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FASTSTÄLLD
td

SHUNT REACTORS 145 KV 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
9	Section 2, SS-EN 61869 included.	2018-09-03
9	Section 2, SS-EN 61936-1 included.	2018-09-03
9	Section 2, SEN 280901 included.	2018-09-03
9	Section 2, SS-EN 61558-2-1 included.	2018-09-03
9	Section 2, Cigré Report 673 included.	2018-09-03
9	Section 4.4.1, Table 4.1 updated.	2018-09-03
9	Section 4.4.2, Table 4.2 updated according to SS – EN 61936-1 and IEC 60076-3.	2018-09-03
9	Section 4.4.5, Requirement regarding internal arresters included.	2018-09-03
9	Section 4.6, If not otherwise stated, the cooling type shall be ONAN.	2018-09-03
9	Section 4.8, Requirements regarding core design included.	2018-09-03
9	Section 4.13, Foil windings are normally not accepted.	2018-09-03
9	Section 4.15, Requirements regarding variable shunt reactors included.	2018-09-03
9	Section 5.1, Bushing requirements updated.	2018-09-03
9	Section 5.1, Definition of extended bushing turret clarified	2018-09-03
9	Section 5.5, Reference to SS-EN 62271-211 included.	2018-09-03
9	Section 5.8.4, Allowed tin layer thickness and temperature for copper terminals updated.	2018-09-03

9	Section 5.8.5, Flat terminal dimensions updated.	2018-09-03
9	Section 6.2, More options for oil level indication.	2018-09-03
9	Section 7.2, Each fan group shall equipped with a visible lockable disconnecting switch.	2018-09-03
9	Section 7.2, Requirements regarding fusing of cooling groups revised.	2018-09-03
9	Section 8.1, Definition of erection plane clarified.	2018-09-03
9	Section 8.1, Diameter of padlocks with associated holes clarified.	2018-09-03
9	Section 8.1, Doors shall be equipped with doorstops.	2018-09-03
9	Section 8.1, Blind flanges in the bottom of all boxes and cubicles. Flange size in accordance with standard.	2018-09-03
9	Section 8.2, Boxes and cubicles shall have self-ventilation.	2018-09-03
9	Section 8.2, Certain cubicles shall always be equipped with thermal insulation.	2018-09-03
9	Section 8.2, Optimisation of heater switch on and switch off temperatures.	2018-09-03
9	Section 8.3.1, Requirements regarding terminal blocks updated.	2018-09-03
9	Section 9.1, Location and labelling of metering core specified.	2018-09-03
9	Section 9.2.6.1.2, Rated output for rated currents ≥500 A modified. Accuracy class shall range from 1 VA to 7.5 VA.	2018-09-03
9	Section 9.2.6.1.2, Accuracy class for metering cores simplified.	2018-09-03
9	Section 9.2.6.4, Requirements regarding secondary winding resistance for relay cores included.	2018-09-03
9	Section 10, Power and control cable requirements supplemented.	2018-09-03

9	Section 11.1, Tank bottom shall be self-supported.	2018-09-03
9	Section 11.1, Requirements regarding welders, welding and preparation grade clarified.	2018-09-03
9	Section 11.3, Requirements regarding ladder slip protection and fasten eyelets.	2018-09-03
9	Section 11.3, Requirements regarding opening and sealing of welded covers included.	2018-09-03
9	Section 11.5, Requirements regarding designation plates.	2018-09-03
9	Section 11.6.3, A possibility for heat recovery is included.	2018-09-03
9	Section 11.7, Requirements regarding pressure relief valve updated.	2018-09-03
9	Section 11.8, Requirements regarding surge arresters and earthing of surge arresters changed. Surge arresters may be a part of the delivery, if a bracket is specified.	2018-09-03
9	Section 11.9, Requirements regarding seals and gaskets completely updated.	2018-09-03
9	Section 11.10, Transportation must be possible on railway wagons with home location in Sweden.	2018-09-03
9	Section 11.10, Reactors having a transport mass 80 tons and above shall be possible to transport by wagons, hanging on brackets between the beams.	2018-09-03
9	Section 11.10, Reference to the Swedish Transport Administration document “Network Statement” included.	2018-09-03
9	Section 11.10, Erection of reactors clarified. If wheels are specified, wheel holders shall be included in the supply.	2018-09-03
9	Section 11.10, Requirements regarding anti-vibration plates.	2018-09-03
9	Section 11.10, The limit where only one impact recorder is required, is increased.	2018-09-03
9	Section 11.13, Sound reduction tank constructions restricted.	2018-09-03

9	Section 12.2, Surface treatment for connection boxes, cubicles and OLTC motor drive simplified. Corrosion category modified.	2018-09-03
9	Section 12.3, Requirement for washers included. Screws, washers and nuts shall be of acid proof steel.	2018-09-03
9	Section 12.4, Surface treatment for radiators clarified.	2018-09-03
9	Section 12.5, Surface treatment for coolers, fans and pumps clarified.	2018-09-03
9	Section 13.2.1, If specified, the lower end of the neutral bus shall be provided with four holes.	2018-09-03
9	Section 13.3, Protective earthing shall be arranged by means of a visible green/yellow earthing connection.	2018-09-03
9	Section 13.3.2, The current transformers shall be earthed by a cable with grey insulation.	2018-09-03
9	Section 13.3.2, A plate “Ansluts till marklinenät” shall be located in the vicinity of the accessing point.	2018-09-03
9	Section 14.1, Oil used at FAT shall be compatible with the delivered oil.	2018-09-03
9	Section 14.3, Additional requirements for the main conservator design included.	2018-09-03
9	Section 15.1, All plates shall be in Swedish. English languish can be accepted for plates belonging to accessories from sub suppliers. Outdoor plates shall be weather resistant.	2018-09-03
9	Section 15.1.6, Oil diagram plate requirement updated.	2018-09-03
9	Section 15.2, Requirements regarding terminal markings included.	2018-09-03
9	Section 19.7.2.2, For PD-levels >100 pC an explanation must be presented.	2018-09-03
9	Section 19.7.3, For variable shunt reactors, sound level measurement shall be performed at the tapping giving the highest core flux density.	2018-09-03
9	Section 19.7.11, A painting inspection certificate shall accompany the delivery.	2018-09-03

9	Section 20.2, Tests in service shall be carried out by the supplier or the client (specified in Data compilation).	2018-09-03
9	Section 20.3, The service certificate shall be included in the site test certificates.	2018-09-03
9	Section 22.3, Documents for approval updated and clarified.	2018-09-03
9	Section 22.3, Terminal diagram shall be supplemented to the circuit diagram.	2018-09-03
9	Section 22.3, Drawings in dwg-format required.	2018-09-03
9	Section 22.3, Each AUTOCAD drawing shall be delivered as an individual file.	2018-09-03
9	Section 22.3, CD is replaced with USB.	2018-09-03
9	Section 22.3, Documents for approval shall be supplied in PDF format preferable at agreed common web places or by electronic mail.	2018-09-03
9	Section 22.4, The instruction manual in paper file shall be delivered in two samples. In addition, a corresponding digital manual in pdf-format shall be delivered.	2018-09-03
9	Section 22.4, Accessories for programmable equipment shall be attached to the instruction manual.	2018-09-03
9	Section 22.4, Instructions for all programmable equipment's included.	2018-09-03
9	Section 22.4, Painting inspection certificate included.	2018-09-03
9	Section 23, Information to be filled in in Data compilation clarified.	2018-09-03
9	Section 23, Revision management included.	2018-09-03

Content

1 SCOPE

These guidelines cover three phase 50 Hz oil immersed shunt reactors with highest voltage for equipment 145 kV and above.

2 STANDARDS

If standards referred to have been revised, the ones in force at the ordering date shall be considered as valid. 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
IEC 60076-4	Part 4: Guide to the lightning impulse and switching impulse testing –Power transformers and reactors
IEC 60076-6	Part 6: Reactors
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
IEC 60076-14	Part 14: Design and application of liquid-immersed power transformers using high-temperature insulation materials
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/A1	Part 3: Amendment No. A1
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/A1	Part 5: Amendment No. A1
SS-EN 50216-5/A2	Part 5: Amendment No. A2
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 50216-10	Oil-to air heat exchangers (not published)
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 50180	Bushings above 1 kV up to 36 kV and from 250 A to 3,15 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
CLC TS 50458	Capacitance graded outdoor bushings 52 kV up to 420 kV for oil immersed transformers (not published)
IEC 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 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 60617	Graphical symbols for diagrams
SS-EN 60664-1	Insulation co-ordination for equipment within low-voltage systems
IEC TR 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
IEC TR 61462	Composite insulators – Hollow insulators for use in outdoor and indoor electrical equipment – Definitions, test methods, acceptance criteria and design recommendations
IEC 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-Earthing
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 673	Guide on transformer transportation
ELSÄK-FS 2004:1	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
SEN 280901	Flänsöppningar (Flange openings)
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 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 reactors shall if not otherwise specified be designed for outdoor erection and continuous operation.
The reactors will be switched in and out once a day as an average.

3.2 Ambient temperature

As a lower limit of ambient air temperature –40°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 reactor tank which is assumed to reach 105 °C on the cover. The lower limit ambient temperature –40°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°C
- maximum daily average temperature 105°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.

Highest voltage for equipment, U_m (kV)	System earthing	X0/X+ (-)
145 – 170	Effectively earthed	1 – 3 (IEC)
245	-"-	1 – 3 (IEC)
420	-"-	1 – 3 (IEC)

Table 3.1 System earthing

Highest voltage for equipment (kV)	Short circuit power (reference voltage = Um) (MVA)
145 – 170	10000
245	17000
420	25000

Table 3.2 Network short circuit power

3.4 Specific site conditions

The supplier shall claim detailed information of how the reactor 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 reactor. A drawing with a proposal of the reactor arrangement shall be enclosed with the tender. The reactor shall be constructed in such a way that the allowed temperature rises shall not exceed the stated requirements in IEC 60076 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 420 kV power rating 165 Mvar shall be selected if not other specified. For other voltages, the power rating shall be specified in the tender.

4.2 Connection symbol

The reactors shall normally have the connection symbol YN.

4.3 Tapping range

Tappings are normally not required.

4.4 Insulation levels, creepage distances and air clearances.

4.4.1 Insulation levels

Insulation levels shall fulfil the requirements in Table 4.1.

Highest voltage for equipment (kV)	Insulation level according to IEC 60076-3 (phase-earth) (neutral-earth)
145 – 170	LI550 AC230 – LI125 AC50
245	SI750 LI850 – LI125 AC50
420	SI1050 LI1300 - LI125 AC50

Table 4.1 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

4.4.2 Air clearances

The requirements on minimum air clearances are summarised in Table 4.2.

Highest voltage for equipment, Um (kV)	Minimum free air clearance phase - earth (mm)	phase - phase (mm)
145 – 170	1100	1100
245	1700	2300
420	2600	3600

Table 4.2 Minimum air clearances

Notes to Table 4.2:
-Air clearances for 170 kV and below are based upon SS – EN 61936-1
-Air clearances for 245 and 420 kV 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 4.3.

Highest voltage for equipment, Um (kV)	Minimum creepage distance		
	Ceramic type		Polymeric type
	Clean environment Class I (mm)	Polluted environment Class II and III (mm)	Clean environment Class I (mm)
145 – 170	2750	4300	2050
245	6000		
420	10000		

Table 4.3 Creepage distances

Notes to Table 4.3:
-Pollution classes according to IEC 60815
-For an alternative method of ceramic type insulator performance in polluted environment refers to Clause 19.8.6. in this guideline.
-For polymeric insulators the creepage distance is not a relevant parameter for the performance in polluted environment. For the performance verification refer to Clause 19.8.6. in this guideline.
-For reactors having highest voltage for equipment 245 and 420 kV environmental Class II shall apply.

-The ratio (creepage distance) / (insulator length) must not exceed 3.5 for ceramic type insulators.
-In case of environmental 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 Loading capability

4.5.1 General

If not otherwise explicitly stated it shall be possible to operate the reactors continuously at maximum voltage 1.1 pu of rated voltage (Umax=1.1×Ur, however, not higher than the highest voltage for equipment without exceeding the allowable standardised temperature rises, including winding hot spot temperature rise.

If not otherwise explicitly stated, it shall be possible to operate the reactor at 105% of rated voltage, irrespective of highest voltage for equipment.

At an ambient temperature of about 20 °C, rated voltage and steady state it shall be possible to operate the reactors for one hour with disconnected cooler power supply

(not applicable for cooling type ONAN) without any damages in the reactor (i.e. the core and winding hot spot temperatures must not exceed 140 °C).

Bushings 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 reactor itself can withstand.

For built in current transformers refer to Clause 9.

The reactor neutral and its bushings as well as built in bushing current transformers shall have the same loading capability as the corresponding line terminals.

4.6 Type of cooling

If not otherwise stated, the cooling type shall be ONAN. Other cooling types may be accepted after written approval.

For type OD.. cooling the same maximum allowable temperature rise as for type OF.. shall apply (***Deviation from SS-EN 60076-2, Cl 4.2***). Furthermore when disconnecting a fully loaded reactor at max ambient temperature it shall not be required to pump oil through the windings, i.e. no post tripping cooling.

4.7 Sound levels

If not otherwise specified the sound power levels in Table 4.4 shall apply:

Max allowable sound level	
Rated power Mvar	Sound power level – L_{WA} dB(A)
25 40 63	77 80 83
100 165 200	86 90 92

Table 4.4 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 IEC 60076-10 and shall apply both with and without cooling equipment in operation.

For variable shunt reactors, 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.

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.

4.8 Core design

If not otherwise specified the reactor core shall be of five limbed core type. Three limbed core or shell type may be used in special cases if explicitly specified in the inquiry.

4.9 Tank vibrations

In operation at rated voltage, rated frequency and normal operating temperature, the vibration amplitude must not exceed 200 μm peak-to-peak value.

4.10 Harmonic production

For reactors having effectively earthed neutral points the following shall apply:

If connected to a 50 Hz voltage equal to rated voltage free of distortion the total r.m.s. value of current harmonic No. three (150 Hz) and higher must not exceed 0.5 % of the line current.

4.11 Reactance unbalance

The phase reactances of reactors having highest voltage for equipment Um ≥ 145 kV must not deviate from the average by more than 1 %.

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 reactor in the most unfavourable phase position and at the highest overexitation according to Clause 4.5. 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 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 reactor ready for shipping (calculated value)

Thermally upgraded paper is to be used.

Foil windings are normally not accepted.

The reactor 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.

4.14 Other data

4.14.1 Supply voltages for motors, control equipment etc.:

4.14.1.1. Cooling equipment motors
400/230 V ac

4.14.1.2. Cooling equipment control
- operation voltage 230 V ac, single phase
- signalling voltage 110 V or 220 V dc

4.14.1.3. Other control equipment
- operation voltage 110 or 220 V dc
- signalling voltage 110 or 220 V dc

4.14.1.4. Lighting and heater
230 V ac, single phase

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

4.14.2 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

4.14.3 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.

4.14.4 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 4.5 Insulation categories

4.14.5 Disturbance requirements

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

4.15 Variable shunt reactors

The adjustment method shall be stepwise control, in which an OLTC is used to change the number of turns on the shunt reactor winding. All requirements regarding on-load tap-changers and equipment related to on-load tap-changers, stated in TR01-10E, are valid for variable shunt reactors.

5 BUSHINGS

5.1 General

Condenser type bushings shall be used. Applicable standard is SS-EN 60137. Bushings shall be of either resin impregnated paper (RIP) or resin impregnated synthetic (RIS) type.

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.

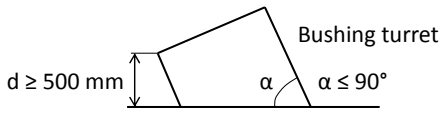

Figure 5.1 Extended bushing turret.

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 reactor.

5.3 Measuring taps

Phase bushings for highest voltage for equipment Um ≥ 145 kV shall be equipped with measuring taps. The taps shall normally be short circuited.

5.4 Oil level indication

Oil filled bushings for highest voltage for equipment Um ≥ 245 kV shall be provided with oil level indication.

5.5 Special requirements for oil-SF_6 connection assemblies.

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

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

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

The over all responsibility of the interface lies on the reactor 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 145 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 reactor supplier.

Other requirements such as cable box with SF_6, oil or air etc. are specified in every single case.

5.7 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 IEC publication IEC 61462 and the relevant parts of IEC 62217. The design of the composite insulators shall be tested and verified according to IEC 61462 (design test and type test). Each composite insulator shall undergo routine tests according to IEC 61462.

5.8 Terminals

5.8.1 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 were the terminal is a natural termination of the internal conductor arrangement.

5.8.2 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	Highest voltage for equipment
2 - 40	400 A
4 - 75	630 - 1250 A
9 - 125	1600 - 3150 A
12 - 165	4000 A

Table 5.1 Flat terminals

5.8.3 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	800 - 1250 A	800 - 1600 A
40	1600 A	2000 - 2500 A
60	2000 - 2500 A	3150 - 4000 A

Table 5.2 Cylindrical terminals

5.8.4 Material

Terminals of copper or a copper alloy must not exceed a temperature of 105 °C 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 H_B min 75.

5.8.5 Flat terminal dimensions

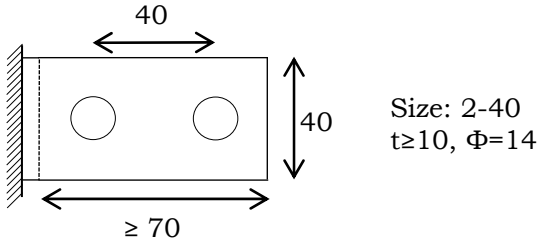

Figure 5.2 Flat terminal size 2-40

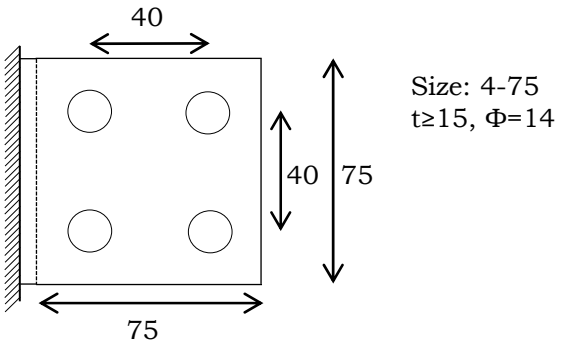

Figure 5.3 Flat terminal size 4-75

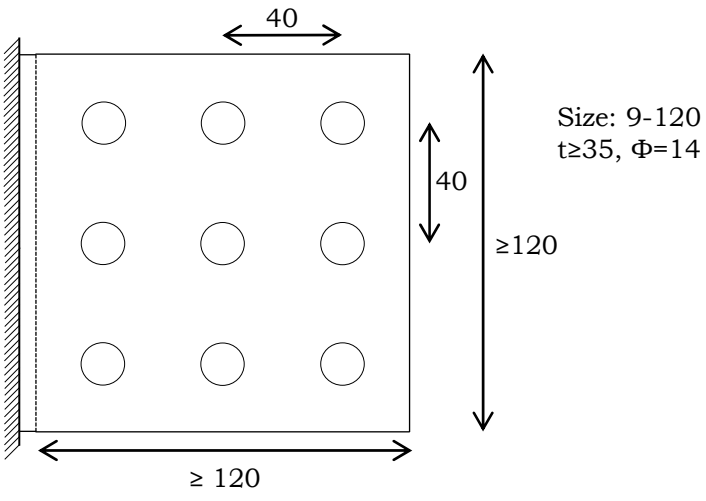

Figure 5.4 Flat terminal size 9-125

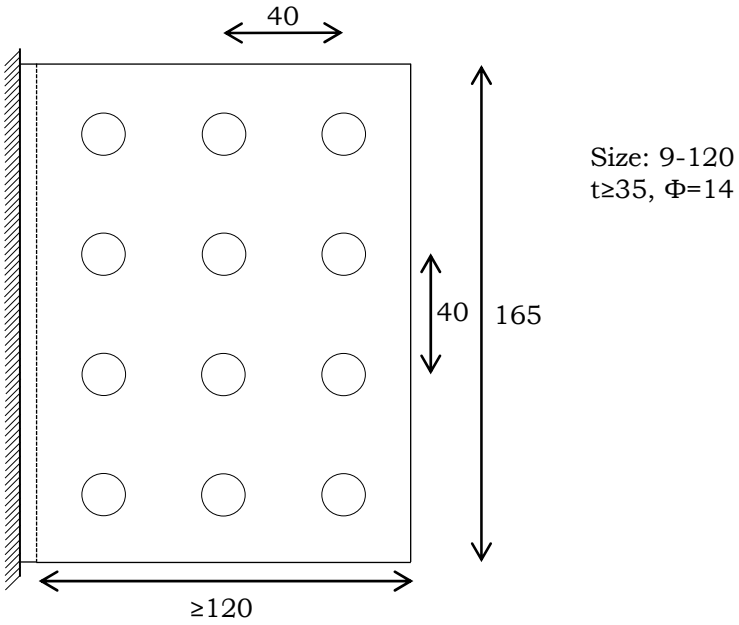

Figure 5.5 Flat terminal size 12-125

5.8.6 Cylindrical terminal dimensions

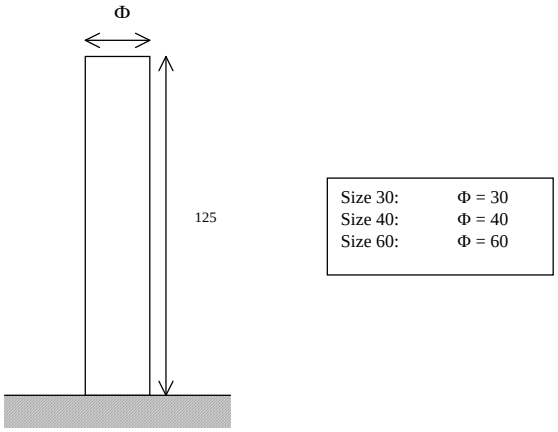

Figure 5.6 Cylindrical terminal

5.9 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 SUPERVISORY EQUIPMENT

The reactors shall normally be provided 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.

6.1 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 no shut off possibility in order to facilitate relay exchange when the reactor is in service.

Gas sampling and functional testing shall be possible to carry out when the reactor 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 11.11 can not reach within the safety distance according to Clause 4.4.4. If specified, a device for gas sampling at service level shall be included.

6.2 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, closing at a level 5% (North Sweden) or 15% (South Sweden) above the “too low” oil level. The contacts will be used for signalling.

The oil level indicators shall be located at service level (not on the conservator) and, if specified, be provided with remote indication possibility (potentiometer).

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

6.3 Temperature gauges (thermometers)

The temperature gauge shall at least have four independently adjustable contacts closing when the temperature reaches the adjusted value. The contacts shall be electrically separated. One contact shall be used for signalling/tripping the others will be used optionally e.g. for control of cooling.

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

The reactors shall be provided with one temperature gauge for top oil temperature. The location of the thermometer pocket shall allow the outgoing top oil to the cooling equipment to be measured.

The temperature gauge shall be provided with Pt100 resistors for remote temperature indication.

In addition to thermometer pocket for the above gauge 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.

6.4 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.

6.5 On-line dissolved gas monitor

If specified, 420 kV reactors shall be equipped with an on-line dissolved gas monitor indicating at least a weighted sum of some of the combustible gases and moisture in the oil.

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 or 220 V dc.

7 COOLING EQUIPMENT

7.1 General

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.

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.

7.2 Cooler control equipment

In the normal case the top oil thermometer will control the coolers. 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 reactor breaker.

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.

The control circuits shall be voltage supervised and this signal shall be separated from all other signals. This facility may be used to block the closing of the reactor circuit breaker.

The control shall normally have one switch with a handle for operation mode selection.

The switches shall be labelled:

FRÅN	(off)
TILL	(on)
VAKT t1	(gauge t1)
VAKT t2	(gauge t2)
temperature setting t1<t2	

Table 7.1 Cooling selector

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.

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.

In case of cooling equipment power consumption higher than 20 kW half the number of fans must be delayed in order to limit the total starting current.

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.

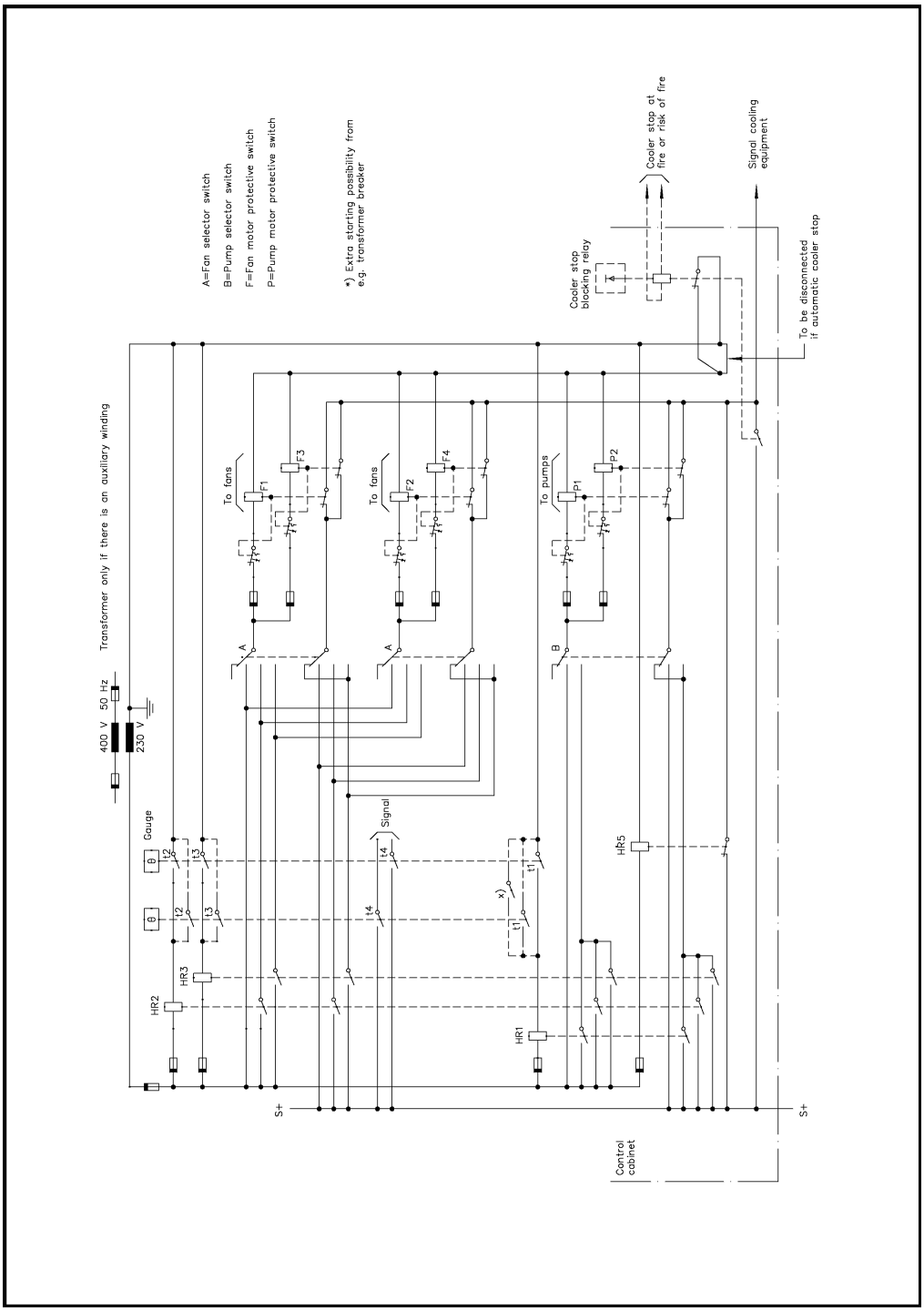

Figure 7.1 Principal cooling circuit diagram

8 CONTROL EQUIPMENT DESIGN

8.1 General design

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

- Supervisory equipment
- Cooling equipment

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

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

Boxes and cubicles shall be lockable by means of a padlock ($\varnothing_{padlock}$=5-6 mm, $\varnothing_{hole}\approx$8-10 mm) and located for easy access. Doors shall be equipped with doorstops. The cubicles shall always be mounted on the reactor tank so that it is readily and safely accessible from ground level with the reactor 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.

8.2 Ventilation, heating and lighting

Boxes and cubicles shall have draining and self-ventilation. As protection for insects openings shall be provided with e.g. 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.

If applicable, boxes and cubicles for the on-load tap-changer drive and for the cooling equipment shall be provided with lighting and an earthed 230 V socket with a residual current circuit breaker. A heater to prevent condensation shall also be provided.

Boxes or cubicles containing equipment which requires extra heating to secure its function at – 40°C ambient temperature the heater shall be controlled by a thermostat. Switch on and switch off temperatures of the thermostat shall be optimised with respect to a low temperature in combination with avoidance of moisture. An extra thermostat shall be provided to give an alarm before the temperature drops below the limit of safe equipment function.

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

Cubicles containing cooling control equipment shall always be provided with thermal insulation. Thermal insulation shall be of incombustible material.

Heaters shall be protected against unintentional contact.

8.3 Terminal blocks

8.3.1 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 preferable 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 mm² (single stranded) and 1 - 6 mm² (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.

All components shall be provided with individual markings for easy identification in the circuit diagram.

8.3.2 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 | X10	Power supply and auxiliary supply	Power supply to have lower numbers than auxiliary power Incoming feeder to have lower number than outgoing.
X11 | X50	Pumps, fans Flow indicators, manometers Cooler circuit faults	Pumps to have lower numbers than fans. Signalling and indication in group X50
X54	Gas and oil actuated relay	
X55 X56	Oil level indicator	
X57	Remote cooler control	E.g. reactor breaker

X61 | X70	Temperature transmitter	If supply from current transformer this shall be connected to this group
X91 | X99	Gauges for oil-SF6 bushings	

Table 8.1 Control cabinet terminal blocks

8.3.3 Disposition of terminal groups in the current transformer cubicle

8.3.3.1. Disposition
The terminal blocks shall be grouped as follows:

Terminal group	Use
X11	Core No. 1 for all three phases
X12	Core No. 2 for all three phases
X13	Core No. 3 ...
X14	Core No. 4 ...
X15	Core No. 5 ...
...	
X101	Core No. 1 in the neutral
X102	Core No. 2 "-
...	

Table 8.2 CT cubicle terminal blocks

8.3.3.2. Terminal numbering for current transformers around phase bushings

Example: Core No. 2 of the highest voltage winding

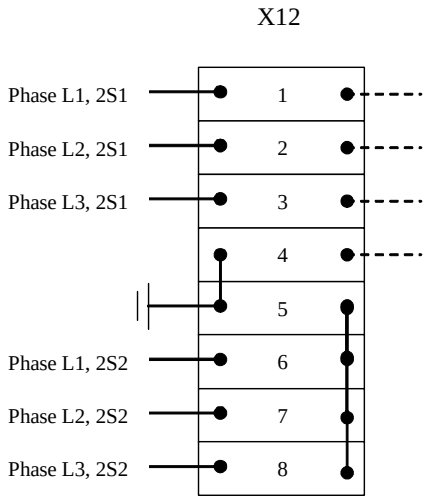

Figure 8.1 Phase CT terminal block numbering

8.3.3.3. Terminal numbering for current transformers around neutral bushings

Example: Core No. 1 for the neutral terminal

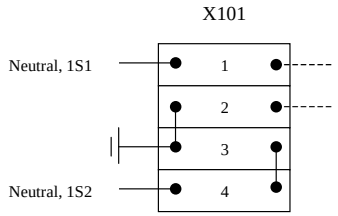

Figure 8.2 Neutral CT terminal block numbering

9 BUSHING CURRENT TRANSFORMERS

9.1 General

Of redundancy reasons one of the relaying cores in each phase shall be connected to the terminal box by a separate cable.

The bushing current transformer shall be mounted with P2 closest to the reactor. 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).

9.2 Electrical data

9.2.1 Rated primary currents

The current transformers shall be designed for a rated primary current according to Table 9.1. The highest rated current should be the value closest above 1.0 times the reactor rated current.

Phase bushing (A)	Neutral bushing (A)
150	150
300	300
500	500
1000	1000

Table 9.1 Rated bushing CT currents

9.2.2 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.

9.2.3 Rated continuous thermal current

The rated continuous thermal current shall be 1.1 times rated current of the reactor.

9.2.4 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.

9.2.5 Insulation levels

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

9.2.6 Cores and windings

9.2.6.1. Phase bushings

9.2.6.1.1. General

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

- Maximum four relaying cores
- Maximum two metering cores

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

9.2.6.1.2. Accuracy classes

Relaying cores shall fulfil the following requirements:

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

Table 9.2 Relaying accuracy requirements for line terminal CT:s

Metering cores shall fulfil the following requirements:

Rated output (VA)	Accuracy class
7.5	0.2SFs10

Table 9.3 Metering accuracy requirements for line terminal CT:s

Accuracy class shall range from 1 VA to 7.5 VA.

9.2.6.2. Neutral bushings

9.2.6.2.1. 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.

9.2.6.2.2. Accuracy classes
The cores shall fulfil the following requirements:

Rated output (VA)	Accuracy class
15	5P20

Table 9.4 Relaying accuracy requirements for neutral terminal CT:s

9.2.6.3. 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 "overcurrent number (n)" will be used in these guidelines.

9.2.6.4. Secondary winding resistance for relay cores
The secondary winding resistance, at 75 °C winding temperature, must not exceed the values in Table 9.5 below.

Ir (A)	≤500	1000
Rct (Ω)	5	5

Table 9.5 Maximal secondary winding resistance for relay cores

9.2.6.5. Test conductor
The cores shall be provided with a common test conductor (~35 mm²), by means of which current transformer testing can be carried out without magnetizing and loading of the reactor.

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

9.3 Design

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

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

9.3.3 Secondary terminals
Earthing of the secondary terminals (S2) shall be made at the CT-earth in the common connection cubicle, illustrated in Figure 13.1.

10 POWER AND CONTROL CABLES

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

To prevent excessive heating the cables must not come into contact with the reactor cover and they shall be laid 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 laid cables shall be provided with a threading protection, 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.

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.

Cable insulation 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.

11 REACTOR TANK

11.1 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.

11.2 Vacuum safety

The reactor tank must withstand a full internal vacuum. A vacuum proof tank shall have a marking indicating this.

11.3 Cover

The cover must be welded to the tank. The edge of the cover should be equipped with a slip protection, for separate ladders. On the cover there should be a necessary number of fasten eyelets, located on the cover or on each bushing turret. Tank and cover shall be designed for opening and sealing.

11.4 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.

11.5 Designation plates

In the middle, approximately at ¾ 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.

11.6 Valves

11.6.1 General

Butterfly valves and ball valves are preferred

11.6.2 Sampling valves

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

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".

11.6.3 Valves for extra heat exchanger

If specified, reactors 100 MVA and above 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 reactor guarantee shall be valid without any limitations due to the external heat exchanger system.

11.7 Pressure relief valve

The reactor 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 reactor oil pit.

11.8 Surge arresters

An external bracket on the tank may be specified to facilitate installation of surge arresters close to the reactor. 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 50 mm² Cu) with low wave impedance, mounted on cable ladders or equivalent. The earthing cables must not be assembled together with other cables. 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.
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=170 kV. $Ø_{plate}$ ≈320 mm. Holes might be drilled at a later stage.
- Um>170 kV. To be designed by the supplier.

11.9 Gaskets and seals

Any person who is responsible for the design, manufacture and installation/assembly, respectively, of items concerning sealing solutions for reactors shall possess necessary competence within seals and sealing technology. Seals and gaskets must be resistant to reactor 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: For reactors 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. 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 should 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 reactor 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.

11.10 Erection, Lifting devices, Transport

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

Reactors shall be designed for dragging and will normally be placed on oak beams. Erection of reactors 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 11.12 Track gauges.

The reactor tank shall be provided with clearly marked attaching plates for jacks minimum 300 mm above the rail or the erection plane.

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.

Reactors 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 preferable.

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

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

Reactors 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 reactors 80 MVA and below, or if the reactor 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.

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.

11.11 Gas and oil actuated relay inspection

Reactors shall be provided with a platform for inspection of the gas and oil actuated relay. The platform and the 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 6.1.
It shall be possible to attach the ladder to three of the platform sides. A separate ladder (non-metallic) with slip protection may be accepted, but only after written agreement.

The platform shall be constructed with a floor of lattice type and have raised borders (slip protection). Furthermore bars or chains shall be provided at the ladder opening.

Permanently assembled ladder shall be provided with protections against falling down in accordance with AFS 2000:42, 61§.

11.12 Track gauges

11.12.1 General

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

11.12.2 Longitudinal movement

Track gauge 1435 mm

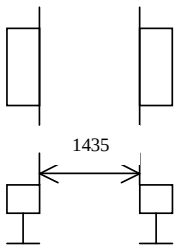

Figure 11.1 Longitudinal track gauge

11.12.3 Lateral movement

Alternative A – track gauge 1435 mm[1]

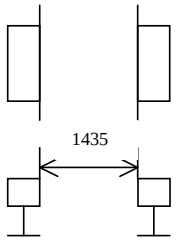

Figure 11.2 Lateral track gauge A

Alternative B – Track gauge 2940 mm, possibly a centrally located support wheels[1]

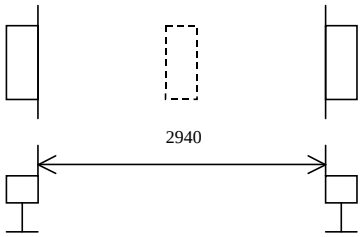

Figure 11.3 Lateral track gauge B

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

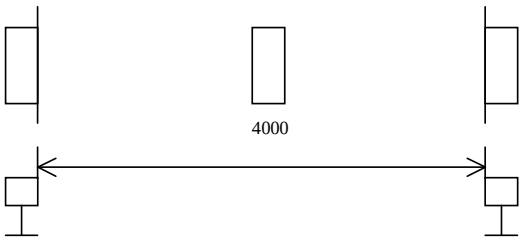

Figure 11.4 Lateral track gauge C

[1] For 130 kV reactors the track gauge 1435 mm shall be chosen if possible.

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

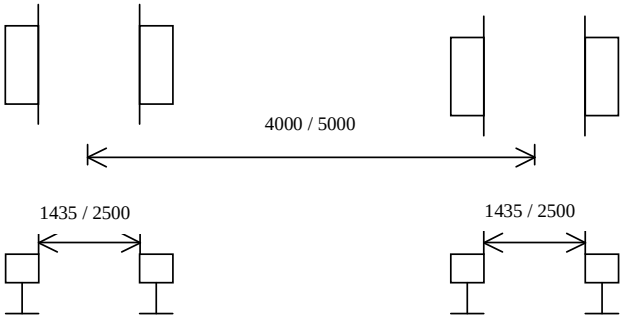

Figure 11.5 Lateral track gauge D

11.13 Sound proofing

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

12 CORROSION PROTECTION AND SURFACE TREATMENT

12.1 Reactor 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.

12.2 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.

12.3 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.

12.4 Radiators

The radiators shall be hot dip galvanized in accordance with SS-EN ISO 1461. The 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.

12.5 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 reactor oil.

13 EARTHING

13.1 Principal earthing diagram

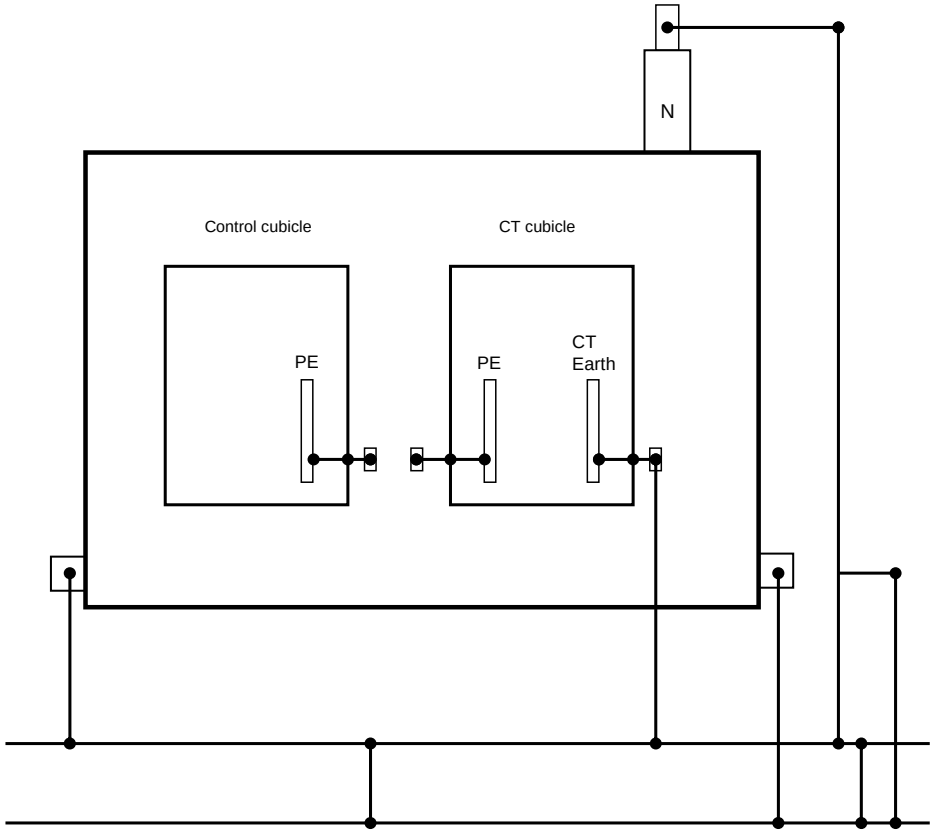

Figure 13.1 Principal earthing diagram

13.2 System earthing

13.2.1 Neutral point earthing

For direct earthing of windings the reactor 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 Φ 14 mm with a vertical c/c 40 mm distance. If specified, four holes shall be provided.

13.3 Protective earthing

13.3.1 Reactor tank

For the protective earthing of the reactor tank two earthing terminals diagonally located close to the tank bottom shall be provided. The earthing cable comprises a few-wire copper conductor, 95 mm² for highest voltage for equipment Um = 145 kV and 185 or 240 mm² for higher voltages.
The terminals shall be flat with four holes, Φ 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.

13.3.2 Connection cubicles and control cabinet

Connection cubicles and cabinets shall have a protective earthing to the reactor 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 mm². A plate "Ansluts till marklinenät" shall be located in the vicinity of the accessing point. The current transformers shall be earthed by a cable with grey insulation.

13.3.3 Separately erected cooling equipment

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

13.3.4 Other equipment

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

13.4 Core earthing

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

14 OIL AND OIL SYSTEM

14.1 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 (group I in accordance with SS EN 60296). and contain at least 0.3% (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^2/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 reactors for among others PCB check (even if the oil will not be shipped with the reactor). 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

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

14.2 Oil system

The main conservator shall be provided with a rubber bag or membrane to prevent humidity to and air access.

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

After oil filling the leakage of air into the reactor 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^2 rubber and year at 20°C. The aging properties of the rubber material shall be presented.

14.3 Conservator

At -40°C ambient temperature, off circuited reactor 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 at steady state not overflow at +40°C ambient temperature and fully loaded reactor.

Separately mounted conservators 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.

14.4 Dehydrating breather

The reactor 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.

14.5 Oil sampling

Refer to Clause 11.6.2

14.6 On-line monitoring

Refer to Clause 6.5

15 MARKING

15.1 Plates

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

15.1.1 Rating plate

The rating plate shall contain the information according to IEC 60076-6, Clause 7.7 and also:

- IEC/EN/SS-EN-standard
- highest voltage for equipment
- maximum continous operating voltage

15.1.2 Diagram plate

A diagram plate is required for all reactors.

15.1.3 Accessory plate

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

15.1.4 Oil circuit diagram

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

15.1.5 Bushing current transformer plate and marking

15.1.5.1. 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 fictious primary terminal marking P1 - P2, where P2 is closest to the reactor. The test conductor terminal marking, M, shall correspond to P1.

15.1.5.2. Rating plate

Beside the reactor 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 calculated (not rated) values of the winding resistance (R) and the over current factor (n) shall be specified.

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

15.1.5.3. Diagram plate

Beside the reactor 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.

15.1.6 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 ...

Labels showing the direction of rotation shall also be provided.

A plate with a diagram showing the oil level or oil volume as a function of top oil temperature and loading conditions (0, 100 %) 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.

15.2 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.

16 INFORMATION IN THE BID

16.1 General

In addition to IEC 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.

16.2 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 reactor will not exceed the Swedish railway transport sections.

- Data compilation as per chapter 23 properly completed. The data compilation shall be updated if design changes are agreed, for instance during tender negotiations or a design review.
- Connection diagram
- Test connection diagram for impulse and power frequency tests
- Oil specification in accordance with Clause 14.1
- 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).

17 QUALITY ASSURANCE

17.1 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 reactors 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.

17.2 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.

17.3 Quality inspection. Inspection plans

The manufacturer shall for each reactor 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.

18 DESIGN REVIEW

A design review includes an electrical and a mechanical part. A design review 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.

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.

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

Special attention shall be paid concerning the thermal and mechanical design.

19 FACTORY ACCEPTANCE TESTS. FINAL INSPECTION.

19.1 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 reactor shall be assembled as for service, i.e. complete with conservator, coolers, supervisory equipment etc. This means that even 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 on a representative reactor may be referred to if the type test report 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.

19.2 Standards. Testing specifications.

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

Bushings shall be tested in accordance with IEC if not specified otherwise below.

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

19.3 Testing environment

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

19.4 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.

19.5 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.

19.6 Test results and test reports

19.6.1 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 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 reactor 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.

19.6.2 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 Rct (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.

19.7 Routine tests

19.7.1 Measurement of loss (IEC 60076-6, Cl 7.8.6)

As reference for future field tests three single phase load current measurements shall be performed feeding each phase with 230 V.

19.7.2 Dielectric tests

19.7.2.1. Induced AC withstand voltage test (IEC 60076-6, Cl 7.8.10.3)
Reactors with the high voltage side highest voltage for equipment Um=145–170 kV shall be subjected to a three phase induced voltage test with 275 kV between phases.

19.7.2.2. Induced AC withstand voltage test and partial discharge measurement (IEC 60076-6, Cl 7.8.10.3)

The test shall always be carried out as a three phase test.

The following PD guarantee levels shall apply:

- 250 pC when U=1.58×Ur/√3 (For PD-levels >100 pC an explanation must be presented.)
- 100 pC when U=1.2×Ur/√3

Measured partial discharge levels and the inception voltage, Ui, as well as the extinction voltage, Ue, shall be recorded and presented in the final test report. Neither of Ui or Ue is allowed to fall below Ur/√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.

19.7.2.3. Lightning impulse test (IEC 60076-6, Cl 7.8.10.4)
For reactors with a high-voltage winding having Um ≥ 145 kV, lightning impulse test is a routine test. (IEC 60076-3, Cl 7.2.1). Subsequently, lightning impulse tests shall be performed as a routine test on all phase terminals as well as the neutral terminal.

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

Category of winding	**Highest voltage for equipment U_m** kV	**Lightning impuls test** kV	**Chopped wave lightning impuls test** kV	**Switching impuls test** kV	**Induced AC voltage tests**				**Separate source AC test** kV
					IVPD		**IVW**		
					1-phase	**3-phase**	**1-phase**	**3-phase**	
					Phase-earth kV	**Phase-phase** kV	**Phase-earth** kV	**Phase-phase** kV	
Non-uniform insulation	**145**	550	Not applicable	Not applicable	Not applicable	U_1=275 U_2=1,58×U_r	U_1=230 U_2=1,58×U_r	Not applicable	Dependant on insulation-level of the neutral
	170	550				U_1=275 U_2=1,58×U_r	U_1=230 U_2=1,58×U_r		
	245	850	1.1×850	750		U_1=1,8×U_r U_2=1,58×U_r	Not applicable		
	420	1300	1.1×1300	1050		U_1=1,8×U_r U_2=1,58×U_r			
Clarification: U_1 = Enhancement voltage, U_2 = One hour PD-measurement voltage									

Table 19.1 Summary of dielectric tests with test voltages for different categories of windings and Um-levels

19.7.3 Sound level measurement (IEC 60076-6, Cl 7.8.12)

To be performed as a routine test, at rated voltage, on all reactors.

For variable shunt reactors, 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 IEC 60076-10.

19.7.4 Measurement of vibration (IEC 60076-1, Cl 7.8.13)

To be performed as a routine test on all reactors.

19.7.5 FRA

Reactors shall be subjected to a frequency response analysis (FRA) fingerprint measurement as a routine test. 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.

19.7.6 Pressure testing

The reactor tank and the coolers shall be subjected to a 12 h over-pressure test on the liquid surface corresponding to an oil column equal to the internal tank height.

19.7.7 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.

19.7.8 Core insulation resistance measurement

The following insulation resistances shall be measured:

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

19.7.9 Winding insulation resistance measurement

The following insulation resistance and polarisation index measurements shall be performed:

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

19.7.10 Tests and inspections on accessories

Inspections shall be carried out to assure that the reactor 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 MΩ measured with 500 V DC.

19.7.11 Painting inspection

Examination of the corrosive protection and the surface treatment requirements in Clause 12 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.

19.8 Type tests

19.8.1 Determination of linearity of reactance (IEC 60076-6, Cl 7.8.5.3)

Determination of linearity shall be performed as a type test

19.8.2 Measurement of zero sequence reactance on three-phase reactors (IEC 60076-6, Cl 7.8.8)

Measurement of zero sequence reactance on three-phase reactors shall be performed as a type test. At all tests, neutral current, phase to phase voltage and active power consumption shall be measured.

19.8.3 Measurement of mutual reactance on three-phase reactors (IEC 60076-6, Cl 7.8.9)

Measurement of mutual reactance on three-phase reactors shall be performed as a type test

19.8.4 Temperature rise test (IEC 60076-6, Cl 7.8.14)

Temperature rise test shall be performed as a three phase test. In the test certificate the voltage measured during the test shall be stated.

The applied voltage levels shall be based upon the highest value of Um and Maximum continuous operating voltage (***Deviation from SS-EN 60076***).

When determining oil temperature rise both method a and b according to SS-EN 60076-2 may be used.

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.

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.

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:

H2	<18 ppm/24 h (<25 ppm/24 h for cooling type ON..)
ΣCH4+C2H4+C2H6	<12 ppm/24 h
C2H2	<0.1 ppm/24 h
CO	<40 ppm/24 h
CO2	<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.

19.8.5 Loss of cooling temperature rise test (Addition to IEC 60076-6, Cl 7.8.14)

To verify the loadability at a trip of the cooling equipment (not applicable for cooling type ONAN) as requested in Clause 4.5.1 the normal temperature rise test shall be followed by an additional temperature rise test for one hour with the coolers not in operation. Before switching off the coolers the oil temperature rise shall have reached a steady state condition. Determination of oil and winding temperatures shall be made as for the conventional temperature rise test.

19.8.6 Bushings creepage distance verification for polluted conditions

19.8.6.1. Ceramic type insulator

As an alternative to creepage distances in Table 4.3 the insulation may be verified by means of a functional test in accordance with IEC 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.

19.8.6.2. Polymeric type insulator

To provide good pollution performance, the polymeric insulator profile must comply with certain profile parameters stated in IEC/TS 60815-3. Values for these parameters are specified below:

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

Table 19.2 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 60815-3.

19.8.7 Bushing current transformers

19.8.7.1. Temperature rise test

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

19.8.7.2. 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 (Rct) shall be measured and corrected to 75°C.

In addition to SS-EN 61869-2 the actual instrument security factor shall be calculated as

$$n=Fs=Iexc/Isn$$

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

$$n=ALF=Iexc/Isn$$

19.8.8 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.

20 SITE TESTS

20.1 Tests on a reactor ready for operation

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

20.1.1 400 kV reactors

- Oil quality test
- Dissolved gas analysis (DGA)
- Frequency dielectric spectroscopy fingerprint (FDS)
- Frequency response analysis (FRA)
- 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 load current measurement
- Operational tests on ALL accessories

20.1.2 All other reactors

- Oil quality test
- Dissolved gas analysis (DGA)
- Frequency response analysis (FRA)
- 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 load current measurement
- Operational tests on ALL accessories

20.2 Tests in service

The tests specified 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 of the choice.

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

20.3 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.

21 TIME SCHEDULES

After the reactor 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.

22 DOCUMENTATION

22.1 General

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

22.2 Tender documents

Refer to Clause 16.2.

22.3 Documents for approval

The following documents shall be provided for approval:

Pos	Date	Activity	Executed by
1	1 month after order	Document A1, A2, A3 and C1 to Client for comments.	Supplier
2	Within two weeks after Pos 1	Comments on document A1, A2, A3 and C1 in Pos 1 to Supplier.	Client
3	After completion of designs but before start of any manufacturing activities	Document B1-B9, C3 to Client for comments.	Supplier
4	Within two weeks after Pos 3	Comments on Pos 3 to Supplier.	Client
5	Two weeks before design review, if applicable	Document C2, if applicable.	Supplier

6	One month before factory acceptance test	Document D to Client for comments.	Supplier
7	Within two weeks after Pos 6	Comments on Pos 6 to Supplier.	Client
8	Three weeks before factory acceptance test	Document C2-C3, B1-B9 and D in two complete sets to Client.	Supplier
9	At the delivery of reactor	Document E to Client.	Supplier
10	Within one month after Pos 9	Complete sets of the final documentation (including documents C2 (if applicable), C3 and C4) to Client.	Supplier

Doc.	**Drawings as to layout, building basis, transport and assembly:**
A1	Reactor outline drawings showing - principal dimensions with tolerance - weights with tolerance - location of jacking positions and supports - location of coolers and conservator - location of bushings - location of control cabinet
A2	Transport drawings
A3	Airflow for building ventilation system
	Binding drawings and diagrams:
B1	Reactor outline drawings including accessories.
B2	Reactor circuit diagram
B3	Connections, detailed specification
B4	Cooler circuit diagram
B5	Control equipment circuit diagram including terminal table
B6	Auxiliary equipment circuit diagram
B7	Oil circuit diagram
B8	Dimension drawing of control cabinet with placing of apparatuses Overview drawing of control cabinet. List of apparatuses with complete data and descriptions.
B9	Rating plate drawings
	Quality control documents:
C1	Quality control, *environmental management plan, organization structure*, inspection plans and time schedule for manufacturing, testing and transport.
C2	Design review report, if applicable
C3	Factory acceptance test program
C4	Test reports
D	Instruction manual for assembly, maintenance and service including identification of equipment and spare parts specific to the actual order.
E	Shipping documents including a valid transportation permission from the Swedish authority “Trafikverket”.

Table 22.1 Documents for approval

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

When delivering the final documentation (in PDF format) one additional drawing set on USB shall be supplied.

In case of computer-produced drawings (CAD) a set of USB with format AUTOCAD shall be submitted. The AUTOCAD drawings shall comply with version 2004 and later Each AUTOCAD drawing shall be delivered as an individual file and shall be submitted with the format dwg. Any manual or descriptions shall be submitted as format PDF.

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

22.4 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 by indication easily 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.
- Conclusive data sheet (Compilation of Technical Data)
- Dimension / Outline drawing with equipment / accessory list
- Circuit diagram with equipment / apparatus list
- Control cabinet
- Current transformers
- Bushings
- Painting inspection certificate
- Cooling equipment
- Oil circuit diagram
- Supervisory equipment and other accessories
- Transport
- Erection/Assembly
- Oil specification and information in accordance with Clause 14.1
- Gasket and sealing solution
- Operation and maintenance instructions
- Diagnostic maintenance
- Instructions for all programmable equipment's
- Product and safety information for all included chemical products
- Other information
- Design review report (if applicable)
- Test reports (type test reports shall always include a reference to the type tested unit)
- Photographs of the active part and complete reactor

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.

23 DATA COMPILATION FOR SHUNT REACTORS

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 TR01-11E. Several, not explicitly stated values and information, are determined by TR01-11E. Remaining values and information in Data compilation, which not are determined by TR01-11E, 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 TR1-11E

2 NETWORK DATA

Network	kV	
Short circuit power from resp. network	MVA	
Reference voltage	kV	
Relation X0/X+	-	

3 RATINGS

Rated voltage	kV	
Maximum continuous operating voltage	kV	
Maximum switch on voltage	kV	
Rated power	Mvar	
Connection mode	-	

4 INSULATION LEVELS

		Line	Neutral
Highest voltage for equipment, Um	kV		
Rated withstand voltages			
Lightning impulse	kV		
Switching impulse	kV		
Power frequency	kV		

Air clearances			
phase-phase	mm		
phase-ground	mm		

5 LOSS

Reference voltage	kV		
Load loss	kW		

6 CORE DESIGN

☐ core type ☐ windings on all limbs ☐ limbs without windings ☐ shell type

Flux density at no load and OLTC in principal position (with two decimals) at 1,0 × Ur

Limb		T, yoke		T, shell / side limb		T

7 SOUND LEVELS

Guaranteed max sound POWER level measured in accordance with IEC (tolerance +0 dB(A))				
- reactor with /without coolers in operation		/		dB(A); LWA
- cooling equipment including pumps (if separate)		/		dB(A); LWA

8 BUSHINGS

Terminal		Line	Neutral
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		☐	☐
Capacitance tap		☐	☐

Bushing type designation	

9 CURRENT TRANSFORMERS

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

10 COOLING EQUIPMENT

Type of cooling					
☐ ONAN ☐ ONAF ☐ OFAF ☐ ODAF ☐ OFWF ☐ To be optimised by the supplier					
Cooler location					
☐ on the reactor ☐ on wall brackets ☐ on concrete shelf ☐ on separate support ☐ supports / brackets included ☐ others:					
Oil system					
	parallel groups on the oil side		cooler(s) in each group		pump(s) in each group
Oil type					
Fan arrangement					
☐ horizontally blowing, ☐ vertically blowing, ☐ vertical suction					

Cooler (Radiator) data			Fan data		
manufacturer			manufacturer		
type designation			type designation		
number of coolers (radiators)		pcs	number of fans		pcs
cooling capacity per cooler at K average oil temperature rise		kW	fan speed		r/min
oil pressure drop per cooler		bar	air flow per fan		m3/s
			power requirement per fan		kW
Oil pump data			Water system		
manufacturer			max water flow per cooler		l/s
type designation			min water flow per cooler		bar
oil flow per pump		l/s	water pressure drop per cooler		bar
power requirement per pump		kW			
			Cooler losses		
			total cooler power consumption		kW
Power supply for pumps and fans			Control voltage		
☐ 400/230 V	☐ from auxiliary winding		☐ 230 V AC, ☐		
☐ others:	☐ from station network		Signalling voltage ☐ 110 V DC ☐ 220 V DC ☐ others:		
Oil flow gauge	Manufacturer		Type designation		
☐ oil flow gauges included (OF..)					

11 EXTRA HEAT EXCHANGER

Oil flow	l/s		
Manufacturer		Type designation	
Valve size	mm		

12 TEMPERATURE GAUGES AND TRANSMITTERS

Winding		Top oil
☐ centre phase ☐ all windings	☐ reading at the reactor ☐ Pt100 transmitters included ☐ transducers included	☐ reading at the reactor ☐ Pt100 transmitters included ☐ transducers included

Power supply for transducers
☐ 110 V DC ☐ 220 V DC ☐ others:

Other gauges and transmitters
☐ oil temperature in and out of the forced oil coolers

Gauge / Transmitter	Manufacturer	Type designation
Top oil thermometer		
Pt100 – top oil		

13 EXPANSION SYSTEM

General
☐ open air system ☐ with rubber membrane

Conservator location
☐ on the reactor ☐ on wall brackets ☐ on concrete shelf ☐ on separate support
☐ brackets / support included

Volumes

Oil volume in main tank and coolers (radiators) at –40°C		m^3
Conservator oil volume		m^3

Gas and oil actuated relay
☐ with by-pass tube ☐ with inspection platform

Manufacturer		Type designation	

Oil level indication
☐ at service level ☐ on the main conservator

Manufacturer		Type designation	

☐ Extra contact closing at an adjustable level ☐ Remote indication possibility

Dehydrating breathers
☐ maintenance-free ☐ non maintenance-free

Manufacturer		Type designation	

14 TANK

General					
☐ welded cover	☐ bolted cover		☐ pressure relief valve		
Surface treatment					
	Externally		Internally		
Corrosivity category	☐ C3 ☐ C4 ☐ C4H ☐ C5 ☐ C5M				
Primer paint					
Cover paint					
Cover paint colour					
Total thickness		µm		µm	

15 DIMENSIONS & 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

16 SITE INSTALLATION & TRANSPORT

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

17 WINDING DESIGN

Winding design				
Winding type	Winding material	0,2% proof stress (N/mm^2)	Paper DP-number	
			new	processed

☐ windings equipped with a high temperature varnish layer
☐ thermally upgraded paper

18 AIR CORE INDUCTANCES

Inductance line - neutral		
Air core inductance		mH/limb

19 CAPACITANCES

Capacitance winding to ground		
-total capacitance		nF/limb

20 TEMPERATURE RISES

Mean winding rise	
Hot spot winding rise	
Mean oil rise	
Top oil rise	

21 INRUSH CURRENTS

Max terminal inrush current		
peak inrush current		kApeak
half value time		s
-at highest voltage for equipment		

22 SURGE ARRESTERS

	Line	Neutral
Bracket attachment	☐	☐
Bracket attachment and bracket	☐	☐
Bracket attachment, bracket and surge arresters	☐	☐
Manufacturer		
Type designation		

23 REQUESTED ALTERNATIVES

Requested alternatives according to these guidelines and / or IEC			
	Guideline Clause	IEC 60076-1 Clause	Requested alternative
☐	5.1		Extended bushing turrets
☐	11.9		Gas and oil actuated relay inspection platform
☐	15.1.3		Accessory summary plate
☐	15.1.4		Oil circuit diagram
☐	18		Design review
☐	20.2		Tests in service carried out by the client
☐	20.2		Tests in service carried out by the supplier
☐		10.1.3.h	Measurement of power taken by fans and oil pumps (if applicable)
☐			
☐			
☐			
☐			
☐			

24 TENDER ENCLOSURES

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

Principal gauge arrangement drawing	☐	
	☐	
	☐	
	☐	
	☐	
	☐	
	☐	
	☐	
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25 OTHERS