High Voltage Products
The complete portfolio from one source

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Answers for energy.
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High-voltage products and devices are the basis for an efficient, high-performance, safe and reliable energy transmission. Our high-voltage products meet your requirements in terms of low life cycle costs with optimum availability in continuous operation. They have a long service life and are also extremely earthquake-resistant and weatherproof.

The technology of our products sets international standards. We ensure the high quality of the high-voltage products through optimized production processes, continuous product development and a certified quality management system.

This brochure showcases our portfolio of high-voltage products and devices. The portfolio comprises circuit breakers and disconnectors, surge arresters, instrument transformers, coil products, and last but not least bushings. All high-voltage products meet a wide variety of local requirements, offering additional benefit to customers. They represent key technologies for the future. At the same time, all our developments and innovations are distinguished by energy efficiency, economy, reliability, and make a contribution to protecting the environment and sustainability.

Our high-voltage products are an important part of our comprehensive energy conversion portfolio. We are the only company worldwide that supports customers along the entire chain of energy conversion with our own efficient products, solutions and know-how – from the oil and gas production to power generation and the transmission and distribution of electrical energy. By choosing Siemens, you choose experience and expertise – and a partner that can meet all your power transmission and distribution needs.

Our specialist subsidiaries Hochspannungsgeräte GmbH, Troisdorf (HSP) and Trench Electric are global leaders in their field: HSP is a leading company in the production of bushings. The Trench Group is a worldwide leading manufacturer of high voltage products such as instrument transformers, bushings and reactors. This includes a wide range of bushings products for Power Transformers, Gas Insulated Substations, Breakers, Generators, Buildings, Test Equipment, Rail Road Systems, HVDC and other specialty applications.
Circuit Breakers for 72.5 kV up to 800 kV

Circuit Breakers and Disconnectors

Circuit breakers are the central part of AIS and GIS switchgear. They have to meet high requirements in terms of:

- Reliable opening and closing
- Consistent quenching performance with rated and short-circuit currents even after many switching operations
- High-performance, reliable, maintenance-free operating mechanisms.

Technology reflecting the latest state of the art and years of operating experience are put to use in constant further development and optimization of Siemens circuit breakers. This makes Siemens circuit breakers able to meet all the demands placed on high-voltage switchgear.

The comprehensive quality system is certified according to DIN EN ISO 9001. It covers development, manufacturing, sales, commissioning and after-sales service. Test laboratories are accredited to EN 45001 and PEHLA/STL.

The modular design

Circuit breakers for air-insulated switchgear are individual components, and are assembled together with all individual electrical and mechanical components of an AIS installation on site.

Due to the consistent application of a modular design, all Siemens circuit breaker types, whether air-insulated or gas-insulated, are made up of the same range of components based on our well-proven platform design (fig. 1):

- Interrupter unit
- Operating mechanism
- Sealing system
- Operating rod
- Control elements.

Interrupter unit – self-compression arc-quenching principle

The Siemens product range from 72.5 kV up to 800 kV includes high-voltage circuit breakers with self-compression interrupter units – for optimum switching performance under every operating condition for every voltage level.

Self-compression circuit breakers

3AP high-voltage circuit breakers for the complete voltage range ensure optimum use of the thermal energy of the arc in the contact cylinder. This is achieved by the self-compression interrupter unit.

Siemens patented this method for arc quenching in 1973. Since that time, Siemens has continued to develop the technology of the self-compression interrupter unit. One of its technical innovations is that the arc energy is increasingly used to extinguish the arc. In short-circuit breaking operations, the actuating energy required is reduced to the energy needed for mechanical contact movement.

That means that the operating energy is truly minimized. The self-compression interrupter unit allows the use of a compact stored-energy spring mechanism that provides unrestricted high dependability.

Stored-energy spring mechanism – for the complete product range

The operating mechanism is a central part of the high-voltage circuit breakers. The drive concept of the 3AP high-voltage circuit breakers is based on the stored-energy spring principle. The use of such an operating mechanism for voltage ranges of up to 800 kV became appropriate as a result of the development of a self-compression interrupter unit that requires minimal actuating energy.

Advantages of the stored-energy spring mechanism are:

- Highest degree of operational safety: It is a simple and sturdy design and uses the same principle for rated voltages from 72.5 kV up to 800 kV with just a few
Fig. 1: Circuit breaker parts: circuit breaker for air-insulated switchgear (top), circuit breaker in SF$_6$-insulated switchgear (bottom)
moving parts. Due to the self-compression design of the interrupter unit, only low actuating forces are required.

- Availability and long service life: Minimal stressing of the latch mechanisms and rolling-contact bearings in the operating mechanism ensure reliable and wear-free transmission of forces.
- Maintenance-free design: The spring charging gear is fitted with wear-free spur gears, enabling load-free decoupling.

Siemens circuit breakers for rated voltage levels from 72.5 kV up to 800 kV are equipped with self-compression interrupter units and stored-energy spring mechanisms.

For special technical requirements such as rated short-circuit breaking currents of 80 kA, Siemens can offer twin-nozzle circuit breaker series 3AQ or 3AT with an electrohydraulic mechanism.

### The interrupter unit: self-compression system

#### The conducting path

The current conducting path of the interrupter unit consists of the contact support (2), the base (7) and the movable contact cylinder (6). In the closed position, the current flows via the main contact (4) and the contact cylinder (6); (fig. 2).

#### Breaking operating currents

During the opening operation, the main contact (4) opens first, and the current commutates to the still closed arcing contact. During the further course of opening, the arcing contact (5) opens and an arc is drawn between the contacts. At the same time, the contact cylinder (6) moves into the base (7) and compresses the SF$_6$ gas located there. This gas compression creates a gas flow through the contact cylinder (6) and the nozzle (3) to the arcing contact, extinguishing the arc.
Breaking fault currents
In the event of interrupting high short-circuit breaking currents, the SF₆ gas is heated up considerably at the arcing contact due to the energy of the arc. This leads to a pressure increase in the contact cylinder. During the further course of opening, this increased pressure initiates a gas flow through the nozzle (3), extinguishing the arc. In this case, the arc energy is used to interrupt the fault current. This energy needs not be provided by the operating mechanism.

Major features:
• Self-compression interrupter unit
• Use of the thermal energy of the arc
• Minimized energy consumption
• High reliability for a long time.

The operating mechanism
Stored-energy spring mechanism
Siemens circuit breakers for voltages up to 800 kV are equipped with stored-energy spring mechanisms. These operating mechanisms are based on the same principle that has been prove its worth in Siemens low-voltage and medium-voltage circuit breakers for decades. The design is simple and robust, with few moving parts and a vibration-isolated latch system of the highest reliability. All components of the operating mechanism, the control and monitoring equipment and all terminal blocks are arranged in a compact and convenient way in one cabinet.

Depending on the design of the operating mechanism, the energy required for switching is provided by individual compression springs (i.e., one per pole) or by springs that function jointly on a 3-pole basis.
The principle of the operating mechanism with charging gear and latching is identical on all types (fig. 3, fig. 4). Differences between mechanism types are in the number, size and arrangement of the opening and closing springs.

Main features at a glance:
• Uncomplicated, robust construction with few moving parts
• Maintenance-free
• Vibration-isolated latches
• Load-free uncoupling of charging mechanism
• Easy access
• 10,000 operating cycles.
Live-Tank Circuit Breakers for 72.5 kV up to 800 kV

Live-tank circuit breakers for air-insulated switchgear
All live-tank circuit breakers are of the same general modular design, as shown in fig. 5 to fig. 9.

They consist of the following main components based on our well established platform concept:
- Self-compression interrupter unit
- Stored-energy spring mechanism
- Insulator column (AIS)
- Operating rod
- Circuit breaker base
- Control unit.

The uncomplicated design of the circuit breakers and the use of many similar components, such as interrupter units, operating rods, control cubicles and operating mechanisms, ensure high reliability. The experience Siemens has gained from the use of the many circuit breakers in service has been applied in improvement of the design. The self-compression interrupter unit, for example, has proven its reliability in more than 100,000 installations all over the world.

The control unit includes all necessary devices for circuit breaker control and monitoring, such as:
- Pressure / SF₆ density monitors
- Relays for alarms and lockout
- Operation counters (upon request)
- Local circuit breaker control (upon request)
- Anti-condensation heaters.

Transport, installation and commissioning are performed with expertise and efficiency. The routine-tested circuit breaker is dismantled into a few subassemblies for transportation.

If desired, Siemens can provide appropriately qualified personnel for installation and commissioning.
<table>
<thead>
<tr>
<th>Type</th>
<th>3AP1</th>
<th>3AP2</th>
<th>3AP4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated voltage [kV]</td>
<td>72.5</td>
<td>123</td>
<td>145</td>
</tr>
<tr>
<td>Number of interrupter units per pole</td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Rated power-frequency withstand voltage/min [kV]</td>
<td>140</td>
<td>230</td>
<td>275</td>
</tr>
<tr>
<td>Rated lightning impulse withstand voltage/min [kV]</td>
<td>325</td>
<td>550</td>
<td>650</td>
</tr>
<tr>
<td>Rated switching impulse withstand voltage/min [kV]</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Rated normal current, up to [A]</td>
<td>4,000</td>
<td>4,000</td>
<td>4,000</td>
</tr>
<tr>
<td>Rated short-time withstand current (1 s – 3 s), up to $[kA_{(rms)}]$</td>
<td>40</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Rated peak withstand current, up to $[kA_{(peak)}]$</td>
<td>108</td>
<td>108</td>
<td>108</td>
</tr>
<tr>
<td>Rated short-circuit breaking current, up to $[kA_{(rms)}]$</td>
<td>40</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Rated short-circuit making current, up to $[kA_{(peak)}]$</td>
<td>108</td>
<td>108</td>
<td>108</td>
</tr>
<tr>
<td>Temperature range [°C]</td>
<td>–30 or –40 ... +40 or +50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rated operating sequence</td>
<td>0-0.3 s-CO-3 min-CO or CO-15 s-CO</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rated break time</td>
<td>3 cycles</td>
<td>2 cycles</td>
<td></td>
</tr>
<tr>
<td>Rated frequency [Hz]</td>
<td>50/60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type of operating mechanism</td>
<td>Stored-energy spring mechanism</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control voltage [V, DC]</td>
<td>48 ... 250</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motor voltage [V, DC] [V, AC]</td>
<td>48/60/110/125/220/250</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flashover distance phase-to-earth across open circuit breaker [mm]</td>
<td>700</td>
<td>1,200</td>
<td>1,200</td>
</tr>
<tr>
<td>Min. creepage distance phase-to-earth across open circuit breaker [mm]</td>
<td>2,248</td>
<td>3,625</td>
<td>3,625</td>
</tr>
<tr>
<td>Dimensions height [mm] width [mm] depth [mm]</td>
<td>3,810</td>
<td>4,360</td>
<td>4,360</td>
</tr>
<tr>
<td>Phase spacing (min.) [mm]</td>
<td>1,350</td>
<td>1,700</td>
<td>1,850</td>
</tr>
<tr>
<td>Circuit breaker mass [kg]</td>
<td>1,350</td>
<td>1,500</td>
<td>1,680</td>
</tr>
<tr>
<td>Maintenance after</td>
<td>25 years</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Values in accordance with IEC; other values available on request

Table 1: Technical data of circuit breakers 3AP1, 3AP2 and 3AP4
Dead-Tank Circuit Breakers for 72.5 kV up to 550 kV

Circuit breakers in dead-tank design
For certain substation designs, dead-tank circuit breakers might be required instead of the standard live-tank circuit breakers. The main feature of dead-tank technology is that the interrupter unit is accommodated in an earthed metal housing. The dead-tank circuit breaker offers particular advantages if the protection design requires the use of several current transformers per pole assembly. For this purpose, Siemens can offer dead-tank circuit breaker types (fig. 10, fig. 11).

Main features at a glance:
• Reliable opening and closing
  – Proven contact and self-compression arc-quenching system
  – Consistent quenching performance with rated and short-circuit currents – even after many switching operations
  – Similar uncomplicated design for all voltage levels
• High-performance, reliable operating mechanisms
  – Easy-to-actuate spring operating mechanisms
  – Low maintenance, economical and long service life
• Economy
  – Perfect finish
  – Simplified, quick installation process
  – Long maintenance intervals
  – High number of operating cycles
  – Long service life.
• Individual service
  – Close proximity to the customer
  – Order-specific documentation
  – Solutions tailored to specific problems
  – After-sales service available promptly worldwide
• The right qualifications
  – Expertise in all power supply matters
  – More than 40 years of experience with SF₆-insulated circuit breakers
  – A quality system certified to ISO 9001, covering development, manufacture, sales, installation and after-sales service
  – Our dead tank circuit breakers are developed according to the latest version of IEC 62271-1, IEC 62271-100 and ANSI C37.04, ANSI C37.06, C37.09
  – Test laboratories accredited to EN 45001 and PEHLA/STL.

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**Table 2: Technical data of dead-tank circuit breaker**

<table>
<thead>
<tr>
<th>Type</th>
<th>3AP1 DT / SPS2</th>
<th>3AP2/3 DT / SPS2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated voltage</td>
<td>72.5</td>
<td>123</td>
</tr>
<tr>
<td>Rated power-frequency withstand voltage [kV]</td>
<td>140 / 160</td>
<td>230 / 260</td>
</tr>
<tr>
<td>Rated lighting impulse withstand voltage [kV]</td>
<td>325 / 350</td>
<td>550</td>
</tr>
<tr>
<td>Rated switching impulse withstand voltage [kV]</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Rated nominal current up to [A]</td>
<td>4,000</td>
<td>4,000</td>
</tr>
<tr>
<td>Rated breaking current up to [kA]</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Operating mechanism type</td>
<td>Stored-energy spring mechanism</td>
<td></td>
</tr>
</tbody>
</table>

---

**Dead-tank circuit breaker**

**Type SPS2 and 3AP DT**

The type SPS2 power circuit breakers (table 2) are used for the US and ANSI markets, and the 3AP DT breaker types are offered in IEC markets. Both types are designed as general, definite-purpose circuit breakers for use at maximum rated voltages of 72.5 kV up to 550 kV.

**The design**

Dead-tank circuit breakers (except for the 550 kV version) consist of three identical pole units mounted on a common support frame. The opening and closing spring of the FA-type operating mechanism is transferred to the moving contacts of the interrupter unit through a system of connecting rods and a rotating seal at the side of each phase.

The connection to the overhead lines and busbars is realized by SF₆-insulated air bushings. The insulators are available in either porcelain or composite (epoxy-impregnated fiberglass tube with silicone rubber sheds) materials.
The tanks and the bushings are charged with SF$_6$ as at a rated pressure of 6.0 bar. The SF$_6$ is used for insulation and arc-quenching purposes.

The 3AP2/3 DT for 550 kV (fig. 12, fig. 13) consists of two interrupter units in a series that features a simple design. The proven Siemens arc-quenching system ensures faultless operation, consistently high arc-quenching capacity and a long service life, even at high switching frequencies.

Thanks to constant further development, optimization and consistent quality assurance, Siemens self-compression arc-quenching systems meet all the requirements placed on modern high-voltage technology.

A control cubicle mounted at one end of the circuit breaker houses the spring operating mechanism and circuit breaker control components. The interrupter units are located in the aluminum housing of each pole unit.

The interrupters use the latest Siemens self-compression arc-quenching system.

The stored-energy spring mechanism is the same design as used within the Siemens 3AP live-tank circuit breakers, GIS and compact switchgear. This design has been documented in service for more than 10 years, and has a well-documented reliability record.

Operators can specify up to four (in some cases, up to six) bushing-type current transformers (CT) per phase. These CTs, mounted externally on the aluminum housings, can be removed without dismantling the bushings.

**Operating mechanism**
The mechanically and electrically trip-free spring mechanism type FA is used on type SPS2 and 3AP1/2 DT circuit breakers. The closing and opening springs are loaded for “O-C-O” operations.
A weatherproofed control cubicle (degree of protection IP55) has a large door, sealed with rubber gaskets, for easy access during inspection and maintenance. Condensation is prevented by heaters that maintain a difference in inside/outside temperature, and by ventilation.

The control system includes all the secondary technical components required for operating the circuit breaker, which are typically installed in the control cubicle. The current transformer connections are also located in the control cubicle.

The control, tripping, motor and heating power supplies are selectable in a great extent. Depending on customer requirements, two standard control versions are available.

Basic version
The basic variant includes all control and monitoring elements that are needed for operation of the circuit breaker. In addition to the elementary actuation functions, it includes:
- 19 auxiliary switch contacts (9 normally open, 9 normally closed, 1 passing contact)
- Operations counter
- Local actuator

Compact version
In addition to the basic version, this type includes:
- Spring monitoring by motor runtime monitoring
- Heating monitoring (current measuring relay)
- Luminaire and socket attachment with a common circuit breaker to facilitate servicing and maintenance work
- Overvoltage attenuation
- Circuit breaker motor
- Circuit breaker heating.

Fig. 13: 3AP2 DT 550 kV pole
Fig. 14: Possible components for the 3AP1 DTC
The DTC – Dead Tank Compact – a Compact Switchgear up to 245 kV

The hybrid concept
The hybrid concept combines SF₆-encapsulated components and air-insulated devices. The application of gas-insulated components increases availability of switchgear. According to CIGRE analyses, gas-insulated components are four times more reliable than air-insulated components. The level of encapsulation can be defined in accordance with the requirements of the individual substation layout and the system operator’s project budget. This leads to optimized investments and can be combined with further air-insulated devices.

The modular design
Based on the well-proven modular design, the core components of the main units are based on the same technology that is used in the well-established high-voltage circuit breakers, disconnectors and GIS product family of Siemens.

These components are:
- Self-compression arc-quenching interrupter unit of the AIS 3AP circuit breaker
- Stored-energy spring mechanism
- SF₆-insulated disconnector/earthing switch from the GIS type 8DN8
- Outdoor earthing switch from the disconnector product range (fig. 14 and fig. 15).

This allows for providing flexible solutions according to different substation configurations:
- Circuit breaker with single-pole or three-pole operating mechanism
- Disconnector, earthing switch, high-speed earthing switch
- Current transformer, voltage transformer and voltage detecting system
- Cable connections possible at various positions
- Bushings available as porcelain or composite insulators
- Additional separations of gas compartment, with SF₆ density monitor on request
- Double breaker modules for ultra compact substation designs
- Possibility of combination with stand-alone components, e.g. disconnector module with voltage transformer (fig. 16).
Highlights and characteristics

- Simple SF₆ filling and monitoring, one gas compartment possible (separation optional)
- Flexibility in confined spaces and extreme environmental conditions, e.g. low temperature applications down to –55 °C
- Single-pole encapsulation: no 3-phase fault possible and fast replacement of one pole (spare part: one pole)
- Safety can be enhanced by separated gas compartments, e.g. between circuit breaker and disconnector.
- Complete module can be moved with a fork-lift truck
- Fast installation and commissioning: easy assembly of fully manufactured and tested modular units
- Less maintenance effort: first major inspection after 25 years
- Service life minimum 50 years
- Single-pole and three-pole operated drive system for 145 kV and 245 kV (fig. 17).

Our compact switchgear is fully type-tested in accordance with this standard.

We have one of the most modern testing laboratories available which are certified and part of the European network of independent testing organizations (PEHLA).

Also other international testing laboratories (KEMA, CESI) certify our circuit breakers’ high quality standards (fig. 18, table 3).

Standard

The international IEC 62271-205 standard treats compact switchgear assemblies for rated voltages above 52 kV. The used terminology for the hybrid concept is the so-called mixed technology switchgear (MTS).
The DCB – Disconnecting Circuit Breaker

ONE device – TWO functions
In switchgear, isolating distances in air combined with circuit breakers are used to protect the circuit state in the grid.

Siemens developed a combined device in which the isolating distance has been integrated in the SF₆ gas compartment on the basis of an SF₆-insulated circuit breaker in order to reduce environmental influence. The combined device (DCB – Disconnecting Circuit breaker) is used as a circuit breaker and additionally as a disconnector – two functions combined in one device (fig. 19, fig. 20).

The DCB was developed on the basis of a higher-rated standard 3AP circuit breaker to provide the higher dielectric properties required and type-tested in accordance with IEC 62271-108 for disconnecting circuit breakers. Due to the SF₆-insulated disconnector function there is no visible opening distance anymore. The proper function of the kinematic chain has been most thoroughly verified. The closest attention was paid to developing a mechanical interlock which guarantees that the circuit breaker remains in open position when used as a disconnector. When this mechanical interlock is activated, it is impossible to close the breaker. The current status of the DCB can also be controlled electrically and is shown by well visible position indicators.

In addition, an air-insulated earthing switch could be mounted onto the supporting structure. Its earthing function was implemented by a well-established earthing switch with a maintenance-free contact system from Ruhrtal, a Siemens Company.

The disconnecting circuit breakers are type tested according to class M2 and C2 of IEC 62271-108, a specific standard for combined switching devices.
Combining the strengths of our well proven product portfolio, we can provide a new type of device which fulfills the system operator’s needs for highest reliability and safety, while saving space and costs at the same time (table 4).

**Highlights and characteristics**
- Maximum reliability by applying well-proven and established components from Siemens circuit breakers and Ruhrtal earthing switches
- Maximum availability due to longer maintenance intervals
- Economical, space-saving solution by combining the circuit breaker and the disconnector in one device
- Minimized costs for transportation, maintenance, installation and commissioning as well as civil works (foundation, steel, cable ducts, etc.)
- Compact and intelligent interlocking and position indicating device
- Optionally available without earthing switch
- Porcelain or composite insulators obtainable (fig. 19).

**High Voltage Disconnectors and Earthing Switches**

**General**
Disconnectors are an essential part of electrical power substations. They indicate a visible isolating distance in air isolated gap.

Modern production technologies and investments in our production sites worldwide ensure sustained product and process quality in accordance with the high standards of Siemens.

Siemens disconnectors fulfil the system operators’ requirements for low life-cycle costs with maximum availability and continuous economic service by:
- Delivery of completely routine-tested and pre-adjusted assembly groups
- Easy erection and commissioning
- Maintenance-free bearings and contact systems
- Lifetime technical support
- The contact systems have proved their reliability through decades of service.

### Table 4: Technical data of 3AP DCB

<table>
<thead>
<tr>
<th>Parameter</th>
<th>3AP1 DCB</th>
<th>3AP2 DCB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated voltage [kV]</td>
<td>145</td>
<td>420</td>
</tr>
<tr>
<td>Number of interrupter units per pole</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Rated power frequency withstand voltage [kV]</td>
<td>275/315</td>
<td>520/610</td>
</tr>
<tr>
<td>Rated lightning impulse withstand voltage [kV]</td>
<td>650/750</td>
<td>1,425/1,665</td>
</tr>
<tr>
<td>Rated switching impulse withstand voltage [kV]</td>
<td>n.a.</td>
<td>1,050/1,245</td>
</tr>
<tr>
<td>Rated normal current up to [A]</td>
<td>3,150</td>
<td>4,000</td>
</tr>
<tr>
<td>Rated short-circuit breaking current [kArms]</td>
<td>40 (31.5)</td>
<td>40</td>
</tr>
<tr>
<td>Ambient air temperature *) [°C]</td>
<td>-40 ... +40</td>
<td>-40 ... +40</td>
</tr>
<tr>
<td>Insulating medium</td>
<td>SF₆</td>
<td>SF₆</td>
</tr>
<tr>
<td>Classification CB</td>
<td>M2, C2</td>
<td>M2, C2</td>
</tr>
<tr>
<td>Classification DS</td>
<td>M2</td>
<td>M2</td>
</tr>
<tr>
<td>Insulators</td>
<td>composite **</td>
<td>composite</td>
</tr>
<tr>
<td>Attached earthing switch (optional)</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Type-tested according to</td>
<td>IEC 62271-108</td>
<td></td>
</tr>
</tbody>
</table>

*) Other ambient temperature values on request

**) Or porcelain

Fig. 21: 3AP2 DCB 420 kV
The most important features are:
- Self-resilient contact fingers – no further spring elements are necessary to generate the contact force
- Silver-plated contact surface provides maximum conductivity without regular greasing lubrication
- Factory set contact forces; no re-adjustments required during service life
- Ice layers up to 20 mm can be broken without difficulties
- Maintenance-free contact system for up to 25 years.

The reliability of Siemens disconnectors and earthing switches over many decades is ensured by a comprehensive testing and quality assurance system certified according to DIN EN ISO 9001.

**Center-break disconnectors**
The center-break disconnector is the most frequently used disconnector type. The disconnector base supports the operating mechanism and two rotating porcelain support insulators. The current path arms which are fixed to the insulators open in the center. Each rotating unit comprises two high-quality ball bearings and is designed for high mechanical loads. They are lubricated and maintenance-free for the entire service life (fig. 22).

The current path of the center-break disconnector consists of only a few components, thus the number of contact resistances is reduced to a minimum. The main contact system of block contact and spread contact fingers assures a steady contact force even after decades of operation (fig. 23).

**Pantograph disconnectors**
This type is generally used in double-busbar systems to connect the two busbars or a busbar to a line.

The main components of a pantograph disconnector are (fig. 24):
- Scissor arms (1)
- Bearing frame (2)
- Support insulator (3)
- Rotating insulator (4)
- Motor operating mechanism (5).

Rotary contact systems inside the joints, which have thermal and dynamic current carrying capacity, are used for current transfer. The geometry of the pantograph ensures optimum operational behavior.

The specific contact force is adjusted in the factory and remains unchanged during service life. Ice loads of up to 20 mm can be broken without difficulties.
In both end positions of the disconnector, the rotary arm in the bearing frame is switched beyond the dead center point. The switch position cannot be changed by external forces. The rigidity of the scissor arms prevents opening during a short-circuit.

Pantograph disconnectors with rated voltages from 123 kV up to 362 kV are optionally equipped with group operating mechanisms or 1-pole operating mechanisms. All pantograph disconnectors for higher rated voltages are equipped with 1-pole operating mechanisms.

**Vertical-break disconnectors**

The current path of the vertical-break disconnector opens vertically and requires a minimum phase distance (fig. 25).

The current path performs two movements:
- A vertical swinging movement
- A rotary movement around its own longitudinal axis.

The rotary movement generates the contact force and breaks possible ice layers.

In both end positions, the rotary arm is switched beyond the dead center point. This locks the current path in the short-circuit-proof CLOSED position, and prevents the current path from switching to the OPEN position under external forces.

The ample distance between support insulator and rotating insulator ensures dielectric strength of the parallel insulation even under saline fog conditions.

The movable part of the current path is one single subassembly which is pre-adjusted and routine-tested at the factory. This allows for easy and quick installation and commissioning on site.

**Double-side break disconnectors**

The double-side break disconnector features three support insulators. The support insulator in the center is mounted
Fig. 26: Double-side break disconnector with integrated surge arrester

Fig. 27: Knee-type disconnector

on a rotating unit and carries the current path. Both end support insulators are fixed.

The main application of double-side break disconnectors are substations with limited phase distances and where vertical opening of the current path is not possible. High mechanical terminal loads are possible due to the compact and stable design. It can also be combined with an integrated surge arrester (fig. 26).

For voltage levels up to 245 kV, the contact fingers of the double-side break disconnectors are integrated into the current path tube, and the fixed contacts consist of contact blocks. The current path performs a horizontal swinging movement, and the contact force is generated by spreading the contact fingers while sliding on the contact blocks.

For voltage levels higher than 245 kV, contact strips are attached to the ends of the current path tubes. The contact fingers are part of the fixed contacts. In this design, the current path performs a combined swinging and rotary movement. After completion of the swinging movement, the contact force is generated by the rotation of the current path around its own axis.

Knee-type disconnectors
This disconnector type has the smallest horizontal and vertical space requirements. The knee-type disconnector has two fixed and one rotating insulator. Thanks to its folding-arm design, only limited overhead clearance is required, which results in lower investment costs (fig. 27).

Earthing switches
The use of earthing switches (fig. 28) ensures absolute de-energization of high-voltage components in a circuit or switchgear. Free-standing earthing switches are available for all voltage levels up to 800 kV.
Suitable built-on earthing switches are available for all disconnector types of the Siemens scope of supply.

According to the system operators’ requirements, built-on earthing switches can be arranged laterally or in integrated arrangement with respect to the position of the main current path of the disconnector when needed.

Optionally, all earthing switches can be designed for switching induced inductive and capacitive currents according to IEC 62271-102, Class A or Class B.

Motor operating mechanisms
The motor operating mechanisms consist of three main subassemblies:
- Corrosion-resistant housing
- Gear unit with motor
- Electrical equipment with auxiliary switch.

The motor operating mechanism can also be operated manually by a hand crank which can be inserted in the cubicle. The insertion of the hand crank automatically isolates the motor circuit for safety purposes. Heaters are provided to prevent condensation (fig. 29).

The auxiliary switch is custom-fit to the gear unit and signals the switch position with absolute reliability. This ensures safe substation operation.

After the motor starts, the auxiliary switch moves and the switch position signal is cancelled. The disconnector operates thereafter until the end position is reached.

The auxiliary switch then moves again and issues the switch position signal.

This sequence ensures that the CLOSED position is indicated only after the disconnector is locked and short-circuit-proof, and the rated current can be carried. The OPEN position is indicated only after the opened current path has reached the nominal dielectric strength.

An overview of Siemens disconnectors is shown in table 5 to table 9.
### Table 5: Center-break disconnector

#### Technical data

<table>
<thead>
<tr>
<th>Design</th>
<th>Center break</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated voltage</td>
<td>72.5 123 145 170 245 300 362 420 550</td>
</tr>
<tr>
<td>Rated power-frequency withstand voltage 50 Hz/1 min</td>
<td></td>
</tr>
<tr>
<td>To earth and between phases [kV]</td>
<td>140 160 230 265 275 315 325 460 530</td>
</tr>
<tr>
<td>Across the isolating distance [kV]</td>
<td>380 380 435 450 520 610 520 620 800</td>
</tr>
<tr>
<td>Rated lightning impulse withstand voltage 1.2/50 µs</td>
<td></td>
</tr>
<tr>
<td>To earth and between phases [kV]</td>
<td>325 375 550 630 650 750 860 1,050 1,200 1,175 1,425 1,550</td>
</tr>
<tr>
<td>Across the isolating distance [kV]</td>
<td>1,050 (+170) 1,050 (+205) 1,050 1,050 (+240) 1,050 (+315)</td>
</tr>
<tr>
<td>Rated switching impulse withstand voltage 250/2,500 µs</td>
<td></td>
</tr>
<tr>
<td>To earth and between phases [kV]</td>
<td>– – – – – – 850 700 (+245) 950 800 (+295)</td>
</tr>
<tr>
<td>Across the isolating distance [kV]</td>
<td>– – – – – – 950 900 (+345) 1,050 900 (+450)</td>
</tr>
<tr>
<td>Rated normal current up to [A]</td>
<td>4,000</td>
</tr>
<tr>
<td>Rated peak withstand current up to [kA]</td>
<td>160</td>
</tr>
<tr>
<td>Rated short-time withstand current up to [kA]</td>
<td>63</td>
</tr>
<tr>
<td>Rated duration of short circuit [s]</td>
<td>1/3</td>
</tr>
<tr>
<td>Icing class</td>
<td>10/20</td>
</tr>
<tr>
<td>Temperature range [°C]</td>
<td>–50/+50</td>
</tr>
<tr>
<td>Operating mechanism type</td>
<td>Motor operation/Manual operation</td>
</tr>
<tr>
<td>Control voltage [V, DC] [V, AC]</td>
<td>60/110/125/220 220…230, 1~, 50/60 Hz</td>
</tr>
<tr>
<td>Motor voltage [V, DC] [V, AC]</td>
<td>60/110/125/220 110/125/220, 1~, 50/60 Hz 220/380/415, 3~, 50/60 Hz</td>
</tr>
<tr>
<td>Maintenance</td>
<td>25 years</td>
</tr>
</tbody>
</table>
## Table 6: Pantograph disconnector

<table>
<thead>
<tr>
<th>Design</th>
<th>Pantograph</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated voltage</td>
<td>123 145 170 245 300 362 420 550</td>
</tr>
<tr>
<td>Rated power-frequency withstand voltage 50 Hz/1 min</td>
<td></td>
</tr>
<tr>
<td>To earth and between phases</td>
<td>[kV]</td>
</tr>
<tr>
<td>Across the isolating distance</td>
<td>[kV]</td>
</tr>
<tr>
<td>Rated lightning impulse withstand voltage 1.2/50 µs</td>
<td></td>
</tr>
<tr>
<td>To earth and between phases</td>
<td>[kV]</td>
</tr>
<tr>
<td>Across the isolating distance</td>
<td>[kV]</td>
</tr>
<tr>
<td>Rated switching impulse withstand voltage 250/2,500 µs</td>
<td></td>
</tr>
<tr>
<td>To earth and between phases</td>
<td>[kV]</td>
</tr>
<tr>
<td>Across the isolating distance</td>
<td>[kV]</td>
</tr>
<tr>
<td>Rated normal current up to</td>
<td>[A]</td>
</tr>
<tr>
<td>Rated peak withstand current up to</td>
<td>[kA]</td>
</tr>
<tr>
<td>Rated short-time withstand current up to</td>
<td>[kA]</td>
</tr>
<tr>
<td>Rated duration of short circuit</td>
<td>[s]</td>
</tr>
<tr>
<td>Icing class</td>
<td></td>
</tr>
<tr>
<td>Temperature range</td>
<td>[°C]</td>
</tr>
<tr>
<td>Operating mechanism type</td>
<td></td>
</tr>
<tr>
<td>Control voltage</td>
<td>[V, DC]</td>
</tr>
<tr>
<td></td>
<td>[V, AC]</td>
</tr>
<tr>
<td>Motor voltage</td>
<td>[V, DC]</td>
</tr>
<tr>
<td></td>
<td>[V, AC]</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance</td>
<td></td>
</tr>
</tbody>
</table>
## Technical data

**Vertical-break disconnector**

<table>
<thead>
<tr>
<th>Design</th>
<th>Vertical break</th>
</tr>
</thead>
</table>

### Rated voltage

<table>
<thead>
<tr>
<th>Voltage [kV]</th>
<th>123</th>
<th>145</th>
<th>170</th>
<th>245</th>
<th>300</th>
<th>362</th>
<th>420</th>
<th>550</th>
</tr>
</thead>
</table>

### Rated power-frequency withstand voltage 50 Hz/1 min

<table>
<thead>
<tr>
<th>Voltage [kV]</th>
<th>230</th>
<th>265</th>
<th>275</th>
<th>325</th>
<th>460</th>
<th>380</th>
<th>450</th>
<th>520</th>
<th>520</th>
<th>620</th>
<th>620</th>
</tr>
</thead>
</table>

### Rated lightning impulse withstand voltage 1.2/50 μs

<table>
<thead>
<tr>
<th>Voltage [kV]</th>
<th>550</th>
<th>630</th>
<th>650</th>
<th>750</th>
<th>1,050</th>
<th>1,050</th>
<th>1,175</th>
<th>1,425</th>
<th>1,550</th>
</tr>
</thead>
</table>

### Rated switching impulse withstand voltage 250/2,500 μs

<table>
<thead>
<tr>
<th>Voltage [kV]</th>
<th>850</th>
<th>700 (+245)</th>
<th>950</th>
<th>800 (+295)</th>
<th>1,050</th>
<th>900 (+345)</th>
<th>1,175</th>
<th>900 (+450)</th>
</tr>
</thead>
</table>

### Rated normal current up to [A]

<table>
<thead>
<tr>
<th>Current [A]</th>
<th>4,000</th>
</tr>
</thead>
</table>

### Rated peak withstand current up to [kA]

<table>
<thead>
<tr>
<th>Current [kA]</th>
<th>160</th>
</tr>
</thead>
</table>

### Rated short-time withstand current up to [kA]

<table>
<thead>
<tr>
<th>Current [kA]</th>
<th>160</th>
</tr>
</thead>
</table>

### Rated duration of short circuit [s]

<table>
<thead>
<tr>
<th>Duration [s]</th>
<th>1/3</th>
</tr>
</thead>
</table>

### Icing class

<table>
<thead>
<tr>
<th>Class</th>
<th>10/20</th>
</tr>
</thead>
</table>

### Temperature range [°C]

<table>
<thead>
<tr>
<th>Range</th>
<th>-50/+50</th>
</tr>
</thead>
</table>

### Operating mechanism type

<table>
<thead>
<tr>
<th>Type</th>
<th>Motor operation/Manual operation</th>
</tr>
</thead>
</table>

### Control voltage [V, DC/AC]

<table>
<thead>
<tr>
<th>Voltage</th>
<th>60/110/125/220/220...230, 1~, 50/60 Hz</th>
</tr>
</thead>
</table>

### Motor voltage [V, DC/AC]

<table>
<thead>
<tr>
<th>Voltage</th>
<th>60/110/125/220/110/125/230, 1~, 50/60 Hz/220/380/415, 3~, 50/60 Hz</th>
</tr>
</thead>
</table>

### Maintenance

<table>
<thead>
<tr>
<th>Years</th>
<th>25</th>
</tr>
</thead>
</table>

*Table 7: Vertical-break disconnector*
<table>
<thead>
<tr>
<th><strong>Technical data</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Design</strong></td>
<td>Knee-type</td>
</tr>
<tr>
<td><strong>Rated voltage</strong></td>
<td>123</td>
</tr>
<tr>
<td><strong>Rated power-frequency withstand voltage 50 Hz/1 min</strong></td>
<td></td>
</tr>
<tr>
<td>To earth and between phases</td>
<td>[kV]</td>
</tr>
<tr>
<td>Across the isolating distance</td>
<td>[kV]</td>
</tr>
<tr>
<td><strong>Rated lightning impulse withstand voltage 1.2/50 µs</strong></td>
<td></td>
</tr>
<tr>
<td>To earth and between phases</td>
<td>[kV]</td>
</tr>
<tr>
<td>Across the isolating distance</td>
<td>[kV]</td>
</tr>
<tr>
<td><strong>Rated switching impulse withstand voltage 250/2,500 µs</strong></td>
<td></td>
</tr>
<tr>
<td>To earth and between phases</td>
<td>[kV]</td>
</tr>
<tr>
<td>Across the isolating distance</td>
<td>[kV]</td>
</tr>
<tr>
<td><strong>Rated normal current up to</strong></td>
<td>[A]</td>
</tr>
<tr>
<td><strong>Rated peak withstand current up to</strong></td>
<td>[kA]</td>
</tr>
<tr>
<td><strong>Rated short-time withstand current up to</strong></td>
<td>[kA]</td>
</tr>
<tr>
<td><strong>Rated duration of short circuit</strong></td>
<td>[s]</td>
</tr>
<tr>
<td><strong>Icing class</strong></td>
<td>10/20</td>
</tr>
<tr>
<td><strong>Temperature range</strong></td>
<td>[°C]</td>
</tr>
<tr>
<td><strong>Operating mechanism type</strong></td>
<td>Motor operation/Manual operation</td>
</tr>
<tr>
<td><strong>Control voltage</strong></td>
<td>[V, DC]</td>
</tr>
<tr>
<td></td>
<td>[V, AC]</td>
</tr>
<tr>
<td><strong>Motor voltage</strong></td>
<td>[V, DC]</td>
</tr>
<tr>
<td></td>
<td>[V, AC]</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Maintenance</strong></td>
<td>25 years</td>
</tr>
</tbody>
</table>

*Table 8: Knee-type disconnector*
### Technical data

<table>
<thead>
<tr>
<th>Design</th>
<th>Double-side break</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated voltage</td>
<td>123 145 170 245 300 420 550 800</td>
</tr>
<tr>
<td>Rated power-frequency withstand voltage 50 Hz/1 min</td>
<td></td>
</tr>
<tr>
<td>To earth and between phases [kV]</td>
<td>230 265 275 315 325 460 435 520 610 450 520 830</td>
</tr>
<tr>
<td>Across the isolating distance [kV]</td>
<td>230 265 275 315 325 460 435 520 610 450 520 830</td>
</tr>
<tr>
<td>Rated lightning impulse withstand voltage 1.2/50 µs</td>
<td></td>
</tr>
<tr>
<td>To earth and between phases [kV]</td>
<td>550 630 650 750 860 1,050 1,050 (+170) 1,425 1,425 (+240) 1,550 1,550 (+315) 2,100 2,100 (+455)</td>
</tr>
<tr>
<td>Across the isolating distance [kV]</td>
<td>550 630 650 750 860 1,050 1,050 (+170) 1,425 1,425 (+240) 1,550 1,550 (+315) 2,100 2,100 (+455)</td>
</tr>
<tr>
<td>Rated switching impulse withstand voltage 250/2,500 µs</td>
<td></td>
</tr>
<tr>
<td>To earth and between phases [kV]</td>
<td>– – – – – 850 700 (+245) 1,050 900 (+345) 1,175 900 (+450) 1,550 1200 (+650)</td>
</tr>
<tr>
<td>Across the isolating distance [kV]</td>
<td>– – – – – 850 700 (+245) 1,050 900 (+345) 1,175 900 (+450) 1,550 1200 (+650)</td>
</tr>
<tr>
<td>Rated normal current up to [A]</td>
<td>4000</td>
</tr>
<tr>
<td>Rated peak withstand current up to [kA]</td>
<td>160</td>
</tr>
<tr>
<td>Rated short-time withstand current up to [kA]</td>
<td>63</td>
</tr>
<tr>
<td>Rated duration of short circuit [s]</td>
<td>1/3</td>
</tr>
<tr>
<td>Icing class</td>
<td>10/20</td>
</tr>
<tr>
<td>Temperature range [°C]</td>
<td>–50/+50</td>
</tr>
<tr>
<td>Operating mechanism type</td>
<td>Motor operation/Manual operation</td>
</tr>
<tr>
<td>Control voltage [V, DC] [V, AC]</td>
<td>60/110/125/220 220…230, 1~, 50/60 Hz</td>
</tr>
<tr>
<td>Motor voltage [V, DC] [V, AC]</td>
<td>60/110/125/220 110/125/230, 1~, 50/60 Hz 220/380/415, 3~, 50/60 Hz</td>
</tr>
<tr>
<td>Maintenance</td>
<td>25 years</td>
</tr>
</tbody>
</table>

*Table 9: Double-side break*
The main task of an arrester is to protect equipment from the effects of overvoltages. During normal operation, an arrester should have no negative effect on the power system. Moreover, the arrester must be able to withstand typical surges without incurring any damage. Non-linear resistors with the following properties fulfill these requirements:

- Low resistance during surges so that overvoltages are limited
- High resistance during normal operation so as to avoid negative effects on the power system
- Sufficient energy absorption capability for stable operation.

With this kind of non-linear resistor, there is only a small flow of current when continuous operating voltage is being applied. When there are surges, however, excess energy can be quickly removed from the power system by a high discharge current.

### Surge Arresters

#### High-Voltage Surge Arresters

**Non-linear resistors**

Non-linear resistors, comprising metal oxide (MO), have proved especially suitable for this use. The non-linearity of MO resistors is considerably high. For this reason, MO arresters, as the arresters with MO resistors are known today, do not need series gaps (fig. 30).

Siemens has many years of experience with arresters – with the previous gapped SiC arresters and the new gapless MO arresters – in low-voltage systems, distribution systems and transmission systems. They are usually used for protecting transformers, generators, motors, capacitors, traction vehicles, cables and substations.

There are special applications such as the protection of:

- Equipment in areas subject to earthquakes or heavy pollution
- Surge-sensitive motors and dry-type transformers

---

![Fig. 30: Current/voltage characteristics of a non-linear MO arrester](image1)

---

![Fig. 31: Surge arrester in traditional porcelain housing; available for system voltages up to 800 kV](image2)

---

![Fig. 32: Cross-section of a polymer-housed arrester in tube design](image3)
• Generators in power stations with arresters that possess a high degree of short-circuit current strength
• Gas-insulated high-voltage metal-enclosed switchgear (GIS)
• Valves in HVDC transmission installations
• Static compensators
• Airport lighting systems
• Electric smelting furnaces in the glass and metals industries
• High-voltage cable sheaths
• Test laboratory apparatus.

MO arresters are used in medium, high and extra-high-voltage power systems. Here, the very low protection level and the high energy absorption capability provided during switching surges are especially important. For high-voltage levels, the simple construction of MO arresters is always an advantage. Another very important advantage of MO arresters is their high degree of reliability when used in areas with a problematic climate, for example, in coastal and desert areas, or in regions affected by heavy industrial air pollution. Furthermore, some special applications have become possible only with the introduction of MO arresters. One instance is the protection of capacitor banks in series reactive-power compensation equipment that requires extremely high energy absorption capabilities.

Tradition and innovation
Fig. 31 shows a Siemens MO arrester in a traditional porcelain housing, a well proven technology representing decades of Siemens experience. Siemens also offers surge arresters with polymer housings for all system voltages and mechanical requirements.

These arresters are divided into two subgroups:
• Cage design™ arresters
• Tube design arresters.

Fig. 32 shows the sectional view of a tube design arrester. The housing consists of a fiberglass-reinforced plastic tube with insulating sheds made of silicone rubber. The advan-
tages of this design, which has the same pressure relief device as an arrester with porcelain housing, are absolutely safe and reliable pressure relief characteristics, high mechanical strength even after pressure relief and excellent pollution-resistant properties. The very good mechanical features mean that Siemens arresters with a polymer housing (type 3EQ) can serve as post insulators as well. The pollution-resistant properties are the result of the water-repellent effect (hydrophobicity) of the silicone rubber, which even transfers its effects to pollution.

The newest types of polymer surge arresters also feature the cage design. While using the same MO resistors, they have the same excellent electrical characteristics as the 3EP and 3EQ types. The difference is that the 3EL (fig. 33) types get their mechanical performance from a cage built up by fiber-reinforced plastic rods. Furthermore, the whole active part is directly and completely molded with silicone rubber to prevent moisture ingress and partial discharges. The polymer-housed high-voltage arrester design chosen by Siemens and the high-quality materials used by Siemens provide a whole series of advantages, including long life and suitability for outdoor use, high mechanical stability and ease of disposal.

Another important design are the gas-insulated metal-enclosed surge arresters (GIS arresters, fig. 34). Siemens has been making these arresters for more than 25 years. There are two reasons why, when GIS arresters are used with gas-insulated switchgear, they usually offer a higher protective safety margin than when outdoor-type arresters are used: First, they can be installed closer to the item to be protected so that traveling wave effects can be limited more effectively. Second, compared with the outdoor type, inductance of the installation is lower (both that of the connecting conductors and that of the arrester itself). This means that the protection offered by GIS arresters is much better than that offered by any other method, especially in the case of surges with a very steep rate of rise or high frequency, to which gas-insulated switchgear is exceptionally sensitive.

Monitoring
Siemens also offers a wide range of products for diagnosis and monitoring of surge arresters. The innovative arrester condition monitor (fig. 35) is the heart of the future-proof (IEC 61850) monitoring product line.

Low-Voltage and Medium-Voltage Surge Arresters and Limiters
Surge arresters and limiters protect operational equipment both from external overvoltages caused by lightning strikes in overhead lines and from internal overvoltages produced by switching operations or earth faults. Normally, the arrester is installed between phase and earth. The built-in stack of non-linear, voltage-dependent resistors (varistors) made of metal oxide (MO) or zinc oxide (ZnO) becomes conductive from a defined overvoltage limit value onward, so that the load can be discharged to earth. When the power-frequency voltage underflows this limit value, called discharge voltage, the varistors return to their original resistance value so that only a so-called leakage current of a few mA flows at operating voltage. Because this leakage current heats up the resistors, and thus the arrester, the device must be designed according to the neutral-point treatment of the system in order to prevent impermissible heating of the arrester.

In contrast to the normal surge arrester, the surge limiter contains a series gap in addition to the MO resistor stack. If the load generated by the overvoltage is large enough, the series gap ignites, and the overvoltage can be discharged to earth until the series gap extinguishes and the varistors return to their non-conductive state. This process is repeated again and again throughout the entire duration of the fault. This makes it possible to design the device with a considerably lower discharge voltage as a conventional surge arrester, and is especially useful for the protection of motors with – normally – a poor dielectric strength. To guarantee a sufficient protective function, the discharge voltage value of the arresters or limiters must not exceed the dielectric strength of the operational equipment to be protected.

The medium-voltage product range includes (fig. 39):
• The 3EF group of surge arresters and limiters for the protection of motors, dry-type transformers, airfield lighting systems and cable sheath as well as for the protection of converters for drives.
• The 3EE2 porcelain-housed surge arrester for the protection of generators, motors, melting furnaces and power plants as well as for 6-arrester connections.
• The 3EK silicone-housed surge arrester for distribution systems, medium-voltage switchgear up to 72.5 kV and line surge arresters for outdoor use (fig. 37 and fig. 38). An overview of the complete range of Siemens arresters appears in the table 10 to table 12.
<table>
<thead>
<tr>
<th>Special applications</th>
<th>Railway applications</th>
<th>Medium-voltage distribution class</th>
</tr>
</thead>
<tbody>
<tr>
<td>3EF1; 3EF3; 3EF4; 3EF5</td>
<td>3EE2</td>
<td>3EB2</td>
</tr>
</tbody>
</table>

**Applications**

| Applications | Motors, dry-type transformers, airfield lighting systems, sheath voltage limiters, protection of converters for drives | Generators, motors, melting furnaces, 6-arrester connection, power plants | DC overhead contact lines | DC systems (locomotives, overhead contact lines) | AC and DC systems (locomotives, overhead contact lines) | AC and DC systems (locomotives, overhead contact lines), for highest speed | Distribution systems and medium-voltage switchgear | Distribution systems and medium-voltage switchgear |

**Highest voltage for equipment ($U_{in}$)**

| kV | 12 | 36 | 2 | 4 | 72.5 | 30 | 45 | 72.5 |

**Maximum rated voltage**

| kV | 15 | 53 | 2 | 4 | 60 (AC); 4 (DC) | 37 (AC); 4 (DC) | 36 | 60 |

**Nominal discharge current**

| kA | 3EF1 | 3EF3 | 3EF4 | 3EF5 | 10 | 10 | 10 | 10 | 10 | 10 |

**Maximum thermal energy absorption capability (per kV of $U_{in}$)**

| kJ/kV | 3EF1 | 3EF3 | 3EF4 | 3EF5 | 0.8 | 12.5 | 10 | 10 | 10 | 8 (AC); 10 (DC) | 8 (AC); 10 (DC) | 3.5<sup>1)</sup> | 3.5<sup>1)</sup> |

**Maximum long-duration current impulse, 2 ms**

| A | 3EF4 | 3EF5 | 1,600 | 1,200 | 1,200 | 1,200 | 850 (AC); 1,200 (DC) | 850 (AC); 1,200 (DC) | 325 | 325 |

**Rated short circuit current**

| kA | 40 | 300 | 40 | 40 | 40 | 40 | 20 | 20 |

**Housing material**

| | Polyethylene | Porcelain | Silicone | Porcelain | Silicone | Silicone | Silicone | Silicone |

**Design principle**

| 3EF1 – polyethylene directly molded onto MO; 3EF3/3EF4/3EF5 – Hollow insulator | Hollow insulator | Directly molded | Hollow insulator | Hollow insulator, silicone directly molded onto FRP tube | Hollow insulator, silicone directly molded onto FRP tube | Cage design, silicone directly molded onto MO | Cage design, silicone directly molded onto MO |

**Pressure relief device**

| No | Yes | No | Yes | Yes | Yes | No | No |

<sup>1)</sup> Energy absorption capability under the conditions of the operating duty test according to IEC 60099-4

Table 10: Medium-voltage metal-oxide surge arresters and limiters (300 V to 72.5 kV)
<table>
<thead>
<tr>
<th>Applications</th>
<th>Porcelain</th>
<th>Silicone</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3EP5</td>
<td>3EP4</td>
</tr>
<tr>
<td>Highest voltage for equipment ($U_m$) kV</td>
<td>123</td>
<td>362</td>
</tr>
<tr>
<td>Maximum rated voltage kV</td>
<td>96</td>
<td>288</td>
</tr>
<tr>
<td>Maximum nominal discharge current kA</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Maximum line discharge class</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Maximum thermal energy absorption capability (per kV of $U_r$) kJ/kV</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Maximum long-duration current impulse, 2 ms A</td>
<td>1,100</td>
<td>1,100</td>
</tr>
<tr>
<td>Rated short circuit current kA</td>
<td>40</td>
<td>65</td>
</tr>
<tr>
<td>Maximum permissible service load kNm</td>
<td>2.0 (SSL)</td>
<td>3 (SSL)</td>
</tr>
<tr>
<td>Housing material</td>
<td>Porcelain</td>
<td>Silicone</td>
</tr>
<tr>
<td>Design principle</td>
<td>Hollow insulator</td>
<td>Silicone directly molded onto MO</td>
</tr>
<tr>
<td>Pressure relief device</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

1) SSL = Specified short-term load

*Table 11: High-voltage metal-oxide surge arresters (72.5 to 1,200 kV)*
<table>
<thead>
<tr>
<th>Applications</th>
<th>High-voltage systems, protection of metal-enclosed, gas-insulated switchgear and transformers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highest voltage for equipment ($U_{m}$) kV</td>
<td>170/245</td>
</tr>
<tr>
<td>Maximum rated voltage kV</td>
<td>156/216</td>
</tr>
<tr>
<td>Maximum nominal discharge current kA</td>
<td>20</td>
</tr>
<tr>
<td>Maximum line discharge class</td>
<td>4</td>
</tr>
<tr>
<td>Maximum thermal energy absorption capability (per kV of $U_{r}$) kJ/kV</td>
<td>10</td>
</tr>
<tr>
<td>Maximum long-duration current impulse, 2 ms A</td>
<td>1,200</td>
</tr>
<tr>
<td>Rated short circuit current kA</td>
<td>50</td>
</tr>
<tr>
<td>Maximum permissible service load kNm</td>
<td>–</td>
</tr>
<tr>
<td>Housing material</td>
<td>Metal</td>
</tr>
<tr>
<td>Pressure relief device</td>
<td>Yes</td>
</tr>
</tbody>
</table>

*Table 12: Metal-oxide surge arresters for GIS (72.5 to 800 kV)*
High-Voltage Instrument Transformers

Introduction
Electrical instrument transformers transform high currents and voltages to standardized low and easily measurable values that are isolated from the high voltage. When used for metering purposes, instrument transformers provide voltage or current signals that are very accurate representations of the transmission line values in both magnitude and phase. These signals allow accurate determination of revenue billing.

When used for protection purposes, the instrument transformer outputs must accurately represent the transmission line values during both steady-state and transient conditions. These critical signals provide the basis for circuit breaker operation under fault conditions, and as such are fundamental to network reliability and security.

Reliability and security
Reliability of an instrument transformer refers to its ability to consistently satisfy prescribed performance criteria over its expected useful lifetime under specified operating conditions. Security refers to the acceptability and consequences of the instrument transformer failure mode in the event that it does fail, due either to being subjected to stresses in excess of those for which it was designed, or due to its reaching the end of its expected service life.

The reliability and security characteristics of an instrument transformer are governed by the electrical and insulation design, the manufacturing and processing technology used and the specific physical arrangement. The partial discharge performance under in-service conditions is a
key determining factor in the life expectancy and long-term reliability of an instrument transformer.

IEC standards for oil-immersed or gas-filled devices require a partial discharge value of less than 10 pC at $U_{\text{max}}$. Due to the demanding requirements of today’s HV and UHV networks, the Trench Group has elected to adopt even more stringent internal requirements. As such, Trench instrument transformers typically perform much better than required by these standards with proven field experience with hundreds of thousands in operation over more than 50 years in almost every country worldwide. Typical designs are oil-immersed (fig. 40), gas-insulated (fig. 39).

**Oil-immersed instrument transformers**
The reliability and security of Trench oil-immersed inductive instrument transformers is proven by in-service experience spanning up to 50 years and more than 100,000 units in service under a wide variety of different environmental conditions. The transformer is based on state-of-the-art design and a secure failure mode approach. In the event of unexpected stresses from the network, secure failure is achieved through the use of a “barrier construction” design in the free oil section. This approach consists of inserting insulating barriers at critical points through the free oil space, thereby preventing the formation of fiber bridges.

Furthermore a rupture of the housing, particularly of the hollow insulator with built-in finely graded capacitor bushing, is improbable because of the safe dimensioning of the bushing and the solid electrical connection between the core housing and the ground.

If over pressure occurs, the protection is guaranteed by the:

- Welded elastic housing
- Stainless-steel bellows for the oil expansion.
Both the welded seam, which connects the upper and lower portions of the head housing, and the metallic bellows are designed to act as pressure relief points in the event of severe internal pressure buildup.

Because the unit has a normal internal oil pressure of approximately 1 bar absolute, it is possible to design these pressure relief points to rupture at very moderate pressures. Additional safety is achieved by the selection of composite insulators, available in the whole range as an alternative to the traditional porcelain.

Pressure relief for capacitor voltage transformers is provided by a bellows puncture pin and through the use of porcelain, which is strong enough to result in any rapid pressure rise being released through the seal plates at the ends of the porcelain rather than via explosion of the porcelain itself.

Gas-insulated instrument transformers
The reliability and security of Trench gas-insulated instrument transformers is based on:

• 50 years of experience as a manufacturer of instrument transformers covering epoxy resin and oil-paper
• Thousands of gas-insulated instrument transformers in service under a wide variety of different environmental conditions.

Explosion-proof design
The present Trench gas-insulated instrument transformers were initially designed in 1965 at the request of customers who sought to achieve explosion-proof operation. SF₆ gas insulation, combined with composite insulators, is particularly suitable for this, because in the event of an internal flashover, the pressure increase will be linear and hence technically manageable. A controlled pressure relief device at the head of the transformer (rupture disc) eliminates unacceptable mechanical stresses in the housing; i.e., only the rupture disc is released. Gas escapes, but the complete transformer remains intact and no explosion occurs.

Most reliable insulation properties
SF₆ gas is the main insulation medium between high-voltage and earth potential. A stable quality can be guaranteed by the use of SF₆ gas according to IEC 60137 (2005) I ASTM 2472 D and the fact that this inert gas shows no ageing even under the highest electrical and thermal stresses. The insulation properties remain unchanged.
throughout its lifetime. All of these features guarantee an operation period over many years without any control of the insulation condition.

**Full functional security and monitoring**
The guaranteed SF₆ leakage rate is less than 0.5 % per year. The gas pressure can be checked on site or by means of a remote control device, i.e., a densimeter with contacts for remote control. In the case of loss of SF₆ pressure, the transformer still operates at rated pressure.

**Environmentally beneficial under extremely severe conditions**
SF₆ gas is absolutely safe for humans. It bears no ecologically toxic potential and its decomposition products have no deleterious effects on the environment, e.g., groundwater pollution. This SF₆ gas insulation medium allows easy waste management of the transformers. Furthermore, the hydrophobic features of the composite insulator result in problem-free service even under saline fog or polluted conditions. As a long-term benefit, the change of cores or windings, even after years, can be realized easily for new requirements like additional metering.

**Current transformers**
All Trench current transformer (CT) designs are based on “head type” construction. CTs are available with either oil (fig. 40) or SF₆ gas dielectric systems (fig. 41).

**Features of oil-immersed type**
- Low weight and minimum oil volume
- Excellent seismic performance as a consequence of the optimized design of flanges, vast choice of porcelain strengths and their interconnection and low weight
- Available for the full voltage range of 72.5 kV up to 550 kV and full current range of few Amperes up to 5,000 A with multiple-turn primaries for small primary currents. Ratio change available either on primary side or secondary side
- Short, symmetrically arranged low-reactance bar-type primary conductor permits higher short-circuit currents up to 80 kA and avoids large voltage drop across the primary winding
- Excellent control of internal and external insulation stresses through the use of a proprietary finely graded bushing system
- Hermetically sealed by stainless-steel metallic bellows and high-quality gaskets
- Uniformly distributed secondary windings guarantee accurate transformation at both rated and high currents
Features of gas-insulated transformer
- Essentially unaffected by stray external magnetic fields
- Stable accuracy over life-time
- Perfect transient performance
- Exclusive use of corrosion-resistant materials
- Full range of products available with composite insulator.

Features of gas-insulated transformer
- Explosion-proof design by the compressible insulation medium SF6 gas and rupture disc
- Excellent seismic performance due to the properties of the composite insulator
- Available for the full voltage range of 72.5 kV up to 800 kV and full current range of 100 A up to 4,800 A
- Low-reactance, bar-type primary providing optimal short-circuit performance
- Optimum field grading is accomplished by a fine condenser grading system especially developed for this application
- Multiple-turn primaries for small primary currents and uniformly distributed secondary windings guarantee accurate transformation at both rated and high currents
- Stable accuracy over life-time
- Perfect transient performance
- Exclusive use of corrosion-resistant materials
- Replacing cores on assembled units is possible without affecting the integrity of the high-voltage insulation.

Inductive voltage transformers
Inductive voltage transformers are designed for 72.5 kV to 800 kV systems and are used to provide voltage for meter-
ing and protection applications. They are available with either oil (fig. 42) or SF₆ gas dielectric systems (fig. 43).

Features of oil-immersed type
• Low weight and minimum oil volume
• Excellent seismic performance as a consequence of optimized designs of flanges, large choice of porcelain strengths and their interconnection and low weight
• Available for the full voltage range of 72.5 kV up to 550 kV

• Excellent control of internal and external insulation stresses through the use of a proprietary finely graded bushing system
• Optimized high-voltage coil ensures identical electric stresses under both transient and steady-state conditions
• Essentially unaffected by stray external magnetic fields
• Hermetically sealed stainless-steel metallic bellows for units rated 123 kV and above

Voltage Transformers / RC-Dividers for Gas Insulated Substations (GIS)

<table>
<thead>
<tr>
<th>Type</th>
<th>Voltage range [kV]</th>
<th>Insulation medium</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUD/SU</td>
<td>72.5 – 800</td>
<td>SF₆</td>
</tr>
<tr>
<td>RCD</td>
<td>72.5 – 550</td>
<td>Oil / SF₆</td>
</tr>
</tbody>
</table>

### Technical data SUD/SU

<table>
<thead>
<tr>
<th>Voltage level [kV]</th>
<th>72.5</th>
<th>123</th>
<th>145</th>
<th>170</th>
<th>245</th>
<th>300</th>
<th>362</th>
<th>420</th>
<th>550</th>
<th>800</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated power frequency withstand voltage [kV]</td>
<td>140</td>
<td>230</td>
<td>275</td>
<td>325</td>
<td>460</td>
<td>460</td>
<td>510</td>
<td>630</td>
<td>680</td>
<td>975</td>
</tr>
<tr>
<td>Rated lightning impulse withstand voltage [kV]</td>
<td>325</td>
<td>550</td>
<td>650</td>
<td>750</td>
<td>1,050</td>
<td>1,050</td>
<td>1,175</td>
<td>1,425</td>
<td>1,550</td>
<td>2,100</td>
</tr>
<tr>
<td>Rated switching impulse withstand voltage [kV]</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>850</td>
<td>950</td>
<td>1,050</td>
<td>1,175</td>
<td>1,550</td>
</tr>
<tr>
<td>Output voltage [V]</td>
<td>110√3 – 200√3 (other values upon request)</td>
<td>(AC &amp; DC RC Divider: 5 – 200V)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rated voltage factor</td>
<td>1.2 – 1.5 – 1.9 (other values upon request)</td>
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<td></td>
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</tr>
<tr>
<td>Rated frequency [Hz]</td>
<td>16 ⅔ – 50 – 60</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Temperature range [°C]</td>
<td>–35 – +40 (other values upon request)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Insulation class</td>
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<td></td>
<td></td>
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<td>Metering accuracy class</td>
<td>0.1 - 0.2 - 0.5 - 1</td>
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<td></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Output burden</td>
<td>for different classes according to customer specification</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Protection accuracy class</td>
<td>3P - 6P</td>
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<td></td>
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</tr>
<tr>
<td>Output burden</td>
<td>for different classes according to customer specification</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Thermal limiting output</td>
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<td></td>
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<td></td>
<td></td>
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<td></td>
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<tr>
<td>IID</td>
<td>x x x x x x x x x</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3,000</td>
<td>x x x x x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Values in accordance with IEC; other values like ANSI are available; ¹) valid only for voltage transformers

Table 14: Technical data of Trench voltage transformers for gas-insulated substations (GIS)
### Current Transformers for Air Insulated Substations (AIS)

<table>
<thead>
<tr>
<th>Type</th>
<th>SAS</th>
<th>TAG</th>
<th>IOSK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage range</td>
<td>[kV]</td>
<td>72.5 – 800</td>
<td>72.5 – 550</td>
</tr>
<tr>
<td>Insulation medium</td>
<td></td>
<td>SF₆</td>
<td>SF₆</td>
</tr>
<tr>
<td>Composite insulator</td>
<td></td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>Porcelain insulator</td>
<td></td>
<td>×</td>
<td></td>
</tr>
</tbody>
</table>

### Technical data

<table>
<thead>
<tr>
<th>Voltage level</th>
<th>[kV]</th>
<th>72.5</th>
<th>123</th>
<th>145</th>
<th>170</th>
<th>245</th>
<th>300</th>
<th>362</th>
<th>420</th>
<th>550</th>
<th>800</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated power frequency withstand voltage</td>
<td>[kV]</td>
<td>140</td>
<td>230</td>
<td>275</td>
<td>325</td>
<td>460</td>
<td>460</td>
<td>510</td>
<td>630</td>
<td>680</td>
<td>975</td>
</tr>
<tr>
<td>Rated lightning impulse withstand voltage</td>
<td>[kV]</td>
<td>325</td>
<td>550</td>
<td>650</td>
<td>750</td>
<td>1,050</td>
<td>1,050</td>
<td>1,175</td>
<td>1,425</td>
<td>1,550</td>
<td>2,100</td>
</tr>
<tr>
<td>Rated switching impulse withstand voltage</td>
<td>[kV]</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>850</td>
<td>950</td>
<td>1,050</td>
<td>1,175</td>
<td>1,550</td>
</tr>
<tr>
<td>Rated normal current up to</td>
<td>[A]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5,000</td>
<td></td>
</tr>
<tr>
<td>Output current</td>
<td>[A]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1 – 2 – 5</td>
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<tr>
<td>Rated short-time thermal current</td>
<td>[kA]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>63 (80 on special request)</td>
<td></td>
</tr>
<tr>
<td>Rated duration of short circuit</td>
<td>[s]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1 – 3</td>
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</tr>
<tr>
<td>Rated dynamic current</td>
<td>[kA]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>160 (200 on special request)</td>
<td></td>
</tr>
<tr>
<td>Rated frequency</td>
<td>[Hz]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>16 ⅔ – 50 – 60</td>
<td></td>
</tr>
<tr>
<td>Creepage distance</td>
<td>[mm/kV]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>25 – 31 (higher upon request)</td>
<td></td>
</tr>
<tr>
<td>Temperature range</td>
<td>[°C]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>–40 – +40 (other values upon request)</td>
<td></td>
</tr>
<tr>
<td>Insulation class</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>E (SF₆ insulated devices) – A (oil insulated devices)</td>
<td></td>
</tr>
<tr>
<td>Metering accuracy class</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.1 – 0.2 – 0.25 – 0.5 – 0.5S – 1</td>
<td></td>
</tr>
</tbody>
</table>

Values in accordance with IEC; other values like ANSI are available

**Table 15: Technical data of Trench current transformers for air-insulated substations (AIS)**
### Table 16: Technical data of Trench voltage transformers for air-insulated substations (AIS)

<table>
<thead>
<tr>
<th>Type</th>
<th>SVS</th>
<th>TVG</th>
<th>VEOT/VEOS</th>
<th>TCVT</th>
<th>AC RCD</th>
<th>DC RCD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage range [kV]</td>
<td>72.5 – 800</td>
<td>72.5 – 420</td>
<td>72.5 – 550</td>
<td>72.5 – 1200</td>
<td>72.5 – 800</td>
<td>72.5 – 800</td>
</tr>
<tr>
<td>Insulation medium</td>
<td>$\text{SF}_6$</td>
<td>$\text{SF}_6$</td>
<td>Oil</td>
<td>Oil</td>
<td>Oil</td>
<td>Oil / $\text{SF}_6$</td>
</tr>
<tr>
<td>Composite insulator</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Porcelain insulator</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
</tbody>
</table>

#### Technical data

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage level [kV]</td>
<td>72.5, 123, 145, 170, 245, 300, 362, 420, 550, 800</td>
</tr>
<tr>
<td>Rated power frequency withstand voltage [kV]</td>
<td>140, 230, 275, 325, 460, 460, 510, 630, 680, 975</td>
</tr>
<tr>
<td>Rated lightning impulse withstand voltage [kV]</td>
<td>325, 550, 650, 750, 1,050, 1,050, 1,175, 1,425, 1,550, 2,100</td>
</tr>
<tr>
<td>Rated switching impulse withstand voltage [kV]</td>
<td>–, –, –, –, –, 850, 950, 1,050, 1,175, 1,550</td>
</tr>
<tr>
<td>Output voltage [V]</td>
<td>110$/\sqrt{3}$ – 200$/\sqrt{3}$ (other values upon request) (AC &amp; DC RC Divider: 5 – 200V)</td>
</tr>
<tr>
<td>Rated voltage factor</td>
<td>1.2 – 1.5 – 1.9 (other values upon request)</td>
</tr>
<tr>
<td>Rated frequency [Hz]</td>
<td>16 ⅔ – 50 – 60 (AC &amp; DC RC Divider: 0 – 1 MHz)</td>
</tr>
<tr>
<td>Creepage distance [mm/kV]</td>
<td>25 – 31 (higher upon request)</td>
</tr>
<tr>
<td>Temperature range [°C]</td>
<td>–40 – +40 (other values upon request)</td>
</tr>
<tr>
<td>Insulation class</td>
<td>E ($\text{SF}_6$ insulated devices) – A (oil insulated devices)</td>
</tr>
<tr>
<td>Metering accuracy class</td>
<td>0.1 · 0.2 · 0.5</td>
</tr>
<tr>
<td>Output burden (only AC)</td>
<td>for different classes according to customer specification (very low output burden for RC Divider &gt; 100 kΩ)</td>
</tr>
<tr>
<td>Protection accuracy class</td>
<td>3P – 6P</td>
</tr>
<tr>
<td>Output burden (only AC)</td>
<td>for different classes according to customer specification</td>
</tr>
<tr>
<td>Thermal limiting output [VA]</td>
<td>3,000 ¹</td>
</tr>
</tbody>
</table>

Values in accordance with IEC; other values like ANSI are available; ¹ valid only for voltage transformers
• Stable accuracy over a long period of time
• Perfect transient performance
• Suitable for line discharging
• Applicable as a low-cost alternative to small power transformer
• Exclusive use of corrosion-resistant materials
• Full range of products available with composite insulator.

Features of gas-insulated transformer
• Explosion-proof design by the compressible insulation medium SF₆ gas and rupture disc
• Excellent seismic performance due to the properties of the composite insulator
• Available for the full voltage range of 72.5 kV up to 800 kV
• Optimum field grading is accomplished by a fine condenser grading system especially developed for this application
• Wide range ferro-resonance-free design without the use of an external damping device (please ask for details)
• Essentially unaffected by external stray magnetic fields
• Stable accuracy over a long period of time
• Suitable for line discharging
• Optimized high-voltage coil ensures identical electric stresses under both transient and steady state conditions

• Exclusive use of corrosion-resistant materials
• Applicable as a low-cost alternative to small power transformer.

Capacitor voltage transformer (oil-immersed)
Coupling capacitors (CC) are utilized to couple high-frequency carrier signals to the power line. A CC supplied with an electromagnetic unit is called a capacitor voltage transformer (CVT) and is used to provide voltage for metering and protection applications (fig. 44).

Features
• Capable of carrier coupling PLC signals to the network
• Optimized insulation system design utilizing state-of-the-art processing techniques with either mineral oil or synthetic insulating fluids
• Stability of capacitance and accuracy over a long period of time due to superior clamping system design
• Oil expansion by way of hermetically sealed stainless-steel bellows ensures the integrity of the insulation system over time
• Bellows puncture pin provides for release of internal pressure in the event of severe service conditions leading to internal discharges
• Extra-high-strength porcelains provide both superior seismic performance and the ability to mount large line
traps directly on the CVT with corresponding savings in installed cost
• Maintenance-free oil-filled cast aluminum basebox
• Superior transient response characteristics
• Internal company routine tests and quality requirements exceed those of international standards with impulse tests and partial discharge test being performed on a routine basis
• Not subject to ferroresonance oscillations with the network or circuit breaker capacitor
• High-capacitance CVTs, when installed in close proximity to EHV circuit breakers, can provide enhanced circuit breaker short line fault/TRV performance.

Electronic voltage measuring system for HVDC
Trench offers special voltage transformers for HVDC systems. These units are primarily used to control the HV valves of the rectifiers or inverse rectifiers. The measuring system consists of an RC voltage divider that provides inputs to a specially designed electronic power amplifier. The high-voltage divider can be supplied either for outdoor operation (fig. 45) or for installation into SF₆ gas insulated switchgear (GIS) (fig. 50).

The resulting system can accurately transform voltages within a defined burden range with linear frequency response of up to approximately 10 kHz. Thus, the system is ideal for measurement of dynamic and transient phenomena and harmonics associated with HVDC systems.

Combined instrument transformer
The combined instrument transformer offers the station designer the ability of being able to accommodate the current transformer and the voltage transformer in one free-standing unit. This allows optimum use of substation space while yielding cost savings by elimination of one set of mounting pads and support structures. In addition, installation time is greatly reduced. Combined ITs are available with either oil (fig. 47) or SF₆ gas dielectric systems (fig. 48).

Features of oil-immersed combined instrument transformers
• Low weight and minimum oil volume
• Short symmetrically arranged low-reactance, bar-type primary conductor permits higher short-circuit currents and avoids large voltage drop across primary winding
• Excellent control of internal and external insulation stresses through the use of a proprietary finely graded bushing system
• Available for the full voltage range of 72.5 kV up to 300 kV and full current range of 0.5 A up to 5,000 A
• Excellent seismic capability as a consequence of optimized design of flanges, large choice of porcelain strengths and their interconnection and low weight
• Hermetically sealed by stainless-steel metallic bellows and high-quality gaskets
• Only one foundation required in the switchyard as a consequence of combining the voltage and current-sensing functions in one transformer
• Uniformly distributed secondary windings guarantee accurate transformation at both rated and high current
• Essentially unaffected by stray external magnetic fields
• Stable accuracy over a long period of time
• Perfect transient performance
• Suitable for line discharging
• Exclusive use of corrosion-resistant materials
• Full range of products available with composite insulator.

Features of gas-insulated combined instrument transformers
• Head-type design with voltage transformer section located on top of the current transformer
• Low weight and compact SF₆ design
• Explosion-proof design by the compressible insulation medium SF₆ gas and rupture disc
• Excellent seismic performance due to the properties of the composite insulator
• The single-section high-voltage coil (not cascaded) of the voltage transformer section enables a product range for combined instrument transformers of up to 800 kV
• Optimum field grading is accomplished by a fine condenser grading system especially developed for this application
Wide-range ferroresonance-free design without the use of an external damping device
• Low-reactance type primary conductor allows for high short-circuit currents and covers all core standards
• Less foundation space required compared to individual current transformers and voltage transformers
• Suitable for line discharging
• Essentially unaffected by external stray magnetic fields
• Exclusive use of corrosion-resistant materials.

Instrument transformer for GIS
In addition to the measurement of the voltages and currents, this instrument transformer type for voltage measurement (inductive) has the best discharge capabilities for HV lines (fig. 51).

Features of inductive type
• Custom-designed instrument transformers for each specific application and extended function designs comply with dimensional restrictions, flange sizes and insulator requirements
• Standard designs for 1-phase and 3-phase units
• Meets all national and international standards in regard to pressure vessel codes

RC types
Resistive-capacitive voltage dividers, also called resistive-capacitive voltage transformers, are designed for measurement of the voltage in HVDC transmission systems, air-insulated (AIS) or gas-insulated (GIS) switchgear (fig. 52). In AC transmission systems, the transformers are used for the measurement of harmonics and they give an accurate representation of the voltage over a wide frequency band (typically from DC up to 500 kHz).
Features of RC-types
• RC divider for voltage measurements
• Conform to microprocessor-based secondary technology
• Ferroresonance-free
• Able to perform voltage test on site
• 1-phase or 3-phase system
• Significant size and weight reduction.

LoPo – the low-power transducers
The low-power current transducers (LPCT) and low-power voltage transducers (LPVT) can be used for a wide range of medium and high-voltage applications in which they replace the conventional measuring transformers for measurement and protection purposes.

Features
• The voltage transducers are based on resistive, capacitive, as well as resistive-capacitive dividers
• The current transducers are based on an iron-core or an air-core design and provide a secondary voltage that represents the primary current
• Standard cables and connectors; twisted pair and double shielded cable
• Connection capability for multiple protection and measuring devices
• Metal-clad housing ensuring operator safety
• Immune to all methods of online switchgear and cable testing
• Current transducers provide a linear transmission up to short-circuit current
• Completely EMC shielded: immune to RFI/EMI.

Advantages
• System conforms to low-power digital microprocessor-based technology for protection and metering
• Simple assembly with compact size and low weight
• No secondary circuit problems; voltage transducers are short-circuit-proof, current transducers can have an open secondary
• Voltage transducers are ferroresonance-free
• Environment-friendly (no oil).

Power Voltage Transformers

Power Voltage Transformers for AIS
Power Voltage Transformers (Power VTs) avoid major investments to achieve power supply for remote customers. The Power VTs just have to be connected directly to the high voltage overhead line to ensure customized power supply. A power VT for AIS is shown in fig. 46.

Features of Power VTs for AIS
• Available for the full voltage range of 72.5 up to 800 kV
• SF₆ or oil insulated power enhanced instrument voltage transformer with proven reliability
• Composite insulator (fibre-glass insulator with silicone sheds)
• Maintenance free
• Single phase unit

Applications
• Power supply for remote farms and small villages
• Power supply for relay stations for mobile phones
• Auxiliary power supply for substations
• Power supply during substation construction works.

Power Voltage Transformers for GIS
Inductive Voltage Transformer with different active parts becomes a „Power VT”, which then allows for a high voltage test of the primary system without special high voltage test equipment. A Power VT for GIS is shown in fig. 53.

Features of Power VTs for GIS
• Same dimension as standard VTs and also usable like a standard VT
• No extra space needed for installation of huge high voltage testing facilities
• No SF₆-gas handling at site needed for test preparation
• Reduced transport and packages requirements
• After test the switchgear can be put into operation without mechanical work on the primary circuit (i.e. normally the high voltage test set must be removed)
• Easy support by neutral testing companies (e.g. OMICRON) or testing institutes
• With a “Power VT” the high voltage test becomes like testing a protection relay
• Light weight units allow handling at site without lifting facilities or cranes
• Power supply via standard socket outlet (e.g. 1-phase, 230 V, 16 A)
• Test facilities available with transport cases allowing transport as carry-on luggage during travelling to site or the use of standard parcel services
• Test preparation within minutes e.g. after S/S-extension, re-assembling or extensive service activities
• Low investment in site-based testing facilities
• Possibility for investigation into sporadic effects at PD-test voltage levels.

An overview of the range of Trench instrument transformers appers in tables 13–16.
Introduction
With 40 years of successful field experience, Trench is the recognized world leader in the design and manufacture of air-core, dry-type, power reactors for all utility and industrial applications. The unique custom design approach, along with fully integrated engineering and manufacturing facilities in North America, Europe and China have enabled Trench to become the technical leader for high-voltage inductors worldwide.

A deep commitment to the power industry, along with extensive investment in engineering, manufacturing and test capability, give Trench customers the utmost in high-quality, reliable products that are individually designed for each application. Trench reactor applications have grown from small-distribution class, current-limiting reactors to complex EHV-applied reactors surpassing 300 MVA per coil.

Reactors are manufactured in accordance with the ISO 9001 quality standard. Trench’s highly developed research and development program constantly addresses new technologies and their potential application in reactor products. Trench welcomes challenges for new applications for power reactors.

Design features
Design features of air-core dry-type reactors are:
- Epoxy impregnated, fiberglass-encapsulated construction
- Aluminum construction throughout with all current carrying connections welded
- Highest mechanical and short-circuit strength
- Essentially zero radial-voltage stress, with uniformly graded axial-voltage distribution between terminals
- Low noise levels are maintained throughout the life of the reactor
• Weatherproof construction, with minimum maintenance requirements
• Design service life in excess of 30 years
• Designs available in compliance with ANSI/IEEE, IEC and other major standards.

Construction
A Trench air-core dry-type reactor consists of a number of parallel-connected, individually insulated, aluminum (copper on request) conductors (fig. 55). These conductors can be small wire or proprietary cables custom-designed and custom-manufactured. The size and type of conductor used in each reactor is dependent on the reactor specification. The various styles and sizes of conductors available ensure optimum performance at the most economical cost.

The windings are mechanically reinforced with epoxy resin-impregnated fiberglass, which after a carefully defined oven-cure cycle produces an encapsulated coil. A network of horizontal and vertical fiberglass ties coupled with the encapsulation minimizes vibration in the reactor and achieves the highest available mechanical strength. The windings are terminated at each end to a set of aluminum bars called a spider. This construction results in a very rigid unit capable of withstanding the stresses developed under the most severe short-circuit conditions.

Exceptionally high levels of terminal pull, tensile strength, wind loading and seismic withstand can be accommodated with the reactor. This unique design can be installed in all types of climates and environments and still offer optimum performance.

Trench air-core dry-type reactors are installed in polluted and corrosive areas and supply trouble-free operation. In addition to the standard fixed reactance type of coil, units can be supplied with taps for variable inductance. A
number of methods are available to vary inductance for fine-tuning or to provide a range of larger inductance steps.

In addition, Trench utilizes various other designs for reactors, e.g., iron-core and water-cooled.

**Series reactors**
Reactors are connected in series with the line or feeder. Typical uses are fault-current reduction, load balancing in parallel circuits, limiting inrush currents of capacitor banks, etc.

**Current-limiting reactors**
Current-limiting reactors reduce the short-circuit current to levels within the rating of the equipment on the load side of the reactor (fig. 56). Applications range from the simple distribution feeder reactor to large bus-tie and load-balancing reactors on systems rated up to 765 kV/2100 kV BIL.

**Capacitor reactors**
Capacitor reactors are designed to be installed in series with a shunt-connected capacitor bank to limit inrush currents due to switching, to limit outrush currents due to close-in faults, and to control the resonant frequency of the system due to the addition of the capacitor banks. Reactors can be installed on system voltages through 765 kV/2100 kV BIL. When specifying capacitor reactors, the requested continuous current rating should account for harmonic current content, tolerance on capacitors and allowable system overvoltage.

**Buffer reactors for electric arc furnaces**
The most effective use of buffer reactors for electric arc furnaces (EAF) is achieved by operating the furnace at low electrode current and long arc length. This requires the use of a series reactor in the supply system of the arc furnace transformer for stabilizing the arc.
Duplex reactors
Duplex reactors are current limiting reactors that consist of two half coils, wound in opposition. These reactors provide a desirable low reactance under normal conditions and a high reactance under fault conditions.

Load-flow control reactors
Load-flow control reactors are series-connected on transmission lines of up to 800 kV. The reactors change the line impedance characteristic such that load flow can be controlled, thus ensuring maximum power transfer over adjacent transmission lines.

Filter reactors
Filter reactors are used in conjunction with capacitor banks to form series tuned harmonic filter circuits, or in conjunction with capacitor banks and resistors to form broadband harmonic filter circuits. When specifying filter reactors, the magnitudes of fundamental and harmonic frequency currents should be indicated. If inductance adjustment for fine-tuning is required, the required tapping range and tolerances must be specified. Many filter applications require a Q factor that is very much lower than the natural Q of the reactor. This is often achieved by connecting a resistor in the circuit.

An economical alternative is the addition of a de-Q'ing ring structure on a reactor. This can reduce the Q factor of the reactor by as much as one tenth without the necessity of installing additional damping resistors. These rings, mounted on the reactor, are easily coupled to the magnetic field of the reactor. This eliminates the concern of space, connection and reliability of additional components such as resistors.

Shunt reactors
Shunt reactors are used to compensate for capacitive VARs generated by lightly loaded transmission lines or underground cables. They are normally connected to the transformer tertiary winding but can also be directly connected on systems of up to 115 kV.

Thyristor-controlled shunt reactors (TCR) are extensively used in static VAR systems in which reactive VARs are adjusted by thyristor circuits (fig. 57). Static VAR compensator reactor applications normally include:
- Thyristor-controlled shunt reactors. The compensating power is changed by controlling the current through the reactor by means of the thyristor valves.
- Thyristor-switched reactors (TSR)
- Thyristor-switched capacitor reactors (TSC)
- Filter reactors (FR).

HVDC reactors
HVDC lines are used for long-distance bulk power transmission as well as back-to-back interconnections between different transmission networks. HVDC reactors normally include smoothing reactors, AC and DC harmonic filter reactors, as well as AC and DC PLC noise filter reactors.

Smoothing reactors
Smoothing reactors (fig. 58) are used to reduce the magnitude of the ripple current in a DC system. They are used in power electronics applications such as variable-speed drives and UPS systems. They are also required on HVDC transmission lines for system voltages of up to 500 kV. Several design and construction techniques are offered by Trench.

Test lab reactors
Test lab reactors are installed in high-voltage and high-power test laboratories. Typical applications include current limiting, synthetic testing of circuit breakers, inductive energy storage and artificial lines.

Neutral earthing reactors
Neutral earthing reactors limit the line-to-earth fault current to specified levels. Specification should also include unbalanced condition continuous current and duration.

Arc-suppression coils
Single-phase neutral earthing (grounding) reactors (arc-suppression coils) are intended to compensate for the capacitive line-to-earth current during a 1-phase earth fault. The arc-suppression coil (ASC) represents the central element of the Trench earth-fault protection system (fig. 59).

Because the electric system is subject to changes, the inductance of the ASC used for neutral earthing must be variable. The earth-fault detection system developed by Trench utilizes the plunger core coil (moveable-core design). Based on extensive experience in design, construction and application of ASCs, Trench products can meet the most stringent requirements for earth-fault compensating techniques.
High-Voltage Bushings

A bushing is an electrical engineering component that insulates a high-voltage conductor passing through a metal enclosure or a building. Bushings are needed on:

- Transformers
- Buildings
- Gas-insulated switchgear (GIS)
- Generators
- Other high-voltage equipment.

Typical environmental conditions are:

- Oil-to-air
- Oil-to-gas
- Oil-to-oil
- SF₆-to-air
- Air-to-air.

The internal insulation of a bushing is made of a combination of different isolation materials:

- Oil-impregnated paper
- Epoxy resin-impregnated paper
- SF₆ gas.

The external insulation is made of:

- Epoxy resin for indoor applications
- Porcelain or fiberglass tubes with silicone rubber sheds for outdoor application.

Selected state-of-the-art bushing designs are described in the sections that follow.

Transformer bushings

**oil-impregnated paper (OIP) design**

An oil-impregnated paper transformer bushing is made of the following components (fig. 62):

1. Terminal
   Terminal (Al or Cu) for connection of overhead lines or busbars and arcing horns. State-of-the-art designs provide maintenance-free termination and ensures that the connection will not become loose in service.

2. Assembly
   The whole bushing is tightened together by the central tube or conductor.

3. Head
   Al-casted head with oil expansion chamber and oil level indicator. The chamber is hermetically sealed against the atmosphere.

4. Oil filling
   State-of-the-art bushings are filled with dried, degassed insulating mineral oil.

5. Insulator
   Porcelain insulator made of high-grade electrotechnical porcelain according to IEC 815. The insulator is connected to the mounting flange using Portland cement and sealed with O-ring gasket. Composite insulators are increasingly demanded and are readily available.

6. Active part
   The active part is made of oil-impregnated wide-band paper with layers of aluminum foil to control the electrical field radially and axially. Depending on the current rating, the paper and foil are wound on either a central tube or a solid conductor.

7. Flange
   The mounting flange with integrated test tap made of corrosion free aluminum alloy is machined to ensure an excellent seal between the bushing and the transformer.

8. CT pocket
   If current transformers are required on the bushing, the ground sleeve can be extended.

9. Oil-side end
   The insulator on the oil side is made of an epoxy resin tube. It is designed to stay installed during the in-tank drying process of the transformer and can withstand temperatures of up to 130 °C.

10. End shielding
    For voltages starting with 52 kV, a special aluminum electrode is cast into the end of the epoxy resin tube. This end shielding controls the electrical field strength in this area to earth.
Test-tap principle:
The pin of the test-tap insulator is earthed over the omega spring inside the screwed-on cap. For testing purposes, a 4 mm spring socket must be slipped over the pin and then a 4 mm plug can be inserted into the spring socket.
Transformer bushings: epoxy resin-impregnated paper (ERIP) design

Modular system
Modern ERIP bushings (fig. 63) are constructed in a modular system. They have standardized components. An adaptation to requested creepage distances, flange dimensions and so on is easily possible.

Connections
The modular bushing systems offer a large choice of connecting systems. At the upper end of the bushing head, there is a clamp through which the conductor or the cable bolt is fixed. A releasable cross-pinned fitting at the clamping device prevents it from slipping into the transformer during operation. In addition, it serves as locking element. The bolt is sealed through double seals. The clamp is made of stainless steel and all screws are of non-corrosive steel. The venting of the central tube is located on one side under the edge of the clamp and can be operated independently of the conductor bolt. In addition to the cable bolt, solid conductor bolts are available, e.g., for higher-current applications. These bolts are wedged against the inner wall of the central tube with insulated spacers. Solid conductor bolts can be provided with a separation point, preferably at the flange or to suit any particular case. The bolts are equipped with a threaded hole at the top, so that a draw wire or a rod can be screwed in and the bolt pulled through the central tube.

Transformer bushings: high current
High current bushings for transformer-to-phase busbar-isolated connections are designed for 17.5 kV to 36 kV and currents from 6,300 A to 31,500/40,000 A. Conductors are either aluminum or copper. The main insulation is vacuum-impregnated epoxy condenser (fig. 60).

Other transformer bushings: oil-to-gas and oil-to-oil
Oil-to-gas types are intended for the direct connection of power transformers to gas-insulated switchgear. Oil-to-oil types are intended for the direct connections within the power transformer (fig. 61). Both consist of a main insulating body of RIP (epoxy resin-impregnated paper). The condenser core is made of special epoxy resin vacuum-impregnated paper incorporating grading foils to ensure uniform voltage distribution. This insulation has proven its reliability in over 40 years of service in various network applications. A high-quality insulation enables a compact design. Bushings with this insulation have, furthermore, a low partial discharge level, not only at service voltage but far in excess.
HVDC bushings: transformer and wall

The growing demand for HVDC transmission requires reliable and efficient transformer and wall bushings of up to 800 kV DC (fig. 66). ERIP solutions are often preferred due to their superior performance in heavily polluted areas or due to their mechanical strength especially the seismic behavior. Examples of state-of-the-art solutions are the project Tian-Guang/China (fig. 64), which has:

- 515 kV wall bushings
- 412/212 kV transformer bushings

Wall bushings

Wall bushings (fig. 65 above, fig. 69) are designed for use in high-voltage substations as roof or wall by their positioning:

- Indoor/indoor bushings for dry indoor conditions
- Outdoor/indoor bushings for use between open air (outer atmosphere) and dry indoor conditions
- Outdoor/outdoor bushings where both ends are in contact with the open air (outer atmosphere)

The main insulating body is capacitive-graded. A number of conductive layers are coaxially located at calculated distances between the central tube and the flange, and this leads to a virtual linearization of the axial distribution of voltage on the bushing surface, resulting in minimum stress on the surrounding air.

GIS bushings

These bushings are designed for use in GIS substations, mainly to connect to overhead lines. Designs are either electrode design up to 245 kV and condenser design above 245 kV (fig. 68). Composite design are increasingly demanded, especially for higher voltage ranges and polluted areas.

Generator bushings

Generator bushings (fig. 67 above) are designed for leading the current induced in the stator windings through the pressurized hydrogen-gastight, earthed generator housing. Generator bushings are available from 12 kV through 36 kV and current ratings of up to 45,000 A. They are natural, gas or liquid-cooled.
Long rod insulators

3FL silicone long rod insulators – performance meets durability

Good reasons for the 3FL
The new Siemens silicone long rod insulators type 3FL combine the highest levels of electrical insulation and mechanical tensile strength with a compact, lightweight design. Thanks to their superior design and minimized weight, 3FL long rod insulators are especially suitable for overhead compact-line applications where low tower design and short line spans are required. Furthermore, they can also be more economically transported and installed.

Design
The 3FL insulator housing is a one-piece HTV¹ silicone rubber housing made by the one-shot injection molding process. The HTV silicone is directly molded onto the core rod by overlapping the triple junction point and part of the metal end fittings. The design ensures a total enclosure of the most sensitive part of a silicone insulator – the junction zone (metal end fitting/FRP rod/silicone housing), where usually the highest electrical field strength is concentrated. This overlapping system eliminates any need of traditional sealing systems while preventing any moisture ingress attacks.

Core
The core rod is a boron-free, corrosionresistant ECR² glass-fiber-reinforced plastic rod (FRP rod). Due to the extremely high hydrolysis and acid resistance of the FRP rod the risk of so-called brittle fracture is completely eliminated on 3FL insulators.

End fittings
The end fittings, made of hot-dip galvanized forged steel or ductile cast iron, are directly attached to the FRP core rod by a circumferential crimping process. Each
The crimping process is strongly monitored with a special control system. A complete range of end fittings according to the latest IEC and ANSI standards is available up to 120 kN of SML. The 3FL is 100% exchangeable and compatible with existing insulators and line hardware of all types.

The special design of the end fitting in the junction zone reduces to a minimum the electrical field strength and partial discharge accordingly inside the junction zone as well as on the silicone housing surface by modeling an integrated grading ring. This reliably prevents corrosion of the insulating material and eliminates the risk of subsequent failure of the insulator.

3FL – HTV silicone rubber housing for best pollution performances
The excellent pollution layer characteristics of the HTV silicone rubber ensure maximum reliability of the 3FL insulator, even under extreme service conditions. The extremely hydrophobic housing prevents the formation of conductive film on its surface. Even the most severe ambient conditions, such as salt fog in coastal regions or dust-laden air in industrial areas, cannot impair the intrinsic hydrophobicity of the HTV silicone rubber. Surface currents and discharges are ruled out. Neither water nor dirt on the housing surface can cause insulator flashovers – a significant factor in insulator performance.
Quality from Siemens
According to long-established Siemens tradition and making use of the experience of producing high-voltage equipment for more than a century, each production step for the 3FL – beginning with numerous incoming raw material inspections through the assembly of the individual components to routine tests of the finished product – are rigorously monitored and well controlled.

Standards and tests
All 3FL long rod insulators are designed and tested in compliance with the latest standards IEC 61109, IEC 62217, IEC 60815, and IEC 61466-2. All design and type tests have been successfully performed. Each Siemens 3FL insulator that leaves the factory is routinely tested with a corresponding mechanical tensile test load of at least 50 percent of the defined SML load for at least ten seconds.

Accessories
Arc protection devices such as arcing horns and corona rings (also known as grading rings) for field/corona reduction are available as standard solutions. Customer-specific solutions as well as other connection and cable clamps are also available on request.

3FL2 long rod insulators for distribution overhead power lines
3FL2 long rod insulators are designed to meet the highest requirements in distribution power systems up to 72 kV. They have high lightning impulse and power frequency withstand voltages and a long creepage class (> 3 mm/kV). 3FL2 insulators are available with mechanical ratings up to SML = 70 kN.

Fig. 75: 3FL2 end fittings

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1HTV: High-temperature vulcanizing
2ECR glass: Electrical- and corrosion-resistant glass
Product standards

<table>
<thead>
<tr>
<th>Standard</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEC 61109</td>
<td>Insulators for overhead lines – composite suspension and tension insulators for AC systems with a nominal voltage greater than 1,000 V – definitions, test methods, and acceptance criteria</td>
</tr>
<tr>
<td>IEC 62217</td>
<td>Polymeric insulators for indoor and outdoor use with a nominal voltage greater than 1,000 V – general definitions, test methods, and acceptance criteria</td>
</tr>
<tr>
<td>IEC 60815</td>
<td>Selection and dimensioning of high-voltage insulators intended for use in polluted conditions</td>
</tr>
<tr>
<td>IEC 61466-1</td>
<td>Composite string insulator units for overhead lines with a nominal voltage greater than 1,000 V – Part 1: Standard strength classes and end fittings</td>
</tr>
<tr>
<td>IEC 61466-2</td>
<td>Composite string insulator units for overhead lines with a nominal voltage greater than 1,000 V – Part 2: Dimensional and electrical characteristics</td>
</tr>
<tr>
<td>IEC 60120</td>
<td>Dimensions of ball and socket couplings of string insulator units</td>
</tr>
<tr>
<td>IEC 60471</td>
<td>Dimensions of clevis and tongue couplings of string insulator units</td>
</tr>
</tbody>
</table>

Table 17: Product standards

<table>
<thead>
<tr>
<th>Maximum values</th>
<th>3FL2</th>
<th>3FL4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highest voltage for equipment $U_m$</td>
<td>kV</td>
<td>72.5</td>
</tr>
<tr>
<td>Nominal system voltage $U_n$</td>
<td>kV</td>
<td>69</td>
</tr>
<tr>
<td>Specified mechanical load (SML)</td>
<td>kN</td>
<td>70</td>
</tr>
<tr>
<td>Minimum unified specific creepage distance</td>
<td>mm/kV$_m$</td>
<td>31</td>
</tr>
</tbody>
</table>

Table 18: Maximum values
3FL4 long rod insulators for transmission overhead power lines

3FL4 long rod insulators are designed to meet the highest requirements in transmission power systems up to 170 kV. They have a long creepage class (> 31 mm/kV) as well as high lightning impulse and power frequency withstand voltages. 3FL4 insulators are available with mechanical ratings up to SML = 120 kN.
### Technical data 3FL2

<table>
<thead>
<tr>
<th>Highest voltage for equipment</th>
<th>Typical nominal system voltages</th>
<th>Rated* lightning impulse withstand voltage (1.2/50 µs, dry)</th>
<th>Rated* power frequency withstand voltage (50 Hz, 1 min, wet)</th>
<th>Flashover distance</th>
<th>Creepage distance</th>
<th>Housing length</th>
<th>Section length** (with ball and socket)</th>
<th>Catalog number</th>
<th>Specified mechanical load</th>
<th>Routine test load</th>
<th>Corona ring diameter</th>
<th>Weight (with ball and socket)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Um kV</td>
<td>Un kV</td>
<td>LIWL min kV</td>
<td>PfWL min kV</td>
<td>S mm</td>
<td>C mm</td>
<td>H mm</td>
<td>L mm</td>
<td>SML kN</td>
<td>RTL kN</td>
<td>D mm</td>
<td>W kg</td>
<td></td>
</tr>
<tr>
<td>12.0</td>
<td>10, 11, 12</td>
<td>95</td>
<td>28</td>
<td>214</td>
<td>420</td>
<td>178</td>
<td>332</td>
<td>3FLL2-009-4xx00-1xx1</td>
<td>70</td>
<td>35</td>
<td>–</td>
<td>1.6</td>
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<tr>
<td>24.0</td>
<td>15, 20, 22, 24</td>
<td>145</td>
<td>50</td>
<td>304</td>
<td>799</td>
<td>268</td>
<td>422</td>
<td>3FLL2-014-4xx00-1xx1</td>
<td>70</td>
<td>35</td>
<td>–</td>
<td>2.0</td>
</tr>
<tr>
<td>36.0</td>
<td>30, 33, 35, 36</td>
<td>170</td>
<td>70</td>
<td>394</td>
<td>1178</td>
<td>358</td>
<td>512</td>
<td>3FLL2-017-4xx00-1xx1</td>
<td>70</td>
<td>35</td>
<td>–</td>
<td>2.4</td>
</tr>
<tr>
<td>72.5</td>
<td>60, 66, 69, 72</td>
<td>325</td>
<td>140</td>
<td>664</td>
<td>2315</td>
<td>628</td>
<td>782</td>
<td>3FLL2-032-4xx00-1xx1</td>
<td>70</td>
<td>35</td>
<td>–</td>
<td>3.55</td>
</tr>
</tbody>
</table>

*Rated lightning impulse withstand voltage and power frequency withstand voltage in accordance with IEC 60071. The physical value is higher.

**Reference value of the section length of the insulator for version with ball-and-socket end fittings of size 16 in accordance with IEC 60120. In order to obtain the section length of the insulator implemented with other end fittings, the housing length and connection lengths (see table “End fittings”) of both end fittings must be added together. All electrical values refer to an insulator without arcing horns or corona rings.

### Technical data 3FL4

<table>
<thead>
<tr>
<th>Highest voltage for equipment</th>
<th>Typical nominal system voltages</th>
<th>Rated* lightning impulse withstand voltage (1.2/50 µs, dry)</th>
<th>Rated* power frequency withstand voltage (50 Hz, 1 min, wet)</th>
<th>Flashover distance</th>
<th>Creepage distance</th>
<th>Housing length</th>
<th>Section length** (with ball and socket)</th>
<th>Catalog number</th>
<th>Specified mechanical load</th>
<th>Routine test load</th>
<th>Corona ring diameter</th>
<th>Weight (with ball and socket)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Um kV</td>
<td>Un kV</td>
<td>LIWL min kV</td>
<td>PfWL min kV</td>
<td>S mm</td>
<td>C mm</td>
<td>H mm</td>
<td>L mm</td>
<td>SML kN</td>
<td>RTL kN</td>
<td>D mm</td>
<td>W kg</td>
<td></td>
</tr>
<tr>
<td>72.5</td>
<td>60, 66, 69, 72</td>
<td>325</td>
<td>140</td>
<td>674</td>
<td>2325</td>
<td>638</td>
<td>846</td>
<td>3FLL4-032-4xx00-1xx1</td>
<td>120</td>
<td>60</td>
<td>–</td>
<td>3.8</td>
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<tr>
<td>123.0</td>
<td>110, 115, 120</td>
<td>550</td>
<td>230</td>
<td>1034</td>
<td>3841</td>
<td>998</td>
<td>1206</td>
<td>3FLL4-055-4xx00-1xx1</td>
<td>120</td>
<td>60</td>
<td>–</td>
<td>5.3</td>
</tr>
<tr>
<td>145.0</td>
<td>132, 138</td>
<td>650</td>
<td>275</td>
<td>1214</td>
<td>4599</td>
<td>1178</td>
<td>1386</td>
<td>3FLL4-065-4xx00-1xx1</td>
<td>120</td>
<td>60</td>
<td>260</td>
<td>6.1</td>
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<tr>
<td>170.0</td>
<td>150, 154</td>
<td>750</td>
<td>325</td>
<td>1439</td>
<td>5546</td>
<td>1403</td>
<td>1611</td>
<td>3FLL4-075-4xx00-1xx1</td>
<td>120</td>
<td>60</td>
<td>260</td>
<td>7.1</td>
</tr>
</tbody>
</table>

*Rated lightning impulse withstand voltage and power frequency withstand voltage in accordance with IEC 60071. The physical value is higher.

**Reference value of the section length of the insulator for version with ball-and-socket end fittings of size 16 in accordance with IEC 60120. In order to obtain the section length of the insulator implemented with other end fittings, the housing length and connection lengths (see table “End fittings”) of both end fittings must be added together. All electrical values refer to an insulator without arcing horns or corona rings.
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