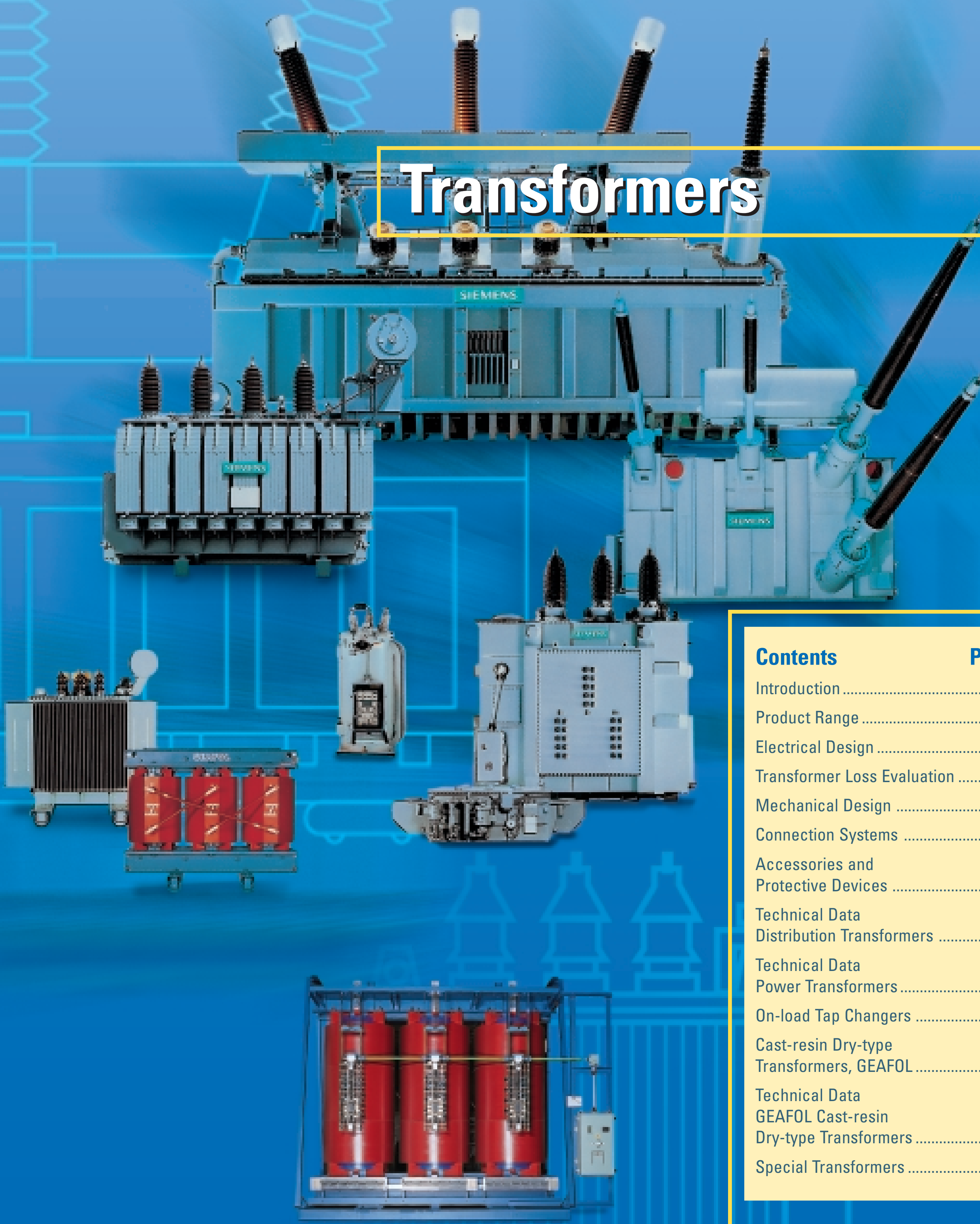

Transformers

Contents **Page**

Introduction

Transformers are one of the primary components for the transmission and distribution of electrical energy.
Their design results mainly from the range of application, the construction, the rated power and the voltage level.

The scope of transformer types starts with generator transformers and ends with distribution transformers.
Transformers which are directly connected to the generator of the power station are called generator transformers. Their power range goes up to far above 1000 MVA. Their voltage range extends to approx. 1500 kV.

The connection between the different high-voltage system levels is made via network transformers (network interconnecting transformers). Their power range exceeds 1000 MVA. The voltage range exceeds 1500 kV.

Distribution transformers are within the range from 50 to 2500 kVA and max. 36 kV. In the last step, they distribute the electrical energy to the consumers by feeding from the high-voltage into the low-voltage distribution network. These are designed either as liquid-filled or as dry-type transformers.

Transformers with a rated power up to 2.5 MVA and a voltage up to 36 kV are referred to as distribution transformers; all transformers of higher ratings are classified as power transformers.

In addition, there are various special-purpose transformers such as converter transformers, which can be both in the range of power transformers and in the range of distribution transformers as far as rated power and rated voltage are concerned.

As special elements for network stabilization, arc-suppression coils and compensating reactors are available. Arc-suppression coils compensate the capacitive current flowing through a ground fault and thus guarantee uninterrupted energy supply. Compensating reactors compensate the capacitive power of the cable networks and reduce overvoltages in case of load rejection; the economic efficiency and stablility of the power transmission are improved.

The general overview of our manufacturing/delivery program is shown in the table "Product Range".

	Rated power [MVA]	**Max. operating voltage [kV]**	**Figs. on page**
Oil distribution transformers	0.05–2.5	≤ 36	**5**/13–**5**/17
Power transformers	2.5–3000	36–1500	**5**/18–**5**/25
GEAFOL-cast-resin transformers	0.10–20	≤ 36	**5**/27–**5**/34

Fig. 1: Transformer types

Standards and specifications, general

The transformers comply with the relevant VDE specifications, i.e. DIN VDE 0532 "Transformers and reactors" and the "Technical conditions of supply for three-phase transformers" issued by VDEW and ZVEI.

Therefore they also satisfy the requirements of IEC Publication 76, Parts 1 to 5 together with the standards and specifications (HD and EN) of the European Union (EU).

Enquiries should be directed to the manufacturer where other standards and specifications are concerned. Only the US (ANSI/NEMA) and Canadian (CSA) standards differ from IEC by any substantial degree. A design according to these standards is also possible.

Important additional standards

- **DIN 42 500, HD 428:** oil-immersed three-phase distribution transformers 50–2500 kVA
- **DIN 42 504:** oil-immersed three-phase transformers 2–10 MVA
- **DIN 42 508:** oil-immersed three-phase transformers 12.5–80 MVA
- **DIN 42 523, HD 538:** three-phase dry-type transformers 100–2500 kVA
- **DIN 45 635 T30:** noise level
- **IEC 289:** reactance coils and neutral grounding transformers
- **IEC 551:** measurement of noise level
- **IEC 726:** dry-type transformers
- **RAL:** coating/varnish

Product Range

Oil-immersed distribution transformers, TUMETIC, TUNORMA

- 50 to 2 500 kVA, highest voltage for equipment up to 36 kV, with copper or aluminum windings, hermetically sealed (TUMETIC®) or with conservator (TUNORMA®) of three- or single-phase design

Generator and power transformers

- Above 2.5 MVA up to more than 1000 MVA, above 30 kV up to 1500 kV (system and system interconnecting transformers, with separate windings or auto-connected), with on-load tap changers or off-circuit tap changers, of three- or single-phase design

Cast-resin distribution and power transformers GEAFOL

- 100 kVA to more than 20 MVA, highest voltage for equipment up to 36 kV, of three- or single-phase design
  GEAFOL®-SL substations

Special transformers for industry, traction and HVDC transmission systems

- Furnace and converter transformers
- Traction transformers mounted on rolling stock and appropriate on-load tap-changers
- Substation transformers for traction systems
- Transformers for train heating and point heating
- Transformers for HVDC transmission systems
- Transformers for audio frequencies in power supply systems
- Three-phase neutral electromagnetic couplers and grounding transformers
- Ignition transformers

Reactors

- Liquid-immersed shunt and current-limiting reactors up to the highest rated powers
- Reactors for HVDC transmission systems

Accessories

- Buchholz relays, oil testing equipment, oil flow indicators and other monitoring devices
- Fan control cabinets, control cabinets for parallel operation and automatic voltage control
- Sensors (PTC, Pt 100)

Service

- Advisory services for transformer specifications
- Organization, coordination and supervision of transportation
- Supervision of assembly and commissioning
- Service/inspection troubleshooting services
- Training of customer personnel
- Investigation and assessment of oil problems

Fig. 2

5

Electrical Design

Power ratings and type of cooling

All power ratings in this guide are the product of rated voltage (times phase-factor for three-phase transformers) and rated current of the line side winding (at center tap, if several taps are provided), expressed in kVA or MVA, as defined in IEC 76-1. If only one power rating and no cooling method are shown, natural oil-air cooling (ONAN or OA) is implied for oil-immersed transformers. If two ratings are shown, forced-air cooling (ONAF or FA) in one or two steps is applicable.

For cast resin transformers, natural air cooling (AN) is standard. Forced air cooling (AF) is also applicable.

Temperature rise

In accordance with IEC-76 the standard temperature rise for oil-immersed power and distribution transformers is:

- 65 K average winding temperature (measured by the resistance method)
- 60 K top oil temperature (measured by thermometer)

The standard temperature rise for Siemens cast-resin transformers is

- 100 K (insulation class F) at HV and LV winding.

Whereby the standard ambient temperatures are defined as follows:

- 40 °C maximum temperature,
- 30 °C average on any one day,
- 20 °C average in any one year,
- –25 °C lowest temperature outdoors,
- –5 °C lowest temperature indoors.

Higher ambient temperatures require a corresponding reduction in temperature rise, and thus affect price or rated power as follows:

- 1.5% surcharge for each 1 K above standard temperature conditions, or
- 1.0% reduction of rated power for each 1 K above standard temperature conditions.

These adjustment factors are applicable up to 15 K above standard temperature conditions.

Altitude of installation

The transformers are suitable for operation at altitudes up to 1000 meters above sea level. Site altitudes above 1000 m necessitate the use of special designs and an increase/or a reduction of the transformer ratings as follows (approximate values):

- 2% increase for every 500 m altitude (or part there of) in excess of 1000 m, or
- 2% reduction of rated power for each 500 m altitude (or part there of) in excess of 1000 m.

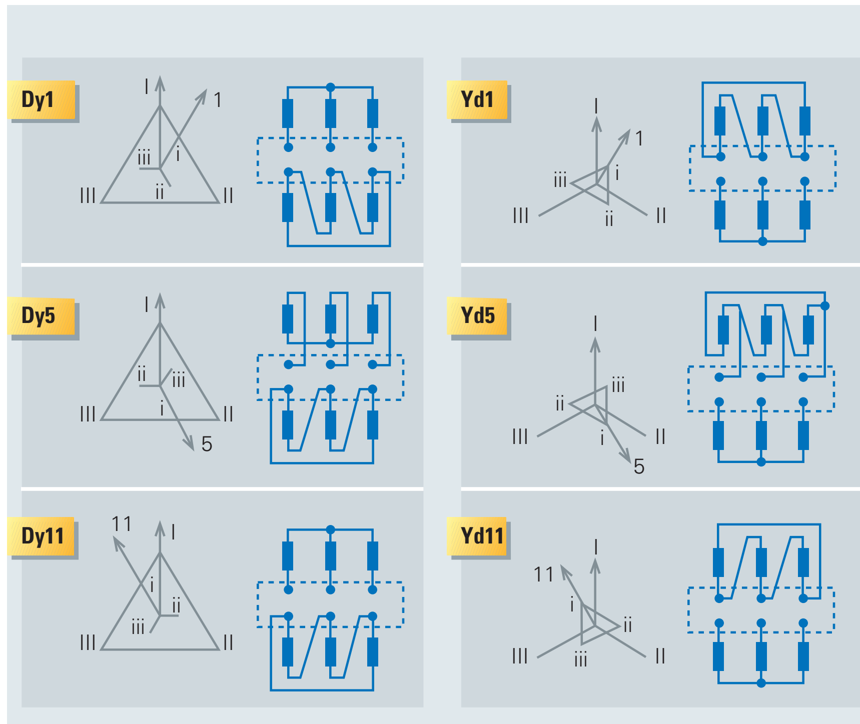

Fig. 3: Most commonly used vector groups

Transformer losses and efficiencies

Losses and efficiencies stated in this guide are average values for guidance only. They are applicable if no loss evaluation figure is stated in the inquiry (see following chapter) and they are subject to the tolerances stated in IEC 76-1, namely +10% of the total losses, or +15% of each component loss, provided that the tolerance for the total losses is not exceeded.

If optimized and/or guaranteed losses without tolerances are required, this must be stated in the inquiry.

Connections and vector groups

Distribution transformers

The transformers listed in this guide are all three-phase transformers with one set of windings connected in star (wye) and the other one in delta, whereby the neutral of the star-connected winding is fully rated and brought to the outside.

The primary winding (HV) is normally connected in delta, the secondary winding (LV) in wye. The electrical offset of the windings in respect to each other is either 30, 150 or 330 degrees standard (Dy1, Dy5, Dy11). Other vector groups as well as single-phase transformers and autotransformers on request (Fig. 3).

Power transformers

Generator transformers and large power transformers are usually connected in Yd. For HV windings higher than 110 kV, the neutral has a reduced insulation level. For star/star-connected transformers and autotransformers normally a tertiary winding in delta, whose rating is a third of that of the transformer, has to be added. This stabilizes the phase-to phase voltages in the case of an unbalanced load and prevents the displacement of the neutral point.

Single-phase transformers and autotransformers are used when the transportation possibilities are limited. They will be connected at site to three-phase transformer banks.

Electrical Design

Insulation level

Power-frequency withstand voltages and lightning-impulse withstand voltages are in accordance with IEC 76-3, Para. 5, Table II, as follows:

Highest voltage for equipment U_m (r. m. s.) [kV]	Rated short-duration power-frequency withstand voltage (r. m. s.) [kV]	Rated lightning-impulse withstand voltage (peak) List 1 [kV]	List 2 [kV]
≤ 1.1	3	–	–
3.6	10	20	40
7.2	20	40	60
12.0	28	60	75
17.5	38	75	95
24.0	50	95	125
36.0	70	145	170
52.0	95	250	
72.5	140	325	
123.0	185	450	
	230	550	
145.0	275	650	
170.0	325	750	
	360	850	
245.0	395	950	

Higher test voltage withstand requirements must be stated in the inquiry and may result in a higher price.

Fig. 4: Insulation level

Conversion to 60 Hz – possibilities

All ratings in the selection tables of this guide are based on 50 Hz operation.
For 60 Hz operation, the following options apply:

- 1. Rated power and impedance voltage are increased by 10%, all other parameters remain identical.
- 2. Rated power increases by 20%, but no-load losses increase by 30% and noise level increases by 3 dB, all other parameters remain identical (this layout is not possible for cast-resin transformers).
- 3. All technical data remain identical, price is reduced by 5%.
- 4. Temperature rise is reduced by 10 K, load losses are reduced by 15%, all other parameters remain identical.

Overloading

Overloading of Siemens transformers is guided by the relevant IEC-354 "Loading guide for oil-immersed transformers" and the (similar) ANSI C57.92 "Guide for loading mineral-oil-immersed power transformers".

Overloading of GEAFOL cast-resin transformers on request.

Routine and special tests

All transformers are subjected to the following routine tests in the factory:

- Measurement of winding resistance
- Measurement of voltage ratio and check of polarity or vector group
- Measurement of impedance voltage
- Measurement of load loss
- Measurement of no-load loss and no-load current
- Induced overvoltage withstand test
- Seperate-source voltage withstand test
- Partial discharge test (only GEAFOL cast-resin transformers).

The following special tests are optional and must be specified in the inquiry:

- Lightning-impulse voltage test (LI test), full-wave and chopped-wave (specify)
- Partial discharge test
- Heat-run test at natural or forced cooling (specify)
- Noise level test
- Short-circuit test.

Test certificates are issued for all the above tests on request.

Transformer cell (indoor installation)

The transformer cell must have the necessary electrical clearances when an open air connection is used. The ventilation system must be large enough to fulfill the recommendations for the maximum temperatures according to IEC.

For larger power transformers either an oil/water cooling system has to be used or the oil/air cooler (radiator bank) has to be installed outside the transformer cell.

In these cases a ventilation system has to be installed also to remove the heat caused by the convection of the transformer tank.

Transformer Loss Evaluation

The sharply increased cost of electrical energy has made it almost mandatory for buyers of electrical machinery to carefully evaluate the inherent losses of these items. In case of distribution and power transformers, which operate continuously and most frequently in loaded condition, this is especially important. As an example, the added cost of loss-optimized transformers can in most cases be recovered via savings in energy use in less than three years.

Low-loss transformers use more and better materials for their construction and thus initially cost more. By stipulating loss evaluation figures in the transformer inquiry, the manufacturer receives the necessary incentive to provide a loss-optimized transformer rather than the low-cost model.

Detailed loss evaluation methods for transformers have been developed and are described accurately in the literature, taking the project-specific evaluation factors of a given customer into account.

The following simplified method for a quick evaluation of different quoted transformer losses is given, making the following assumptions:

- The transformers are operated continuously
- The transformers operate at partial load, but this partial load is constant
- Additional cost and inflation factors are not considered
- Demand charges are based on 100% load.

The total cost of owning and operating a transformer for one year is thus defined as follows:

- A. Capital cost C_c taking into account the purchase price C_p, the interest rate p, and the depreciation period n
- B. Cost of no-load loss C_{P0}, based on the no-load loss P_0, and energy cost C_e
- C. Cost of load loss C_{pk}, based on the copper loss P_k, the equivalent annual load factor a, and energy cost C_e
- D. Demand charges C_d, based on the amount set by the utility, and the total kW of connected load.

These individual costs are calculated as follows:

A. Capital cost

$$C_c = \frac{C_p \cdot r}{100} \quad \left[\frac{\text{amount}}{\text{year}}\right]$$

C_p = purchase price

$r = \frac{p \cdot q^n}{q^n - 1}$ = depreciation factor

$q = \frac{p}{100} + 1$ = interest factor

p = interest rate in % p.a.

n = depreciation period in years

B. Cost of no-load loss

$$C_{P0} = C_e \cdot 8760\ \text{h/year} \cdot P_0 \quad \left[\frac{\text{amount}}{\text{year}}\right]$$

C_e = energy charges $\left[\frac{\text{amount}}{\text{kWh}}\right]$

P_0 = no-load loss [kW]

C. Cost of load loss

$$C_{Pk} = C_e \cdot 8760\ \text{h/year} \cdot \alpha^2 \cdot P_k \quad \left[\frac{\text{amount}}{\text{year}}\right]$$

$\alpha = \frac{\text{constant operation load}}{\text{rated load}}$

P_k = copper loss [kW]

D. Cost resulting from demands charges

$$C_D = C_d\,(P_0 + P_k) \quad \left[\frac{\text{amount}}{\text{year}}\right]$$

C_d = demand charges $\left[\frac{\text{amount}}{\text{kW} \cdot \text{year}}\right]$

Fig. 5

Transformer Loss Evaluation

To demonstrate the usefulness of such calculations, the following arbitrary examples are shown, using factors that can be considered typical in Germany, and neglecting the effects of inflation on the rate assumed:

Example: 1600 kVA distribution transformer

Depreciation period	n = 20 years	Depreciation factor
Interest rate	p = 12% p. a.	r = 13.39
Energy charge	C_e = 0.25 DM/kWh	
Demand charge	$C_d = 350 \dfrac{\text{DM}}{\text{kW} \cdot \text{yr}}$	
Equivalent annual load factor	α = 0.8	

A. Low-cost transformer

P_0 = 2.6 kW — no-load loss
P_k = 20 kW — load loss
C_p = DM 25 000 — purchase price

$$C_c = \frac{25000 \cdot 13.39}{100} = \text{DM } 3348/\text{year}$$

$$C_{P0} = 0.25 \cdot 8760 \cdot 2.6 = \text{DM } 5694/\text{year}$$

$$C_{Pk} = 0.25 \cdot 8760 \cdot 0.64 \cdot 20 = \text{DM } 28\,032/\text{year}$$

$$C_D = 350 \cdot (2.6 + 20) = \text{DM } 7910/\text{year}$$

Total cost of owning and operating this transformer is thus:

DM 44 984.–/year

B. Loss-optimized transformer

P_0 = 1.7 kW — no-load loss
P_k = 17 kW — load loss
C_p = DM 28 000 — purchase price

$$C_c = \frac{28000 \cdot 13.39}{100} = \text{DM } 3\,749/\text{year}$$

$$C_{P0} = 0.25 \cdot 8760 \cdot 1.7 = \text{DM } 3\,723/\text{year}$$

$$C_{Pk} = 0.25 \cdot 8760 \cdot 0.64 \cdot 17 = \text{DM } 23\,827/\text{year}$$

$$C_D = 350 \cdot (1.7 + 17) = \text{DM } 6\,545/\text{year}$$

Total cost of owning and operating this transformer is thus:

DM 37 844.–/year

The energy saving of the optimized distribution transformer of **DM 7140 per year** pays for the increased purchase price in less than one year.

Fig. 6

Mechanical Design

General mechanical design for oil-immersed transformers:

- Iron core made of grain-oriented electrical sheet steel insulated on both sides, core-type.
- Windings consisting of copper section wire or copper strip. The insulation has a high disruptive strength and is temperature-resistant, thus guaranteeing a long service life.
- Designed to withstand short circuit for at least 2 seconds (IEC).
- Oil-filled tank designed as tank with strong corrugated walls or as radiator tank.
- Transformer base with plain or flanged wheels (skid base available).
- Cooling/insulation liquid: Mineral oil according to VDE 0370/IEC 296. Silicone oil or synthetic liquids are available.
- Standard coating for indoor installation. Coatings for outdoor installation and for special applications (e.g. aggressive atmosphere) are available.

5

Tank design and oil preservation system

Sealed-tank distribution transformers, TUMETIC®

In ratings up to 2500 kVA and 170 kV LI this is the standard sealed-tank distribution transformer without conservator and gas cushion. The TUMETIC transformer is always completely filled with oil; oil expansion is taken up by the flexible corrugated steel tank (variable volume tank design), whereby the maximum operating pressure remains at only a fraction of the usual. These transformers are always shipped completely filled with oil and sealed for their lifetime. Bushings can be exchanged from the outside without draining the oil below the top of the active part.

The hermetically sealed system prevents oxygen, nitrogen, or humidity from contact with the insulating oil. This improves the aging properties of the oil to the extent that no maintenance is required on these transformers for their lifetime. Generally the TUMETIC transformer is lower than the TUNORMA transformer. This design has been in successful service since 1973. A special TUMETIC-Protection device has been developed for this transformer.

Distribution transformers with conservator, TUNORMA®

This is the standard distribution transformer design in all ratings. The oil level in the tank and the top-mounted bushings is kept constant by a conservator vessel or expansion tank mounted at the highest point of the transformer. Oil-level changes due to thermal cycling affect the conservator only. The ambient air is prevented from direct contact with the insulating oil through oil-traps and dehydrating breathers.

Tanks from 50 to approximately 4000 kVA are preferably of the corrugated steel design, whereby the sidewalls are formed on automatic machines into integral cooling pockets. Suitable spot welds and braces render the required mechanical stability. Tank bottom and cover are fabricated from rolled and welded steel plate.

Conventional radiators are available.

Power transformers

Power transformers of all ratings are equipped with conservators. Both the open and closed system are available.

With the closed system "TUPROTECT®" the oil does not come into contact with the surrounding air. The oil expansion is compensated with an air bag. (This design is also available for greater distribution transformers on request).
The sealing bag consists of strong nylon braid with a special double lining of ozone and oil-resistant nitrile rubber. The interior of this bag is in contact with the ambient air through a dehydrating breather;
the outside of this bag is in direct contact with the oil.
All tanks, radiators and conservators (incl. conservator with airbag) are designed for vacuum filling of the oil.
For transformers with on-load tap changers a seperate smaller conservator is necessary for the diverter switch compartment. This seperate conservator (without air bag) is normally an integrated part of the main conservator with its own magnetic oil level indicator.
Power transformers up to 10 MVA are fitted with weld-on radiators and are shipped extensively assembled; shipping conditions permitting.
Ratings above 10 MVA require detachable radiators with individual butterfly valves, and partial dismantling of components for shipment.
All the usual fittings and accessories for oil treatment, shipping and installation of these transformers are provided as standard. For monitoring and protective devices, see the listing on page **5**/11.

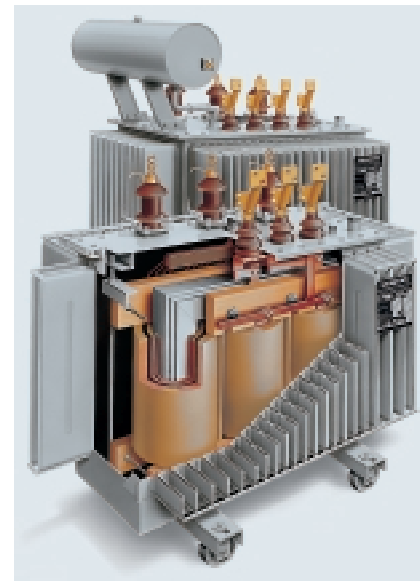

Fig. 7: Cross section of a TUMETIC three-phase distribution transformer

Fig. 8: 630 kVA, three-phase, TUNORMA 20 kV ± 2.5 %/0.4 kV distribution transformer

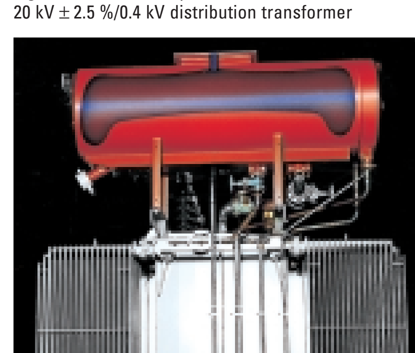

Fig. 9: Practically maintenancefree: transformer with the TUPROTECT air-sealing system built into the conservator

Connection Systems

Distribution transformers

All Siemens transformers have top-mounted HV and LV bushings according to DIN in their standard version. Besides the open bushing arrangement for direct connection of bare or insulated wires, three basic insulated termination systems are available:

Fully enclosed terminal box for cables (Fig. 11)

Available for either HV or LV side, or for both. Horizontally split design in degree of protection IP 44 or IP 54. (Totally enclosed and fully protected against contact with live parts, plus protection against drip, splash, or spray water.)

Cable installation through split cable glands and removable plates facing diagonally downwards. Optional conduit hubs. Suitable for single-core or three-phase cables with solid dielectric insulation, with or without stress cones. Multiple cables per phase are terminated on auxiliary bus structures attached to the bushings. Removal of transformer by simply bending back the cables.

Insulated plug connectors (Fig. 12)

For substation installations, suitable HV can be attached via insulated elbow connectors in LI ratings up to 170 kV.

Flange connection (Fig. 13)

Air-insulated bus ducts, insulated busbars, or throat-connected switchgear cubicles are connected via standardized flanges on steel terminal enclosures. These can accommodate either HV, LV, or both bushings. Fiberglass-reinforced epoxy partitions are available between HV and LV bushings if flange/flange arrangements are chosen.

The following combinations of connection systems are possible besides open bushing arrangements:

HV	LV
Cable box	Cable box
Cable box	Flange/throat
Flange	Cable box
Flange	Flange/throat
Elbow connector	Cable box
Elbow connector	Flange/throat

Fig. 10: Combination of connection systems

Fig. 11: Fully enclosed cable connection box

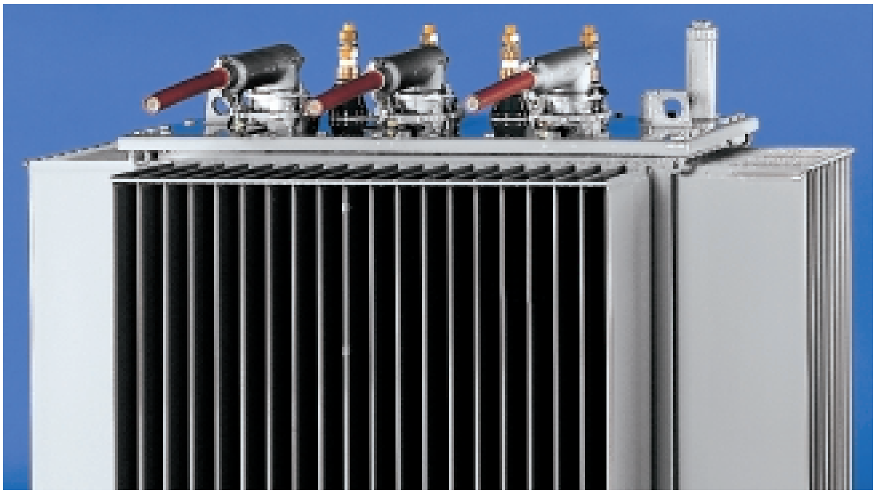

Fig. 12: Grounded metal-elbow plug connectors

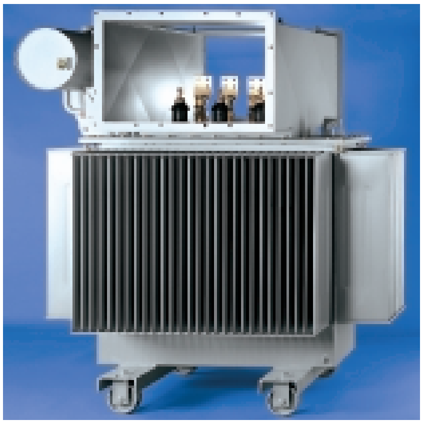

Fig 13: Flange connection for switchgear and bus ducts

Connection Systems

Power transformers

The most frequently used type of connection for transformers is the outdoor bushing.

Depending on voltage, current, system conditions and transport requirements, the transformers will be supplied with bushings arranged vertically, horizontally or inclined. Up to about 110 kV it is usual to use oil-filled bushings according to DIN; condenser bushings are normally used for higher voltages.

Limited space or other design considerations often make it necessary to connect cables directly to the transformer. For voltages up to 30 kV air-filled cable boxes are used. For higher voltages the boxes are oil-filled. They may be attached to the tank cover or to its walls (Fig. 14).

The space-saving design of SF_6-insulated switchgear is one of its major advantages. The substation transformer is connected directly to the SF_6 switchgear. This eliminates the need for an intermediate link (cable, overhead line) between transformer and system (Fig. 15).

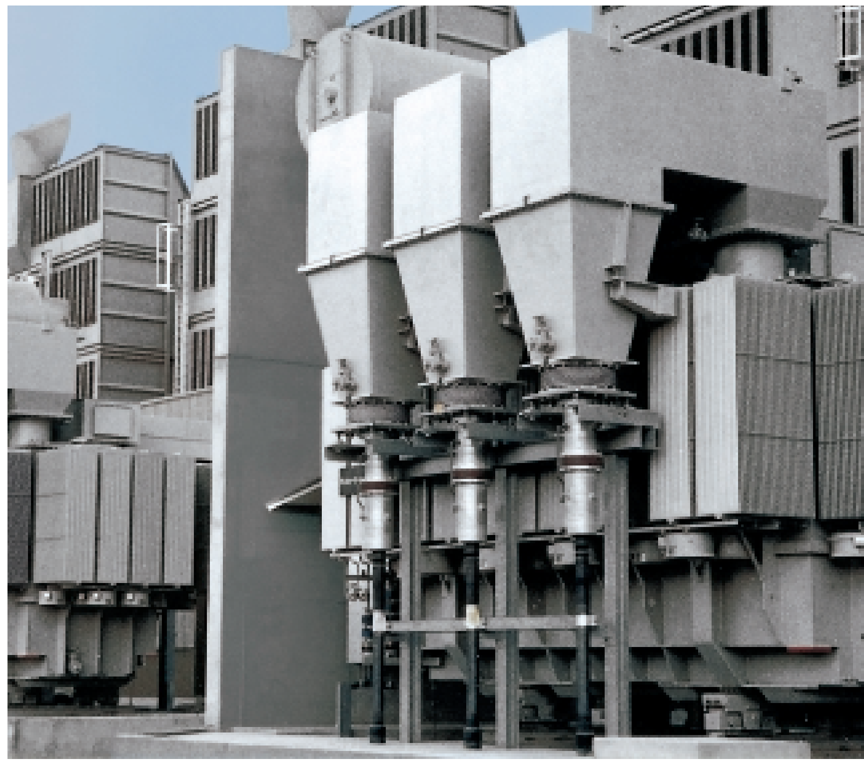

Fig. 14: Transformers with oil-filled HV cable boxes

Fig. 15: Direct SF_6-connection of the transformer to the switchgear

5

Accessories and Protective Devices

Accessories not listed completely.
Deviations are possible.

Double-float Buchholz relay (Fig. 16)

For sudden pressure rise and gas detection in oil-immersed transformer tanks with conservator. Installed in the connecting pipe between tank and conservator and responding to internal arcing faults and slow decomposition of insulating materials. Additionally, backup function of oil alarm.

The relay is actuated either by pressure waves or gas accumulation, or by loss of oil below the relay level. Seperate contacts are installed for alarm and tripping.

In case of a gas accumulation alarm, gas samples can be drawn directly at the relay with a small chemical testing kit. Discoloring of two liquids indicates either arcing byproducts or insulation decomposition products in the oil. No change in color indicates an air bubble.

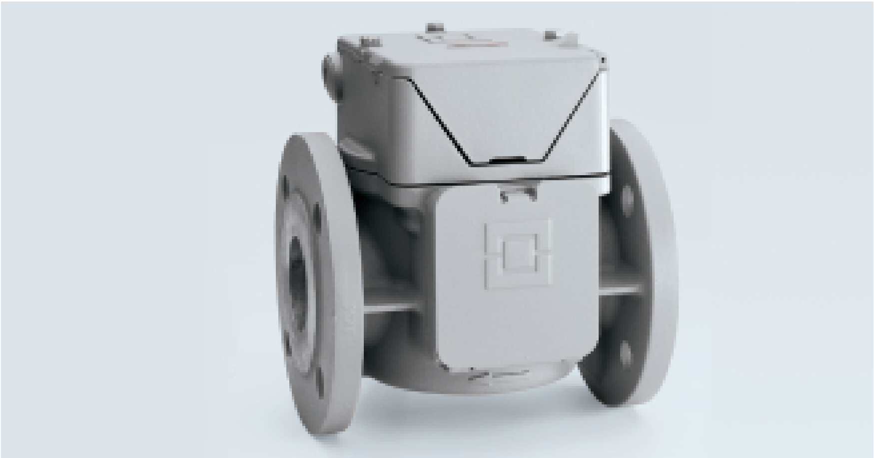

Fig. 16: Double-float Buchholz relay

Dial-type contact thermometer (Fig. 17)

Indicates actual top-oil temperature via capillary tube. Sensor mounted in well in tank cover. Up to four separately adjustable alarm contacts and one maximum pointer are available. Installed to be readable from the ground.

With the addition of a CT-fed thermal replica circuit, the simulated hot-spot winding temperature of one or more phases can be indicated on identical thermometers. These instruments can also be used to control forced cooling equipment.

Fig. 17: Dial-type contact thermometer

Magnetic oil-level indicator (Fig. 18)

The float position inside of the conservator is transmitted magnetically through the tank wall to the indicator to preserve the tank sealing standard device without contacts; devices supplied with limit (position) switches for high- and low-level alarm are available. Readable from the ground.

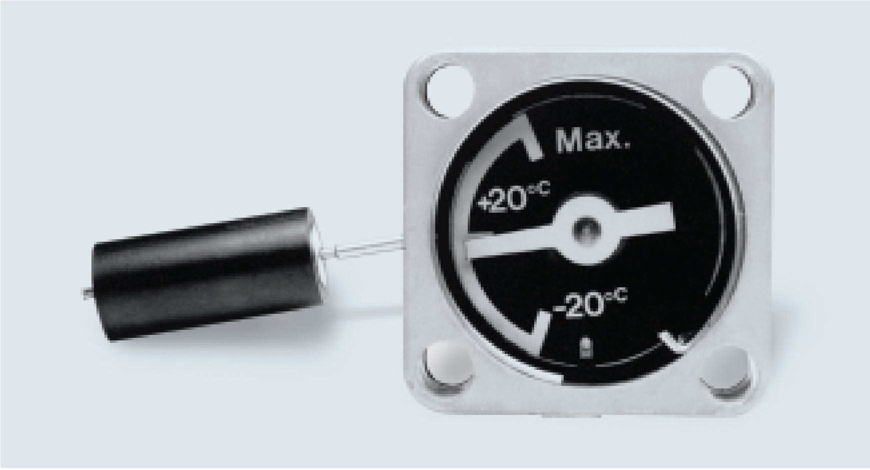

Fig. 18: Magnetic oil-level indicator

Accessories and Protective Devices

Fig. 19: Protective device for hermetically sealed transformers (TUMETIC)

Fig. 20: Pressure relief device with alarm contact and automatic resetting

Fig. 21: Dehydrating breather A DIN 42 567 up to 5 MVA

Fig. 22: Dehydrating breather L DIN 42 562 over 5 MVA

Protective device (Fig. 19) for hermetically sealed transformers (TUMETIC)

For use on hermetically sealed TUMETIC distribution transformers. Gives alarm upon loss of oil and gas accumulation. Mounted directly at the (permanently sealed) filler pipe of these transformers.

Pressure relief device (Fig. 20)

Relieves abnormally high internal pressure shock waves. Easily visible operation pointer and alarm contact. Reseals positively after operation and continues to function without operator action.

Dehydrating breather (Fig. 21, 22)

A dehydrating breather removes most of the moisture from the air which is drawn into the conservator as the transformer cools down. The absence of moisture in the air largely eliminates any reduction in the breakdown strength of the insulation and prevents any buildup of condensation in the conservator. Therefore, the dehydrating breather contributes to safe and reliable operation of the transformer.

Bushing current transformer

Up to three ring-type current transformers per phase can be installed in power transformers on the upper and lower voltage side. These multiratio CTs are supplied in all common accuracy and burden ratings for metering and protection. Their secondary terminals are brought out to short-circuiting-type terminal blocks in watertight terminal boxes.

Additional accessories

Besides the standard accessories and protective devices there are additional items available, especially for large power transformers. They will be offered and installed on request.

Examples are:

- Fiber-optic temperature measurements
- Permanent gas-in-oil analysis
- Permanent water-content measurement
- Sudden pressure rise relay,

etc.