                                                                                      |  |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|-------------------------|--|------------------------------------------------------------------------------------------------------|--|
| Type of cooling                                                                                                                                                                                                     |  |                         |  |                                                                                                      |  |
| <input type="checkbox"/> ONAN <input type="checkbox"/> ONAN/ONAF <input type="checkbox"/> OFAF <input type="checkbox"/> ODAF <input type="checkbox"/> OFWF <input type="checkbox"/> To be optimised by the supplier |  |                         |  |                                                                                                      |  |
| Cooler location                                                                                                                                                                                                     |  |                         |  |                                                                                                      |  |
| <input type="checkbox"/> on the transformer <input type="checkbox"/> on wall brackets <input type="checkbox"/> on concrete shelf <input type="checkbox"/> on separate support                                       |  |                         |  |                                                                                                      |  |
| <input type="checkbox"/> supports / brackets included <input type="checkbox"/> others:                                                                                                                              |  |                         |  |                                                                                                      |  |
| Oil system                                                                                                                                                                                                          |  |                         |  |                                                                                                      |  |
| parallel groups on oil side                                                                                                                                                                                         |  | cooler(s) in each group |  | pump(s) in each group                                                                                |  |
| Oil type                                                                                                                                                                                                            |  |                         |  |                                                                                                      |  |
| Fan arrangement                                                                                                                                                                                                     |  |                         |  |                                                                                                      |  |
| <input type="checkbox"/> horizontally blowing, <input type="checkbox"/> vertically blowing                                                                                                                          |  |                         |  |                                                                                                      |  |
| Cooler (Radiator) data                                                                                                                                                                                              |  |                         |  | Fan data                                                                                             |  |
| manufacturer                                                                                                                                                                                                        |  |                         |  | manufacturer                                                                                         |  |
| type designation                                                                                                                                                                                                    |  |                         |  | type designation                                                                                     |  |
| number of coolers (radiators)                                                                                                                                                                                       |  | pcs                     |  | number of fans                                                                                       |  |
| cooling capacity per cooler at K average oil temperature rise                                                                                                                                                       |  | kW                      |  | fan speed                                                                                            |  |
| oil pressure drop per cooler                                                                                                                                                                                        |  | bar                     |  | air flow per fan                                                                                     |  |
|                                                                                                                                                                                                                     |  |                         |  | power requirement per fan                                                                            |  |
|                                                                                                                                                                                                                     |  |                         |  | <input type="checkbox"/> variable fan speed                                                          |  |
| Oil pump data                                                                                                                                                                                                       |  |                         |  | Water system                                                                                         |  |
| manufacturer                                                                                                                                                                                                        |  |                         |  | max water flow per cooler                                                                            |  |
| type designation                                                                                                                                                                                                    |  |                         |  | min water flow per cooler                                                                            |  |
| oil flow per pump                                                                                                                                                                                                   |  | l/s                     |  | water pressure drop per cooler                                                                       |  |
| power requirement per pump                                                                                                                                                                                          |  | kW                      |  |                                                                                                      |  |
|                                                                                                                                                                                                                     |  |                         |  | Cooler losses                                                                                        |  |
|                                                                                                                                                                                                                     |  |                         |  | total cooler power consumption                                                                       |  |
|                                                                                                                                                                                                                     |  |                         |  | kW                                                                                                   |  |
| Power supply for pumps and fans                                                                                                                                                                                     |  |                         |  | Control voltage                                                                                      |  |
| <input type="checkbox"/> 400/230 V <input type="checkbox"/> from auxiliary winding                                                                                                                                  |  |                         |  | <input type="checkbox"/> 230 V AC, <input type="checkbox"/>                                          |  |
| <input type="checkbox"/> others: <input type="checkbox"/> from station network                                                                                                                                      |  |                         |  | Signalling voltage                                                                                   |  |
|                                                                                                                                                                                                                     |  |                         |  | <input type="checkbox"/> 110 V DC <input type="checkbox"/> 220 V DC <input type="checkbox"/> others: |  |
| Oil and water meters and gauges                                                                                                                                                                                     |  |                         |  |                                                                                                      |  |
| <input type="checkbox"/> oil flow gauges included (OF..)                                                                                                                                                            |  |                         |  | <input type="checkbox"/> water flow gauges included (..WF)                                           |  |
| <input type="checkbox"/> oil pressure gauges included (..WF)                                                                                                                                                        |  |                         |  | <input type="checkbox"/> water pressure gauges included (..WF)                                       |  |
| <input type="checkbox"/> absolute pressure <input type="checkbox"/> differential pressure                                                                                                                           |  |                         |  | <input type="checkbox"/> absolute pressure <input type="checkbox"/> differential pressure            |  |
| Meter / Gauge                                                                                                                                                                                                       |  | Manufacturer            |  | Type designation                                                                                     |  |
| oil flow meter                                                                                                                                                                                                      |  |                         |  |                                                                                                      |  |
| oil flow gauge                                                                                                                                                                                                      |  |                         |  |                                                                                                      |  |
| water flow meter                                                                                                                                                                                                    |  |                         |  |                                                                                                      |  |
| water pressure gauge                                                                                                                                                                                                |  |                         |  |                                                                                                      |  |

## 14 EXTRA HEAT EXCHANGER

|              |     |                  |
|--------------|-----|------------------|
| Oil flow     | l/s | Type designation |
| Manufacturer |     |                  |
| Valve size   | mm  |                  |

## 15 TEMPERATURE GAUGES AND TRANSMITTERS

|                                                                                                                                             |                                                      |                                                      |
|---------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------|------------------------------------------------------|
| Winding based on top oil                                                                                                                    |                                                      | Top oil                                              |
| Location                                                                                                                                    | reading                                              |                                                      |
| <input type="checkbox"/> low voltage winding                                                                                                | <input type="checkbox"/> at the transformer          | <input type="checkbox"/> doubled                     |
| <input type="checkbox"/> all windings                                                                                                       | <input type="checkbox"/> Pt100 transmitters included | <input type="checkbox"/> Pt100 transmitters included |
|                                                                                                                                             | <input type="checkbox"/> transducers included        | <input type="checkbox"/> transducers included        |
| Winding based on bottom oil (in some cases)                                                                                                 |                                                      | Bottom oil (in some cases)                           |
| Location                                                                                                                                    | reading                                              |                                                      |
| <input type="checkbox"/> low voltage winding                                                                                                | <input type="checkbox"/> at the transformer          | <input type="checkbox"/> doubled                     |
| <input type="checkbox"/> all windings                                                                                                       | <input type="checkbox"/> Pt100 transmitters included | <input type="checkbox"/> Pt100 transmitters included |
|                                                                                                                                             | <input type="checkbox"/> Transducer included         | <input type="checkbox"/> Transducer included         |
| Power supply for transducers                                                                                                                |                                                      |                                                      |
| <input type="checkbox"/> 110 V DC <input type="checkbox"/> 220 V DC <input type="checkbox"/> others:                                        |                                                      |                                                      |
| Other gauges and transmitters                                                                                                               |                                                      |                                                      |
| <input type="checkbox"/> oil temperature in and out of the forced oil coolers                                                               |                                                      |                                                      |
| <input type="checkbox"/> water temperature in and out of water coolers                                                                      |                                                      |                                                      |
| <input type="checkbox"/> optical fibres for monitoring of winding hottest-spot directly <input type="checkbox"/> monitoring device included |                                                      |                                                      |
| Gauge / Transmitter                                                                                                                         | Manufacturer                                         | Type designation                                     |
| Winding thermometer                                                                                                                         |                                                      |                                                      |
| Top oil thermometer                                                                                                                         |                                                      |                                                      |
| Bottom oil thermometer                                                                                                                      |                                                      |                                                      |
| Pt100 – winding                                                                                                                             |                                                      |                                                      |
| Pt100 – top oil                                                                                                                             |                                                      |                                                      |
| Pt100 – bottom oil                                                                                                                          |                                                      |                                                      |
| Pt100 – cooling oil (OFWF)                                                                                                                  |                                                      |                                                      |
| Pt100 – cooling water (OFWF)                                                                                                                |                                                      |                                                      |
| Transducer                                                                                                                                  |                                                      |                                                      |

## 16 MONITORING EQUIPMENT

|                                                                                                                     |                  |  |
|---------------------------------------------------------------------------------------------------------------------|------------------|--|
| <input type="checkbox"/> On-line dissolved gas monitor                                                              |                  |  |
| Manufacturer                                                                                                        | Type designation |  |
| Power supply: <input type="checkbox"/> 110 V DC <input type="checkbox"/> 220 V DC <input type="checkbox"/> 230 V AC |                  |  |
| <input type="checkbox"/>                                                                                            |                  |  |
| Manufacturer                                                                                                        | Type designation |  |

17 DISCONNECTABLE TERMINAL BLOCKS

|                                 |  |                  |  |
|---------------------------------|--|------------------|--|
| On-load tap-changer motor drive |  |                  |  |
| Manufacturer                    |  | Type designation |  |
| Control cubicle                 |  |                  |  |
| Manufacturer                    |  | Type designation |  |
| Current transformer cubicle     |  |                  |  |
| Manufacturer                    |  | Type designation |  |
| Bushing measuring tap cubicle   |  |                  |  |
| Manufacturer                    |  | Type designation |  |

18 EXPANSION SYSTEM

|                                                                                                                                                                                   |  |                                                        |  |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|--------------------------------------------------------|--|
| General                                                                                                                                                                           |  |                                                        |  |
| <input type="checkbox"/> open air system <input type="checkbox"/> with rubber membrane <input type="checkbox"/> separated OLTC system <input type="checkbox"/> common OLTC system |  |                                                        |  |
| Conservator location                                                                                                                                                              |  |                                                        |  |
| <input type="checkbox"/> on the transformer <input type="checkbox"/> on wall brackets <input type="checkbox"/> on concrete shelf <input type="checkbox"/> on separate support     |  |                                                        |  |
| <input type="checkbox"/> brackets / support included                                                                                                                              |  |                                                        |  |
| Volumes                                                                                                                                                                           |  |                                                        |  |
| Oil volume in main tank and coolers (radiators) at -40°C                                                                                                                          |  | m <sup>3</sup>                                         |  |
| Main conservator oil volume                                                                                                                                                       |  | m <sup>3</sup>                                         |  |
| Gas and oil actuated relay                                                                                                                                                        |  |                                                        |  |
| <input type="checkbox"/> with by-pass tube <input type="checkbox"/> with inspection platform <input type="checkbox"/> gas sampling device at service level                        |  |                                                        |  |
| Manufacturer                                                                                                                                                                      |  | Type designation                                       |  |
| OLTC protective relay                                                                                                                                                             |  |                                                        |  |
| Manufacturer                                                                                                                                                                      |  | Type designation                                       |  |
| Main oil level indication                                                                                                                                                         |  |                                                        |  |
| <input type="checkbox"/> at service level <input type="checkbox"/> on the main conservator                                                                                        |  |                                                        |  |
| Manufacturer                                                                                                                                                                      |  | Type designation                                       |  |
| <input type="checkbox"/> Extra contact closing at an adjustable level                                                                                                             |  | <input type="checkbox"/> Remote indication possibility |  |
| OLTC oil level indication                                                                                                                                                         |  |                                                        |  |
| <input type="checkbox"/> at service level <input type="checkbox"/> on the OLTC conservator                                                                                        |  |                                                        |  |
| Manufacturer                                                                                                                                                                      |  | Type designation                                       |  |
| Dehydrating breather                                                                                                                                                              |  |                                                        |  |
| <input type="checkbox"/> maintenance-free <input type="checkbox"/> non maintenance-free                                                                                           |  |                                                        |  |
| Manufacturer, main                                                                                                                                                                |  | Type designation, main                                 |  |
| Manufacturer, OLTC                                                                                                                                                                |  | Type designation, OLTC                                 |  |

## 19 TANK

|                                                                 |                                                                                                                                               |                                                |
|-----------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------|
| General                                                         |                                                                                                                                               |                                                |
| <input type="checkbox"/> welded cover                           | <input type="checkbox"/> bolted cover                                                                                                         | <input type="checkbox"/> pressure relief valve |
| <input type="checkbox"/> leakage flux shunts                    | <input type="checkbox"/> on HV side                                                                                                           | <input type="checkbox"/> on LV side            |
| <input type="checkbox"/> Cu <input type="checkbox"/> Al –screen |                                                                                                                                               |                                                |
| <input type="checkbox"/> stainless steel inlay                  | <input type="checkbox"/> in cover                                                                                                             | <input type="checkbox"/> in tank wall          |
| Surface treatment                                               |                                                                                                                                               |                                                |
|                                                                 | Externally                                                                                                                                    | Internally                                     |
| Corrosivity category                                            | <input type="checkbox"/> C3 <input type="checkbox"/> C4 <input type="checkbox"/> C4H <input type="checkbox"/> C5 <input type="checkbox"/> C5M |                                                |
| Primer paint                                                    |                                                                                                                                               |                                                |
| Cover paint                                                     |                                                                                                                                               |                                                |
| Cover paint colour                                              |                                                                                                                                               |                                                |
| Total thickness                                                 | μm                                                                                                                                            | μm                                             |

## 20 DIMENSIONS &amp; MASSES

|                                |  |      |              |   |      |
|--------------------------------|--|------|--------------|---|------|
| Dimensions                     |  |      |              |   |      |
| -total dimensions L × W × H:   |  | ×    |              | × | mm   |
| Masses                         |  |      |              |   |      |
| -total including oil           |  | tons | -tank        |   | tons |
| -transport with oil            |  | tons | -accessories |   | tons |
| -transport without oil         |  | tons | -pressboard  |   | tons |
| -active part (core + windings) |  | tons | -paper       |   | tons |
| -copper                        |  | tons | -pressboard  |   | tons |
| -oil                           |  | tons |              |   | tons |

## 21 SITE INSTALLATION &amp; TRANSPORT

|                                                                                                                                                                       |   |                                      |                               |                                 |    |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|--------------------------------------|-------------------------------|---------------------------------|----|
| Installation                                                                                                                                                          |   |                                      |                               |                                 |    |
| <input type="checkbox"/> in open air <input type="checkbox"/> within protective walls <input type="checkbox"/> in rock cavity <input type="checkbox"/> others:        |   |                                      |                               |                                 |    |
| -according to drawing No.                                                                                                                                             |   |                                      |                               |                                 |    |
| Erected on                                                                                                                                                            |   |                                      |                               |                                 |    |
| <input type="checkbox"/> supports <input type="checkbox"/> wheels <input type="checkbox"/> skids <input type="checkbox"/> oak planks <input type="checkbox"/> others: |   |                                      |                               |                                 |    |
| pcs of supports and                                                                                                                                                   |   | pcs of wheels included in the supply |                               |                                 |    |
| <input type="checkbox"/> anti-vibration plate                                                                                                                         |   |                                      |                               |                                 |    |
| Rail gauge and support gauge                                                                                                                                          |   |                                      |                               |                                 |    |
| -longitudinal                                                                                                                                                         |   | mm                                   | alternatively                 |                                 |    |
| -lateral                                                                                                                                                              | × | mm                                   | <input type="checkbox"/> with | mm c/c between rail pairs       |    |
|                                                                                                                                                                       |   |                                      | <input type="checkbox"/> with | centrally located support wheel |    |
| Transport                                                                                                                                                             |   |                                      |                               |                                 |    |
| <input type="checkbox"/> designed for railway transport on Swedish coach No.                                                                                          |   |                                      |                               | (Coach No.)                     |    |
| <input type="checkbox"/> designed for road transport                                                                                                                  |   |                                      |                               |                                 |    |
| -transport dimensions L × W × H:                                                                                                                                      |   | ×                                    |                               | ×                               | mm |
| <input type="checkbox"/> impact recorder installed during transport                                                                                                   |   |                                      |                               |                                 |    |

|              |  |                  |  |
|--------------|--|------------------|--|
| manufacturer |  | type designation |  |
|              |  |                  |  |

## 22 WINDING DESIGN & INSULATION SYSTEM

| Winding design                                                                   |                        |              |                  |                                        |                 |           |   |       |  |   |
|----------------------------------------------------------------------------------|------------------------|--------------|------------------|----------------------------------------|-----------------|-----------|---|-------|--|---|
| Physical winding                                                                 | Corresponding terminal | Winding type | Winding material | 0,2% proof stress (N/mm <sup>2</sup> ) | Paper DP-number |           |   |       |  |   |
|                                                                                  |                        |              |                  |                                        | new             | processed |   |       |  |   |
| A                                                                                |                        |              |                  |                                        |                 |           |   |       |  |   |
| B                                                                                |                        |              |                  |                                        |                 |           |   |       |  |   |
| C                                                                                |                        |              |                  |                                        |                 |           |   |       |  |   |
| D                                                                                |                        |              |                  |                                        |                 |           |   |       |  |   |
| E                                                                                |                        |              |                  |                                        |                 |           |   |       |  |   |
| F                                                                                |                        |              |                  |                                        |                 |           |   |       |  |   |
| Insulation system                                                                |                        |              |                  |                                        |                 |           |   |       |  |   |
| total barrier thickness                                                          |                        | HV/MV        |                  | %                                      | HV/LV           |           | % | MV/LV |  | % |
| total spacer width                                                               |                        |              |                  |                                        |                 |           |   |       |  |   |
| <input type="checkbox"/> windings equipped with a high temperature varnish layer |                        |              |                  |                                        |                 |           |   |       |  |   |
| <input type="checkbox"/> thermally upgraded paper                                |                        |              |                  |                                        |                 |           |   |       |  |   |

## 23 LOADING CASES FOR INTER-BUS TRANSFORMERS

| Loading cases for verification and/ or optimising of rated voltages |          |   |           |            |             |            |      |
|---------------------------------------------------------------------|----------|---|-----------|------------|-------------|------------|------|
| Case No.                                                            | OLTC Pos |   | Winding I | Winding II | Winding III | Winding IV | Unit |
| #0<br>No-load, principal tap                                        |          | U |           |            |             |            | kV   |
| #1<br>Normal case                                                   |          | U |           |            |             |            | kV   |
|                                                                     |          | P |           |            |             |            | MW   |
|                                                                     |          | Q |           |            |             |            | Mvar |
| #2<br>Control case                                                  |          | U |           |            |             |            | kV   |
|                                                                     |          | P |           |            |             |            | MW   |
|                                                                     |          | Q |           |            |             |            | Mvar |
| #3<br>Control case                                                  |          | U |           |            |             |            | kV   |
|                                                                     |          | P |           |            |             |            | MW   |
|                                                                     |          | Q |           |            |             |            | Mvar |
| #4<br>Control case                                                  |          | U |           |            |             |            | kV   |
|                                                                     |          | P |           |            |             |            | MW   |
|                                                                     |          | Q |           |            |             |            | Mvar |
| #5<br>Control case                                                  |          | U |           |            |             |            | kV   |
|                                                                     |          | P |           |            |             |            | MW   |
|                                                                     |          | Q |           |            |             |            | Mvar |
| #6<br>Peak load,                                                    |          | U |           |            |             |            | kV   |
|                                                                     |          | P |           |            |             |            | MW   |

|                                            |  |   |  |  |  |  |      |
|--------------------------------------------|--|---|--|--|--|--|------|
| emergency operation                        |  | Q |  |  |  |  | Mvar |
| #7                                         |  | U |  |  |  |  | kV   |
| Temperature rise test                      |  | P |  |  |  |  | MW   |
| (conventional)                             |  | Q |  |  |  |  | Mvar |
| Sign conventions:                          |  |   |  |  |  |  |      |
| -Positive power = power into the winding   |  |   |  |  |  |  |      |
| -Negative power = power out of the winding |  |   |  |  |  |  |      |
| -A reactor is consuming reactive power     |  |   |  |  |  |  |      |
| -A capacitor is producing reactive power   |  |   |  |  |  |  |      |

| Loading cases for verification and/ or optimising of rated voltages                            |          |   |           |                  |             |            |      |
|------------------------------------------------------------------------------------------------|----------|---|-----------|------------------|-------------|------------|------|
| Case No.                                                                                       | OLTC Pos | - | Winding I | Winding II       | Winding III | Winding IV | Unit |
| #0<br>No-load, principal tap                                                                   |          | U |           |                  |             |            | kV   |
| #1<br>Normal case<br>U1= normal UN<br>Pg=Pgr Q1=0                                              |          | U |           |                  |             |            | kV   |
|                                                                                                |          | P |           |                  |             |            | MW   |
|                                                                                                |          | Q |           |                  |             |            | Mvar |
| #2<br>Control case<br>U1=95%UN<br>Pg=Pgr,<br>Q1=1/3×Pgr                                        |          | U |           |                  |             |            | kV   |
|                                                                                                |          | P |           |                  |             |            | MW   |
|                                                                                                |          | Q |           |                  |             |            | Mvar |
| #3<br>Control case<br>U1=100%UN<br>Pg=Pgr,<br>Q1=1/3×Pgr                                       |          | U |           |                  |             |            | kV   |
|                                                                                                |          | P |           |                  |             |            | MW   |
|                                                                                                |          | Q |           |                  |             |            | Mvar |
| #4<br>Control case<br>U1=105%UN<br>Pg=Pgr,<br>Q1=1/4×Pgr                                       |          | U |           |                  |             |            | kV   |
|                                                                                                |          | P |           |                  |             |            | MW   |
|                                                                                                |          | Q |           |                  |             |            | Mvar |
| #5<br>Control case<br>U1=100%UN<br>Pg=Pgr,<br>Q1=+1/6×Pgr                                      |          | U |           |                  |             |            | kV   |
|                                                                                                |          | P |           |                  |             |            | MW   |
|                                                                                                |          | Q |           |                  |             |            | Mvar |
| #6<br>Control case<br><i>Hotspot 98°C, ambient 20°C</i><br>Ug=100%Ugr<br>Pg=Pgr,<br>Qg=1/3×Pgr |          | U |           |                  |             |            | kV   |
|                                                                                                |          | P |           |                  |             |            | MW   |
|                                                                                                |          | Q |           |                  |             |            | Mvar |
| #7<br>Temperature rise test<br>(conventional)<br>Ug=95%Ugr<br>Pg=Pgr,<br>Qg=1/3×Pgr            |          | U |           |                  |             |            | kV   |
|                                                                                                |          | P |           |                  |             |            | MW   |
|                                                                                                |          | Q |           |                  |             |            | Mvar |
| Sign conventions:                                                                              |          |   |           | Legend:          |             |            |      |
| -Positive power = power into the winding                                                       |          |   |           | - N = network    |             |            |      |
| -Negative power = power out of the winding                                                     |          |   |           | - r = rated      |             |            |      |
| -A reactor is consuming reactive power                                                         |          |   |           | - g = generator  |             |            |      |
| -A capacitor is producing reactive power                                                       |          |   |           | - 1 = HV winding |             |            |      |

25 AIR CORE INDUCTANCES

| Inductances in principal position                                                               |   |    |     |    |         |
|-------------------------------------------------------------------------------------------------|---|----|-----|----|---------|
| Winding                                                                                         | I | II | III | IV |         |
| Air core inductance                                                                             |   |    |     |    | mH/limb |
| Note: For auto connection the series and common winding in series are considered as one winding |   |    |     |    |         |
|                                                                                                 |   |    |     |    |         |

26 CAPACITANCES

| Capacitances in principal position - resulting values between terminals and terminal to ground  |      |       |        |    |         |
|-------------------------------------------------------------------------------------------------|------|-------|--------|----|---------|
| Winding pair                                                                                    | I/II | I/III | II/III |    |         |
| -total capacitance                                                                              |      |       |        |    | nF/limb |
| Winding                                                                                         | I    | II    | III    | IV |         |
| -total capacitance                                                                              |      |       |        |    | nF/limb |
| Note: For auto connection the series and common winding in series are considered as one winding |      |       |        |    |         |
|                                                                                                 |      |       |        |    |         |

27 TEMPERATURE RISES

| Winding       | I | II            | III | IV |
|---------------|---|---------------|-----|----|
| Mean rise     |   |               |     |    |
| Hot spot rise |   |               |     |    |
| Top oil rise  |   | Mean oil rise |     |    |

28 FAULT CURRENTS

| Three phase faults (steady state currents in kA)        |    |               |          |                 |                            |
|---------------------------------------------------------|----|---------------|----------|-----------------|----------------------------|
| Winding / Terminal                                      |    | Fault current |          | Faulty terminal | OLTC principal tapping pos |
|                                                         |    | Winding       | Terminal |                 |                            |
|                                                         | kV |               |          |                 |                            |
|                                                         | kV |               |          |                 |                            |
|                                                         | kV |               |          |                 |                            |
|                                                         | kV |               |          |                 |                            |
|                                                         | kV |               |          |                 |                            |
|                                                         |    |               |          |                 |                            |
| Single phase earth faults (steady state currents in kA) |    |               |          |                 |                            |
| Winding / Terminal                                      |    | Fault current |          | Faulty terminal | X0 / X+ OLTC pos           |
|                                                         |    | Winding       | Terminal |                 |                            |
|                                                         | kV |               |          |                 |                            |
|                                                         | kV |               |          |                 |                            |
|                                                         | kV |               |          |                 |                            |
|                                                         | kV |               |          |                 |                            |
|                                                         | kV |               |          |                 |                            |
|                                                         |    |               |          |                 |                            |

### 29 ZERO SEQUENCE IMPEDANCES

|                                                                                  |  |  |  |                          |
|----------------------------------------------------------------------------------|--|--|--|--------------------------|
| Zero sequence no-load impedance at rated line current through the neutral point. |  |  |  |                          |
| winding                                                                          |  |  |  | (principal tapping)      |
| zero sequence impedance                                                          |  |  |  | %                        |
| reference power                                                                  |  |  |  | MVA                      |
| Series zero sequence impedance at rated current in principal tapping             |  |  |  |                          |
| windings                                                                         |  |  |  | Measured/short-circuited |
| zero sequence impedance                                                          |  |  |  | %                        |
| reference power                                                                  |  |  |  | MVA                      |

### 30 INRUSH CURRENTS

|                                                                                                         |   |    |     |    |                    |
|---------------------------------------------------------------------------------------------------------|---|----|-----|----|--------------------|
| Max terminal inrush current                                                                             |   |    |     |    |                    |
| winding                                                                                                 | I | II | III | IV |                    |
| peak inrush current                                                                                     |   |    |     |    | kA <sub>peak</sub> |
| half value time                                                                                         |   |    |     |    | s                  |
| -at rated voltage, in principal tapping and network conditions in accordance with this data compilation |   |    |     |    |                    |
| -remanence flux density T                                                                               |   |    |     |    |                    |

### 31 SURGE ARRESTERS

|                                                 |                          |                          |                          |                          |                          |
|-------------------------------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| Winding / Terminal number                       | I                        | II                       | III                      | N                        | N                        |
| Bracket attachment                              | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Bracket attachment and bracket                  | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Bracket attachment, bracket and surge arresters | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Manufacturer                                    |                          |                          |                          |                          |                          |
| Type designation                                |                          |                          |                          |                          |                          |

### 32 REQUESTED ALTERNATIVES

| Requested alternatives according to these guidelines and / or SS-EN |                  |                      |                                                       |
|---------------------------------------------------------------------|------------------|----------------------|-------------------------------------------------------|
|                                                                     | Guideline Clause | SS-EN 60076-1 Clause | Requested alternative                                 |
| <input type="checkbox"/>                                            | 5.1              | -                    | Extended bushing turret                               |
| <input type="checkbox"/>                                            | 9.7              |                      | Option for optical fibres                             |
| <input type="checkbox"/>                                            | 13.5             |                      | Cooling equipment power supply from auxiliary winding |
| <input type="checkbox"/>                                            | 15.3             |                      | Fixed cover ladder                                    |
| <input type="checkbox"/>                                            | 15.10            |                      | Gas and oil actuated relay inspection platform        |
| <input type="checkbox"/>                                            | 19.1.3           |                      | Accessory summary plate                               |
| <input type="checkbox"/>                                            | 19.1.4           |                      | Oil circuit diagram                                   |
| <input type="checkbox"/>                                            | 20.2             |                      | Winding location diagram                              |
| <input type="checkbox"/>                                            | 20.2             |                      | Voltage stress diagram                                |
| <input type="checkbox"/>                                            | 20.2             |                      | Short circuit stress diagram                          |
| <input type="checkbox"/>                                            | 22               |                      | Design review                                         |
| <input type="checkbox"/>                                            | 24.2             |                      | Tests in service carried out by the client            |

|                          |        |          |                                                                  |
|--------------------------|--------|----------|------------------------------------------------------------------|
| <input type="checkbox"/> | 24.2   |          | Tests in service carried out by the supplier                     |
| <input type="checkbox"/> | 23.8.4 |          | Option for a short circuit withstand test                        |
| <input type="checkbox"/> | 23.8.5 |          | Thermal no-load test                                             |
| <input type="checkbox"/> |        |          | Measurement of no-load current harmonics                         |
| <input type="checkbox"/> |        | 11.1.3.d | Measurement of power taken by fans and oil pumps                 |
| <input type="checkbox"/> | 26.3   |          | Verification of cooling capacity at installation not in open air |
| <input type="checkbox"/> |        |          |                                                                  |
| <input type="checkbox"/> |        |          |                                                                  |
| <input type="checkbox"/> |        |          |                                                                  |
| <input type="checkbox"/> |        |          |                                                                  |

### 33 TENDER ENCLOSURES

| Tender enclosures (X-marked are compulsory as well as the tender references)<br>-item - tender reference No. |                          |  |
|--------------------------------------------------------------------------------------------------------------|--------------------------|--|
| Factory description                                                                                          | <input type="checkbox"/> |  |
| Reference list                                                                                               | <input type="checkbox"/> |  |
| Failure record                                                                                               | <input type="checkbox"/> |  |
| Test resources                                                                                               | <input type="checkbox"/> |  |
| Dimension drawing                                                                                            | <input type="checkbox"/> |  |
| Transport drawing, railway                                                                                   | <input type="checkbox"/> |  |
| Circuit diagram                                                                                              | <input type="checkbox"/> |  |
| Test circuit, impulse tests                                                                                  | <input type="checkbox"/> |  |
| Test circuit, power frequency tests                                                                          | <input type="checkbox"/> |  |
| Recommended priced spare parts                                                                               | <input type="checkbox"/> |  |
| List of technical deviations                                                                                 | <input type="checkbox"/> |  |
|                                                                                                              |                          |  |
| Time schedule                                                                                                | <input type="checkbox"/> |  |
| Valid type test reports                                                                                      | <input type="checkbox"/> |  |
| Quality management system                                                                                    | <input type="checkbox"/> |  |
| Quality management system certificate                                                                        | <input type="checkbox"/> |  |
| Eco management system                                                                                        | <input type="checkbox"/> |  |
| Eco management system certificate                                                                            | <input type="checkbox"/> |  |
| Environmental impact for the complete reactor delivery                                                       | <input type="checkbox"/> |  |
|                                                                                                              |                          |  |
| Surface protection and painting system description                                                           | <input type="checkbox"/> |  |
| Insulating liquid specification                                                                              | <input type="checkbox"/> |  |
| Completed insulating liquid questionnaire                                                                    | <input type="checkbox"/> |  |
| Cable box cross section drawing                                                                              | <input type="checkbox"/> |  |
| Cable termination description                                                                                | <input type="checkbox"/> |  |
| Oil/air or cooler description                                                                                | <input type="checkbox"/> |  |
| Oil/air or cooler data sheet                                                                                 | <input type="checkbox"/> |  |
|                                                                                                              |                          |  |
| Principal gauge arrangement drawing                                                                          | <input type="checkbox"/> |  |

