
Trafo 46

# 4 Products and Devices

## 4.1 High-Voltage Circuit-Breakers

### 4.1.1 Circuit-Breakers for 72.5 kV up to 800 kV

4

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. 4.1-1):

- 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 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.

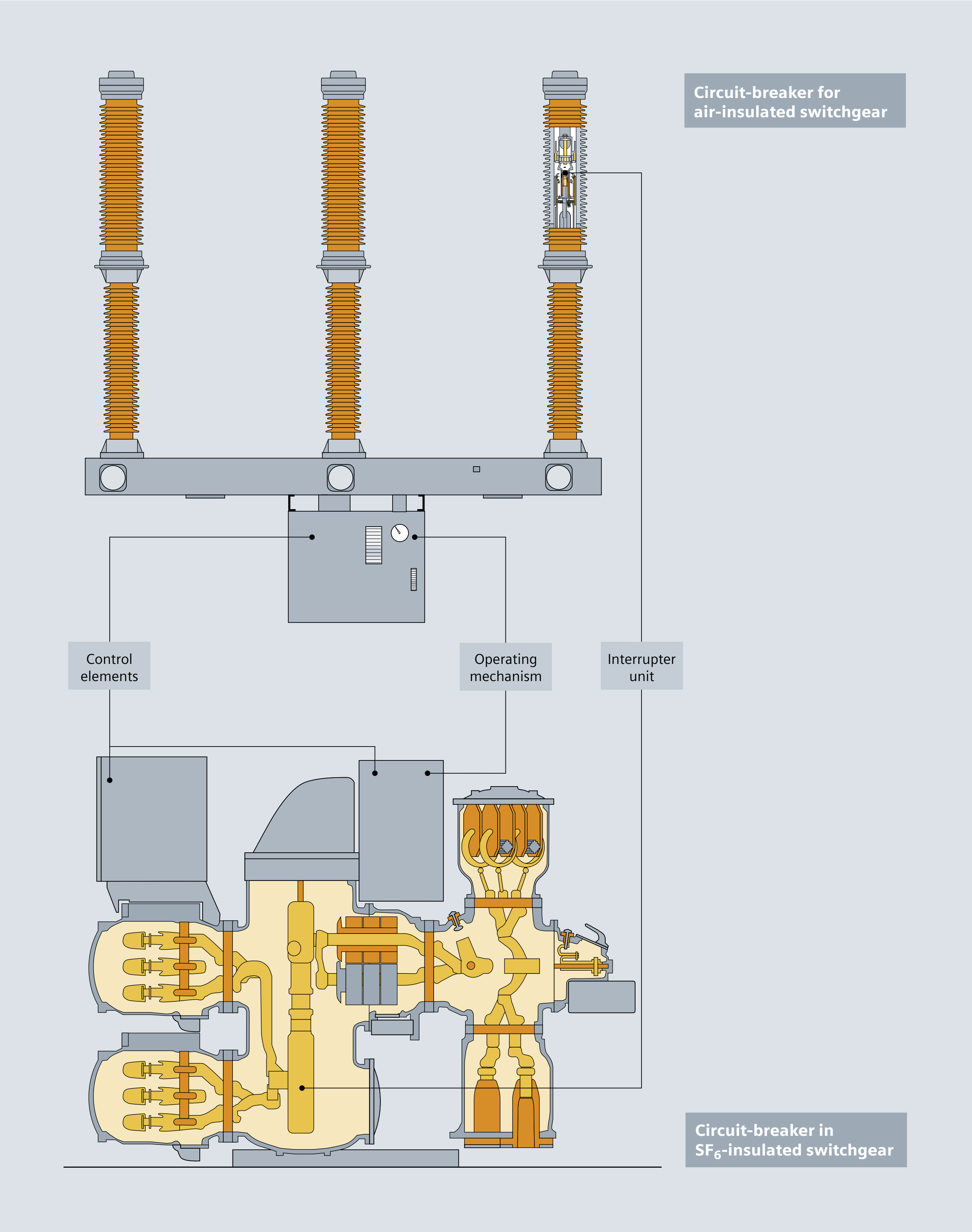



*Fig. 4.1-1:* **Circuit-breaker parts: circuit-breaker for air-insulated switchgear (top), circuit-breaker in $SF_6$-insulated switchgear (bottom)**

4

### 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. 4.1-2).

*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 $SF_6$ 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 proving 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.

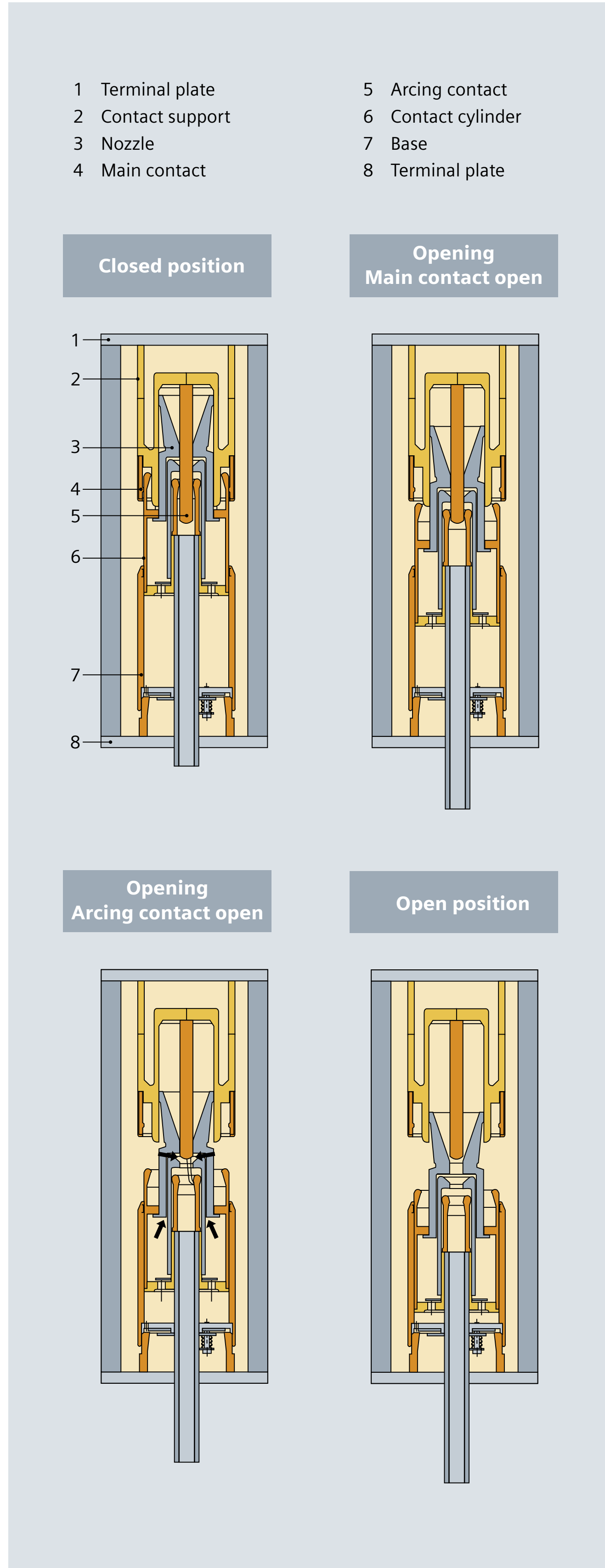
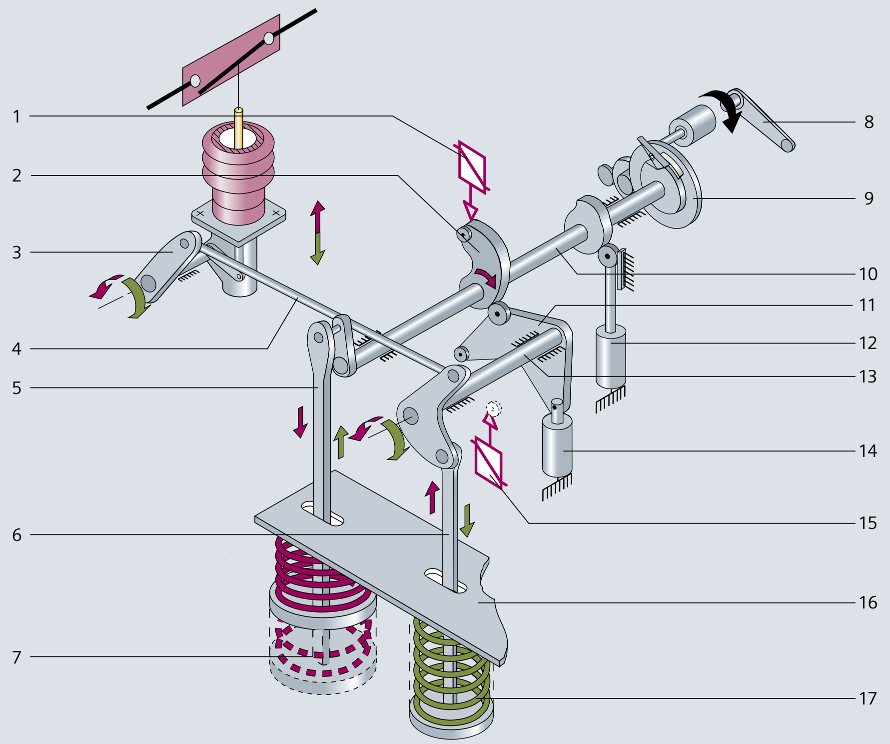



*Fig. 4.1-2:* **The interrupter unit**




1 Trip coil CLOSE
2 Cam plate
3 Corner gear
4 Connecting rod
5 Connecting rod for closing spring
6 Connecting rod for opening spring
7 Closing spring
8 Emergency hand crank
9 Charging gear
10 Charging shaft
11 Roller lever
12 Damper (for closing)
13 Operating shaft
14 Damper (for opening)
15 Trip coil OPEN
16 Operating mechanism housing
17 Opening spring

*Fig. 4.1-3:* **Operating mechanism**

The principle of the operating mechanism with charging gear and latching is identical on all types (fig. 4.1-3, fig. 4.1-4). 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.

The control unit includes all necessary devices for circuit-breaker control and monitoring, such as:
- Pressure / $SF_6$ density monitors
- Relays for alarms and lockout
- Operation counters (upon request)
- Local circuit-breaker control (upon request)
- Anti-condensation heaters.

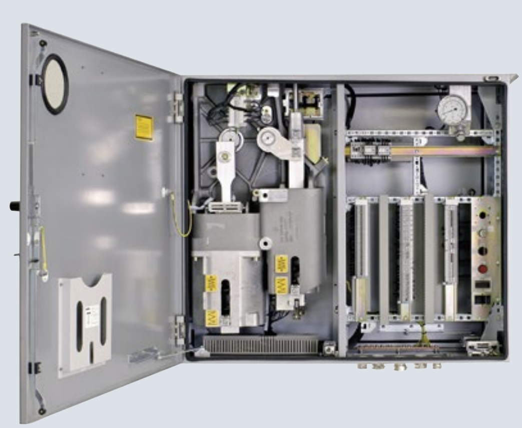


*Fig. 4.1-4:* **Control cubicle**

## 4.1.2 Live-Tank Circuit-Breakers for 72.5 kV up to 800 kV

**Live-tank circuit-breakers for air-insulated switchgear**
The interrupter unit in live-tank circuit-breakers is not earthed during operation; it is exposed to high-voltage potential and therefore these circuit-breakers are called live tanks.

The live-tank circuit-breaker family is available for rated voltages from 72.5 kV up to 800 kV (fig. 4.1-5).

They consist of the following main components based on our well established platform concept (fig. 4.1-6, 4.1-7, 4.1-8):

- Self-compression interrupter unit
- Stored-energy spring mechanism
- Insulator column (AIS)
- Operating rod
- Circuit-breaker base
- Control unit

3AP1 circuit-breakers up to 300 kV are equipped with one interrupter unit per pole, and 3AP2 circuit-breakers up to 550 kV include two interrupter units. For applications from 362 kV to 550 kV, the circuit-breakers can be equipped with optional closing resistors (3AP3). The 3AP4 includes 4 interrupter units per pole and can also be delivered with closing resistors on request (3AP5).

Moreover, our high-voltage live-tank circuit-breakers are available for three-pole operation with a common base (FG) (fig. 4.1-9), for single-pole operation also with a common base (FE) or for single-pole operation with separate bases (FI).

Siemens high-voltage circuit-breakers operate safely, and are capable of withstanding high mechanical loads. Particularly strong porcelain insulators and a circuit-breaker design optimized by using the latest mathematical techniques give them very high seismic stability whilst in operation, enabling them to perform to their full potential during the entire service life of up to 50 years (table 4.1-1).

The uncomplicated design of the circuit-breakers and the use of many similar components 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.

*Fig. 4.1-5:* **3AP4 FI 800 kV pole**

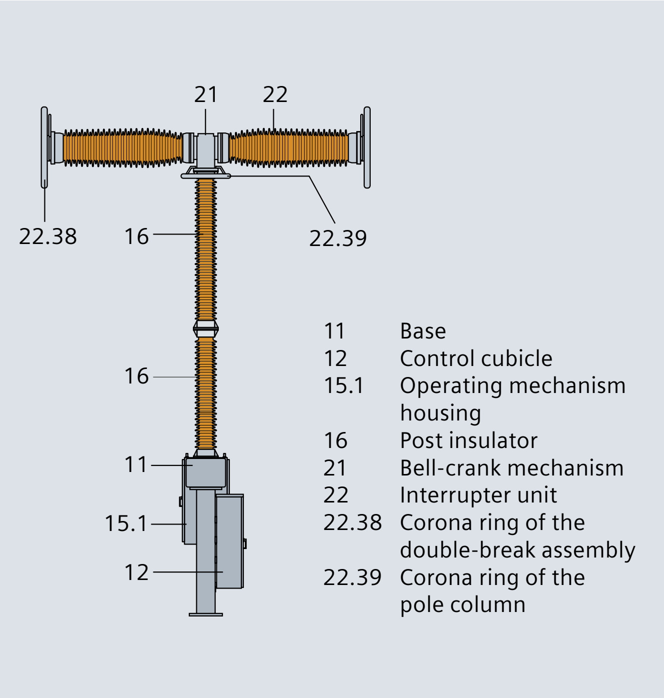



*Fig. 4.1-6:* **3AP2 FI 550 kV pole**

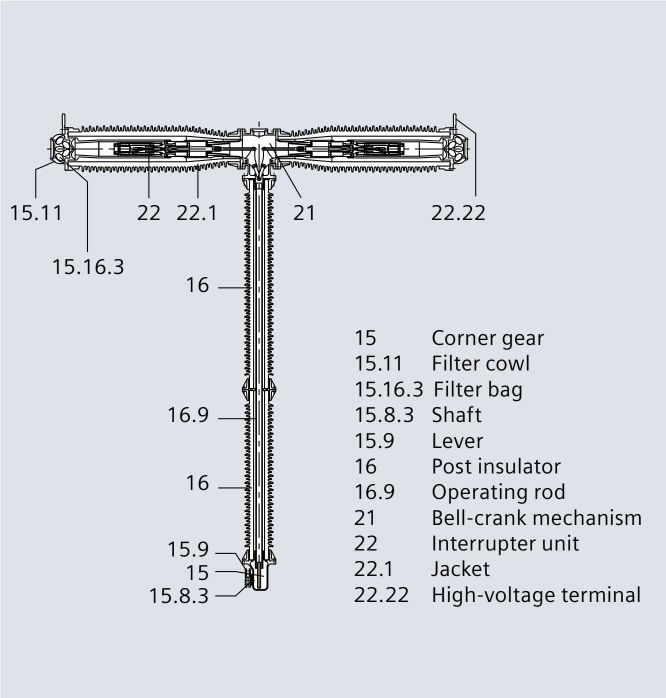



*Fig. 4.1-7:* **Sectional view of pole column**



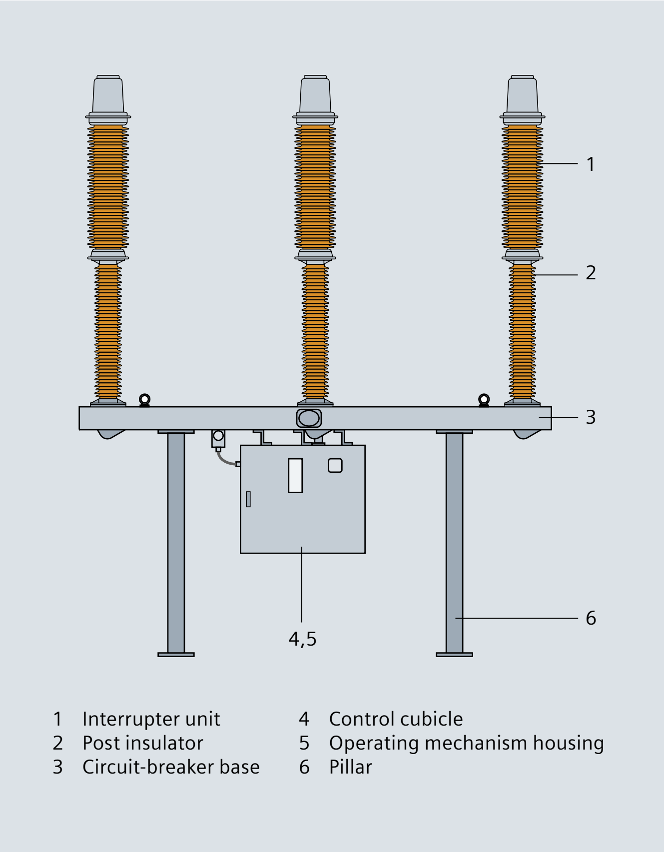



*Fig. 4.1-8:* **3AP1 FG 145 kV with 3-pole stored-energy spring mechanism**

*Fig. 4.1-9:* **3AP1 FG 145 kV**

4

| Type | | 3AP1 | | | | | | 3AP2/3 | | 3AP4/5 |
|---|---|---|---|---|---|---|---|---|---|---|
| Rated voltage | [kV] | 72.5 | 123 | 145 | 170 | 245 | 300 | 420 | 550 | 800 |
| Number of interrupter units per pole | | 1 | | | | | | 2 | | 4 |
| Rated short-duration power-frequency withstand voltage | [kV] | 140 | 230 | 275 | 325 | 460 | 460 | 610 | 800 | 830 |
| Rated lightning impulse withstand voltage/min | [kV] | 325 | 550 | 650 | 750 | 1,050 | 1,050 | 1,425 | 1,550 | 2,100 |
| Rated switching impulse withstand voltage | [kV] | – | – | – | – | – | 850 | 1,050 | 1,175 | 1,425 |
| Rated normal current, up to | [A] | 2,500 | 4,000 | 4,000 | 4,000 | 4,000 | 4,000 | 5,000 | 5,000 | 5,000 |
| Rated short-time withstand current (1 s – 3 s), up to | [$kA_{(ms)}$] | 31.5 | 40 | 40 | 40 | 50 | 40 | 63 | 63 | 63 |
| Rated short-circuit breaking current, up to | [kA] | 31.5 | 40 | 40 | 40 | 50 | 40 | 63 | 63 | 63 |
| Temperature range | [°C] | – 55 up to + 55 | | | | | | | | |
| Rated operating sequence | | 0-0.3 s-CO-3 min-CO or CO-15 s-CO | | | | | | | | |
| Rated break time | | 3 cycles | | | | | | 2 cycles | | |
| Rated frequency | [Hz] | 50/60 | | | | | | | | |
| Maintenance after | | 25 years | | | | | | | | |

| Type | | 3AV1 |
|---|---|---|
| Rated voltage | [kV] | 72.5 |
| Number of interrupter units per pole | | 1 |
| Rated normal current, up to | [A] | 2,500 |
| Rated short-time withstand current, up to | [kA] | 31.5 |
| Rated short-circuit breaking current, up to | [kA] | 31.5 |
| Rated frequency | [Hz] | 50 |
| Rated power-frequency withstand voltage | [kV] | 140 |
| Rated lightning impulse withstand voltage | [kV] | 325 |
| Rated duration of short circuit | [s] | 3 |
| Rated peak withstand current (2.7 p.u.) | [kA] | 85 |
| First-pole-to-clear-factor | [p.u.] | 1.5/1.3 |
| Capacitive voltage factor | [p.u.] | 1.4 |
| Temperature range | [°C] | – 30 up to + 55 |
| Maintenance after | | 25 years |
| Insulating medium | | $N_2$ |
| All values in accordance with IEC; other values on request | | |

*Table 4.1-1:* **Technical data of live-tank circuit-breaker portfolio**

**Efficiency**
- Maintenance-free for 25 years
- Service-free even with frequent breaking operations

**Performance**
- 2 cycle current interruption
- High number of short-circuit interruptions

**Sustainability**
- Vacuum interruption
- Nitrogen insulation
- Beneficial $CO_2$ footprint

**Reliability**
- 40 years of experience in vacuum switching technology
- Perfect for low temperature applications

*Fig. 4.1-10:* **3AV1 FG vacuum circuit-breaker 72.5 kV**



**Live-tank circuit-breakers with vacuum technology**
Based on 40 years of experience producing medium-voltage vacuum interrupters and more than 3 million delivered units, Siemens has now introduced this proven technology to high-voltage power networks.

The new member of our circuit-breaker family meets the same high quality standards as our $SF_6$ portfolio regarding high performance and reliability throughout its long service life, and is also designed according to our well proven modular platform concept.

The new 3AV1 vacuum circuit-breaker has concrete technical advantages: It features reliable switching capacity, requires no maintenance even when subjected to frequent breaking operations, and is also environmentally friendly – thanks to switching operations performed in a vacuum, with nitrogen as the insulating medium.

These circuit-breakers will be the right choice for future projects and a wide range of applications.

A complete set of type tests in accordance with the latest edition of IEC 62271-100 has proven the suitability of the 72.5 kV live-tank vacuum circuit-breaker.

**Field experience**
Prototypes of the new Siemens high-voltage vacuum circuit-breakers have already been installed in European power networks. A number of Energy customers are operating the 3AV1 prototypes in their systems and are sharing operating and field experience with us. In fact, several thousand switching operations have already been performed successfully in the field, and documented (fig. 4.1-10).

## 4.1.3 Dead-Tank Circuit-Breakers for 72.5 kV up to 550 kV

**Circuit-breakers in dead-tank design**
In contrast to live-tank circuit-breakers, dead tanks have a metal-enclosed interrupter unit, and the housing is always earthed. Therefore they are called dead-tank circuit-breakers. For certain substation designs, dead-tank circuit-breakers might be required instead of the standard live-tank circuit-breakers. 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 suitable for different voltage levels (fig. 4.1-11, 4.1-12, 4.1-13).



Most important characteristics of a dead-tank circuit-breaker:
- Toroidal-core current transformers on bushings which give it a compact construction
- High short-circuit breaking currents possible (up to 63 kA with one interrupter unit)
- No creepage path across interrupter unit
- Low impulse load of the bases
- Low center of gravity of the bases which give it a higher seismic withstand capability
- Gas mixture or heating system for lowest temperature applications
- Gas-insulated components ensure highest availability with minimum maintenance effort
- Metal-enclosed interrupter unit (earthed housing)

**Current transformers (CT)**
The dead-tank circuit-breakers can be equipped with bushing current transformers for measurement or protection purposes, fulfilling the requirements according to international standards such as IEC, ANSI, etc. The current transformers are mounted in weatherproof housings on both sides of each circuit-breaker pole and are located at the base of the bushings. The current transformer leads terminate in the control cubicle at short-circuiting type terminal blocks. Our standard housing provides space for up to three current transformers per bushing.

The 3AP DT high-voltage circuit-breaker operates safely and is capable of bearing high loads. Extra-strong porcelain bushings and an optimized circuit-breaker design give it a very high seismic stability while in operation. The circuit-breaker covers the whole temperature range from -60 °C up to 55 °C with pure $SF_6$, which makes it applicable for all climate zones.

Like the other circuit-breakers, our dead tanks are based on our proven modular design using a patented self-compression arc-quenching system and the stored-energy spring drive mechanism. They assure consistent quenching performance with rated and short-circuit currents – even after many switching operations.

*Fig. 4.1-11:* **SPS2/3AP1 DT 72.5 kV**

*Fig. 4.1-12:* **SPS2/3AP1 DT 145 kV**

*Fig. 4.1-13:* **SPS2/3AP1 DT 362 kV (two-cycles)**

**Dead-tank circuit-breaker**

*Type SPS2 and 3AP DT*
The type SPS2 power circuit-breakers are used for the US and ANSI markets, and the 3AP DT circuit-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 (table 4.1-2). In 2012, two new DT circuit-breakers with 2-cycles interruption for 245 kV and 362 kV have complemented our DT portfolio and have been established on the market with great success (fig. 4.1-13).

*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 $SF_6$-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. 4.1-14, fig. 4.1-15) 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.

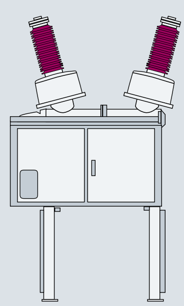
A control cubicle mounted at one end of the circuit-breaker houses the spring operating mechanism and circuit-breaker control components. The interrupter units are located in the aluminum housing of each pole unit. The interrupters use the latest Siemens self-compression arc-quenching system.

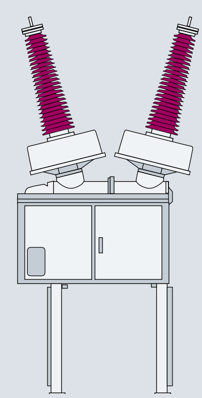
The stored-energy spring mechanism is the same design as used within the Siemens 3AP live-tank circuit-breakers, GIS and compact switchgear. This design has been documented in service for more than 10 years, and has a well-documented reliability record.

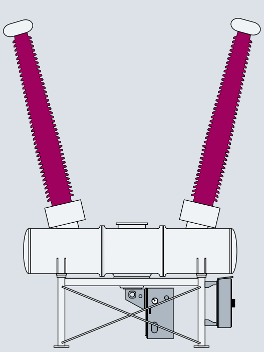
Operators can specify up to four (in some cases, up to six) bushing-type current transformers (CT) per phase. These CTs, mounted externally on the aluminum housings, can be removed without dismantling the bushings.

*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.

**Technical data**

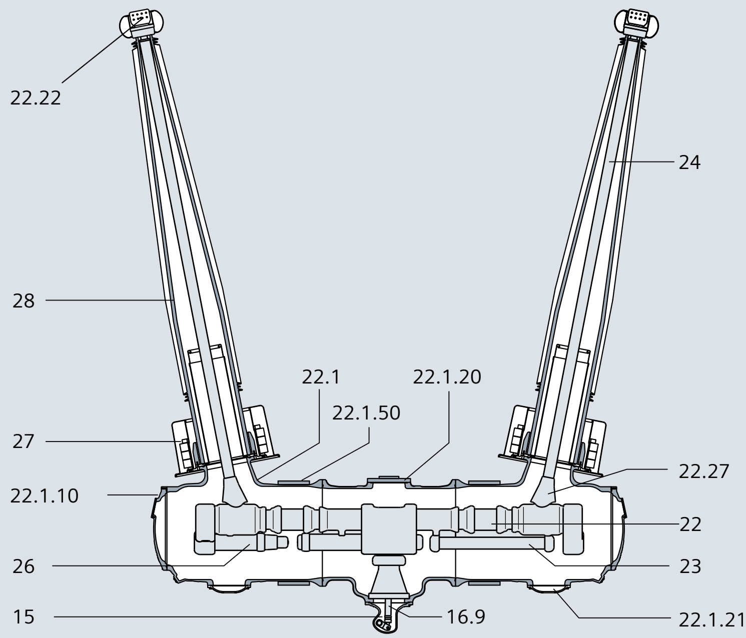






| Type | | 3AP1 DT / SPS2 | | | | | 3AP2/3 DT / SPS2 |
|---|---|---|---|---|---|---|---|
| Rated voltage | [kV] | 72.5 | 123 | 145 | 245 | 362 | 550 |
| Rated power-frequency withstand voltage | [kV] | 140 / 160 | 230 / 260 | 275 / 310 | 460 | 520 | 800 / 860 |
| Rated lighting impulse withstand voltage | [kV] | 325 / 350 | 550 | 650 | 1,050 | 1,380 | 1,865 / 1,800 |
| Rated switching impulse withstand voltage | [kV] | – | – | – | – | 1,095 | 1,350 |
| Rated nominal current up to | [A] | 4,000 | 4,000 | 4,000 | 4,000 | 4,000 | 4,000 / 5,000 |
| Rated breaking current up to | [kA] | 40 | 40 | 63 | 63 | 63 | 63 |
| Operating mechanism type | | Stored-energy spring mechanism | | | | | |

*Table 4.1-2:* **Technical data of dead-tank circuit-breaker**




| | |
|---|---|
| 15 | Corner gear |
| 16.9 | Operating rod |
| 22 | Interrupter unit |
| 22.1 | Housing |
| 22.1.10 | Cover |
| 22.1.10.1 | Cover |
| 22.1.20 | Cover with bursting disc |
| 22.1.21 | Cover with filter material |
| 22.1.50 | Additional heating |
| 22.22 | High-voltage terminal |
| 22.27 | Conductor connection |
| 23 | Grading capacitor |
| 24 | Bushing conductor |
| 26 | Closing resistor |
| 27 | Current transformer |
| 28 | Bushing |

*Fig. 4.1-14:* **Sectional view of a 3AP2/3-DT circuit-breaker pole**

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. 4.1-15:* **3AP2 DT 550 kV**

## 4.1.4 The 3AP1 DTC – Dead-Tank Compact – a Compact Switchgear up to 245 kV

**The hybrid concept**

The hybrid concept combines $SF_6$-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**

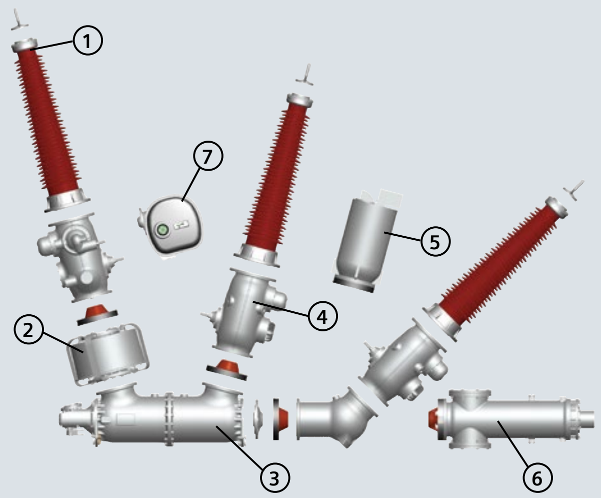
Based on the well-proven modular design, the core components of the main units are based on the same technology that is used in the well-established high-voltage circuit-breakers, disconnectors and GIS product family of Siemens.

These components are (fig. 4.1-16):

- Self-compression arc-quenching interrupter unit of the AIS 3AP circuit-breaker
- Stored-energy spring mechanism
- $SF_6$-insulated disconnector/earthing switch from the GIS type 8DN8
- Outdoor earthing switch from the disconnector product range.

This allows for providing flexible solutions according to different substation configurations (fig. 4.1-17, fig. 4.1-18, fig. 4.1-20):

- 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 $SF_6$ 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.




1. Bushing
2. Current transformer
3. Circuit-breaker with self-compression principle
4. Three-position disconnector and earthing switch
5. Voltage transformer
6. Cable connection assembly
7. High-speed earthing switch

*Fig. 4.1-16:* **Possible components for the 3AP1 DTC**

*Fig. 4.1-17:* **3AP1 DTC 145 kV**

*Fig. 4.1-18:* **3AP1 DTC 245 kV**

### Highlights and characteristics

- Simple $SF_6$ 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. 4.1-19).

### 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).

Our compact switchgear is fully type-tested in accordance with this standard (table 4.1-3).

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.

### Accessories for 3AP1 DTC

To enhance possibility of circuit-breaker monitoring, the Siemens voltage detecting system (VDS) or SIVIS camera systems can be used.

The VDS is an economic alternative to a voltage transformer if there is no requirement for voltage values to be measured. Up to three VDS systems can be integrated in the outgoing units to monitor the voltage. The system is attached directly to the disconnector and earthing switch component of the DTC, and enables the voltage condition of the compact switchgear to be checked.

SIVIS camera systems for the 3AP1 DTC make it possible to quickly and easily check the disconnecting earthing switch module positions. The systems are a complementary solution for preexisting position indicators on earthing switch operating mechanisms. With these camera systems, we have made it easy for your maintenance and service personnel to monitor the disconnector, earthing switch, and high-speed rating positions during maintenance, which further improves the safety standards of your switchgear. According to your individual requirements you have the choice between a stationary and a mobile camera system.

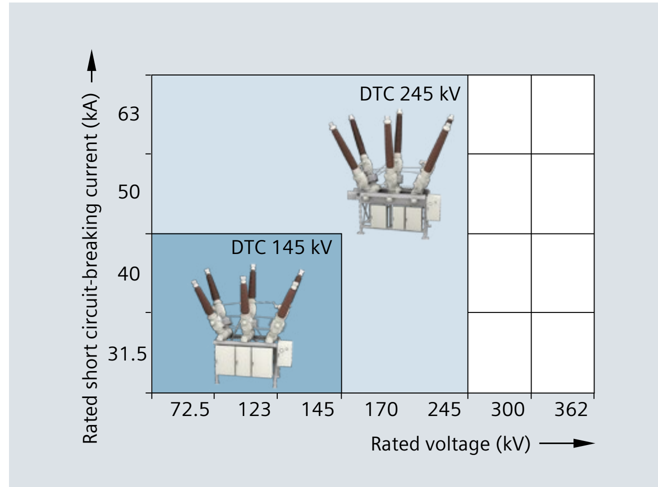



*Fig. 4.1-19:* **DTC product range, 1-pole or 3-pole operation**

*Fig. 4.1-20:* **3AP1 DTC 145 kV with voltage transformer and cable connection**

| High-voltage compact switchgear | | 3AP1 DTC | |
|---|---|---|---|
| Rated voltage | [kV] | 145 | 245 |
| Rated normal current | [A] | 3,150 | 4,000 |
| Rated frequency | [Hz] | 50/60 | 50/60 |
| Rated lightning impulse withstand voltage | [kV] | 650 | 1050 |
| Rated power-frequency withstand voltage | [kV] | 275 | 460 |
| Rated short-time withstand current (3 s) | [kA] | 40 | 63 |
| Rated peak withstand current | [kA] | 108 | 170 |

*Table 4.1-3:* **Technical data of 3AP1 DTC**

## 4.1.5 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 $SF_6$ gas compartment on the basis of an $SF_6$-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. 4.1-21, fig. 4.1-23).

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 $SF_6$-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 (fig. 4.1-22). 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 Ruhrtal designed maintenance-free contact system.

The disconnecting circuit-breakers are type tested according to class M2 and C2 of IEC 62271-108, a specific standard for combined switching devices (table 4.1-4).

*Fig. 4.1-21:* **3AP1 DCB 145 kV**

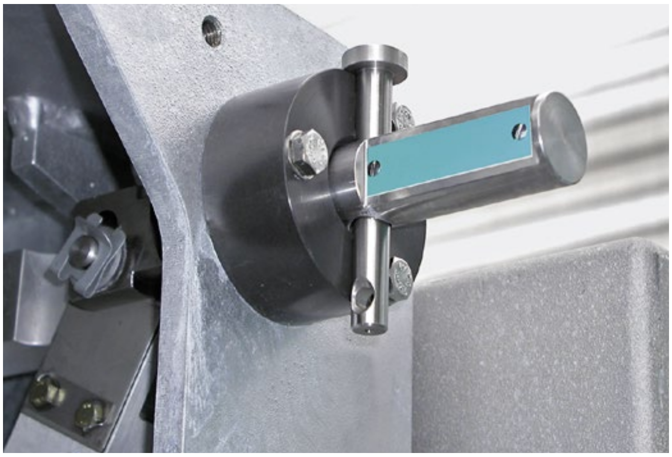


*Fig. 4.1-22:* **3AP2 DCB interlock indicator**

4

| | | 3AP1 DCB | 3AP2 DCB |
|---|---|---|---|
| Rated voltage | [kV] | 145 | 420 |
| Number of interrupter units per pole | | 1 | 2 |
| Rated power-frequency withstand voltage | [kV] | 275/315 | 520/610 |
| Rated lightning impulse withstand voltage | [kV] | 650/750 | 1,425/1,665 |
| Rated switching impulse withstand voltage | [kV] | n.a. | 1,050/1,245 |
| Rated normal current up to | [A] | 3,150 | 4,000 |
| Rated short-circuit breaking current | [$kA_{rms}$] | 40 (31.5) | 40 |
| Ambient air temperature [1)] | [°C] | -40 ... +40 | -40 ... +40 |
| Insulating medium | | $SF_6$ | $SF_6$ |
| Classification CB | | M2, C2 | M2, C2 |
| Classification DS | | M2 | M2 |
| Insulators | | composite [2)] | composite |
| Attached earthing switch (optional) | | yes | no |

[1)] Other ambient temperature values on request
[2)] Or porcelain

*Table 4.1-4:* **Technical data of 3AP DCB**

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.

**Highlights and characteristics**
- Maximum reliability by applying well-proven and established components from Siemens circuit-breakers and Ruhrtal designed 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. 4.1-23:* **3AP2 DCB 420 kV**

**For further information:**
*Email: support.energy@siemens.com*
*or circuit-breaker@siemens.com*

4

# 4.2 High-Voltage Disconnectors

## 4.2.1 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.

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. 4.2-1).

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. 4.2-2).


*Fig. 4.2-1:* **Center-break disconnector**

*Fig. 4.2-2:* **Block and finger contact system**

4

**Pantograph disconnectors**
This type has a vertical isolating distance and is generally used in busbar systems to connect two busbars, a busbar to a line or a busbar to a power transformer.

The main components of a pantograph disconnector are shown in (fig. 4.2-3).

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

Ice loads of up to 20 mm can be broken without difficulties. The specific contact force is adjusted at the factory and remains unchanged during service life.

The rigidity of the scissor arms prevents opening during a short circuit. The switch position cannot be changed by external forces. In both end positions of the disconnector, the rotary arm in the bearing frame is switched beyond the dead center point.

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**
This type is for small phase distances. The current path of the vertical-break disconnector opens vertically and requires a minimum phase distance (fig. 4.2-4).

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


*1. Scissor arms*
*2. Bearing frame*
*3. Support insulator*
*4. Rotating insulator*
*5. Motor operating mechanism*

*Fig. 4.2-3:* **Components of the pantograph disconnector**

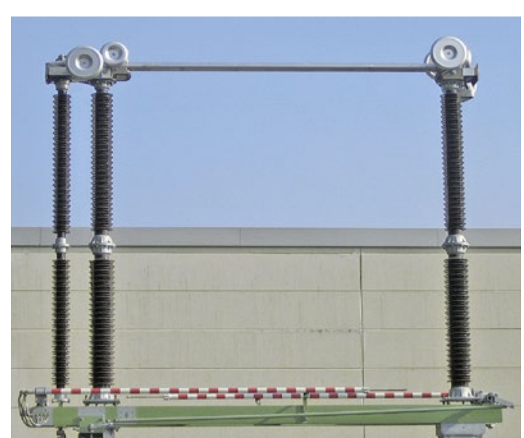


*Fig. 4.2-4:* **Vertical-break disconnector**

**Double-side break disconnectors**
The double-side break disconnector features three support insulators. The support insulator in the center is mounted 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. 4.2-5).

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. 4.2-6).

The very compact design has advantages for indoor applications and mounting on wall or ceiling. This type is also available up to 800kV.

*Fig. 4.2-5:* **Double-side break disconnector with integrated surge arrester**

*Fig. 4.2-6:* **Knee-type disconnector**

### Earthing switches

The use of earthing switches (fig. 4.2-7) 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.

### 3DV8 and MA6/7 motor operating mechanisms

The 3DV8 type is the standard design and the MA6/7 types can be provided optionally with the additional advantages given below:

- Motor operating mechanism is mechanically decoupled in the end positions to prevent damages of the disconnector in case of operating errors
- Aluminum casting housing – very robust.

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. 4.2-8).

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

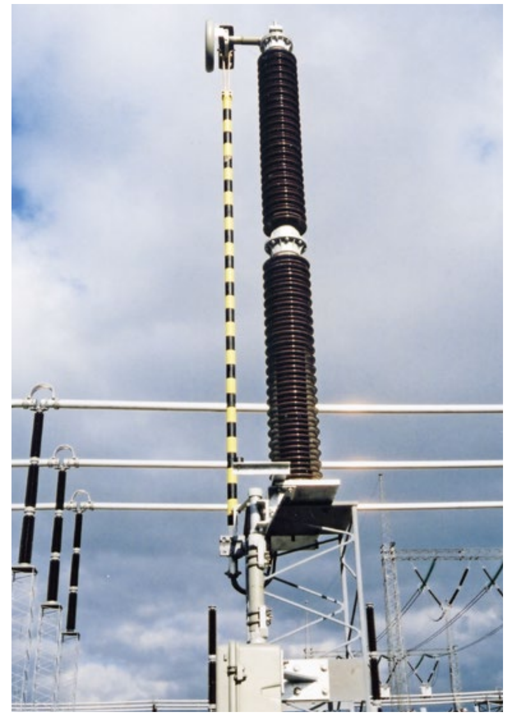
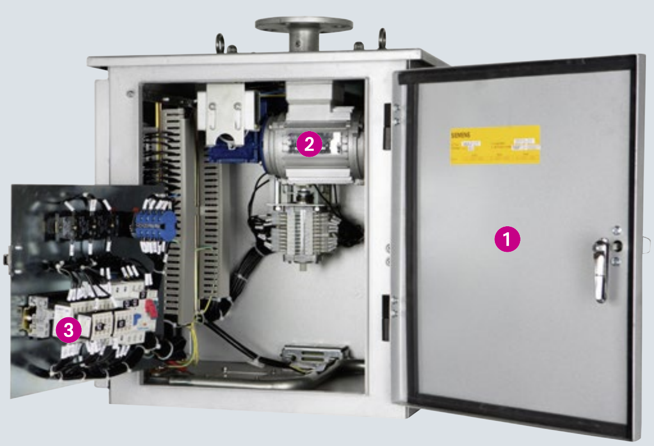
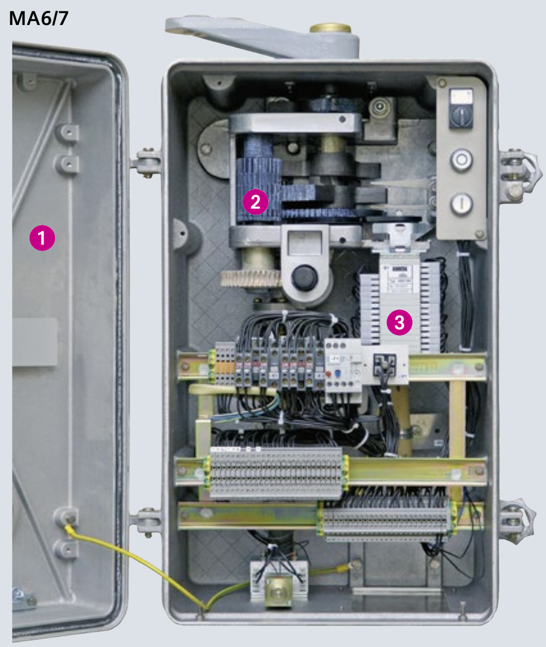


*Fig. 4.2-7:* **Free-standing earthing switch**

3DV8




MA6/7




Steel, spray-zinc and painted (3DV8) / Cast-aluminum housing (MA6/7) with door (1) – degree of protection IP55; gear unit (2) with motor; electrical equipment with auxiliary switch (3)

*Fig. 4.2-8:* **Motor operating mechanism**

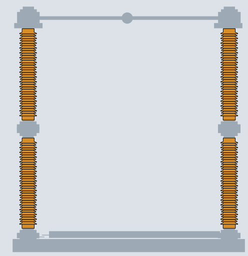
| Technical data | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | |  | | | | | | | | |
| Design | | **Center break** | | | | | | | | |
| Rated voltage | | 72.5 | 123 | 145 | 170 | 245 | 300 | 362 | 420 | 550 |
| Rated power-frequency withstand voltage 50 Hz/1 min | | | | | | |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

*Table 4.2-1:* **Center-break disconnector**

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 4.2-1 to table 4.2-5.

4

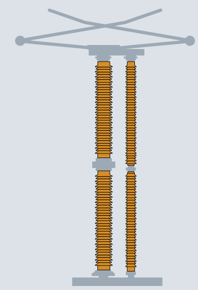
| Technical data |  | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Design | Pantograph | | | | | | | |
| Rated voltage | 123 | 145 | 170 | 245 | 300 | 362 | 420 | 550 |
| Rated power-frequency withstand voltage 50 Hz/1 min | | | | | | | | |
| To earth and between phases [kV]<br>Across the isolating distance [kV] | 230<br>265 | 275<br>315 | 325<br>375 | 460<br>530 | 380<br>435 | 450<br>520 | 520<br>610 | 620<br>800 |
| Rated lightning impulse withstand voltage 1.2/50 μs | | | | | | | | |
| To earth and between phases [kV]<br>Across the isolating distance [kV] | 550<br>630 | 650<br>750 | 750<br>860 | 1,050<br>1,200 | 1,050<br>1,050 (+170) | 1,175<br>1,175 (+205) | 1,425<br>1,425 (+240) | 1,550<br>1,550 (+315) |
| Rated switching impulse withstand voltage 250/2,500 μs | | | | | | | | |
| To earth and between phases [kV]<br>Across the isolating distance [kV] | –<br>– | –<br>– | –<br>– | –<br>– | 850<br>700 (+245) | 950<br>800 (+295) | 1,050<br>900 (+345) | 1,175<br>900 (+450) |
| Rated normal current up to [A] | 5,000 | | | | | | | |
| Rated peak withstand current up to [kA] | 200 | | | | | | | |
| Rated short-time withstand current up to [kA] | 80 | | | | | | | |
| Rated duration of short circuit [s] | 1/3 | | | | | | | |
| Icing class | 10/20 | | | | | | | |
| Temperature range [°C] | −60/+50 | | | | | | | |
| Operating mechanism type | Motor operation/Manual operation | | | | | | | |
| Control voltage [V, DC]<br>[V, AC] | 60/110/125/220<br>220...230, 1~, 50/60 Hz | | | | | | | |
| Motor voltage [V, DC]<br>[V, AC] | 60/110/125/220<br>110/125/220, 1~, 50/60 Hz<br>220/380/415, 3~, 50/60 Hz | | | | | | | |
| Maintenance | 25 years | | | | | | | |

*Table 4.2-2:* **Pantograph disconnector**

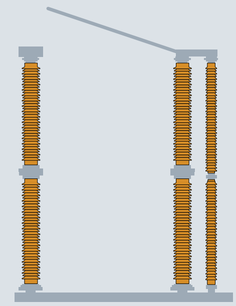
| Technical data |  | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Design | Vertical break | | | | | | | |
| Rated voltage | 123 | 145 | 170 | 245 | 300 | 362 | 420 | 550 |
| Rated power-frequency withstand voltage 50 Hz/1 min | | | | | | | | |
| To earth and between phases [kV]<br>Across the isolating distance [kV] | 230<br>265 | 275<br>315 | 325<br>375 | 460<br>530 | 380<br>435 | 450<br>520 | 520<br>610 | 620<br>800 |
| Rated lightning impulse withstand voltage 1.2/50 µs | | | | | | | | |
| To earth and between phases [kV]<br>Across the isolating distance [kV] | 550<br>630 | 650<br>750 | 750<br>860 | 1,050<br>1,200 | 1,050<br>1,050 (+170) | 1,175<br>1,175 (+205) | 1,425<br>1,425 (+240) | 1,550<br>1,550 (+315) |
| Rated switching impulse withstand voltage 250/2,500 µs | | | | | | | | |
| To earth and between phases [kV]<br>Across the isolating distance [kV] | –<br>– | –<br>– | –<br>– | –<br>– | 850<br>700 (+245) | 950<br>800 (+295) | 1,050<br>900 (+345) | 1175<br>900 (+450) |
| Rated normal current up to [A] | 4,000 | | | | | | | |
| Rated peak withstand current up to [kA] | 160 | | | | | | | |
| Rated short-time withstand current up to [kA] | 160 | | | | | | | |
| Rated duration of short circuit [s] | 1/3 | | | | | | | |
| Icing class | 10/20 | | | | | | | |
| Temperature range [°C] | –60/+50 | | | | | | | |
| Operating mechanism type | Motor operation/Manual operation | | | | | | | |
| Control voltage [V, DC]<br>[V, AC] | 60/110/125/220<br>220…230, 1~, 50/60 Hz | | | | | | | |
| Motor voltage [V, DC]<br>[V, AC] | 60/110/125/220<br>110/125/230, 1~, 50/60 Hz<br>220/380/415, 3~, 50/60 Hz | | | | | | | |
| Maintenance | 25 years | | | | | | | |

*Table 4.2-3:* **Vertical-break disconnector**

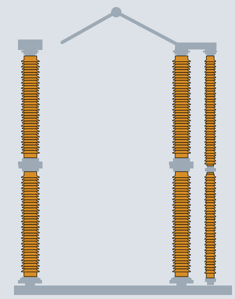
| Technical data | |  | |
|---|---|---|---|
| Design | | Knee-type | |
| Rated voltage | | 123 | 550 |
| Rated power-frequency withstand voltage 50 Hz/1 min | | | |
| To earth and between phases<br>Across the isolating distance | [kV]<br>[kV] | 230<br>265 | 620<br>800 |
| Rated lightning impulse withstand voltage 1.2/50 µs | | | |
| To earth and between phases<br>Across the isolating distance | [kV]<br>[kV] | 550<br>630 | 1,550<br>1,550 (+315) |
| Rated switching impulse withstand voltage 250/2,500 µs | | | |
| To earth and between phases<br>Across the isolating distance | [kV]<br>[kV] | –<br>– | 1,175<br>900 (+450) |
| Rated normal current up to | [A] | 4,000 | |
| Rated peak withstand current up to | [kA] | 100 | 160 |
| Rated short-time withstand current up to | [kA] | 40 | 63 |
| Rated duration of short circuit | [s] | 1/3 | |
| Icing class | | 10/20 | |
| Temperature range | [°C] | −60/+50 | |
| Operating mechanism type | | Motor operation/Manual operation | |
| Control voltage | [V, DC]<br>[V, AC] | 60/110/125/220<br>220…230, 1~, 50/60 Hz | |
| Motor voltage | [V, DC]<br>[V, AC] | 60/110/125/220<br>110/125/230, 1~, 50/60 Hz<br>220/380/415, 3~, 50/60 Hz | |
| Maintenance | | 25 years | |

*Table 4.2-4:* **Knee-type disconnector**

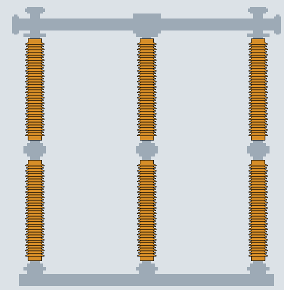
| Technical data |  | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Design | Double-side break | | | | | | | |
| Rated voltage | 123 | 145 | 170 | 245 | 300 | 420 | 550 | 800 |
| Rated power-frequency withstand voltage 50 Hz/1 min | | | | | | | | |
| To earth and between phases [kV]<br>Across the isolating distance [kV] | 230<br>265 | 275<br>315 | 325<br>375 | 460<br>530 | 380<br>435 | 520<br>610 | 450<br>520 | 830<br>1,150 |
| Rated lightning impulse withstand voltage 1.2/50 µs | | | | | | | | |
| To earth and between phases [kV]<br>Across the isolating distance [kV] | 550<br>630 | 650<br>750 | 750<br>860 | 1,050<br>120 | 1,050<br>1,050<br>(+170) | 1,425<br>1,425<br>(+240) | 1,550<br>1,550<br>(+315) | 2,100<br>2,100 (+455) |
| Rated switching impulse withstand voltage 250/2,500 µs | | | | | | | | |
| To earth and between phases [kV]<br>Across the isolating distance [kV] | –<br>– | –<br>– | –<br>– | –<br>– | 850<br>700 (+245) | 1,050<br>900 (+345) | 1,175<br>900 (+450) | 1,550<br>1200 (+650) |
| Rated normal current up to [A] | 4000 | | | | | | | |
| Rated peak withstand current up to [kA] | 160 | | | | | | | |
| Rated short-time withstand current up to [kA] | 63 | | | | | | | |
| Rated duration of short circuit [s] | 1/3 | | | | | | | |
| Icing class | 10/20 | | | | | | | |
| Temperature range [°C] | –60/+50 | | | | | | | |
| Operating mechanism type | Motor operation/Manual operation | | | | | | | |
| Control voltage [V, DC]<br>[V, AC] | 60/110/125/220<br>220…230, 1~, 50/60 Hz | | | | | | | |
| Motor voltage [V, DC]<br>[V, AC] | 60/110/125/220<br>110/125/230, 1~, 50/60 Hz<br>220/380/415, 3~, 50/60 Hz | | | | | | | |
| Maintenance | 25 years | | | | | | | |

*Table 4.2-5:* **Double-side break disconnector**

**For further information, please contact:**
*Fax: + 49 30 3 86-2 58 67*
*Email: support.energy@siemens.com*

# 4.3 Vacuum Switching Technology and Components for Medium Voltage

## 4.3.1 Overview of Vacuum Switching Components



Medium-voltage equipment is available in power stations (in generators and station supply systems) and in transformer substations (of public systems or large industrial plants) of the primary distribution level. Transformer substations receive power from the high-voltage system and transform it down to the medium-voltage level. Medium-voltage equipment is also available in secondary transformer or transfer substations (secondary distribution level), where the power is transformed down from medium to low voltage and distributed to the end consumer.

The product line of the medium-voltage switching devices contains (fig. 4.3-1):
- Circuit-breakers
- Switches
- Contactors
- Disconnectors
- Switch-disconnectors
- Earthing switches

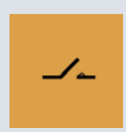
**Requirements**
In CLOSED condition, the switching device has to offer minimum resistance to the flow of normal and short-circuit currents.
In OPEN condition, the open contact gap must withstand the appearing voltages safely. All live parts must be sufficiently isolated to earth and between phases when the switching device is open or closed.

The switching device must be able to close the circuit if voltage is applied. For disconnectors, however, this condition is only requested for the de-energized state, except for small load currents.

The switching device should be able to open the circuit while current is flowing. This is not requested for disconnectors.
The switching device should produce switching overvoltages as low as possible.

**Circuit-breakers**
Circuit-breakers must make and break all currents within the scope of their ratings, from small inductive and capacitive load currents up to the short-circuit current, and this must occur under all fault conditions in the power supply system, including earth faults and phase opposition. Outdoor circuit-breakers have the same applications, but are also exposed to weather influences.

**Switches**
Switches must make and break normal currents up to their rated normal current, and be able to make on existing short circuits (up to their rated short-circuit making current). However, they cannot break any short-circuit currents.



**Contactors**
Contactors are load breaking devices with a limited making and breaking capacity. They are used for high switching rates but can neither make nor break short-circuit currents.

**Switch-disconnectors**
A switch-disconnector is to be understood as the combination of a switch and a disconnector, or a switch with isolating distance.

*Fig. 4.3-1:* **Product line of medium-voltage switching devices**

## 4.3.2 Selection of Components by Ratings

The switching devices and all other equipment must be selected for the system data available at the place of installation. This system data defines the ratings of the components (table 4.3-1)

**Rated insulation level**
The rated insulation level is the dielectric strength from phase to earth, between phases and across the open contact gap, or across the isolating distance.

The dielectric strength is the capability of an electrical component to withstand all voltages with a specific time sequence up to the magnitude of the corresponding withstand voltages. These can be operating voltages or higher-frequency voltages caused by switching operations, earth faults (internal overvoltages) or lightning strikes (external overvoltages). The dielectric strength is verified by a lightning impulse withstand voltage test with the standard impulse wave of 1.2/50 µs and a power-frequency withstand voltage test (50 Hz/1 min).

**Rated voltage**
The rated voltage is the upper limit of the highest system voltage the device is designed for. Because all high-voltage switching devices are zero-current interrupters – except for some fuses – the system voltage is the most important dimensioning criterion. It determines the dielectric stress of the switching device by means of the transient recovery voltage and the recovery voltage, especially while switching off.

**Rated normal current**
The rated normal current is the current that the main circuit of a device can continuously carry under defined conditions. The heating of components – especially of contacts – must not exceed defined values. Permissible temperature rises always refer to the ambient air temperature. If a device is mounted in an enclosure, it is possible that it may not be loaded with its full rated current, depending on the quality of heat dissipation.

**Rated peak withstand current**
The rated peak withstand current is the peak value of the first major loop of the short-circuit current during a compensation process after the beginning of the current flow that the device can carry in closed state. It is a measure for the electrodynamic (mechanical) load of an electrical component. For devices with full making capacity, this value is not relevant (see the paragraph "Rated short-circuit making current" later in this section).

**Rated breaking current**
The rated breaking current is the load breaking current in normal operation. For devices with full breaking capacity and without a critical current range, this value is not relevant (see the paragraph "Rated short-circuit breaking current" later in this section).

**Rated short-circuit breaking current**
The rated short-circuit breaking current is the root-mean-square value of the breaking current in the event of short circuit at the terminals of the switching device.

**Rated short-circuit making current**
The rated short-circuit making current is the peak value of the making current in the event of short circuit at the terminals of the switching device. This stress is greater than that of the rated peak withstand current, because dynamic forces may work against the contact movement.

**Standards**
The switching devices, and also non-switching components, are subject to national and international standards.

4

| Component designation | Rated insulation level | Rated voltage | Rated normal current | Rated peak withstand current | Rated breaking current | Rated short-circuit breaking current | Rated short-circuit making current |
|---|---|---|---|---|---|---|---|
| **Switching devices** | | | | | | | |
| Circuit-breaker | ■ | ■ | ■ | – | – | ■ | ■ |
| Switch | ■ | ■ | ■ | – | ■ | ■ 1) | ■ |
| Switch-disconnector | ■ | ■ | ■ | – | ■ | – | ■ |
| Make-proof earthing switch | ■ | ■ | – | – | – | – | ■ |
| Contactor | ■ | ■ | ■ | – | ■ | ■ 1) | ■ 1) |

■ Influence on selection of component – No influence on selection of component 1) Limited short-circuit making capacity

*Table 4.3-1:* **Table of switching devices according to ratings**

## 4.3.3 Vacuum Circuit-Breakers

Siemens medium-voltage vacuum circuit-breakers are available with rated voltages up to 36 kV and rated short-circuit breaking currents up to 72 kA (table 4.3-2). They are used:

- For universal installation in all customary medium-voltage switchgear types
- As 1-pole or multi-pole medium-voltage circuit-breakers for all switching duties in indoor switchgear
- For breaking resistive, inductive and capacitive currents
- For switching generators
- For switching contact lines (1-pole traction circuit-breakers).

**Switching duties**

The switching duties of the circuit-breaker depend partly upon its type of operating mechanism:

- Stored-energy mechanism
  - For synchronizing and rapid load transfer
  - For auto-reclosing
- Spring-operated mechanism (spring CLOSED, stored-energy OPEN) for normal closing and opening.



**Switching duties in detail**

*Synchronizing*

The closing times during synchronizing are so short that, when the contacts touch, there is still sufficient synchronism between the systems to be connected in parallel.

*Rapid load transfer*

The transfer of consumers to another incoming feeder without interrupting operation is called rapid load transfer. Vacuum circuit-breakers with stored-energy mechanisms feature the very short closing and opening times required for this purpose. Beside other tests, vacuum circuit-breakers for rapid load transfer have been tested with the operating sequence O-3 min-CO-3 min-CO at full rated short-circuit breaking current according to the standards. They even control the operating sequence O-0.3 s-CO-3 min-CO up to a rated short-circuit breaking current of 31.5 kA.

*Auto-reclosing*

This is required in overhead lines to clear transient faults or short circuits that could be caused by, for example, thunderstorms, strong winds or animals. Even at full short-circuit current, the vacuum circuit-breakers for this switching duty leave such short dead times between closing and opening that the de-energized time interval is hardly noticeable to the power supply to the consumers. In the event of unsuccessful auto-reclosing, the faulty feeder is shut down definitively. For vacuum circuit-breakers with the auto-reclosing feature, the operating sequence O-0.3 s-CO-3 min-CO must be complied with according to IEC 62 271-100, whereas an unsuccessful auto-reclosing only requires the operating sequence O-0.3 s-CO.

*Auto-reclosing in traction line systems*

To check the traction line system via test resistors for the absence of short circuits after a short-circuit shutdown, the operating sequence is O-15 s-CO.

*Multiple-shot reclosing*

Vacuum circuit-breakers are also suitable for multiple-shot reclosing, which is mainly applicable in English-speaking countries. The operating sequence O-0.3 s-CO-15 s-CO-15 s-CO is required.

*Switching of transformers*

In the vacuum circuit-breaker, the chopping current is only 2 to 3 A due to the special contact material used, which means that no hazardous overvoltages will appear when unloaded transformers are switched off.

*Breaking of short-circuit currents*

While breaking short-circuit currents at the fault location directly downstream from transformers, generators or current-limiting reactors, the full short-circuit current can appear first; second, the initial rate of rise of the transient recovery voltage can be far above the values according to IEC 62 271-100. There may be initial rates of rise up to 10 kV/s, and while switching off short-circuits downstream from reactors, these may be even higher. The circuit-breakers are also adequate for this stress.

*Switching of capacitors*

Vacuum circuit-breakers are specifically designed for switching capacitive circuits. They can switch off capacitors up to the maximum battery capacities without restrikes, and thus without overvoltages. Capacitive current breaking is generally tested up to 400 A. These values are technically conditioned by the testing laboratory. Operational experience has shown that capacitive currents are generally controlled up to 70 % of the rated normal current of the circuit-breaker. When capacitors are connected in parallel, currents up to the short-circuit current can appear, which may be hazardous for parts of the system due to their high rate of rise. Making currents up to 20 kA (peak value) are permissible; higher values are can be achieved if specifically requested.

*Switching of overhead lines and cables*
When unloaded overhead lines and cables are switched off, the relatively small capacitive currents are controlled without restrikes, and thus without overvoltages.

*Switching of motors*
When small high-voltage motors are stopped during start-up, switching overvoltages may arise. This concerns high-voltage motors with starting currents up to 600 A. The magnitude of these overvoltages can be reduced to harmless values by means of special surge limiters. For individually compensated motors, no protective circuit is required.

*Switching of generators*
When generators with a short-circuit current of < 600 A are operated, switching overvoltages may arise. In this case, surge limiters or arresters should be used.

*Switching of filter circuits*
When filter circuits or inductor-capacitor banks are switched off, the stress for the vacuum circuit-breaker caused by the recovery voltage is higher than when switching capacitors. This is due to the series connection of the inductor and the capacitor, and must be taken into account for the rated voltage when the vacuum circuit-breaker is selected.

*Switching of arc furnaces*
Up to 100 operating cycles are required per day. The vacuum circuit-breaker type 3AH4 is especially adequate for this purpose. Due to the properties of the load circuit, the currents can be asymmetrical and distorted. To avoid resonance oscillations in the furnace transformers, individually adjusted protective circuits are necessary.

4

| Rated short-circuit breaking current | Rated normal current | Rated voltage and frequency | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 7.2 kV 50/60 Hz | | 12 kV 50/60 Hz | | | 15 kV 50/60 Hz | 17.5 kV 50/60 Hz | |
| **12.5 kA** | 800 A | | | | | | | SION | |
| | 1,250 A | | | | | | | SION | |
| **13.1 kA** | 800 A | | | | 3AH5 | | | | |
| **16 kA** | 800 A | SION | | SION | 3AH5 | | | SION | |
| | 1,250 A | SION | | SION | 3AH5 | | | SION | |
| | 2,000 A | | | | | | | SION | |
| **20 kA** | 800 A | SION | | SION | 3AH5 | | | | |
| | 1,250 A | SION | | SION | 3AH5 | | | | |
| | 2,000 A | | | | 3AH5 | | | | |
| | 2,500 A | | | | | | | | |
| **25 kA** | 800 A | SION | | SION | 3AH5 | | | SION | 3AH5 |
| | 1,250 A | SION | | SION | 3AH5 | | | SION | 3AH5 |
| | 2,000 A | SION | | SION | 3AH5 | | | SION | |
| | 2,500 A | | | SION | 3AH5 | | | SION | 3AH5 |
| **31.5 kA** | 800 A | SION | | SION | | | | SION | |
| | 1,250 A | SION | | SION | 3AH5 | 3AH4 | 3AH4 | SION | 3AH5 |
| | 2,000 A | SION | | SION | 3AH5 | 3AH4 | 3AH4 | SION | 3AH5 |
| | 2,500 A | SION | | SION | 3AH5 | | | SION | 3AH5 |
| | 3,150 A | | | | | | | | |
| | 4,000 A | | | | | | | | |
| **40 kA** | 1,250 A | SION | | SION | | 3AH4 | 3AH4 | SION | 3AK7 |
| | 1,600 A | | | | | 3AH4 | 3AH4 | | |
| | 2,000 A | SION | | SION | | 3AH4 | 3AH4 | SION | 3AK7 |
| | 2,500 A | SION | | SION | | 3AH4 | 3AH4 | SION | 3AK7 |
| | 3,150 A | SION | | SION | | 3AH4 | 3AH4 | SION | 3AK7 |
| | 4,000 A | | | | | | | | 3AK7 |
| **50 kA** | 1,250 A | 3AH3 | 3AK7 | 3AH3 | 3AK7 | | 3AH3 | 3AH3 | 3AK7 |
| | 2,000 A | 3AH3 | 3AK7 | 3AH3 | 3AK7 | | 3AH3 | 3AH3 | 3AK7 |
| | 2,500 A | 3AH3 | 3AK7 | 3AH3 | 3AK7 | | 3AH3 | 3AH3 | 3AK7 |
| | 3,150 A | 3AH3 | 3AK7 | 3AH3 | 3AK7 | | 3AH3 | 3AH3 | 3AK7 |
| | 4,000 A | 3AH3 | 3AK7 | 3AH3 | 3AK7 | | 3AH3 | 3AH3 | 3AK7 |
| | 5,000 A | | | | | | | | |
| | 6,300 A | | | | | | | | |
| | 8,000 A | | | | | | | | |
| **63 kA** | 1,250 A | 3AH3 | | 3AH3 | | | 3AH3 | 3AH3 | |
| | 2,000 A | 3AH3 | | 3AH3 | | | 3AH3 | 3AH3 | |
| | 2,500 A | 3AH3 | | 3AH3 | | | 3AH3 | 3AH3 | |
| | 3,150 A | 3AH3 | | 3AH3 | | | 3AH3 | 3AH3 | |
| | 4,000 A | 3AH3 | | 3AH3 | | | 3AH3 | 3AH3 | |
| | 5,000 A | | | | | | | | |
| | 6,300 A | | | | | | | | |
| | 8,000 A | | | | | | | | |
| **72 kA** | 3,150 A | | | | | | | | |
| | 4,000 A | | | | | | | | |
| | 5,000 A | | | | | | | | |
| | 6,300 A | | | | | | | | |
| | 8,000 A | | | | | | | | |

*Table 4.3-2:* **Portfolio of vacuum circuit-breakers**

| Rated short-circuit breaking current | Rated normal current | Rated voltage and frequency | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 17.5 kV 50/60 Hz | 17.5 kV 16 ⅔ Hz | 24 kV 50/60 Hz | | | 27.5 kV 50/60 Hz | 36 kV 50/60 Hz | | 40,5 kV 50/60 Hz | |
| **12.5 kA** | 800 A | | | SION | | | | | | | |
| | 1,250 A | | | SION | | | | | | | |
| **13.1 kA** | | | | | | | | | | | |
| **16 kA** | 800 A | | | SION | 3AH5 | | | | | | |
| | 1,250 A | | | SION | 3AH5 | | | 3AH5 | | | |
| | 2,000 A | | | SION | | | | | | | |
| **20 kA** | 800 A | | | SION | | | | | | | |
| | 1,250 A | | | SION | 3AH5 | | | | | | |
| | 2,000 A | | | SION | 3AH5 | | | | | | |
| | 2,500 A | | | SION | 3AH5 | | | | | | |
| **25 kA** | 800 A | | | SION | | | | | | | |
| | 1,250 A | | | SION | 3AH5 | 3AH4 | 3AH47 | 3AH5 | | | |
| | 2,000 A | | 3AH47 | SION | 3AH5 | 3AH4 | 3AH47 | 3AH5 | | | |
| | 2,500 A | | | SION | 3AH5 | | 3AH47 | | | | |
| **31.5 kA** | 800 A | | | | | | | | | | |
| | 1,250 A | 3AH4 | | | | | 3AH47 | 3AH3 | 3AH4 | 3AH3 | 3AH4 |
| | 2,000 A | 3AH4 | 3AH47 | | | | 3AH47 | 3AH3 | 3AH4 | 3AH3 | 3AH4 |
| | 2,500 A | | | | | | 3AH47 | 3AH3 | 3AH4 | 3AH3 | 3AH4 |
| | 3,150 A | | | | | | | 3AH3 | 3AH4 | 3AH3 | 3AH4 |
| | 4,000 A | | | | | | | 3AH3 | 3AH4 | 3AH3 | 3AH4 |
| **40 kA** | 1,250 A | 3AH4 | | | | | | 3AH3 | | | |
| | 1,600 A | 3AH4 | | | | | | | | | |
| | 2,000 A | 3AH4 | | | | | | 3AH3 | | | |
| | 2,500 A | 3AH4 | 3AH47 | 3AH3 | | 3AH4 | | 3AH3 | 3AH4 | | |
| | 3,150 A | 3AH4 | | | | | | 3AH3 | 3AH4 | | |
| | 4,000 A | | | | | | | 3AH3 | 3AH4 | | |
| **50 kA** | 1,250 A | | | | | | | | | | |
| | 2,000 A | | | 3AH3 | | | | | | | |
| | 2,500 A | | 3AH47 | | | | | | | | |
| | 3,150 A | 3AH38 | | 3AH3 | 3AH38 | | | | | | |
| | 4,000 A | 3AH38 | | 3AH3 | 3AH38 | | | | | | |
| | 5,000 A | 3AH37 | | | 3AH37 | | | | | | |
| | 6,300 A | 3AH37 | | | 3AH37 | | | | | | |
| | 8,000 A | 3AH37 | | | 3AH37 | | | | | | |
| **63 kA** | 1,250 A | | | | | | | | | | |
| | 2,000 A | | | | | | | | | | |
| | 2,500 A | | | | | | | | | | |
| | 3,150 A | 3AH38 | | | 3AH38 | | | | | | |
| | 4,000 A | 3AH38 | | | 3AH38 | | | | | | |
| | 5,000 A | 3AH37 | | | 3AH37 | | | | | | |
| | 6,300 A | 3AH37 | | | 3AH37 | | | | | | |
| | 8,000 A | 3AH37 | | | 3AH37 | | | | | | |
| **72 kA** | 3,150 A | 3AH38 | | | 3AH38 | | | | | | |
| | 4,000 A | 3AH38 | | | 3AH38 | | | | | | |
| | 5,000 A | 3AH37 | | | 3AH37 | | | | | | |
| | 6,300 A | 3AH37 | | | 3AH37 | | | | | | |
| | 8,000 A | 3AH37 | | | 3AH37 | | | | | | |

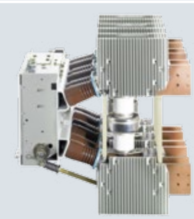
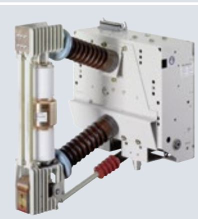
| Portfolio of circuit-breakers | | |
|---|---|---|
| SION | The standard circuit-breaker for variable application:<br>■ Available as standard circuit-breaker or complete slide-in module<br>■ Up to 30,000 operating cycles<br>■ Retrofit solution possible |  |
| 3AH5 | The standard circuit-breaker for small switching capacities:<br>■ Up to 10,000 operating cycles. |  |
| 3AH3 | The circuit-breaker for high switching capacities:<br>■ Rated short-circuit breaking currents of up to 63 kA<br>■ Rated normal currents of up to 4,000 A<br>■ Up to 10,000 operating cycles |  |
| 3AH4 | The circuit-breaker for a high number of operating cycles, i.e. for arc furnace switching:<br>■ Up to 120,000 operating cycles<br>■ Rated normal currents of up to 4,000 A<br>■ Rated short-circuit breaking currents of up to 40 kA |  |
| 3AH37/3AH38 | The circuit-breaker for high-current and generator applications<br>■ Rated short-circuit breaking currents of up to 72 kA (according to IEEE C37.013)<br>■ Rated normal currents up to 6,300 A<br>■ Up to 10,000 operating cycles<br>■ Design for phase segregation up to 24 kV, 80 kA, 12,000 A up to 24 kV, 90 kA, 6,300 A |  |
| 3AH47 | The circuit-breaker for applications in traction systems<br>■ System frequency 16 ⅔, 25, 50 or 60 Hz<br>■ 1-pole or 2-pole<br>■ Up to 60,000 operating cycles |  |
| 3AK7 | The compact, small circuit-breaker for high-current and generator applications<br>■ Rated short-circuit breaking currents of up to 50 kA<br>■ For generator switching according to IEEE C37.013 Rated short-circuit breaking currents of up to 50 kA<br>■ Rated normal currents up to 4,000 A |  |

*Table 4.3-3:* **Different types of vacuum circuit-breakers**

## 4.3.4 Vacuum Circuit-Breaker for Generator Switching Application

In numerous power stations around the world, the 3AH38 high-current and generator circuit-breaker has become the standard for switching rated operating currents up to 4,000 A.

The circuit-breakers has been modularly constructed in order to be able to use the best materials for the current circuit, magnetic flux and cooling. In this way, features such as low resistance of the main circuit, high mechanical stability and ideal cooling behavior have been combined in the 3AH37.

The 3AH37 is the first 72 kA vacuum circuit-breaker in the world that has been type-tested in accordance with the criteria of the generator circuit-breaker guideline IEEE Std C37.013. The 3AH37 high-current and generator circuit-breaker has a classic VCB design and is available to extend the product portfolio to master operating currents up to 6,300 A on a sustained Basis up to 24 kV without forced cooling. With forced cooling the 3AH37 is able to carryoperating currents up to 8,000 A.

For generator switching application with phase segregation the VCB's are designed for pole simultaneity and have been tested with ratings up to 80 kA with 12,000 A continuing current and 90 kA (fig. 4.3-2).

Advantages in daily operation:

- High mechanical stability through the column construction
- Compact dimensions through vertical arrangement of the vacuum interrupters
- Low fire load as solid insulation is not required
- High normal current possible without forced cooling due to free convection also in horizontal installation
- Secondary equipment can be easily retrofitted
- Maintenance-free throughout its entire service life
- Suitable for horizontal and vertical installation

3AK, 3AH37 and 3AH38 are type-tested according to IEEE Std C37.013



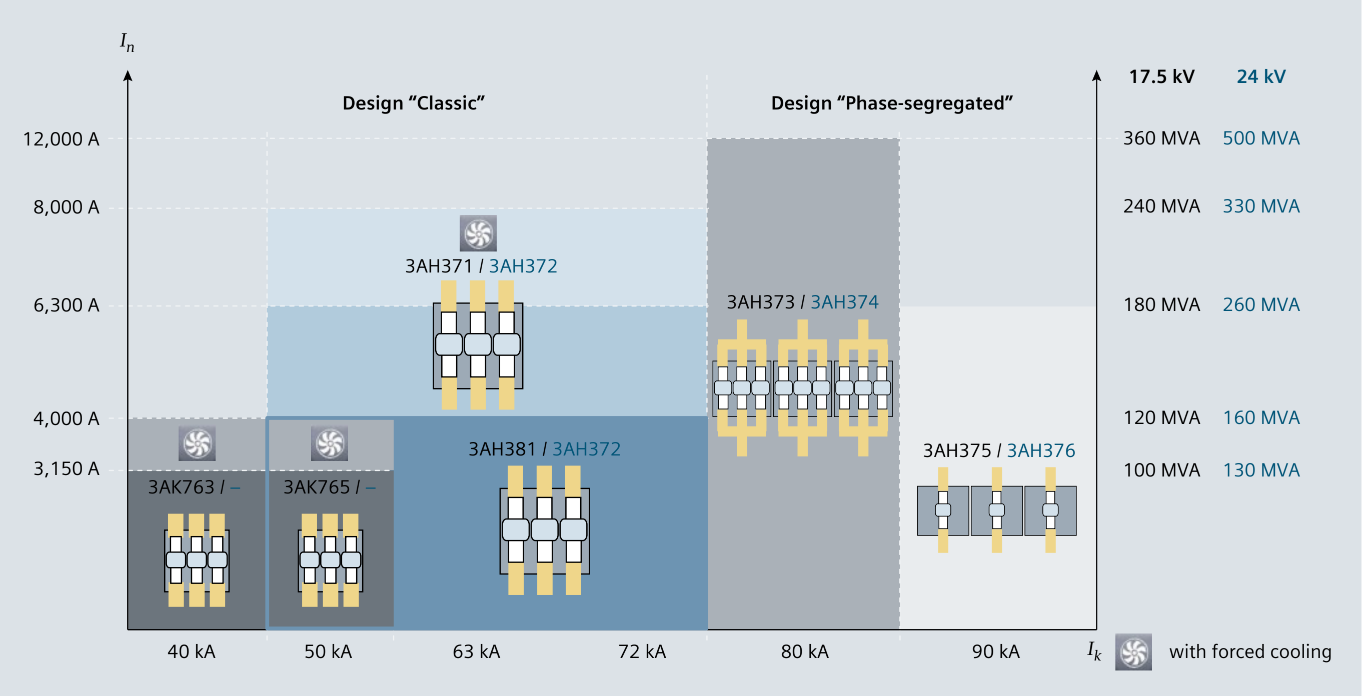



*Fig. 4.3-2:* **Vacuum circuit-breaker for generator switching application 17.5 kV and 24 kV**

## 4.3.5 Outdoor Vacuum Circuit-Breakers

Outdoor vacuum circuit-breakers perform the same functions as indoor circuit-breakers (table 4.3-2) and cover a similar product range. Due to their special design, they are preferred for use in power supply systems with a large extent of overhead lines. When using outdoor vacuum circuit-breakers, it is not necessary to provide for closed service locations for their installation.

The design comprises a minimum of moving parts and a simple structure in order to guarantee a long electrical and mechanical service life. At the same time, these circuit-breakers offer all advantages of indoor vacuum circuit-breakers.



In live-tank circuit-breakers (fig. 4.3-3), the vacuum interrupter is housed inside a weatherproof insulating enclosure, e.g., made of porcelain. The vacuum interrupter is at electrical potential, which means live.

The significant property of the dead-tank technology is the arrangement of the vacuum interrupter in an earthed metal enclosure (fig. 4.3-4).

The portfolio of outdoor vacuum circuit-breakers is shown in table 4.3-4.

*Fig. 4.3-3:* **Live-tank circuit-breaker**

*Fig. 4.3-4:* **Dead-tank circuit-breaker**

| Type | 3AG01 / 3AF01 / 3AF03 | 3AF04 / 3AF05 for AC traction power supply | SDV6 / SDV7 | SDV7M |
|---|---|---|---|---|
| Rated voltage | 12 – 40.5 kV | 27.5 kV | 15.5 – 38 kV | 15.5 – 27.6 kV |
| Rated short-duration power-frequency withstand voltage | 28 – 70 kV | 95 kV | 50 – 80 kV | 50 – 60 kV |
| Rated lightning impulse withstand voltage | 75 – 200 kV | 200 kV | 110 – 200 kV | 110 – 150 kV |
| Rated normal current | 1,250 – 2,500 A | 2,000 A | 1,200 – 3,000 A | 1,200 – 2,000 A |
| Rated short-circuit breaking current | 20 – 31.5 kA | 31.5 kA | 20 – 40 kA | 20 – 25 kA |
| Number of poles | 3 | 1 or 2 | 3 | 3 |
| Operating mechanism | Spring | Spring | Spring | Magnetic |
| Design | Live-tank | Live-tank | Dead-tank | Dead-tank |

*Table 4.3-4:* **Portfolio of outdoor vacuum circuit-breakers**

## 4.3.6 Reclosers

Vacuum reclosers offer dependable protection for overhead lines in order to provide improved reliability of the distribution network. At the core of the system, the controller provides a high level of protection, easiest operation, and high operating efficiency.

Up to 90 % of the faults in overhead line networks are temporary in nature. In case of a fault, a vacuum recloser trips to interrupt the fault current. Technical data and ratings see (table 4.3-5). After a few cycles, it recloses again and will remain closed if a transient fault has disappeared. This cycle is performed up to five times in order to bring the line back to service before the device finally switches to a lockout state should a permanent network fault be present.

Siemens vacuum reclosers can easily be installed anywhere on the overhead line, so network operators can choose an easily accessible location. The reclosers will be parameterized to sequentially protect the feeder in either star, ring or meshed networks.

The included trouble-free operating features are:
- Advanced vacuum switching technology
- A sophisticated solid epoxy insulation system with integrated sensors
- A dual-coil low-energy magnetic actuator
- The advanced Siemens controller
- A weatherproof control cubicle
- Reliable operation due to self-monitoring and standby.

*Controller*
The controller (fig. 4.3-5) – the "brain" of the recloser – comprises indicators and control elements, communication interfaces, and a USB port for convenient connection of a laptop. Access to the user level is protected by multi-level password authentication. The controller is mounted in a cubicle which also contains the auxiliary power supply and a battery-backed UPS unit, fuses, and a general purpose outlet to power a laptop.

The controller provides comprehensive protection functions as:
- Earth fault and sensitive earth fault detection along with overcurrent-time protection (definite and inverse)
- Inrush restraint
- Load shedding.

Further features of the controller are:
- A multitude of inputs and outputs for customer use
- Additional communication modules for data transfer
- Self-monitoring and measuring functions.

*Switch unit*
The switch unit (fig. 4.3-6) contains integrated current transformers and optionally also voltage sensors. It consists of one or three poles and the actuator housing. The poles are made of weatherproof epoxy resin which holds the vacuum interrupter. A switching rod connects the vacuum interrupter with the magnetic actuator.

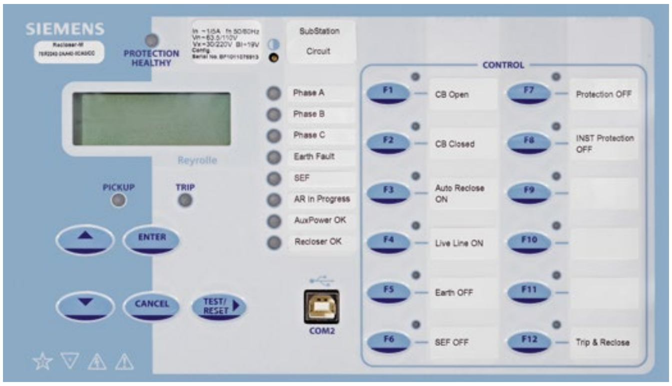



*Fig. 4.3-5:* **Argus-M controller**


*Fig. 4.3-6:* **Vacuum recloser with cubicle and controller**

A mechanical lockout handle, which allows for mechanical tripping and lockout, sticks out of the actuator housing. As long as this handle is extended, the unit can neither be closed electrically nor mechanically. The lockout handle needs to be reset manually to activate the unit.

A position indicator is located underneath the housing. Thanks to its size and the application of reflective materials, the indicator is highly visible from the ground and the switching state can be clearly recognized even at night.

| | |
|---|---|
| Rated operating current | 200 A to 800 A |
| Rated voltage acc. to ANSI C37-60 | 12 kV; 15.5 kV; 27 kV; 38 kV |
| Short-circuit breaking current | 12.5 kA; 16 kA |
| Lightning impulse withstand voltage | 95 kV to 190 kV |
| Number of operating cycles | 10,000 |
| Number of short circuit operations | up to 200 |
| Number of phases | three-phases; single-phases; single-triple |
| Standards | ANSI C37.60; IEC 62271-111; IEC 60255; IEC 62271-100 |

*Table 4.3-5:* **Technical data and ratings**

## 4.3.7 Fusesaver

In most rural network configurations, the feeder is protected by a circuit-breaker or recloser. Lateral lines* are usually protected by fuses.

As a fuse is unable to distinguish between temporary and permanent faults, it blows on ALL faults, causing downstream customers to lose power and requiring a line crew to replace the fuse.

In rural networks it may take hours for the line crew to drive to site, patrol the line (only to find no fault) and reconnect supply. This leads to unnecessary high operating costs for the utility.

Furthermore, downstream users are left without power for extended periods of time potentially resulting in financial penalties to the utility.

Since typically 80 percent of a rural network's faults are transient, 80 percent of its fuses are blown unnecessarily.

Due to the low customer numbers on rural lateral lines* it is often difficult for the utility to find a cost-effective solution to this problem ... until now!

Fusesaver (fig. 4.3-7, fig. 4.3-10), the world's fastest medium-voltage (MV) outdoor vacuum circuit-breaker, is the most cost-effective solution for optimizing reliability while minimizing operating costs of rural overhead MV networks. It is capable of almost completely removing the impacts of temporary faults on lateral lines*. Thanks to its unique fault-clearing speed (as fast as one half-cycle), the Siemens Fusesaver protects the fuse in the case of temporary faults (table 4.3-6, table 4.3-7). Fusesaver is a new class of intelligent, compact and low-cost single-phase circuit-breaker that minimizes lost minutes of supply by protecting lateral line fuses from blowing on transient faults.

The Fusesaver complies with the relevant parts of IEC 62271-100.

** Also referred to as spur lines, T-off or T-taps*

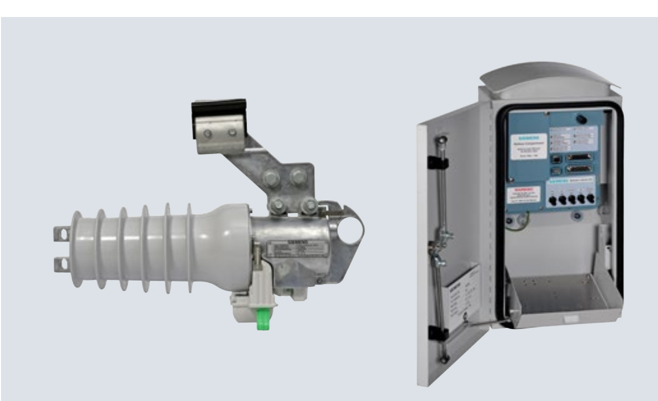


*Fig. 4.3-7:* **Fusesaver (left) and Remote Control Unit – RCU (right)**

Whilst the fuse protects the lateral line, the Fusesaver protects the fuse from translent faults:

- In this case (fig. 4.3-8, the fault disappears during the Fusesaver's dead time. After closing, the power supply is restored. The fuse did not operate, and the Fusesaver is ready for the next fault. Only the customers on the affected lateral line experience an interruption in power during the Fusesaver's dead time, while all other customers on the feeder, including nearby lateral, did not even notice its operation.

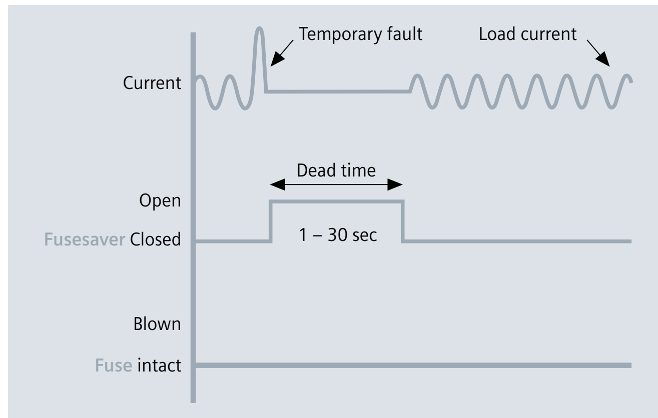



*Fig. 4.3-8:* **Performance with temporary faults**

- When the Fusesaver closes, the fault is still present, resulting in an immediate fault current. The Fusesaver will not operate again and allow the fault current to blow the fuse. Loss of power is unavoidable for customers on this lateral line, while all other customers receive an uninterrupted power supply. The Siemens Fusesaver restrict blown fuses on lateral lines to unavoidable cases of permanent faults (fig. 4.3-9).

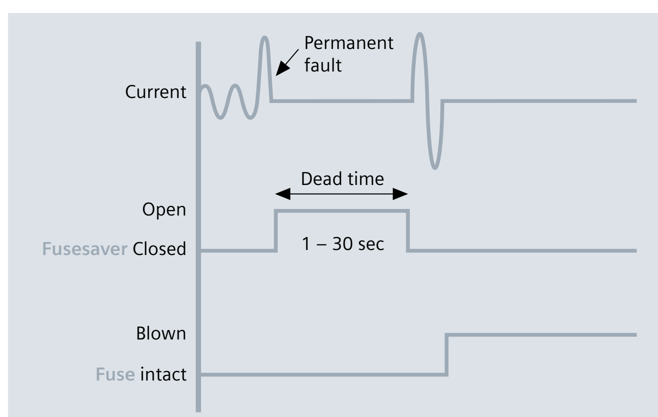



*Fig. 4.3-9:* **Performance with permanent faults**

The Fusesaver is designed to be installed in series with the fuse. When it senses a fault current, it will open and stay open for a pre-determined time (dead time). Then, the Fusesaver closes again reconnecting supply. With on-board microprocessor control and wireless connectivity, Fusesaver has configurable protection, multi-phase operation functions, on-board event history, and can be integrated into a SCADA system for remote control. It is an electrically floating device that hangs directly from the MV line. With no earth connection, it has no electrical stresses on its insulators, resulting in long life. It self-powers by harvesting and storing energy from the lateral line current. Fault detection is achieved with a cutting-edge, high-speed protection algorithm.

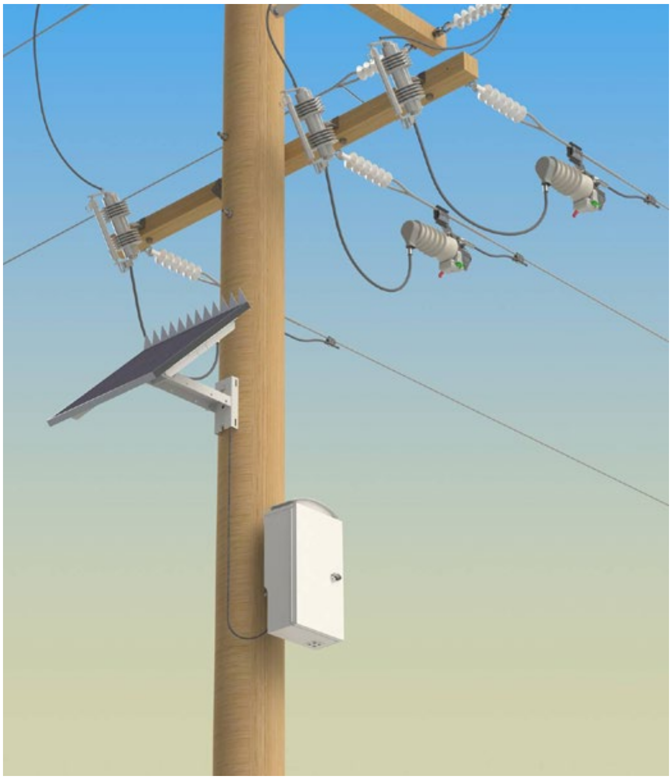


*Fig. 4.3-10:* **Fusesaver and RCU installation (with solar panel for RCU)**



| **Model type** | | **Low range** | **Standard range** | **High range** |
|---|---|---|---|---|
| Minimum line current for operation | A | 0.15 | 0.5 | 1.0 |
| Fuse ratings | A | 2 to 20 | 5 to 50 | 5 to100 |
| Rated current | A | 40 | 100 | 200 |
| Rated short-circuit breaking current $I_{sc}$ | kA | 1.5 | 4 | 4 |
| Rated short-circuit making current $I_{peak}$ | kA | 3.75 | 10 | 10 |
| Rated short-time withstand current | kA | 1.5 | 4 | 4 |
| Rated short-time withstand current duration | s | 0.4 | 0.2 | 1.0 |
| Fault break operations at 100% | No. | 200 | 30 | 30 |

*Table 4.3-6:* **Fusesaver types and rating overview**

The low range, standard range and high range, Fusesavers are all available with the following voltage rating options:

| **Rated voltage** | **kV** | **12** | **15.5** | **24** | **27** |
|---|---|---|---|---|---|
| Rated lightning impulse withstand voltage $U_p$ | kV | 75 | 110 | 125 | 125 |
| Rated power-frequency withstand voltage $U_d$ (60s) | kV | 42 | 50 | 50 | 60 |

*Table 4.3-7:* **Fusesaver voltage rating overview**

## 4.3.8 Vacuum Contactors

3TL vacuum contactors (fig. 4.3-11 to fig. 4.3-13) are 3-pole contactors with electromagnetic operating mechanisms for medium-voltage switchgear. They are load breaking devices with a limited short-circuit making and breaking capacity for applications with high switching rates of up to 1 million operating cycles. Vacuum contactors are suitable for operational switching of alternating current consumers in indoor switchgear.

They can be used, e.g., for the following switching duties:
- AC-3: Squirrel-cage motors: Starting, stopping of running motor
- AC-4: Starting, plugging and inching
- Switching of three-phase motors in AC-3 or AC-4 operation (e.g., in conveying and elevator systems, compressors, pumping stations, ventilation and heating)
- Switching of transformers (e.g., in secondary distribution switchgear, industrial distributions)
- Switching of reactors (e.g., in industrial distribution systems, DC-link reactors, power factor correction systems)
- Switching of resistive consumers (e.g., heating resistors, electrical furnaces)
- Switching of capacitors (e.g., in power factor correction systems, capacitor banks).

Further switching duties are:
- Switching of motors
- Switching of transformers
- Switching of capacitors.

In contactor-type reversing starter combinations (reversing duty), only one contactor is required for each direction of rotation if high-voltage high-rupturing capacity fuses are used for short-circuit protection.

The portfolio of the vacuum contactors is shown in table 4.3-8.



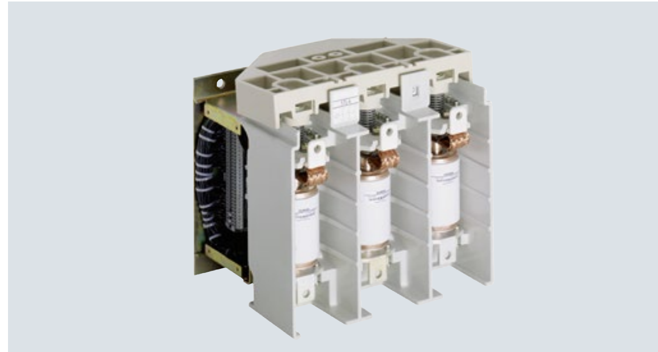


*Fig. 4.3-11:* **Vacuum contactor 3TL6**

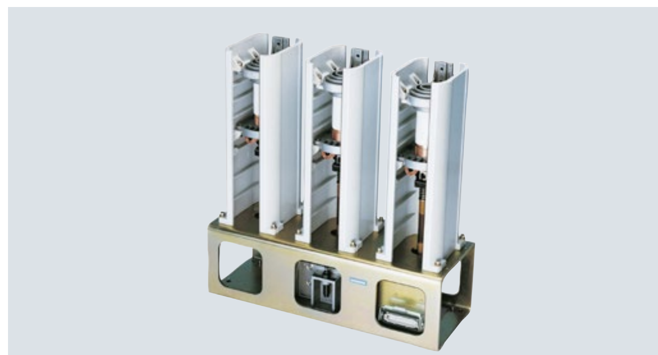


*Fig. 4.3-12:* **Vacuum contactor 3TL71**

*Fig. 4.3-13:* **Vacuum contactor 3TL81**

| Type | 3TL81 | 3TL61 | 3TL65 | 3TL68 | 3TL71 |
|---|---|---|---|---|---|
| Rated voltage | 7.2 kV | 7.2 kV | 12 kV | 15 kV | 24 kV |
| Rated frequency | 50/60 Hz | 50/60 Hz | 50/60 Hz | 50/60 Hz | 50/60 Hz |
| Rated normal current | 400 A | 450 A | 400 A | 320 A | 800 A |
| Rated making current* | 4,000 A | 4,500 A | 4,000 A | 3,200 A | 4,500 A |
| Rated breaking current* | 3,200 A | 3,600 A | 3,200 A | 2,560 A | 3,600 A |
| Mechanical endurance of the contactor* | 1 million operating cycles | 3 million operating cycles | 1 million operating cycles | 1 million operating cycles | 1 million operating cycles |
| Electrical endurance of the vacuum interrupter (rated current)* | 0.25 million operating cycles | 1 million operating cycles | 0.5 million operating cycles | 0.25 million operating cycles | 0.5 million operating cycles |
| * Switching capacity according to utilization category AC-4 (cos φ = 0.35) | | | | | |

*Table 4.3-8:* **Portfolio of vacuum contactors**

## 4.3.9 Contactor-Fuse Combination

Contactor-fuse combinations 3TL62/63/66 are type-tested units comprising contactors and HV HRC (high-voltage high-rupturing capacity) fuses. They have been specially developed for flexible use in restricted spaces and do not require any additional room for HV HRC fuses or any additional conductors between contactor and fuse. The components are laid out on the base plate so as to enable optimum ventilation, thereby allowing a high normal current. This design even meets the high dielectric strength standards required in countries such as China.

A number of different designs are available for integration in the switchgear panel, for example with different pole-center distances and widths across flats. A choice of single and double fuse holders, control transformer and an extensive range of other accessories are available as delivery versions (table 4.3-9).

**Construction**

The contactor-fuse combination (fig. 4.3-14, fig. 4.3-15) consists of the components vacuum contactor (1), insulating cover with fuse holder (2), fuse-links (3), contacts (4) and optionally a control transformer (5). These are accommodated on a base plate (6).

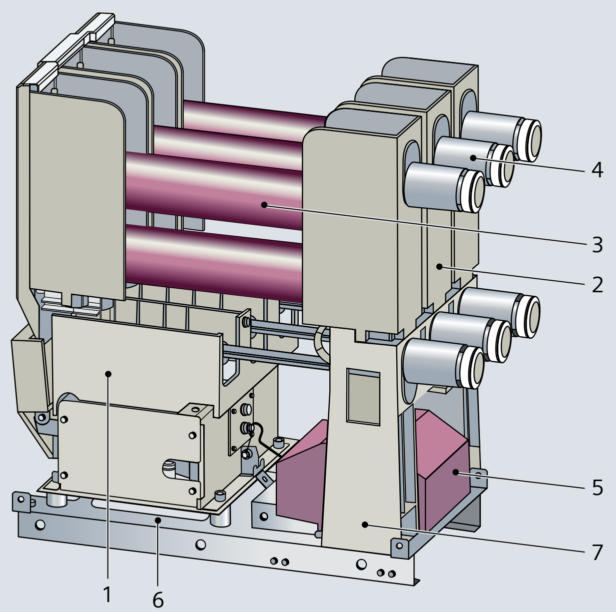
In normal operation, the vacuum contactor (1) breaks the corresponding currents reliably. To do this, the vacuum switching technology, proven for nearly 40 years, serves as arc-quenching principle by using vacuum interrupters. The vacuum interrupters are operated by the magnet system through an integral rocker.

The insulating cover with fuse holder (2) is mounted on one side of the contactor. On the other side it stands on a cross-member (7) under which there is room for the optional control transformer. The holders, which are especially conceived for the use of two HV HRC fuse-links, ensure a homogeneous distribution of the current to the two fuse-links of one phase.

The contactor-fuse combination is optimized for using 3GD2 fuses. But also fuse links from other manufacturers can be used (3). When selecting the fuses for an operational scenario, the technical limit values such as heating due to power dissipation, the limit switching capacity and the maximum let-through current must be taken into account.

The contacts (4) are used to establish the connection to the busbar compartment and the cable compartment via bushings, which can also be delivered optionally.

The optional control transformer (5) is connected to the high-voltage terminals of the contactor-fuse combination on its primary part, so that no additional cables are required. To protect the transformer, a separate upstream fuse is series-connected on the primary side and accommodated in the cross-member. Due to its different versions, the control transformer can be optimally selected to the existing power system.




1 Vacuum contactor
2 Insulating cover with fuse holder
3 Fuse element
4 Disconnecting contacts
5 Optional control transformer
6 Base plate
7 Cross-member

*Fig. 4.3-14:* **Construction of the contactor-fuse combination 3TL6**

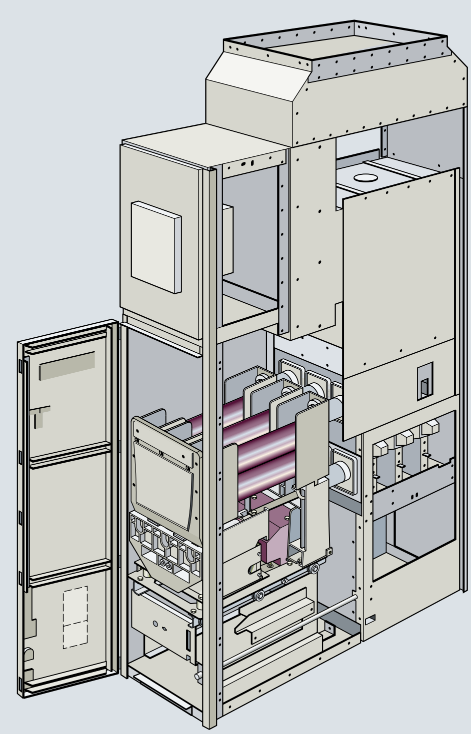


*Fig. 4.3-15:* **Installation of the contactor-fuse combination in the contactor panel**

4

| Type | 3TL62 | 3TL63 | 3TL66 |
|---|---|---|---|
| Rated voltage | 7.2 kV | 7.2 kV | 12 kV |
| Rated normal current (depending on installation and coordination with the selected fuses) | 450 A | 400 A | 400 A |
| Thermal current $I_{th}$ | Depending on installation and coordination with the selected fuses | | |
| Rated short-circuit breaking current $I_{SC}$ (prospective) | 50 kA | 50 kA | 40 kA |
| Max. let-through current $I_D$ | 46 kA | 46 kA | 46 kA |
| Short-circuit capability of the contactor (limit switching capacity) | 5 kA | 4.6 kA | 4.6 kA |
| Rated lightning impulse withstand voltage (to earth / open contact gap) | 60 kV / 40 kV | 60 kV / 40 kV | 75 kV / 60 kV |
| Rated short-duration power-frequency withstand voltage | 20 kV | 32 kV | 28 kV |
| Switching rate | 1,200 operating cycles/h | 600 operating cycles/h | 600 operating cycles/h |
| Mechanical endurance | 1 mio. operating cycles | 1 mio. operating cycles | 1 mio. operating cycles |
| Max. number of fuses per phase | 1 × 315 A or 2 × 250 A | 1 × 315 A or 2 × 250 A | 1 × 200 A or 2 × 200 A |
| Pole-center distances | 120 mm | 120 mm | 120 mm |
| Widths across flats | 205 mm, 275 mm, 310 mm | | |
| Various different contact systems and comprehensive accessories are available | | | |

*Table 4.3-9:* **Portfolio of contactor-fuse combination 3TL6**

**Mode of operation**
Basically, there are three different modes or states of operation: normal operation, short circuit and overload.

During normal operation, the combination behaves like a contactor. To close the contactor, the magnetic system can be operated with a control current, optional taken out of the control transformer. The DC magnet system operates as an economy circuit, proving a high mechanical endurance and a low pickup and holding power. An optional latch may hold the vacuum contactor in closed position even without excitation of the magnet system. The vacuum contactor is released electrically by means of a latch release solenoid or mechanically by an optional cabel operated latch release.

In case of short circuit, the HV HRC fuse melts already during the current rise. The released thermal striker activates an indication and operates the vacuum contactor. In the optimum time sequence, the fuse has already interrupted the short-circuit current at this time.

In case of overload, a high continuous current overloads the fuse-link thermally, thus tripping the thermal striker. The contactor already operates within the arcing time of the fuse, making a take-over current flow through the vacuum interrupters. The take-over current must not exceed maximum switching capability, as this could damage the vacuum interrupter. This is prevented by selecting the correct fuse.

**Application examples**
Contactor-fuse combinations are suitable for operational switching of alternating-current consumers in indoor switchgear. They are used, for example, for the following switching functions:
• Starting of motors
• Plugging or reversing the direction of rotation of motors
• Switching of transformers and reactors
• Switching of resistive consumers (e.g., electric furnaces)
• Switching of capacitors and compressors.

With these duties, contactor-fuse combinations are used in conveyor and elevator systems, pumping stations, air conditioning systems as well as in systems for reactive power compensation, and can therefore be found in almost every industrial sector.

**Standards**
Contactor-fuse combinations 3TL62/63/66 are designed according to the following standards for high-voltage alternating-current contactors above 1 kV to 12 kV:

| | |
|---|---|
| IEC 62271-1 | DIN EN 62271-1 |
| IEC 62271-106 | DIN EN 62271-106 |
| IEC 60529 | DIN EN 60529 |
| IEC 60721 | DIN EN 60721 |
| IEC 60282-1 | DIN EN 60282-1 |
| Test voltage according to GB 14808, DL/T 593 | |

**Advantages at a glance**

- Up to one million electrical operating cycles
- Usable for all kinds of switching duties
- Maintenance-free, reliable operation of vacuum interrupter and magnetic operating mechanism for maximum cost-efficiency
- Wide range of types for the most varied requirements
- Type-tested, compact construction (also for installation in narrow switchgear panels)
- Specially developed fuse holders for homogeneous current distribution
- Optimized construction for high power density
- Reliable for optimized availability
- Excellent environmental compatibility
- Over 35 years experience with vacuum contactors.

## 4.3.10 Switch-Disconnectors

Disconnectors (also called isolators) are used for almost no-load opening and closing of electrical circuits. While doing so, they can break negligible currents (these are currents up to 500 mA, e.g., capacitive currents of busbars or voltage transformers), or higher currents if there is no significant change of the voltage between the terminals during breaking, e.g., during busbar transfer in double-busbar switchgear, when a bus coupler is closed in parallel.

The actual task of disconnectors is to establish an isolating distance in order to work safely on other operational equipment that has been "isolated" by the disconnector. For this reason, stringent requirements are placed on the reliability, visibility and dielectric strength of the isolating distance.

Switch-disconnectors (table 4.3-10, fig. 4.3-16) combine the functions of a switch with the establishment of an isolating distance (disconnector) in one device, and they are therefore used for breaking load currents up to their rated normal current.

While connecting consumers, making on an existing short circuit cannot be excluded. That is why switch-disconnectors today feature a short-circuit making capacity. In combination with fuses, switches (switch-disconnectors) can also be used to break short-circuit currents. The short-circuit current is interrupted by the fuses. Subsequently, the fuses trip the three poles of the switch (switch-disconnector), disconnecting the faulty feeder from the power system.

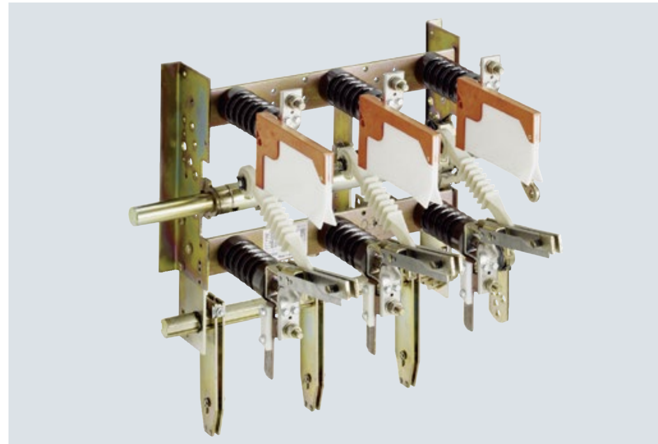


*Fig. 4.3-16:* **Switch-disconnector**



| **Type** | **3CJ2** | | | |
|---|---|---|---|---|
| Rated voltage | 12 kV | 17.5 kV | 24 kV | 36 kV |
| Rated short-duration power-frequency withstand voltage | 28 kV/32 kV | 38 kV/45 kV | 50 kV/60 kV | 70 kV/80 kV |
| Rated lightning impulse withstand voltage | 75 kV/85 kV | 95 kV/110 kV | 125 kV/145 kV | 170 kV/195 kV |
| Rated normal current | 400 A | 400 A | 400 A | 630 A |
| Rated normal current – without fuse-link | 630 A/1000 A | 630 A | 630 A/1000 A | 630 A/1000 A |
| Rated short-time withstand current (1 sec) | 25 kA | 25 kA | 25 kA | 20 kA |
| Rated short-circuit making current | 63 kA | 63 kA | 50 kA | 25 kA |
| Rated closed-loop breaking current | 400 A/630 A | 400 A/630 A | 400 A/630 A | 630 A |
| Rated cable-charging breaking current | 50 A | 75 A | 50 A | 25 A |
| Rated earth-fault breaking current | 150 A | 200 A | 150 A | 70 A |
| Rated cable-charging breaking current under earth-fault conditions | 86 A | 100 A | 86 A | 40 A |
| Number of mechanical operating cycles | 2,500 | 2,500 | 2,500 | 1,000 |
| Torque of spring-operated/stored-energy mechanism | 44/60 | 54/62 | 64/64 | 90/150 |
| Torque of earthing switch | 60 | 65 | 70 | 120 |
| Standard fuse reference dimension "e" | 292 | 362 | 442 | 538 |

*Table 4.3-10:* **Portfolio of switch-disconnectors**

*Arc-extinguishing principle*

Switch-disconnectors operate according to the principle of a hard-gas switch, and so the arc is not extinguished in a vacuum interrupter. The arc splits off some gas from an insulating material that surrounds the arc closely and this gas quenches the arc.

Because the material providing the gas cannot regenerate itself, the number of operating cycles is lower than in vacuum interrupters. Nevertheless, switch-disconnectors that use the hard-gas principle are used most frequently because of their good cost/performance ratio.

3CJ2 switch-disconnectors operate with a flat, hard-gas arcing chamber, (1) in fig. 4.3-17. During the opening movement, the contact blade, (2) in fig. 4.3-17, is separated first. Because the auxiliary blade, (3) in fig. 4.3-17, guided in the arcing chamber is still touching, the current now flows through the auxiliary blade. When the switching blades reach the isolating distance, the auxiliary blade opens the connection suddenly. The opening arc burns in a small gap, and the thermal effect releases enough gas to extinguish the arc rapidly and effectively.

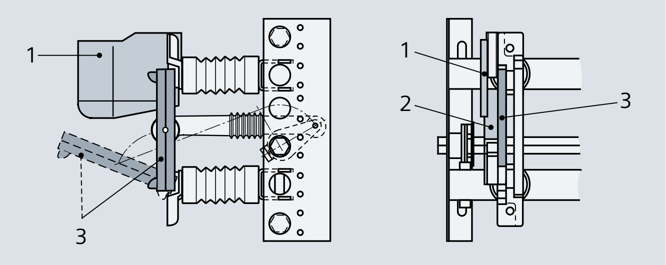



*Fig. 4.3-17:* **3CJ2 switch-disconnector: (1) flat hard-gas arcing chamber, (2) contact blade, (3) auxiliary blade**

# 4.4 Low-Voltage Devices

## 4.4.1 Requirements on Low-Voltage Devices in the Three Circuit Types

**Device application in the supply circuit**
The system infeed is the most "sensitive" circuit in the entire power distribution. A failure here would affect the whole network, leaving the building or the production concerned without power. This worst-case scenario must be considered during the planning. Redundant system supplies and selective protection settings are important preconditions for a safe network configuration. The selection of the correct protective devices is therefore of elementary importance in order to create these preconditions. Some of the key dimensioning data is described in the following.



*Rated current*
The feeder circuit-breaker in the LVMD must be dimensioned for the maximum load of the transformer/generator. When using ventilated transformers, the higher normal current of up to $1.5 \times I_N$ of the transformer must be taken into account.

**Short-circuit strength**
The short-circuit strength of the feeder circuit-breaker is determined by $(n-1) \times I_{k\,max}$ of the transformer or transformers (n = number of transformers). This means that the maximum short-circuit current that occurs at the place of installation must be known in order to specify the appropriate short-circuit strength of the protective device ($I_{cu}$: rated ultimate short-circuit breaking capacity). Exact short-circuit current calculations including attenuations of the medium-voltage levels or the laid cables can be made, for example, with the aid of the SIMARIS design dimensioning software. SIMARIS design determines the maximum and minimum short-circuit currents and automatically dimensions the correct protective devices.

*Utilization category*
When dimensioning a selective network, time grading of the protective devices is essential. When using time grading up to 500 ms, the selected circuit-breaker must be able to carry the short-circuit current that occurs for the set time. Close to the transformer, the currents are very high. This current-carrying capacity is specified by the $I_{cw}$ value (rated short-time withstand current) of the circuit-breaker; this means the contact system must be able to carry the maximum short-circuit current, i.e., the energy contained therein, until the circuit-breaker is tripped. This requirement is satisfied by circuit-breakers of utilization category B (e.g., air circuit-breakers, ACB). Current-limiting circuit-breakers (molded-case circuit-breakers, MCCB) trip during the current rise. They can therefore be constructed more compactly.

*Release*
For a selective network design, the release (trip unit) of the feeder circuit-breaker must have an LSI characteristic. It must be possible to deactivate the instantaneous release (I). Depending on the curve characteristic of the upstream and downstream protective devices, the characteristics of the feeder circuit-breaker in the overload range (L) and also in the time-lag short-circuit range (S) should be optionally switchable ($I^4t$ or $I^2t$ characteristic curve). This facilitates the adaptation of upstream and downstream devices.

*Internal accessories*
Depending on the respective control, not only shunt releases (previously: f-releases), but also undervoltage releases are required.

*Communication*
Information about the current operating states, maintenance, error messages and analyses, etc. is being increasingly required, especially from the very sensitive supply circuits. Flexibility may be required with regard to a later upgrade or retrofit to the desired type of data transmission.

**Device application in supply circuits (coupling)**
If the coupling (connection of network 1 to network 2) is operated in open condition, the circuit-breaker (tie breaker) only has the function of a disconnector or main switch. A protective function (release) is not absolutely necessary.

The following considerations apply to closed operation:
- Rated current
  This must be dimensioned for the maximum possible normal current (load compensation). The simultaneity factor can be assumed to be 0.9.
- Short-circuit strength
  The short-circuit strength of the feeder circuit-breaker is determined by the sum of the short-circuit components that flow through the coupling. This depends on the configuration of the component busbars and their supply.
- Utilization category
  As for the system supply, utilization category B is also required for the current-carrying capacity ($I_{cw}$).
- Release
  Partial shutdown with the couplings must be taken into consideration for the supply reliability. As the coupling and the feeder circuit-breakers have the same current components when a fault occurs, similar to the parallel operation of two transformers, the LSI characteristic is required. The special zone selective interlocking (ZSI) function should be used for larger networks and/or protection settings that are difficult to determine.

**Device application in the distribution circuit**
The distribution circuit receives power from the higher level (supply circuit) and feeds it to the next distribution level (final circuit).

Depending on the country, local practices, etc., circuit-breakers and fuses can be used for system protection; in principle, all protective devices described in this chapter. The specifications for the circuit dimensioning must be fulfilled. The ACB has advantages if full selectivity is required. For cost-reasons, however, the ACB is only frequently used in the distribution circuit with a rated current of 630 A or 800 A. As the ACB is not a current-limiting device, it differs greatly from other protective devices such as MCCB, MCB, and fuses.

Table 4.4-1 shows the major differences and limits of the respective protective devices.

**Device application in the final circuit**

The final circuit receives power from the distribution circuit and supplies it to the consumer (e.g., motor, lamp, non-stationary load (power outlet), etc.). The protective device must satisfy the requirements of the consumer to be protected by it.

_Note:_

All protection settings, comparison of characteristic curves, etc. always start with the load. This means that no protective devices are required with adjustable time grading in the final circuit.

| | | ACB air circuit-breaker | MCCB molded-case circuit-breaker | Fuse switch-disconnector | Switch-disconnector with fuses | MCB miniature circuit-breaker | Reference values, specifications |
|---|---|---|---|---|---|---|---|
| **Standards** | IEC | Yes | Yes | Yes | Yes | Yes | Region |
| **Application** | System protection | Yes | Yes | Yes | Yes | Yes | Power supply system |
| **Installation** | Fixed mounting | Yes | Yes | Yes | Yes | Yes | Availability |
| | Plug-in | – | Up to 800 A | – | Partly | – | |
| | Withdrawable unit | Yes | Yes | – | – | – | |
| **Rated current** | $I_n$ | 6,300 A | 1,600 A | 630 A | 630 A | 125 A | Normal current $I_B$ |
| **Short-circuit breaking capacity** | $I_{cu}$ | Up to 150 kA | Up to 100 kA | Up to 120 kA | Up to 120 kA | Up to 25 kA | Maximum short-circuit current $I_{k\,max}$ |
| **Current-carrying capacity** | $I_{cw}$ | Up to 80 kA | Up to 5 kA | – | – | – | Circuit |
| **Number of poles** | 3-pole | Yes | Yes | Yes | Yes | Yes | Power supply system |
| | 4-pole | Yes | Yes | – | Partly | – | |
| **Tripping characteristic** | ETU | Yes | Yes | – | – | – | Power supply system |
| | TMTU | – | Up to 630 A | Yes | Yes | Yes | |
| **Tripping function** | LI | Yes | Yes | Yes 1) | Yes 1) | Yes | Power supply system |
| | LSI | Yes | Yes | – | – | – | |
| | N | Yes | Yes | – | – | – | |
| | G | Yes | Yes | – | – | – | |
| **Characteristics** | Fixed | – | Yes | Yes | Yes | Yes | Power supply system |
| | Adjustable | Yes | Yes | – | – | – | |
| | Optional | Yes | Yes | – | – | – | |
| **Protection against electric shock, tripping condition** | Detection of $I_{k\,min}$ | No limitation | No limitation 1) | Depends on cable length | Depends on cable length | Depends on cable length | Minimum short-circuit current $I_{k\,min}$ |
| **Communication (data transmission)** | High | Yes | – | – | – | – | Customer specification |
| | Medium | Yes | Yes | – | – | – | |
| | Low | Yes | Yes | Yes | Yes | Yes | |
| **Activation** | Local | Yes | Yes | Yes | Yes | Yes | Customer specification |
| | Remote (motor) | Yes | Yes | – | | – | |
| **Derating** | Full rated current up to | 60 °C | 50 °C | 30 °C | 30 °C | 30 °C | Switchgear |
| **System synchronization** | | Yes | Up to 800 A | – | – | – | Power supply system |

1) According to the fuse characteristic

*Table 4.4-1:* **Overview of the protective devices; *) with electronic trip unit (ETU): no limitation / with thermomagnetic trip unit (TMTU): depends on cable length**

## 4.4.2 Low-Voltage Protection and Switching Devices

The following chapter focuses on the relevant characteristics and selection criteria of the respective devices (table 4.4-2 and table 4.4-3) that are used in the main power distribution circuits in commercial buildings and in industry.

<u>Note:</u>

All figures apply to low-voltage power systems or distribution boards in IEC applications. Different regulations and criteria apply to systems according to UL standards.
Depending on the country, standard specifications, local practices, planning engineer, technical threshold values, etc., low-voltage power distribution systems are made up of various protective devices.*

**Circuits and device assignment**
(see also section 3.3.2 "Dimensioning of Power Distribution Systems")

*Basic configuration of a low-voltage power distribution system and assignment of the protective devices including core functions*
Core functions in the respective circuits:

- Supply circuit
  Task: System protection
  Protective device:
  – ACB (air circuit-breaker)
- Distribution circuit
  Task: System protection
  Protective devices:
  – ACB (air circuit-breaker)
  – MCCB (molded-case circuit-breaker)
  – SD (switch-disconnector)
- Final circuit
  Task: Motor protection
  Protective devices:
  – MCCB (circuit-breaker for motor protection)
  – SD (switch-disconnector)
  – MSP (3RT contactor, 3RU overload relay, 3UF motor protection, and control devices).

| Circuit-breakers | | |
|---|---|---|
| ACB | **Air circuit-breaker**<br>– Non-current-limiting circuit-breaker<br>– Current-zero cut-off circuit-breaker |  |
| MCCB | **Molded-case circuit-breaker**<br>– Current-limiting circuit-breaker |  |
| MCB | **Miniature circuit-breaker** |  |
| MSP | **Motor starter protector** |  |
| MPCB | **Motor protector circuit-breaker**<br>– Circuit-breaker for motor protection |  |

*Table 4.4-2:* **Overview of circuit-breaker devices**

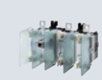
| Switching devices (fuse switch-disconnector/disconnector) | | |
|---|---|---|
| SD | Switch-disconnector<br>Depending on the type of operation, these devices are divided into two main groups: | |
| **Operator-dependent** | | |
| Without circuit-breaker latching system, with protection (fuse); with these devices, the fuse is also moved when making and breaking (= fuse switch-disconnector) | |   |
| With circuit-breaker latching system, with protection (fuse); with these devices, the fuse is not moved when making and breaking (= disconnector with fuse) | |   |
| **Operator-independent** | | |
| With circuit-breaker latching system, without protection (without fuse); these devices are only used to interrupt the circuit, similar to a main switch (= disconnector without fuse) | |   |

*Table 4.4-3:* **Overview of switching devices**

* *If you have questions on UL applications, please contact your local Siemens representative. Siemens provides solutions for these applications, but they must be treated completely differently.*

**Criteria for device selection**
A protective device is always part of a circuit (fig. 4.4-1) and must satisfy the corresponding requirements (see also section 3.3.2 "Dimensioning of Power Distribution Systems"). The most important selection criteria are shown in the following.

**Main selection criteria**
Fig. 4.4-2 shows the seven most important selection criteria that must be at least taken into account for the device selection.

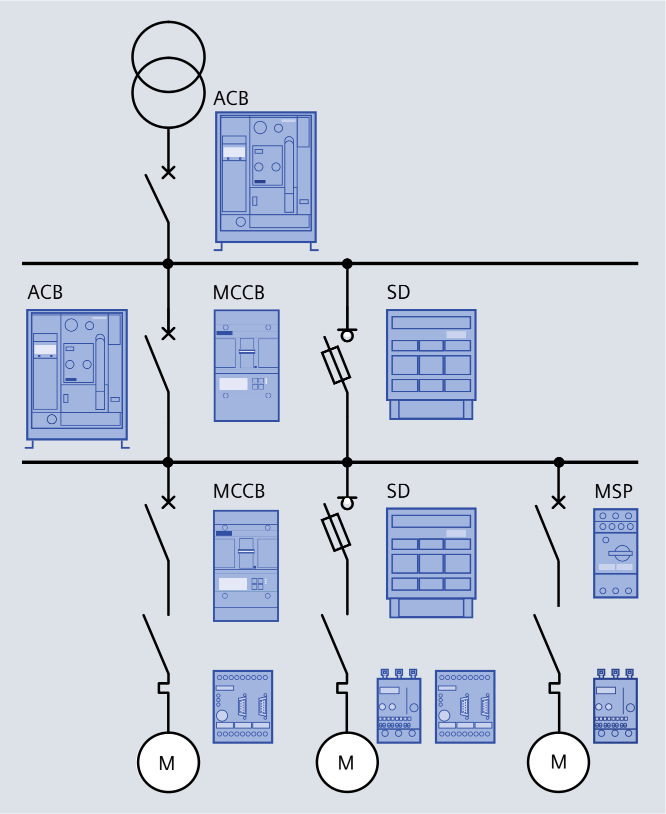
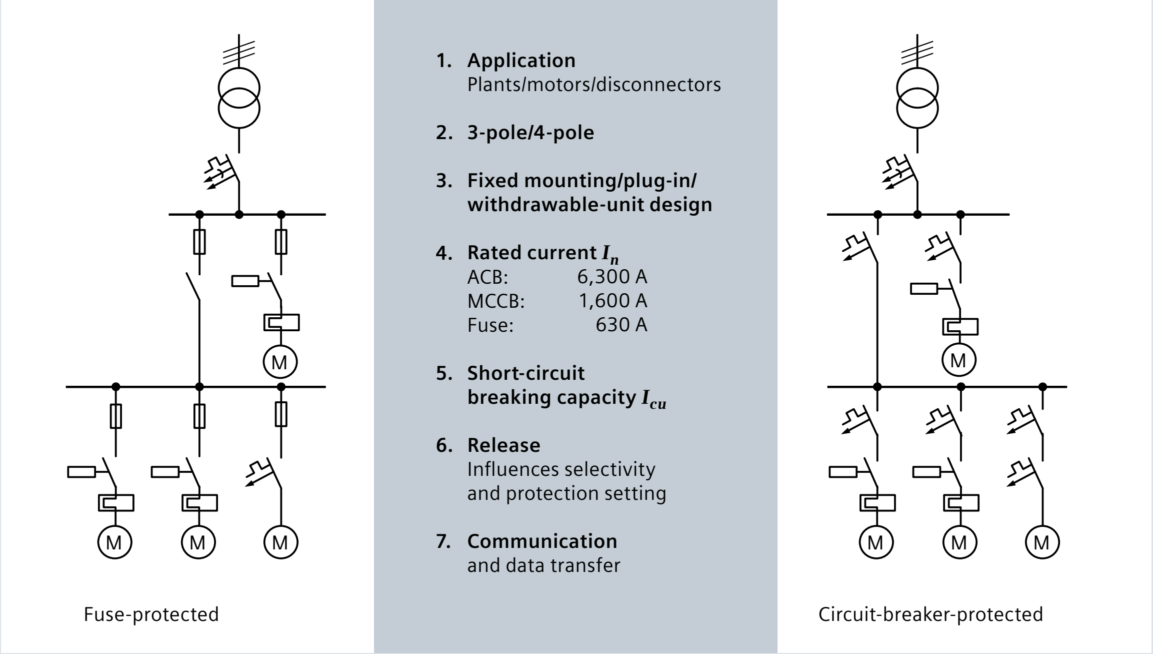



*Fig. 4.4-1:* **Core functions of the protective devices in the individual circuit types**




1. **Application**
   Plants/motors/disconnectors
2. **3-pole/4-pole**
3. **Fixed mounting/plug-in/ withdrawable-unit design**
4. **Rated current $I_n$**
   ACB: 6,300 A
   MCCB: 1,600 A
   Fuse: 630 A
5. **Short-circuit breaking capacity $I_{cu}$**
6. **Release**
   Influences selectivity and protection setting
7. **Communication**
   and data transfer

*Fig. 4.4-2:* **Main selection criteria**

4

## 4.4.3 Power Management System for the Low-Voltage Power Distribution

The focus of a power management system is on the demand for improved transparency of energy consumption and energy quality, as well as on ensuring the availability of power distribution. Holistic transparency is the basis for optimizing power consumption and costs. The information obtained through this transparency provides a realistic basis for cost center allocations as well as for measures to improve the energy efficiency. In addition, it documents the savings achieved.

**Functions of the power management system**

- Analysis of the energy data / energy flows with specific load curve diagrams
- Visualization of the interdependencies
- Detection of savings potentials, assessed minimum and maximum values
- Energy measurements for accounting purposes (internal cost center allocation, external billing)
- Benchmarking, internal (rack-line / building part) or external (property/installations with comparable use based on obtained measured values)
- Visualization of the power supply with switching states and energy flows
- Preparation of decisions, e.g., regarding power supply extensions
- Verifiable efficiency improvements
- Targeted troubleshooting from fast, detailed information about events and faults that occur in the power distribution system inside the server room / building
- Fault and event messages (e.g., switching sequences) are logged with a date and time stamp, so that downtimes can be documented and fault processes traced and analyzed later using the data recorded
- Compliance with purchasing contracts via the selective control of consuming devices
- Automatic notification of the service personnel.

**Levels of the power management system**

Power management is the special energy view on a building or an infrastructure property ranging from the power infeed and distribution through to the power consumers themselves. It comprises the following levels:

- Energy value acquisition using measuring devices 7KM PAC (fig. 4.4-3)
- Processing of the measurement data
- Monitoring including visualization, archiving, report, and messaging.

Data acquisition systems and measuring devices can be directly connected to the server with the power management software, e.g. “powermanager” from Siemens, via Modbus TCP. The software then handles the actual recording, visualization and logging of the acquired values. A SIMATIC S7 controller allows a comparable network for industrial bus systems such as PROFINET or PROFIBUS-DP to be built up. PROFIBUS expansion modules can be used for the direct integration of measuring devices as well as for the 7KM PAC3200, for example. In both cases, a 7KM PAC4200 measuring device can serve as gateway to a subordinate Modbus RTU network linked either via Modbus TCP or via PROFIBUS-DP using PROFIBUS expansion modules (fig. 4.4-4).


*Fig. 4.4-3:* **7KM PAC measuring devices**

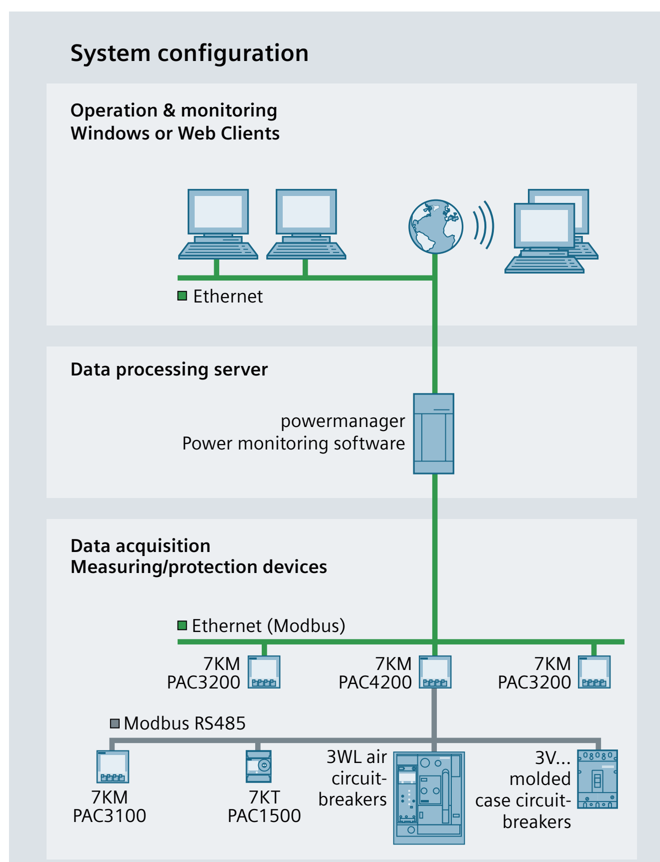



*Fig. 4.4-4:* **Network structure of a power management system**

## 4.4.4 Software for Power System Dimensioning

An exact protective device selection, and thus the dimensioning of power distribution systems, requires extensive short-circuit current and voltage drop calculations. Catalog data for the short-circuit energies, the selectivity and the backup protection of the individual devices and assemblies must also be consulted. In addition, the appropriate regulations and standards must be observed. At this point, a reference should be made to the SIMARIS design dimensioning tool that automatically takes account of the above mentioned conditions, catalog data, standards, and regulations and consequently automatically makes the device selection.

**Selectivity and backup protection**

Rooms used for medical purposes (IEC 60364-7-710, VDE 0100-710) and meeting rooms (IEC 60364-7-718, VDE 0100-718) require the selection of protective devices in subareas. For other building types, such as data centers, there is an increasing demand for a selective grading of the protective devices, because only the circuit affected by a fault would be disabled with the other circuits continuing to be supplied with power without interruption.

Because the attainment of selectivity results in increased costs, it should be decided for which circuits selectivity is useful. Backup protection is the lower-cost option. In this case, an upstream protective device, e.g., an LV HRC fuse as group backup fuse, supports a downstream protective device in mastering the short-circuit current, i.e., both an upstream and a downstream protective device trip. The short-circuit current, however, has already been sufficiently reduced by the upstream protective device so that the downstream protective device can have a smaller short-circuit breaking capacity. Backup protection should be used when the expected solid short-circuit current exceeds the breaking capacity of the switching device or the consumers. If this is not the case, an additional limiting protective device unnecessarily reduces the selectivity or, indeed, removes it.

The following scheme should be followed for the selectivity or backup protection decision:

- Determine the maximum short-circuit current at the installation point
- Check whether the selected protective devices can master this short-circuit current alone or with backup protection using upstream protective devices
- Check at which current the downstream protective devices and the upstream protective devices are selective to each other.

**Selectivity and backup protection exemplified for a data center**

Data centers place very high demands on the safety of supply. This is particularly true for the consumers attached to the uninterruptible power supply, and ensures a reliable data backup in case of a fault and service interruption. Those solutions providing selectivity and backup protection relying on the previously mentioned SIMARIS design configuration tool should be presented at this point. Fig. 4.4-5 shows a distribution system in SIMARIS design. A 3WL circuit-breaker as outgoing feeder switch of the main distribution is upstream to the distribution system shown here.

4

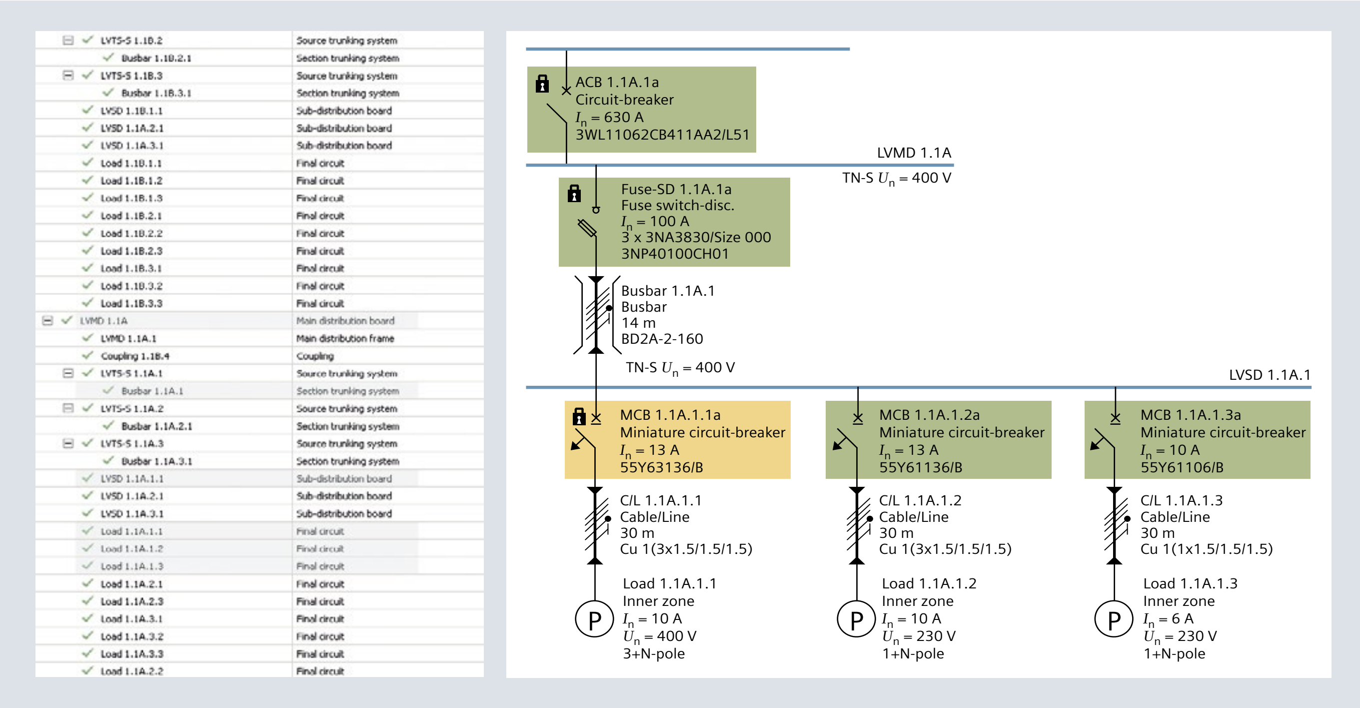



*Fig. 4.4-5:* **Subdistribution in a data center; display in SIMARIS design**

The following figures show the selectivity diagrams for the considered distribution system automatically generated by SIMARIS design (fig. 4.4-6). SIMARIS design specifies the characteristic curve band of the considered circuit (red lines), the envelope curves of all upstream devices (blue line) and all downstream devices (green line). In addition to the specification of the minimum and maximum short-circuit currents, any selectivity limits for the individual circuits are also specified.

Fig. 4.4-7 shows the selective grading of the 3WL circuit-breaker from the main distribution system and the group backup fuse (100 A LV HRC fuse) of the subdistribution system. The consumers critical for functional endurance which are installed in a redundant manner in the subdistribution system should not be protected with the same backup fuse but rather be assigned to different groups.

The selectivity diagram shows the circuit diagram of a single-phase consumer in the subdistribution system. This circuit diagram is protected with a 10 A miniature circuit-breaker with characteristic B and for a maximum short-circuit current of 5,892 kA selective to the 100 A group backup fuse.

The same subdistribution system also contains an example for backup protection. Fig. 4.4-8 shows the selectivity diagram for the combination of the group backup fuse with a 13 A miniature circuit-breaker of the characteristic B. Up to the breaking capacity of the 6 kA miniature circuit-breaker, the two protective devices are selective to each other. Above this value, the current is limited by the fuse and the miniature circuit-breaker protected by a fuse; both devices trip.

SIMARIS design automatically generates these characteristic curves to provide exact information about the maximum and minimum short-circuit currents of the associated circuit. Fig. 4.4-8 also shows up to which current ($I_{\text{sel-short-circuit}}$) the protective devices are selective to each other.

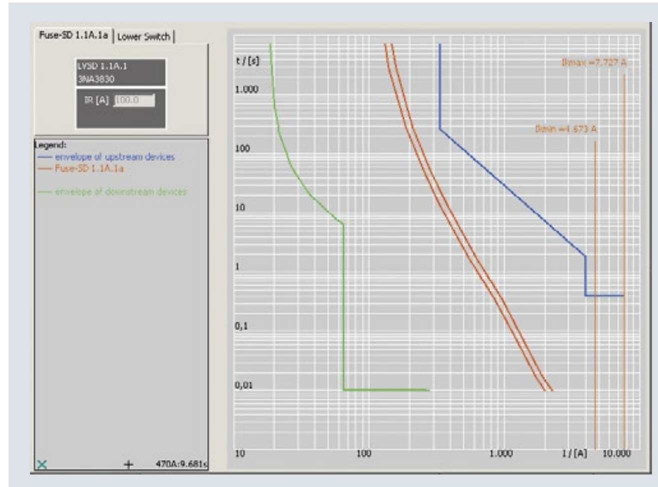


*Fig. 4.4-6:* **Selectivity of the group backup fuse to the upstream protective devices**

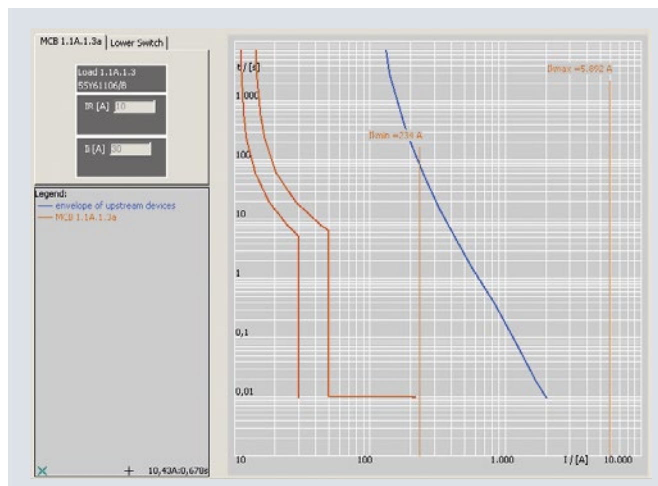


*Fig. 4.4-7:* **Selectivity of the group backup fuse/miniature circuit-diagram combination**

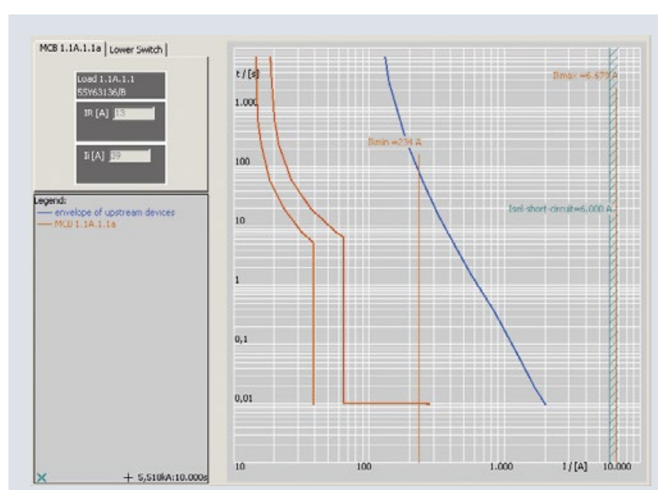


*Fig. 4.4-8:* **Backup protection of the group backup fuse/miniature circuit-breaker**

## 4.4.5 The Safe Power Supply of Tomorrow

Whether for wind power, photovoltaics or electromobility: Siemens' integrated portfolio offers high-quality and standard-compliant components for the implementation of sustainable power concepts.

**Ready for the future**

In view of the limited resources of fossil fuels, the use of renewable energy sources is becoming increasingly important. Alongside wind turbines, photovoltaic systems are a key area of interest. Both the ecological and economic aspects of these systems are of great importance. As a global leading supplier of first-class, standard-compliant components and systems for low-voltage power distribution, Siemens contributes to a responsible and sustainable use of electrical energy.

With a consistent portfolio enabling power supply and distribution, personal, fire and line protection, as well as power monitoring, Siemens supports sustainable energy concepts in the areas of wind energy, photovoltaics, electromobility, and smart buildings, infrastructures, and industry (fig. 4.4-9).

**Wind power plants face demanding ambient conditions**

The power output of a wind turbine can change with the wind strength and direction quickly and unexpectedly. The components used in the nacelle are also subjected to mechanical stresses and climatic effects around the clock – especially low-frequency vibrations and temperature changes between −25 °C and +50 °C. Current-carrying components are also subjected to thermal stress by the frequent on/off switching of the wind turbine.

To reliably maintain the functional capability and availability of the protection equipment under these circumstances, components must be used, which have a safe range that is matched to the requirements of the wind turbine. Siemens' protection, switching and measuring devices with optional communication modules, which support the monitoring of the plant and the adherence to the service intervals, provide an ideal solution.

The main circuit of a wind turbine is responsible for power generation via the generator and the transmission of power up to the infeed into the grid (fig. 4.4-10). High power outputs must be distributed and transmitted in the wind turbine safely and with as little loss as possible. This can be achieved by means of the LI system from the SIVACON 8PS busbar trunking systems, which can be fitted both quickly and safely. It is ideally suited to the distribution and transmission of power within the main circuit for a current range of 800 A to 6,300 A.

The 3WL air circuit-breaker from the SENTRON portfolio protects the main circuit in the event of overload and short circuit. It can be fitted with various electronic trip units, which enable the tripping characteristic to be optimally adapted to the conditions required. The connection between the generator and the con-

*Fig. 4.4-9:* **Key technologies for the power supply of tomorrow**

verter, which has to contend with variable frequencies, is protected by the externally controlled 3WL air circuit-breaker. The sensitive power semiconductors of the converter react sensitively to short circuit and overload. In the event of uncontrolled failure due to extreme circumstances, this can result in substantial damage and downtime for the entire wind turbine. A particularly fast protective device is required for protection. SITOR semiconductor fuses are the ideal solution for meeting these requirements.

The equipment of vital functions of the wind turbine, like pitch and yaw systems as well as ventilation or hydraulic systems, must be fitted with coordinated components to ensure effective protection against overvoltages, overloads, and short circuits. The 3V... molded-case circuit-breakers and the 3NP1 fuse switch-disconnectors protect the infeed system of the auxiliary circuits against short circuit and overload. Miniature circuit-breakers and fuse systems offer perfect protection for feeders and electrical equipment against short circuit and overload. Residual current operated circuit-breakers protect against electrically ignited fires and offer personnel protection, e.g., in the case of insulation faults. UC-sensitive residual-current-operated circuit-breakers of types B and B+ guarantee maximum protection even when smooth DC residual currents arise. These can occur with frequency converters or defective switching network components. Further key functions are available thanks to an extensive range of accessories: remote tripping, remote reconnection, and remote querying of switching states.

Due to their usually exposed positions, wind turbines are at particular risk of being struck by lightning. In order to protect electrical equipment against lightning and overvoltages, Siemens offers a graded portfolio of surge arresters of types 1, 2 and 3.

Within the electric circuits of a wind turbine, measurement technology allows for the precise display and reliable monitoring of electrical variables. By recording changes in harmonic or current mean values, critical system states, and system component defects can be detected at an early stage, and subsequent damage, such as caused by fire, can be prevented. Thanks to their many communication options, the high-quality 7KM PAC measuring devices can be very easily integrated into higher-level communication systems of the wind turbine or wind farm control rooms for further processing of the measured data.

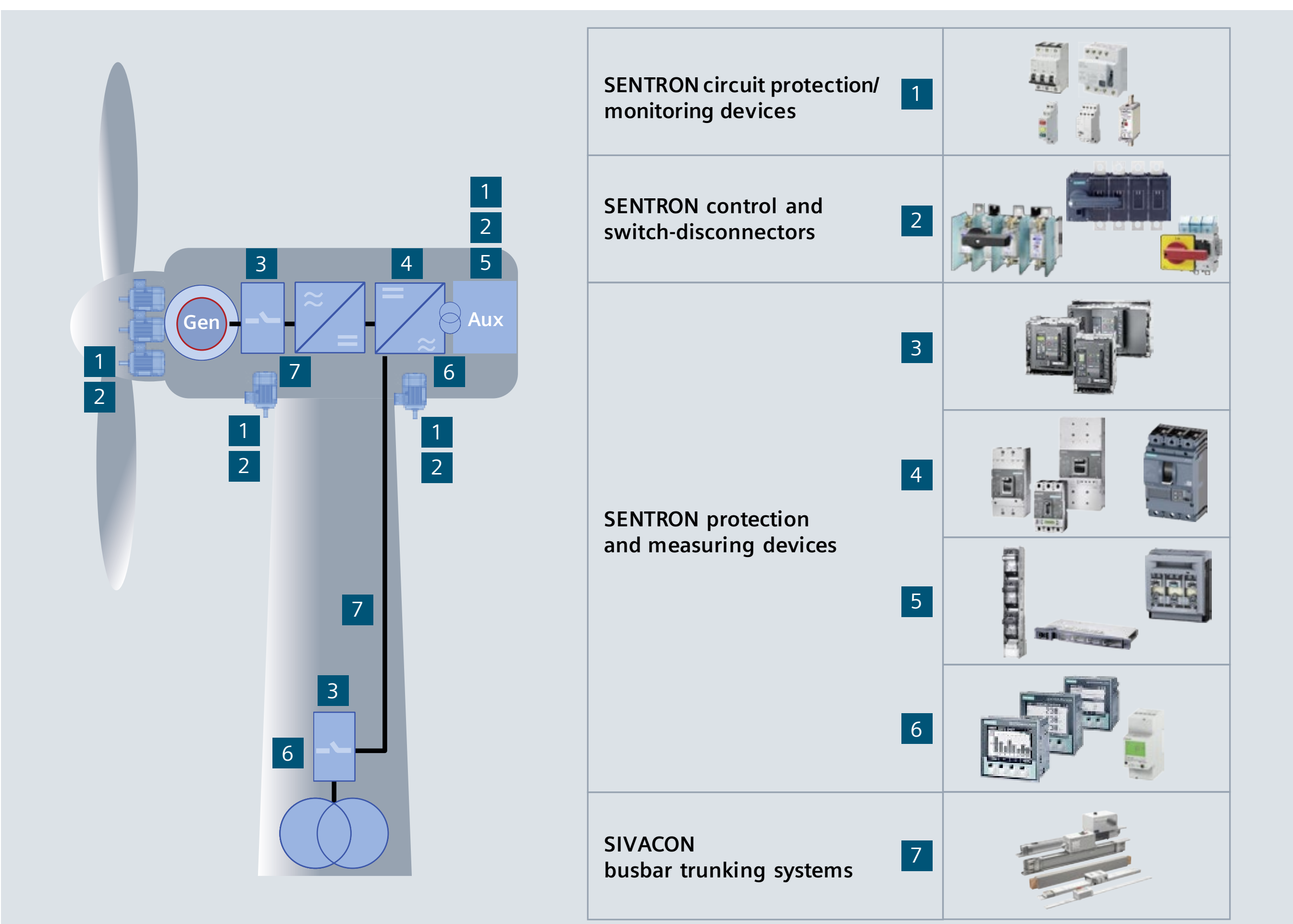



*Fig. 4.4-10:* **Low-voltage power distribution devices in wind turbines (exerpt)**

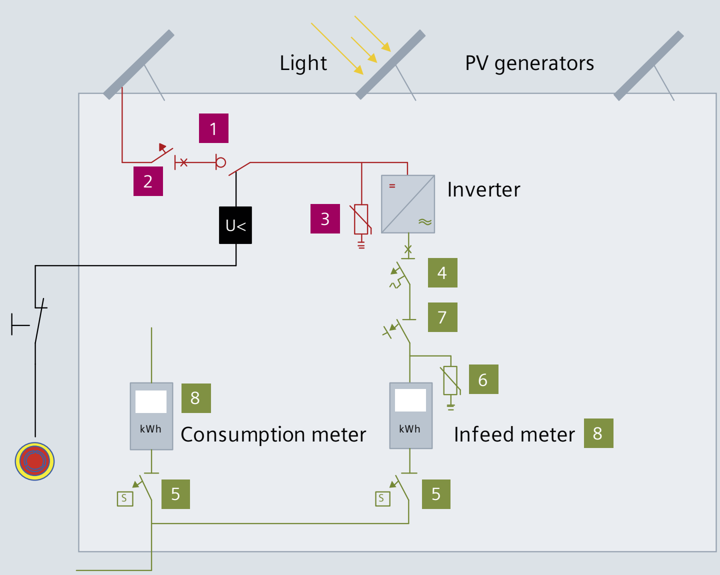
**Standard-compliant components for photovoltaic systems**
Photovoltaic (PV) systems play an important role in $CO_2$ reduction and also make good business sense, not least in view of the feed-in tariffs, guaranteed by local laws (e.g. German Renewable Energy Sources Act – EEG). The construction and operation of photovoltaic systems is now integrated in a couple of standards like IEC 60364-7-712 (VDE 0100-712) and IEC 60269-1/-6, as well as in the series of standards VDE 0126 (also comprising a couple of international standards like EN 50521, EN 50548, and the series IEC 60904).

A central factor in the operation of a PV system that feeds into the local power grid is grid safety. In the event of a fault, the PV modules must be disconnected from the system at the infeed point. It is also necessary to prevent infeed to the grid in the event of grid and system faults. The standards require that isolating arresters be provided on both sides of the inverter. These must feature suitable load-switching capacity on both the DC and AC sides.

It is absolutely necessary that switch-off equipment (disconnection under load for maintenance work, for example) is provided. DC disconnectors designed with a suitable switching capacity for direct currents enable functions such as safe disconnection of the PV generator under load on all poles. According to the standards, isolating equipment must be provided on the AC side. The AC main switch must be able to safely disconnect the AC circuit under load on all poles. The use of switch-disconnectors with suitable AC switching capacity is recommended for this. Overvoltage protection devices for the DC and AC sides limit voltage spikes, caused by lightning strikes or gridside overvoltages, and ensure the safety and uninterrupted availability of the system.

Siemens offers a high-quality, standard-compliant product range for the operation of PV systems (fig. 4.4-11, fig. 4.4-12), which guarantees a high level of operational safety and a long-term stability of yield. Whether for lightning strikes, overloads, or simply maintenance work – the comprehensive and coordinated range of SENTRON protection, switching, measuring, and monitoring devices offers all the components needed for the safe construction and operation of photovoltaic systems – from DC overvoltage protection to universal current sensitive RCCBs – from a single source.

4




1 5TE2 DC disconnector
2 3NW PV cylinder fuse system
3 5SD7 DC overvoltage protection
4 5SL/5SY AC miniature circuit-breaker
5 5SP3 selective main miniature circuit-breaker
6 5SD7 AC overvoltage protection
7 5SM3 residual current circuit-breaker
8 7KT PAC1500 measuring device

- For systems consisting of more than three strings, protection against return currents (PV fuse) should be provided
- Overvoltage protection as well for the AC and DC
- For increased safety in hazardous situations, such as in case of fire, a remotely tripped DC isolator that safely switches off the strings is recommended
- Protection against short circuit and overload on the AC
- Calibrated measuring devices for settlement purposes

*Fig. 4.4-11:* **Example for the setup of a PV system**

**Sustainable technologies for the electromobility of tomorrow**

Electromobility places special demands on the power grid and the power supply companies, but also on personal and fire protection at the charging point. Our comprehensive product portfolio offers components and specific integrated solutions for all requirements in the charging infrastructure (fig. 4.4-12). Our tried-and-tested SENTRON protection, switching, and monitoring devices provide a maximum of safety during the charging operation. Matching components for the charging power, ambient conditions, and point of installation are required from the low-voltage power distribution range. Our offering includes predefined integrated solutions compliant with standards like the series IEC 61851 (VDE 0122) and IEC 62196 (VDE 0623), which can be scaled in their functionality and performance class:

- Miniature circuit-breaker or SIRIUS circuit-breaker for reliable protection against overload and short circuit, as well as an Insta contactor or a SIRIUS power contactor for switching the voltage supply
- For the conductive charging modes 1 to 4 according to IEC 61851-1 (VDE 0122-1), Siemens offers overcurrent protective devices and RCCBs
- Surge arresters and measuring devices are recommended
- For charging mode 3, the standard-compliant charging controller family SIPLUS ECC is available
- For charging mode 4 (DC charging via rectifier), Siemens offers AC/DC sensitive RCCBs and overcurrent protective devices as well as SITOR semiconductor fuses
- The WB140A charging unit is a system-tested, CE-compliant unit for charging electric vehicles in charging mode 3 in accordance with IEC 61851-1 (VDE0122-1) and IEC 62196-1 (VDE 0623-5-1) for indoor and outdoor use, e.g., carports, garages, workshops, underground parking garages, or multistorey parking decks.




3WL/3VA/3VL circuit-breakers protect against short circuit and overload; 7KT/7KM measuring devices monitor energy flows.

Cylindrical fuses and LV HRC fuses ensure the safe operation of photovoltaic systems.

The WB140A charging unit is equipped with tried-and-tested SENTRON protection, switching, and monitoring devices.

*Fig. 4.4-12:* **SENTRON components for sustainable energy concepts (excerpt)**

# 4.5 Surge Arresters

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.

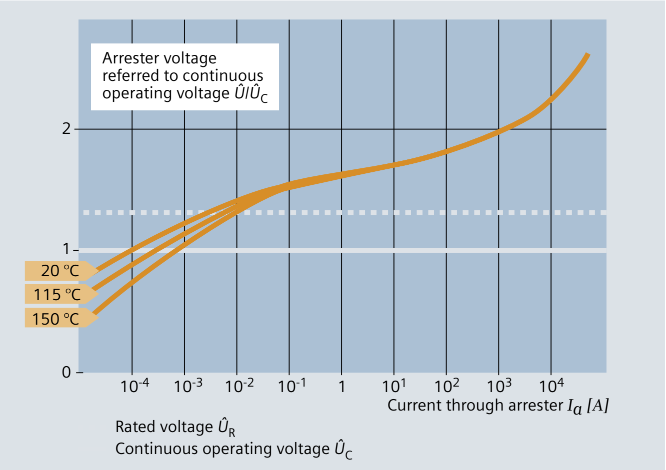



*Fig. 4.5-1:* **Current/voltage characteristics of a non-linear MO arrester**

## 4.5.1 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. 4.5-1).

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
- 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.

*Fig. 4.5-2:* **Surge arrester in traditional porcelain housing; available for system voltages up to 800 kV**

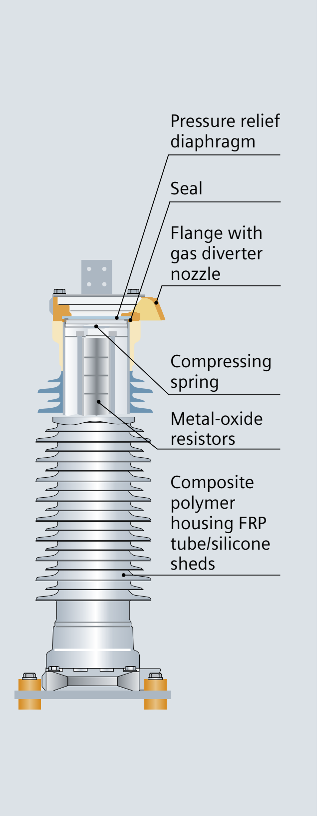



*Fig. 4.5-3:* **Cross-section of a polymer-housed arrester in tube design**

**Tradition and innovation**

Fig. 4.5-2 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. 4.5-3 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 advantages 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. 4.5-4) 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. 4.5-5). 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. 4.5-6) is the heart of the future-proof (IEC 61850) monitoring product line.

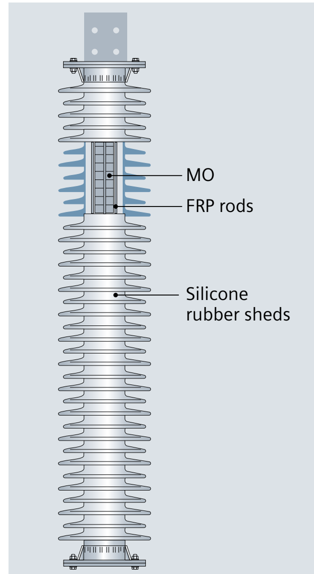



*Fig. 4.5-4:* **3EL-range surge arrester in cage design**

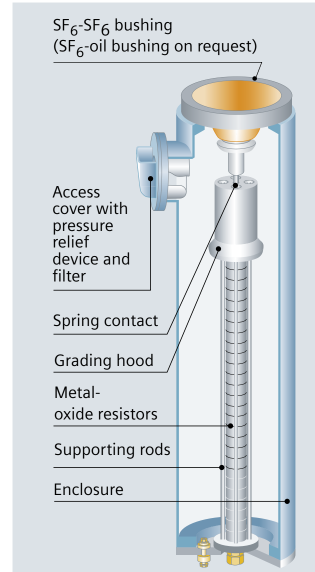



*Fig. 4.5-5:* **Gas-insulated metal-enclosed arrester (GIS arrester)**


*Fig. 4.5-6:* **Arrester condition monitor (ACM)**

## 4.5.2 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:

- The 3EB and 3EC surge arresters for railway DC as well as AC applications (fig. 4.5-7).
- 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 (fig. 4.5-7).
- 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. 4.5-8 and fig. 4.5-9).

An overview of the complete range of Siemens arresters appears in the table 4.5-1 to table 4.5-3.

*Fig. 4.5-7:* **Medium-voltage MO arrester for special applications**

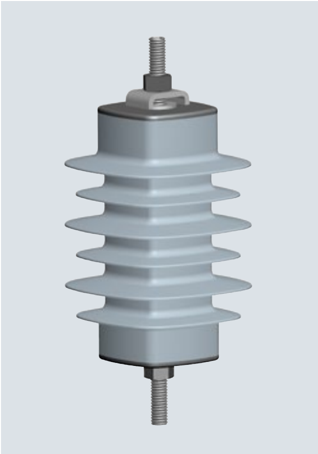


*Fig. 4.5-8:* **Medium-voltage arrester 3EK4 for distribution systems**

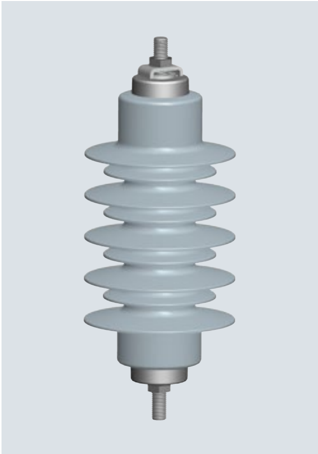
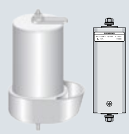
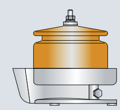
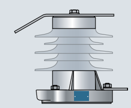
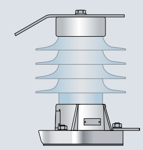
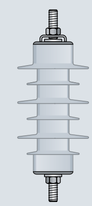
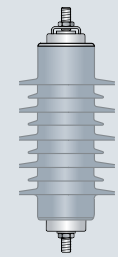


*Fig. 4.5-9:* **Medium-voltage arrester 3EK7 for distribution systems**

| | Special applications | Railway applications | | | | Medium-voltage distribution class | |
|---|---|---|---|---|---|---|---|
| | 3EF1; 3EF3;<br>3EF4; 3EF5 | 3EB2 | 3EC3 | 3EB4 | 3EB1 | 3EK4 | 3EK7 |
| |  |  |  |  |  |  |  |
| Applications | Motors, dry-type transformers, airfield lighting systems, sheath voltage limiters, protection of converters for drives | 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 ($U_m$) kV | 12 | 2 | 4 | 72.5 | 30 | 45 | 72.5 |
| Maximum rated voltage kV | 15 | 2 | 4 | 60 (AC);<br>4 (DC) | 45 (AC);<br>4 (DC) | 36 | 60 |
| Nominal discharge current kA | 3EF1 1<br>3EF3 1<br>3EF4 10<br>3EF5 10 | 20 | 20 | 20 | 10 | 10 (AC);<br>20 (DC) | 10 |
| Maximum thermal energy absorption capability (per kV of $U_r$) kJ/kV | 3EF1 0.8<br>3EF3 4<br>3EF4 12.5<br>3EF5 8 | 10 | 10 | 10 | 7 (AC);<br>10 (DC) | 3.5[1)] | 4.4[1)] |
| Maximum long-duration current impulse, 2 ms A | 3EF4 1,600<br>3EF5 1,200 | 1,500 | 1,500 | 1,600 (AC);<br>1,500 (DC) | 850 (AC);<br>1,200 (DC) | 325 | 325 |
| Rated short-circuit current kA | 40 | 40 | 40 | 40 | 40 | 20 | 20 |
| Housing material | Polyethylene | Silicone | Porcelain | Silicone | Silicone | Silicone | Silicone |
| Design principle | 3EF1 – poly-ethylene directly molded onto MO; 3EF3/3EF4/ 3EF5 – 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 | No | Yes | Yes | Yes | No | No |

[1)] Energy absorption capability under the conditions of the operating duty test according to IEC 60099-4

*Table 4.5-1:* **Medium-voltage metal-oxide surge arresters and limiters (300 V to 72.5 kV)**

| | Porcelain | | | | Silicone | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3EP5 | 3EP4 | 3EP6 | 3EP3 | 3EL5 | 3EL1 | 3EL2 | 3EQ1 | 3EQ4 | 3EQ3 | 3EQ5 |
| |  | | | | | | | | | | |
| Applications | Medium- and high-voltage systems, outdoor installa-tions | Medium- and high-voltage systems, outdoor installa-tions | High-voltage systems, outdoor installa-tions | High-voltage systems, outdoor installa-tions, HVDC, SC&SVC applica-tions | Medium- and high-voltage systems, station and line surge arrester | Medium- and high-voltage systems, station and line surge arrester | Medium- and high-voltage systems, station and line surge arrester | Medium- and high-voltage systems, outdoor installa-tions | High-voltage systems, outdoor installa-tions | High-voltage systems, outdoor installa-tions, HVDC, SC&SVC applica-tions | High-voltage systems, outdoor installa-tions, HVDC ap-plications |
| Highest voltage for equipment ($U_m$) kV | 123 | 362 | 800 | 800 | 145 | 362 | 550 | 362 | 800 | 800 | 1,200 |
| Maximum rated voltage kV | 96 | 288 | 588 | 624 | 126 | 288 | 468 | 288 | 500 | 624 | 850 |
| Maximum nominal discharge current kA | 10 | 10 | 20 | 20 | 10 | 10 | 20 | 10 | 20 | 20 | 20 |
| Maximum line discharge class | 3 | 3 | 5 | 5 | 2 | 3 | 4 | 3 | 5 | 5 | 5 |
| Maximum thermal energy absorption capability (per kV of $U_r$) kJ/kV | 8 | 8 | 14 | 16 | 2 | 6.0 | 10 | 8 | 16 | 16 | 66 |
| Maximum long-duration current impulse, 2 ms A | 1,100 | 1,100 | 2,000 | 3,200 | 550 | 800 | 1,200 | 1,100 | 3,200 | 3,200 | 11,000 |
| Rated short-circuit current kA | 40 | 65 | 65 | 65 | 20 | 65 | 65 | 50 | 80 | 80 | 80 |
| Maximum permissible service load kNm | 2.0 (SSL)[1] | 4.5 (SSL)[1] | 16.0 (SSL)[2] | 34 (SSL)[1] | 0.5 (SSL)[1] | 1.2 (SSL)[1] | 4.0 (SSL)[1] | 6.0 (SSL)[1] | 38 (SSL)[1] | 72 (SSL)[1] | 225 (SSL)[1] |
| Housing material | Porcelain | | | | Silicone | | | | | | |
| Design principle | Hollow insulator | | | | Silicone directly molded onto MO | | | Hollow insulator, silicone directly molded onto FRP tube | | | |
| Pressure relief device | Yes | | | | No | | | Yes | | | |

[1] SSL = Specified short-term load [2] 30.0 available on request

*Table 4.5-2:* **High-voltage metal-oxide surge arresters (72.5 to 1,200 kV)**

4

4

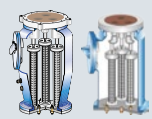
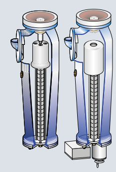
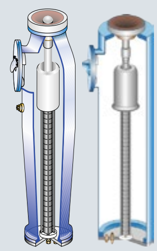
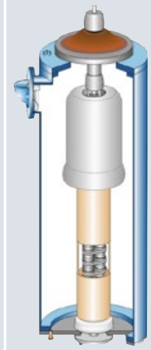
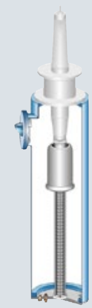
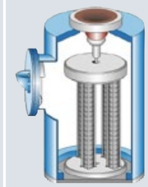
| | 3ES5-C/M/N, 3ES4-K 3-phase | 3ES2-E 1-phase | 3ES4-L, 3ES5-H 1-phase | 3ES9-J 1-phase | 3ES with oil-$SF_6$ 1-phase | 3ES6 3-phase |
|---|---|---|---|---|---|---|
| |  |  |  |  |  |  |
| Applications | High-voltage systems, protection of metal-enclosed, gas-insulated switchgear and transformers | | | | | |
| Highest voltage for equipment ($U_m$) kV | 170 | 245 | 550 | 800 | 550 | 420 |
| Maximum rated voltage kV | 156 | 216 | 444 | 612 | 444 | 336 |
| Maximum nominal discharge current kA | 20 | 20 | 20 | 20 | 20 | 20 |
| Maximum line discharge class | 4 | 4 | 5 | 5 | 5 | 5 |
| Maximum thermal energy absorption capability (per kV of $U_r$) kJ/kV | 10 | 10 | 13 | 18 | 13 | 7 |
| Maximum long-duration current impulse, 2 ms A | 1,200 | 1,200 | 1,600 | 2,100 | 1,600 | 1,600 |
| Rated short-circuit current kA | 63 | 50 | 63 | 63 | 63 | 63 |
| Maximum permissible service load kNm | – | | | | | |
| Housing material | Metal | | | | | |
| Pressure relief device | Yes | | | | | |

*Table 4.5-3:* **Metal-oxide surge arresters for GIS (72.5 to 800 kV)**

**For further information, please contact:**
Fax: ++ 49 30 3 86-3 32 22
E-mail: arrester.energy@siemens.com

# 4.6 Instrument Transformers

## 4.6.1 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.

Instrument transformers used for network control supply important information for determining the state of the operating conditions of the network.

*Fig. 4.6-1:* **800 kV gas-insulated current transformers**

*Fig. 4.6-2:* **550 kV oil-immersed current transformers**

**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 Umax. 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. Typical designs are oil-immersed (fig. 4.6-2) or gas-insulated (fig. 4.6-1).

**Oil-immersed instrument transformers**
The reliability and security of Trench oil-insulated 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 in almost every country worldwide. 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, 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. $SF_6$ 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*

$SF_6$ gas is the main insulation medium between high-voltage and earth potential. A stable quality can be guaranteed by the use of $SF_6$ gas according to IEC 60137 (2005) / 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 $SF_6$ 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 $SF_6$ pressure, the transformer still operates at rated pressure.

*Environmentally beneficial under extremely severe conditions*

$SF_6$ 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 $SF_6$ 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. 4.6-2, fig. 4.6-3) or $SF_6$ gas dielectric systems (fig. 4.6-4).


*Fig. 4.6-3:* **300 kV oil-immersed current transformers**

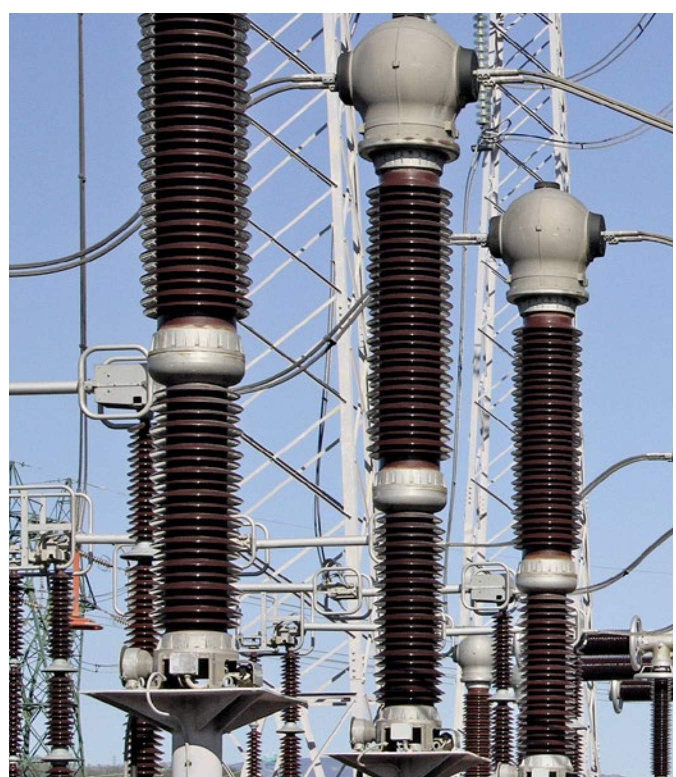


*Fig. 4.6-4:* **420 kV gas-insulated current transformers**

*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
- 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 $SF_6$ 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 metering and protection applications. They are available with either oil (fig. 4.6-5) or $SF_6$ gas dielectric systems (fig. 4.6-6).

*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

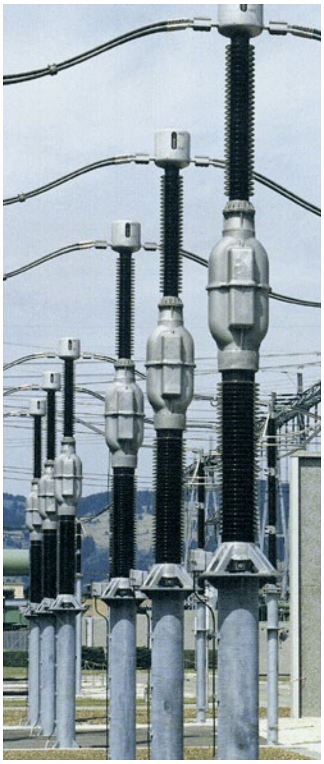


*Fig. 4.6-5:* **420 kV oil-paper insulated inductive voltage transformers**

*Fig. 4.6-6:* **765 kV gas-insulated voltage transformer**

- 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
- 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 $SF_6$ 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 ferroresonance-free design without the use of an external damping device (please ask for details)

4

- 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. 4.6-7).



*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 or for installation into $SF_6$ gas-insulated switchgear (GIS).

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.

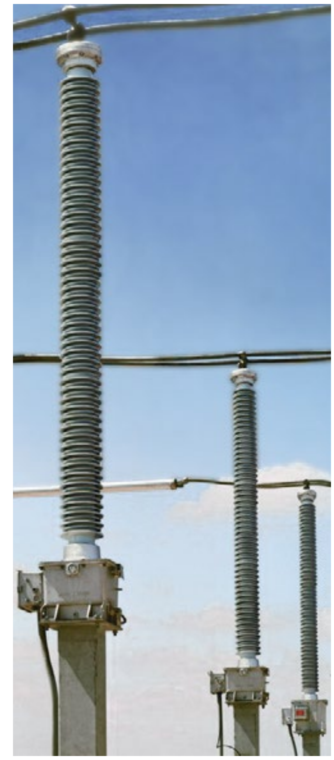


*Fig. 4.6-7:* **245 kV capacitor voltage transformers**

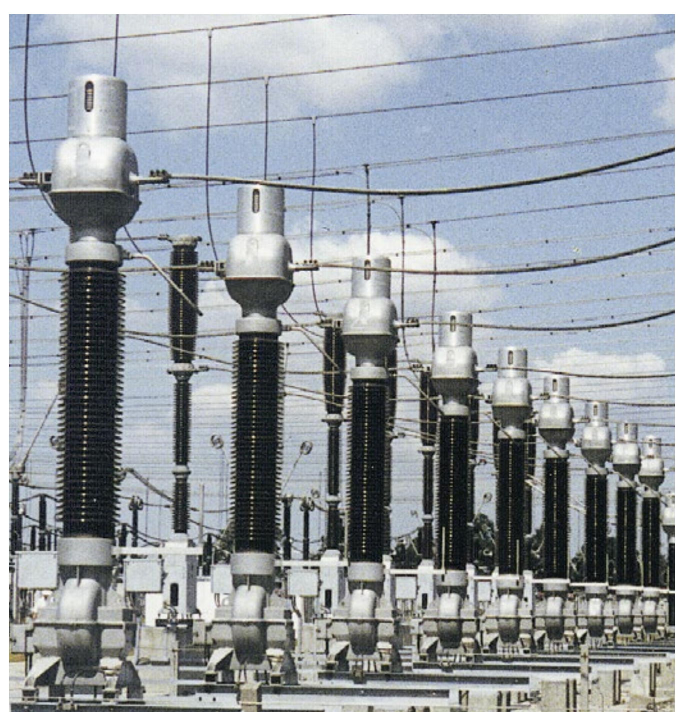


*Fig. 4.6-8:* **245 kV oil-immersed combined instrument transformers**

**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. 4.6-8) or $SF_6$ gas dielectric systems (fig. 4.6-9, fig. 4.6-10).

*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 $SF_6$ design
- Explosion-proof design by the compressible insulation medium $SF_6$ 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.

*Fig. 4.6-9:* **420 kV gas-insulated combined instrument transformers**

*Fig. 4.6-10:* **800 kV gas-insulated combined instrument transformer**

### 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. 4.6-11, fig. 4.6-14, fig. 4.6-15, fig. 4.6-16).

*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
- Prevention of occurrence of stable ferroresonances by integrated ferroresonance suppression
- Shielded against transient overvoltages in accordance with IEC standards. Special additional shielding is available
- Guaranteed $SF_6$ leakage rate of less than 0.5 % per year
- Equipped with pressure relief disc and deflection device
- All components are designed and tested for mechanical stress to withstand up to at least 20 g
- Accuracy classes in accordance with DIN VDE 0414, IEC 60044, ANSI: IEEE C57.13, AS 1243 (other standards or classes on request)
- Shock indicators warn against inadmissible acceleration during transportation.

*Fig. 4.6-11:* **145 kV inductive voltage transformer for GIS**

*Fig. 4.6-12:* **145 kV RC divider for GIS**



### RC dividers

Resistive-capacitive voltage dividers, also called resistive-capacitive voltage transformers, are designed for measurement of the voltage in HVDC transmission systems, air-insulated (AIS) (fig. 4.6-13) or gas-insulated (GIS) switchgear (fig. 4.6-12). 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 dividers*

- 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-voltage and high-voltage applications in which they replace the conventional measuring transformers for measurement and protection purposes.

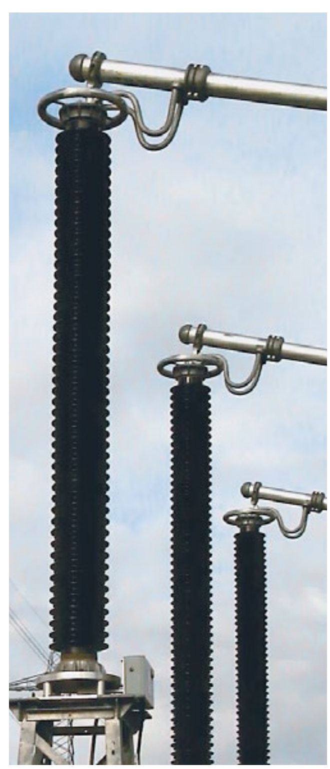


*Fig. 4.6-13:* **420 kV RC dividers (AC) for AIS**

*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).

**Non conventional instrument transformers**
Conventional instrument transformers provide high power output in a proven insulation technology, using mainly inductive technology. Non conventional instrument transformers (NCIT) are current and/or voltage measurement devices that provide a low output power (< 0.5 VA). The NCIT technologies Trench is providing are Low Power Current Transformers with voltage output and RC dividers, which are both described in previous chapters. They have a wide linearity range and their output signals are suitable to match to modern secondary equipment such as Merging Units.

Merging units convert the output signals of both conventional and non conventional instrument transformers into a digital signal according to the IEC 61850-9-2 protocol. The output is a standardized data stream independent from sensor features. The measurements are distributed with one optical Ethernet connection. The only burden of the instrument transformer is the input impedance of the merging unit. A Trench Merging Unit is under preparation.

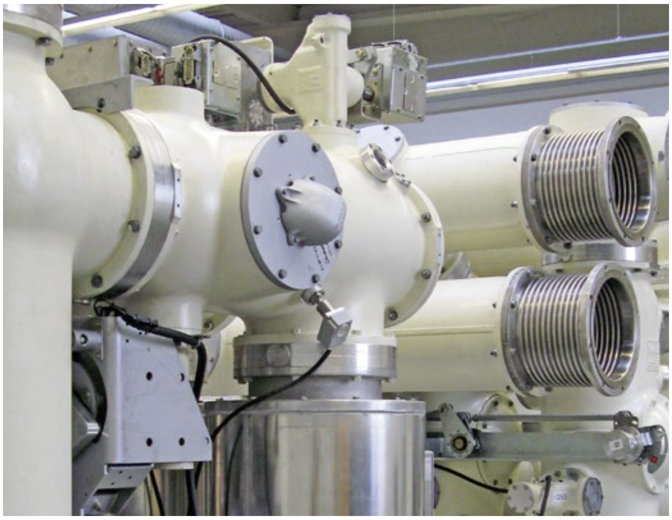


*Fig. 4.6-14:* **420 kV core-in-air current transformer for GIS**

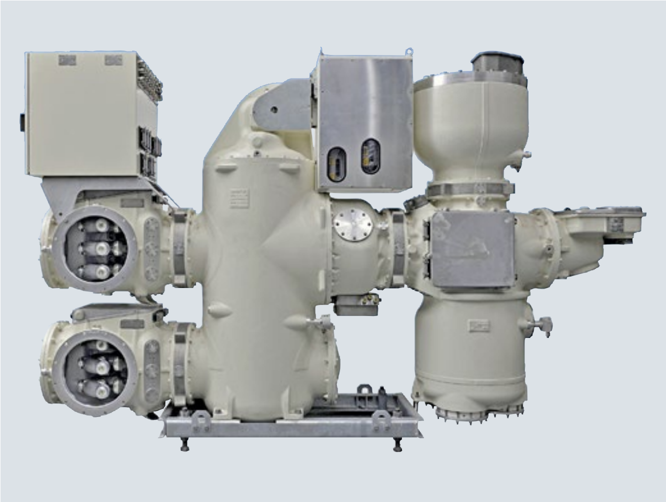


*Fig. 4.6-15:* **145 kV Siemens switchgear 8DN8 with Trench voltage- and current transformer**

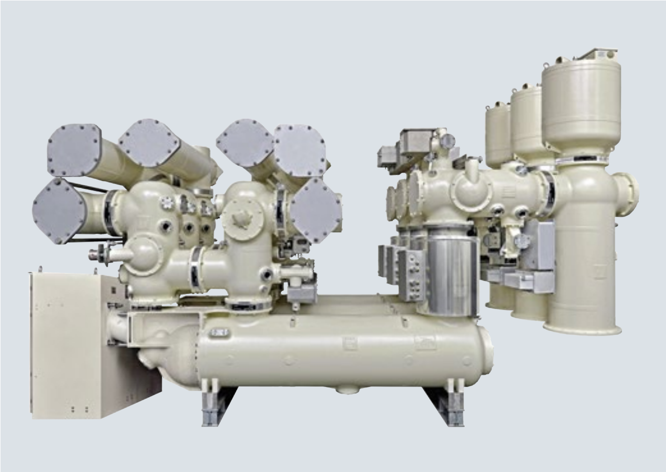


*Fig. 4.6-16:* **420 kV Siemens switchgear 8DQ1 with Trench voltage transformer and Trench core-in-air current transformer**

## 4.6.2 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. 4.6-17.

*Features of Power VTs for AIS*
- Available for the full voltage range of 72.5 up to 800 kV
- $SF_6$ 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.

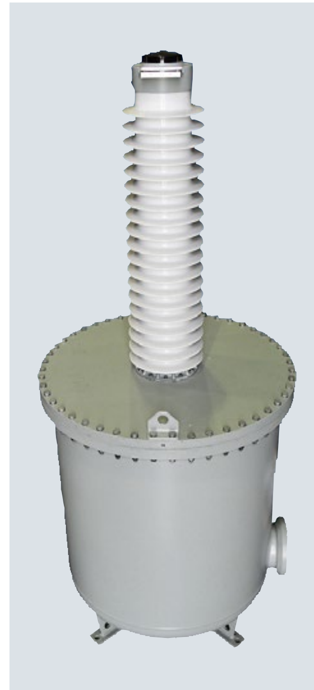


*Fig. 4.6-17:* **145 kV, 100 kVA gas-insulated power VT for AIS**

**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. 4.6-18.

*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 $SF_6$-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 appears in table 4-6.1 to table 4-6.7.

*Fig. 4.6-18:* **145 kV power VT for GIS**

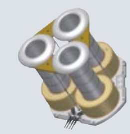
| Current transformers for gas-insulated switchgear (GIS) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | |  | | | | |  | | | |
| Type | | SAD/SA | | | | | LPCT | | | |
| Voltage range | [kV] | 72.5 – 550 | | | | | 72.5 – 550 | | | |
| Insulation medium | | $SF_6$ | | | | | – | | | |
| | | Technical data SAD/SA | | | | | | | | |
| Voltage level | [kV] | 72.5 | 123 | 145 | 170 | 245 | 300 | 362 | 420 | 550 |
| Output current | [A] | 1 – 5 (LoPo: 3.25 V) | | | | | | | | |
| Rated short-time thermal current | [kA] | 31.5 | | | 50 | | 63 | | | |
| Rated duration of short circuit | [s] | 1 – 3 | | | | | | | | |
| Rated dynamic current | [kA] | 78.75 | | | 125 | | 160 | | | |
| Rated frequency | [Hz] | 16 2/3 – 50 – 60 | | | | | | | | |
| Temperature range | [°C] | –35 – +60 | | | | | | | | |
| Insulation class | | E, F | | | | | | | | |
| Metering accuracy class | | 0.1 – 0.2 – 0.2S – 0.5 – 0.5S – 1.0 | | | | | | | | |
| Protection accuracy class | | 5P – 10P – TPY – TPX – TPZ – TPS – PR – PX | | | | | | | | |
| Values in accordance with IEC; other values like ANSI are available | | | | | | | | | | |

*Table 4.6-1:* **Technical data of Trench current transformers for gas-insulated switchgear (GIS)**

4

4

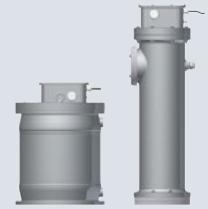
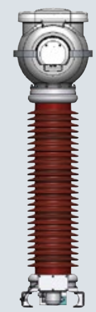
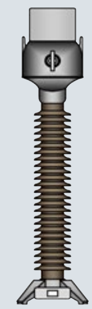
| Voltage transformers / RC dividers for gas-insulated switchgear (GIS) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | |  | | | | |  | | | | |
| Type | | SUD/SU | | | | | RCVD | | | | |
| Voltage range | [kV] | 72.5 – 800 | | | | | 72.5 – 550 | | | | |
| Insulation medium | | $SF_6$ | | | | | Oil / $SF_6$ | | | | |
| | | **Technical data SUD/SU** | | | | | | | | | |
| Voltage level | [kV] | 72.5 | 123 | 145 | 170 | 245 | 300 | 362 | 420 | 550 | 800 |
| Rated power-frequency withstand voltage | [kV] | 140 | 230 | 275 | 325 | 460 | 460 | 510 | 630 | 680 | 975 |
| Rated lightning impulse withstand voltage | [kV] | 325 | 550 | 650 | 750 | 1,050 | 1,050 | 1,175 | 1,425 | 1,550 | 2,100 |
| Rated switching impulse withstand voltage | [kV] | – | – | – | – | – | 850 | 950 | 1,050 | 1,175 | 1,550 |
| Output voltage | [V] | 110/√3 – 200/√3 (other values upon request) (AC & DC RC divider: 5 – 200V) | | | | | | | | | |
| Rated voltage factor | | 1.2 – 1.5 – 1.9 (other values upon request) | | | | | | | | | |
| Rated frequency | [Hz] | 16 ⅔ – 50 – 60 | | | | | | | | | |
| Temperature range | [°C] | –35 – +40 (other values upon request) | | | | | | | | | |
| Insulation class | | E | | | | | | | | | |
| Metering accuracy class | | 0.1 – 0.2 – 0.5 – 1.0 – 3.0 | | | | | | | | | |
| Output burden | | for different classes according to customer specification | | | | | | | | | |
| Protection accuracy class | | 3P – 6P | | | | | | | | | |
| Output burden | | for different classes according to customer specification | | | | | | | | | |
| Thermal limiting output | | 2,000 | | | | | | 3,000 [1)] | | | |
| IID | | × | × | × | × | × | × | × | × | × | |
| Values in accordance with IEC; other values like ANSI are available; [1)] valid only for voltage transformers | | | | | | | | | | | |

*Table 4.6-2:* **Technical data of Trench voltage transformers for gas-insulated switchgear (GIS)**

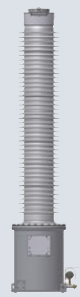
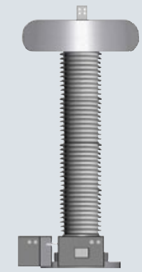
**Current transformers for air-insulated switchgear (AIS)**

| | | | | |
|---|---|---|---|---|
| | |  |  |  |
| Type | | SAS | TAG | IOSK |
| Voltage range | [kV] | 72.5 – 800 | 72.5 – 550 | 72.5 – 550 |
| Insulation medium | | $SF_6$ | $SF_6$ | Oil |
| Composite insulator | | × | × | × |
| Porcelain insulator | | | × | × |

| | | **Technical data** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Voltage level | [kV] | 72.5 | 123 | 145 | 170 | 245 | 300 | 362 | 420 | 550 | 800 |
| Rated power-frequency withstand voltage | [kV] | 140 | 230 | 275 | 325 | 460 | 460 | 510 | 630 | 680 | 975 |
| Rated lightning impulse withstand voltage | [kV] | 325 | 550 | 650 | 750 | 1,050 | 1,050 | 1,175 | 1,425 | 1,550 | 2,100 |
| Rated switching impulse withstand voltage | [kV] | – | – | – | – | – | 850 | 950 | 1,050 | 1,175 | 1,550 |
| Rated normal current up to | [A] | 5,000 | | | | | | | | | |
| Output current | [A] | 1 – 2 – 5 | | | | | | | | | |
| Rated short-time thermal current | [kA] | 63 (80 on special request) | | | | | | | | | |
| Rated duration of short circuit | [s] | 1 – 3 | | | | | | | | | |
| Rated dynamic current | [kA] | 160 (200 on special request) | | | | | | | | | |
| Rated frequency | [Hz] | 16 ⅔ – 50 – 60 | | | | | | | | | |
| Creepage distance | [mm/kV] | 25 – 31 (higher upon request) | | | | | | | | | |
| Temperature range | [°C] | –40 – +40 (other values upon request) | | | | | | | | | |
| Insulation class | | E ($SF_6$ insulated devices) – A (oil insulated devices) | | | | | | | | | |
| Metering accuracy class | | 0.1 – 0.2 – 0.2S – 0.5 – 0.5S – 1.0 | | | | | | | | | |
| Protection accuracy class | | 5P – 10P – TPY – TPX – TPZ – TPS – PR – PX | | | | | | | | | |

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

*Table 4.6-3:* **Technical data of Trench current transformers for air-insulated switchgear (AIS)**

| Voltage transformers / RC dividers for air-insulated switchgear (AIS) | | | | | | | |
|---|---|---|---|---|---|---|---|
| | |  |  |  |  |  |  |
| Type | | SVS | TVG | VEOT/VEOS | TCVT | AC RCD | DC RCD |
| Voltage range | [kV] | 72.5 – 800 | 72.5 – 420 | 72.5 – 550 | 72.5 – 1200 | 72.5 – 800 | 72.5 – 800 |
| Insulation medium | | $SF_6$ | $SF_6$ | Oil | Oil | Oil | Oil / $SF_6$ |
| Composite insulator | | × | × | × | × | × | × |
| Porcelain insulator | | | × | × | × | × | × |

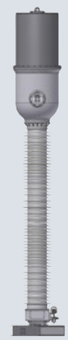
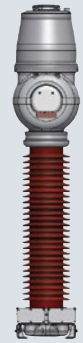
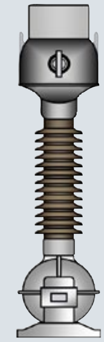
| | | Technical data | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Voltage level | [kV] | 72.5 | 123 | 145 | 170 | 245 | 300 | 362 | 420 | 550 | 800 |
| Rated power-frequency withstand voltage | [kV] | 140 | 230 | 275 | 325 | 460 | 460 | 510 | 630 | 680 | 975 |
| Rated lightning impulse withstand voltage | [kV] | 325 | 550 | 650 | 750 | 1,050 | 1,050 | 1,175 | 1,425 | 1,550 | 2,100 |
| Rated switching impulse withstand voltage | [kV] | – | – | – | – | – | 850 | 950 | 1,050 | 1,175 | 1,550 |
| Output voltage | [V] | 110/√3 – 200/√3 (other values upon request) (AC & DC RC divider: 5 – 200V) | | | | | | | | | |
| Rated voltage factor | | 1.2 – 1.5 – 1.9 (other values upon request) | | | | | | | | | |
| Rated frequency | [Hz] | 16 ⅔ – 50 – 60 (AC & DC RC divider: 0 – 1 MHz) | | | | | | | | | |
| Creepage distance | [mm/kV] | 25 – 31 (higher upon request) | | | | | | | | | |
| Temperature range | [°C] | –40 – +40 (other values upon request) | | | | | | | | | |
| Insulation class | | E ($SF_6$ insulated devices) – A (oil-insulated devices) | | | | | | | | | |
| Metering accuracy class | | 0.1 – 0.2 – 0.5 – 1.0 – 3.0 | | | | | | | | | |
| Output burden (only AC) | | for different classes according to customer specification (very low output burden for RC divider > 100 kΩ) | | | | | | | | | |
| Protection accuracy class | | 3P – 6P | | | | | | | | | |
| Output burden (only AC) | | for different classes according to customer specification | | | | | | | | | |
| Thermal limiting output | [VA] | 3,000 [1)] | | | | | | | | | |

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

*Table 4.6-4:* **Technical data of Trench voltage transformers for air-insulated switchgear (AIS)**

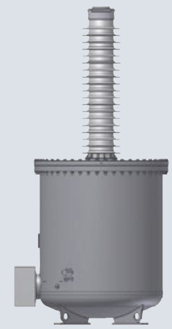
4

**Combined instrument transformers for air-insulated switchgear (AIS)**

| | | | | |
|---|---|---|---|---|
| | |  |  |  |
| Type | | SVAS | AVG | IVOKT |
| Voltage range | [kV] | 72.5 – 800 | 72.5 – 245 | 72.5 – 300 |
| Insulation medium | | $SF_6$ | $SF_6$ | Oil |
| Composite insulator | | × | × | × |
| Porcelain insulator | | | × | × |

| **Technical data** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Voltage level | [kV] | 72.5 | 123 | 145 | 170 | 245 | 300 | 362 | 420 | 550 | 800 |
| Rated power-frequency withstand voltage | [kV] | 140 | 230 | 275 | 325 | 460 | 460 | 510 | 630 | 680 | 975 |
| Rated lightning impulse withstand voltage | [kV] | 325 | 550 | 650 | 750 | 1,050 | 1,050 | 1,175 | 1,425 | 1,550 | 2,100 |
| Rated switching impulse withstand voltage | [kV] | – | – | – | – | – | 850 | 950 | 1,050 | 1,175 | 1,550 |
| Rated frequency | [Hz] | 16 ⅔ – 50 – 60 | | | | | | | | | |
| Creepage distance | [mm/kV] | 25 – 31 (higher upon request) | | | | | | | | | |
| Temperature range | [°C] | –40 – +40 (other values upon request) | | | | | | | | | |
| | | CT ratings | | | | | | | | | |
| Rated normal current up to | [A] | 5,000 | | | | | | | | | |
| Output current | [A] | 1 – 2 – 5 | | | | | | | | | |
| Rated short-time thermal current | [kA] | 63 (80 on special request) | | | | | | | | | |
| Rated duration of short circuit | [s] | 1 – 3 | | | | | | | | | |
| Rated dynamic current | [kA] | 160 (200 on special request) | | | | | | | | | |
| Insulation class | | E ($SF_6$ insulated devices) – A (oil insulated devices) | | | | | | | | | |
| Metering accuracy class | | 0.1 – 0.2 – 0.2S – 0.5 – 0.5S – 1.0 | | | | | | | | | |
| Protection accuracy class | | 5P – 10P – TPY – TPX – TPZ – TPS – PR – PX | | | | | | | | | |
| | | VT ratings | | | | | | | | | |
| Output voltage | [V] | 110/√3 – 200/√3 (other values upon request) | | | | | | | | | |
| Rated voltage factor | | 1.2 – 1.5 – 1.9 (other values upon request) | | | | | | | | | |
| Metering accuracy class | | 0.1 – 0.2 – 0.5 – 1.0 – 3.0 | | | | | | | | | |
| Output burden | | for different classes according to customer specification | | | | | | | | | |
| Protection accuracy class | | 3P – 6P | | | | | | | | | |
| Output burden | | for different classes according to customer specification | | | | | | | | | |
| Thermal limiting output | [VA] | 3000 (other values upon request) | | | | | | | | | |
| Values in accordance with IEC; other values like ANSI are available | | | | | | | | | | | |

*Table 4.6-5:* **Technical data of Trench combined instrument transformers for air-insulated switchgear (AIS)**

| Power voltage transformers for air-insulated switchgear (AIS) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | |  | | | | | | | | |
| Type | | PSVS | | | | | | | | |
| Technical data | | | | | | | | | | |
| Voltage level | [kV] | 72.5 | 123 | 145 | 170 | 245 | 300 | 362 | 420 | 550 |
| Rated power-frequency withstand voltage IEC | [kV] | 140 | 230 | 275 | 325 | 460 | 460 | 510 | 630 | 680 |
| Rated lighting impulse withstand voltage IEC | [kV] | 325 | 550 | 650 | 750 | 1,050 | 1,050 | 1,175 | 1,425 | 1,550 |
| Rated switching impulse withstand voltage IEC | [kV] | – | – | – | – | – | 850 | 950 | 1,050 | 1,175 |
| Rated power frequency withstand voltage IEEE | [kV] | 140 | 230 | 275 | 325 | 460 | 460 | 575 | – | 800 |
| Rated lighting impulse withstand voltage IEEE | [kV] | 350 | 550 | 650 | 750 | 1,050 | 1,050 | 1,300 | – | 1,800 |
| Rated switching impulse withstand voltage IEE | [kV] | – | – | – | – | – | 825 | 825 | – | 1,175 |
| Output power | [kVA] | up to 75 | up to 125 | | | | | | | |
| Output voltage | [V] | 120 to 400 (values in between according to customer specification) | | | | | | | | |
| Rated voltage factor | | 1.5 (30 s) – 1.4 (60 s) | | | | | | | | |
| Rated frequency | [Hz] | 50 – 60 | | | | | | | | |
| Creepage distance | [mm/kV] | 25 – 31 (higher upon request) | | | | | | | | |
| Temperature range | [°C] | –30 [1)] – +40 [1)] | | | | | | | | |
| Insulation class | | E | | | | | | | | |
| Metering accuracy class IEC | | 0.2 [2)] – 0.5 [2)] – 1.0 [2)] – 3.0 | | | | | | | | |
| Metering accuracy class IEEE | | 0.3 [2)] – 0.6 [2)] – 1.2 [2)] | | | | | | | | |
| Protection accuracy class | | 3P [2)] – 6P | | | | | | | | |

Values in accordance with IEC and IEEE; other values upon request  1) lower or higher temperature upon request  2) not under full load condition

*Table 4.6-6:* **Technical data of Trench power voltage transformers for air-insulated switchgear (AIS)**

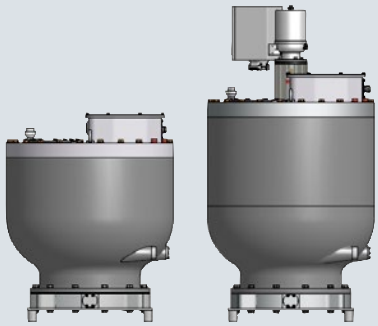
| Power voltage transformers for gas-insulated switchgear (GIS) | | | | |
|---|---|---|---|---|
| | |  | | |
| Type | | PSUD | | |
| Technical data | | | | |
| Voltage level | [kV] | 72.5 | 123 | 145 |
| Rated power-frequency withstand voltage | [kV] | 140 | 230 | 275 |
| Rated lighting impulse withstand voltage | [kV] | 325 | 550 | 650 |
| Rated switching impulse withstand voltage | [kV] | – | – | – |
| Rated frequency | [Hz] | 50 – 60 | | |
| Output power | [kVA] | depends on customer-specific load cycle | | |
| Output voltage | [V] | as required (typically 110/√3) | | |
| Rated voltage factor | | 1.9 for 8 h | | |
| Temperature range | [°C] | –30 – +50 | | |
| Insulation class | | E | | |
| Metering accuracy class | | according to IEC 61869-3 | | |
| Protection accuracy class | | | | |
| Values in accordance with IEC; other values like ANSI are available | | | | |

*Table 4.6-7:* **Technical data of Trench power voltage transformers for gas-insulated switchgear (GIS)**

**For further information:**
Instrument Transformers Portfolio:
*http://www.trenchgroup.com/Products-Solutions/Instrument-Transformers*

# 4.7 Coil Products

### Introduction

With 60 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, Brazil, 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 ISO 9001, 14001 and 18001 standards. 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. 4.7-1). 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.

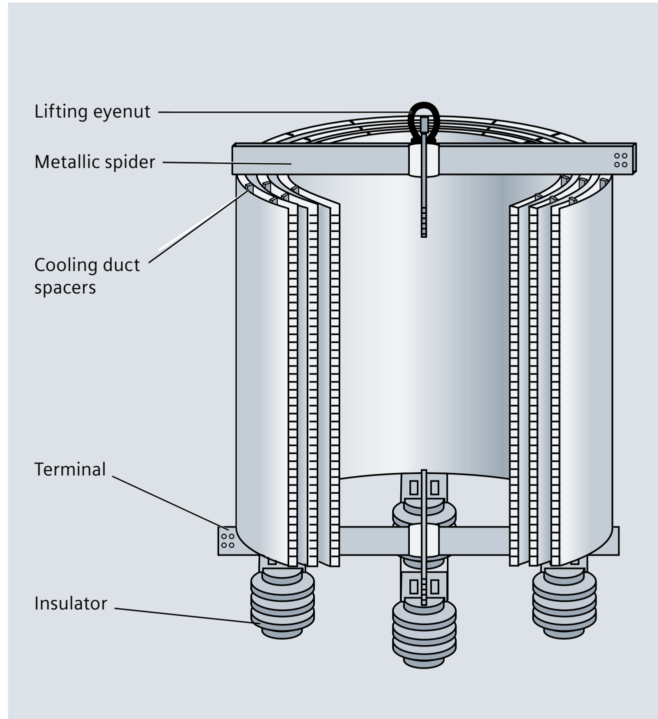



*Fig. 4.7-1:* **Typical Trench air-core dry-type reactor construction**

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. 4.7-2). 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 performance of electric arc furnaces 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, magnetising against each other. 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 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 current 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 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 345 kV.

Thyristor-controlled shunt reactors (TCR) are extensively used in static VAR systems in which reactive VARs are adjusted by

*Fig. 4.7-2:* **3-phase stacked current-limiting reactor**

*Fig. 4.7-3:* **Tertiary-connected shunt reactors**

4

thyristor circuits (fig. 4.7-3). 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)
- Step less adjustable shunt reactors with iron core in oil filled design.

### 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. In addition, self-commutated HVDC schemes include converter reactors.

### Smoothing reactors

Smoothing reactors (fig. 4.7-4) 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 800 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 short-circuit current 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. 4.7-5).

Because the electric system is subject to changes, the inductance of the ASC used for neutral earthing must be variable. The earth-fault protection 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.

*Fig. 4.7-4:* **HVDC smoothing reactor**


*Fig. 4.7-5:* **Arc-suppression coil 110 kV**

**For further information:**
Coil Products Portfolio:
*www.trenchgroup.com/Products-Solutions/Coil-Products*
Coil Products Downloads:
*www.trenchgroup.com/Downloads/Coil-Products*

# 4.8 Bushings

**Introduction**
HSP Hochspannungsgeräte GmbH – known as HSP – and Trench have a long history and a well-known reputation in manufacturing high-voltage bushings and equipment. Both are world leaders in power engineering and design of specialized electrical products.

As 'HSP & Trench Bushing Group' they share their knowledge in the development, design and production of AC and DC bushings up to 1,200 kV. Customers will substantially benefit from their close cooperation in terms of innovation, joint research & development, and common design.

The bushing group provides a wide range of bushing products including bushings for power transformers and HVDC transmission. The portfolio includes epoxy-resin-impregnated bushings (ERIP) up to 1,200 kV, oil-impregnated paper bushings (OIP) up to 1,200 kV, and $SF_6$-gas bushings up to 1,200 kV. Whatever your bushing requirements, the bushing group has the right bushing for your application.

Their technologies have been successfully in service for more than 60 years now. The bushing group operates globally from their production locations in Troisdorf (Germany), St. Louis (France), Shenyang (China) and their sales office in Pickering (Canada).

## 4.8.1 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
- $SF_6$-to-air
- Air-to-air.

The internal insulation of a bushing is made of a combination of different insulating materials:
- Oil-impregnated paper (OIP)
- Epoxy-resin-impregnated paper (ERIP)
- $SF_6$ gas.

The external insulation is made of:
- Epoxy resin for indoor applications
- Porcelain or fiberglass tubes with silicone rubber sheds for outdoor application

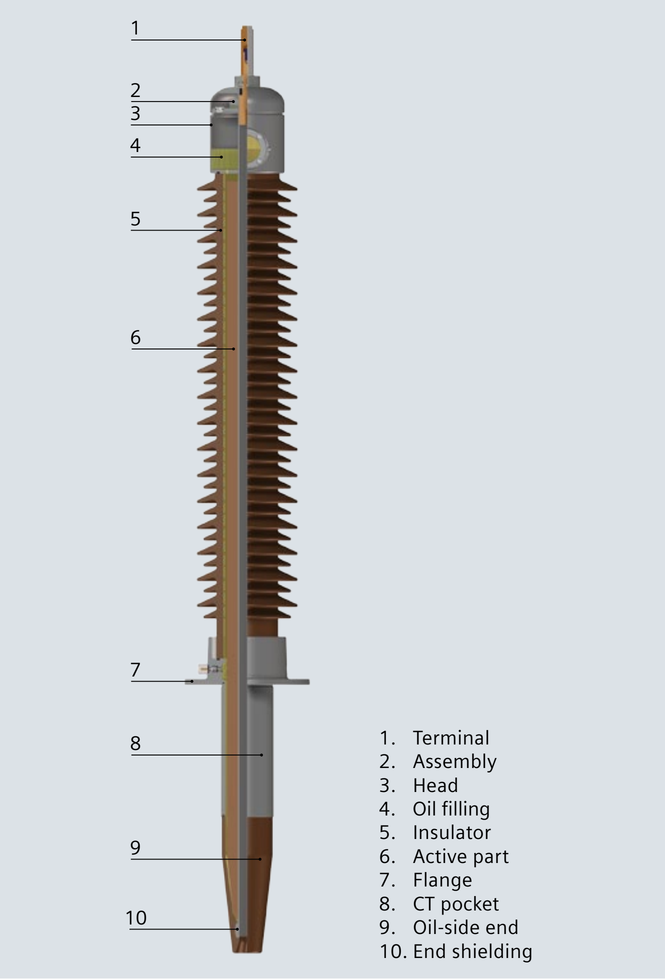



*Fig. 4.8-1:* **Transformer bushing – oil-impregnated paper (OIP) design – sectional view**

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

**Transformer bushings: oil-impregnated paper design (OIP)**
An oil-impregnated paper transformer bushing is made of the following components (fig. 4.8-1):

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 ensure that the connection will not become loose in service.

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

4

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 conductive layers made 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.

**Transformer bushings: epoxy-resin-impregnated paper design (ERIP)**
An epoxy-resin-impregnated paper transformer bushing is made of the following components (fig. 4.8-2).

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 ensure that the connection will not become loose in service.

2. Dry filling
State-of-the-art bushings are filled with dry-type foam.

3. Insulator
The external insulation consists of a composite insulator with silicone sheds. These are vulcanized on the mechanical support, a high-quality wound insulating tube made of epoxy resins with glass fiber laminate structure. In most cases the flange is part of the insulator.

4. Active part
The active part is made of resin-impregnated paper with conductive layers made 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.

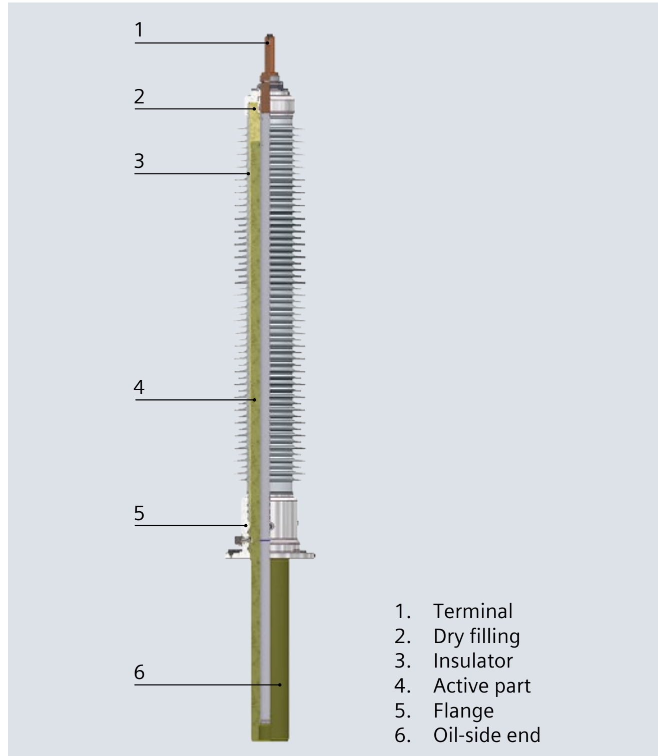



*Fig. 4.8-2:* **Transformer bushing – epoxy-resin-impregnated paper (ERIP) design – sectional view**

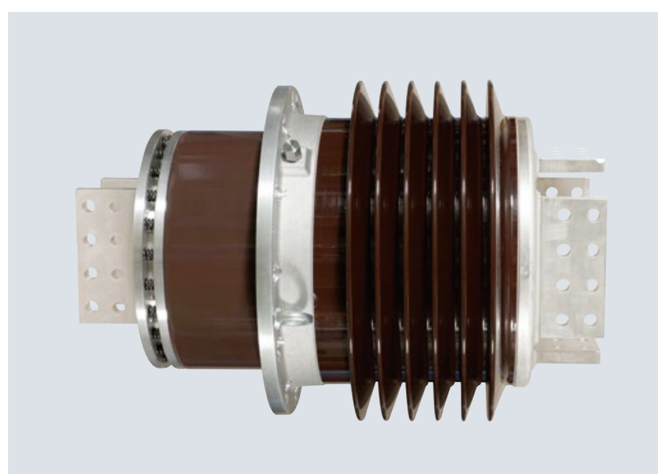


*Fig. 4.8-3:* **Transformer bushing – high current**

5. 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.

6. Oil-side end (including CT pocket if required)
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.

*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 24 kV to 52 kV and currents from 7,800 A to 40,000 A. Conductors are in standard aluminum or copper on request. The main insulation is vacuum-impregnated epoxy condenser (fig. 4.8-3).

**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. 4.8-4). Both consist of a main insulating body of ERIP (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

4

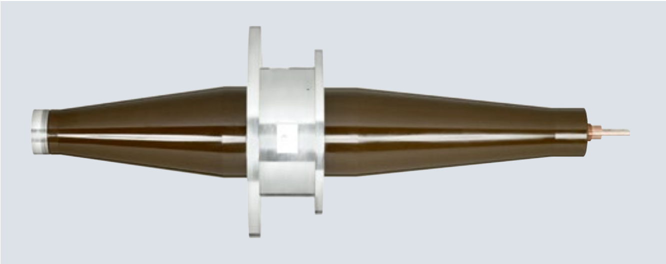


*Fig. 4.8-4:* **Transformer bushing – oil-to-gas**



*Fig. 4.8-5:* **Transformer bushing – 800 kV UHVDC – project Yunnan-Guangdong, China**



*Fig. 4.8-6:* **Transformer bushing – 500 kV HVDC – project Three Gorges, China**

various system applications. A high-quality insulation enables a compact design. Furthermore, bushings with this insulation have 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 1,000 kV DC (fig. 4.8-6). ERIP solutions are often preferred due to their superior performance in heavily polluted areas, or due to their mechanical strength especially regarding seismic behavior.

An example of state-of-the-art solutions is the project Yunnan-Guangdong/China (fig. 4.8-5, fig. 4.8-8), which incorporates wall bushings and transformer bushings up to 800 kV.



**Wall bushings**
Wall bushings (fig. 4.8-7) are designed for use in high-voltage substations for roof or wall according to 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. 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 or condenser design above 245 kV (fig. 4.8-9). Composite designs are increasingly demanded, especially for higher voltage ranges and polluted areas.

**Generator bushings**
Generator bushings (fig. 4.8-10) 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 to 36 kV and current ratings of up to 50,000 A. They are natural, gas or liquid-cooled.

*Fig. 4.8-8:* **Wall bushing – 800 kV HVDC – project Yunnan-Guangdong, China**

*Fig. 4.8-9:* **GIS bushing – 420 kV $SF_6$ outdoor bushing with composite housing**

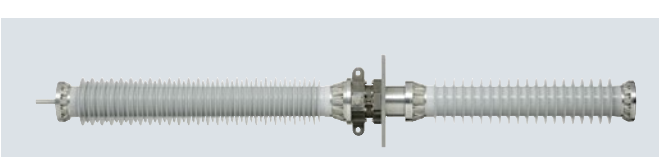


*Fig. 4.8-7:* **Wall bushing – air-to-air**

**For further information:**
*www.siemens.com*
*www.bushing-group.com*
*sales@hspkoeln.de* and *sales-bushing.fr@trench-group.com*

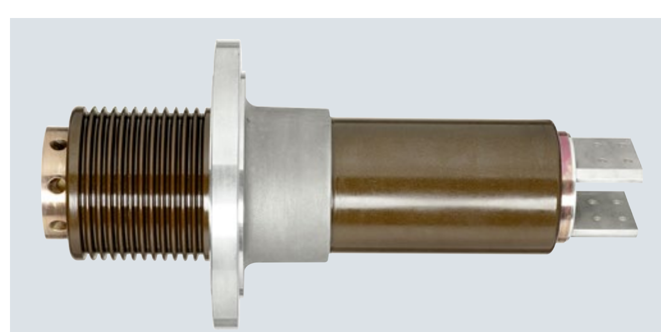


*Fig. 4.8-10:* **Generator bushing**

# 4.9 Medium-Voltage Fuses

HV HRC (high-voltage high-rupturing-capacity) fuses are used for short-circuit protection in high-voltage switchgear (frequency range of 50 to 60 Hz). They protect devices and parts of the system such as transformers, motors, capacitors, voltage transformers and cable feeders against the dynamic and thermal effects of high short-circuit currents by breaking them when they arise.

Fuses consist of the fuse-base and the fuse-links. The fuse-links are used for one single breaking of overcurrents and then they must be replaced. In a switch-fuse combination, the thermal striker tripping of the 3GD fuse prevents the thermal destruction of the fuse. The fuses are suitable both for indoor and outdoor switchgear. They are fitted in fuse-bases available as individual 1-phase or 3-phase components, or as built-in components in combination with the corresponding switching device.

*Fig. 4.9-2:* **3-phase fuse-link with fuse monitor**



*Fig. 4.9-1:* **Fuse-link**

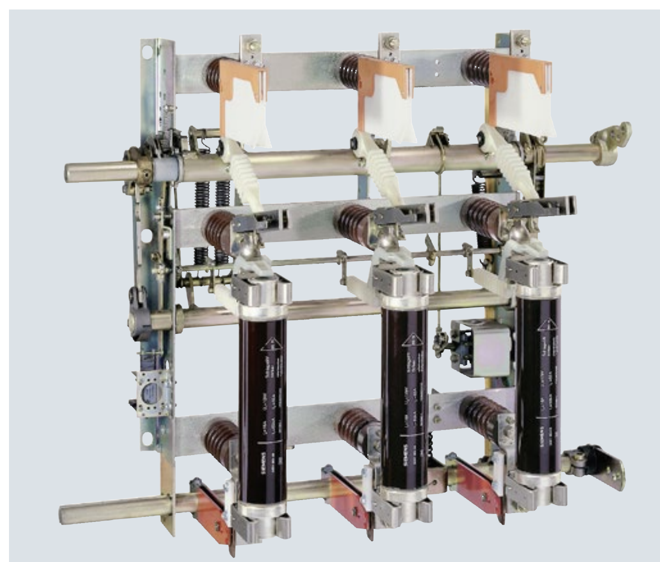


*Fig. 4.9-3:* **Switch-disconnector with fuse-links**

| Rated voltage | Reference dimension | Rated current (A) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 6 | 10 | 16 | 20 | 25 | 31.5 | 40 | 50 | 63 | 80 | 100 | 125 | 160 | 200 | 250 | 315 |
| 7.2 kV | 192 mm | × | × | × | × | × | × | × | × | × | × | × | | | | | |
| | 442 mm | | | | | | | | | | | | × | × | × | × | × |
| | 442 mm for motor protection | | | | | | | | × | × | × | × | × | × | × | × | × |
| 12 kV | 292 mm | × | × | × | × | × | × | × | × | × | × | × | | | | | |
| | 442 mm | | | | | | | | | | | | × | × | | | |
| | 442 mm for motor protection | | | | | | | | | | | × | × | × | × | | |
| 24 kV | 442 mm | × | × | × | × | × | × | × | × | × | × | × | | | | | |
| 36 kV | 537 mm | × | × | × | × | × | × | × | × | × | × | × | | | | | |

*Table 4.9-1:* **Portfolio of fuses**

# 4.10 Silicone Long Rod Insulators for Overhead Power Lines



## 4.10.1 3FL Silicone Long Rod Insulators – Performance Meets Durability

**Good reasons to use 3FL**
The new Siemens silicone long rod insulators type 3FL (fig. 4.10-1) 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 suited for overhead compact-line applications where low tower design and short line spans are required. They are also more economical to transport and install.

**Design**
The 3FL insulator housing is a one-piece HTV[1] 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 (fig. 4.10-2).

**Core**
The core rod is a boron-free, corrosion-resistant ECR[2] 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 for 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 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 210 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 minimizes the electrical field strength and partial discharge inside the junction zone as well as on the silicone housing surface, by utilizing an integrated grading ring. This reliably prevents corrosion of the insulating material and eliminates the risk of subsequent failure of the insulator.

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

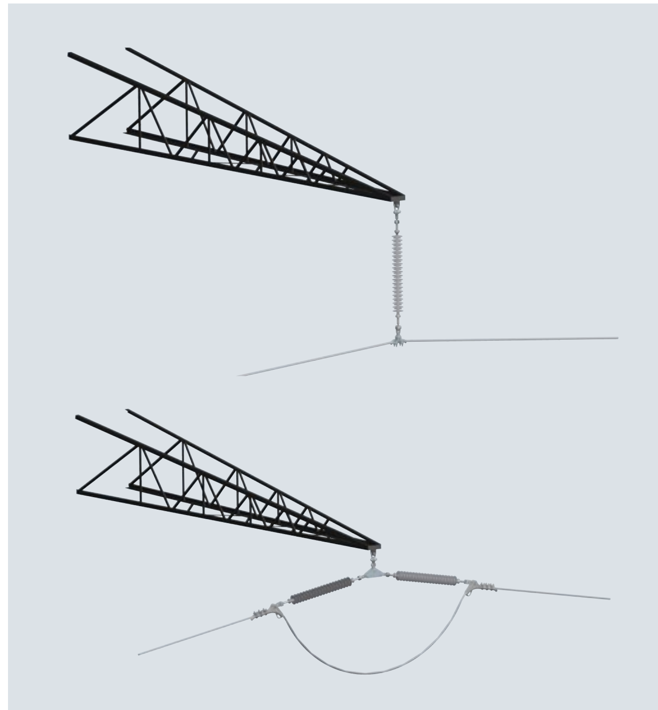


*Fig. 4.10-1:* **3FL long rod insulators can be used either as suspension or tension insulatorsrequirements**

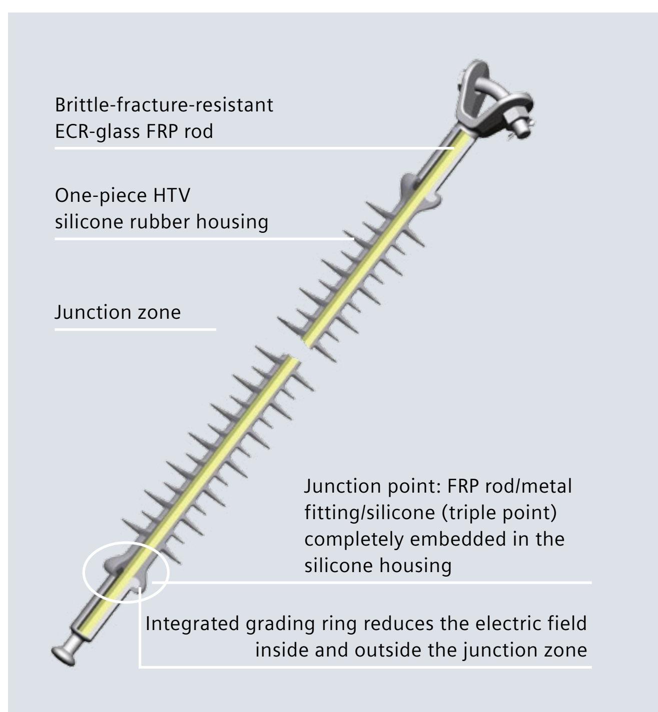



*Fig. 4.10-2:* **3FL – a superior design to meet the highest requirements**

**3FL – HTV silicone rubber housing for best pollution performances (fig. 4.10-3)**
The excellent pollution layer characteristics of the HTV silicone rubber ensure maximum reliability of the 3FL insulator, even under extreme service conditions. The high 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 for insulator performance.

**Quality from Siemens**
According to long-established Siemens tradition and experience in 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 – is rigorously monitored and well controlled.

*Fig. 4.10-3:* **HTV silicone rubber for best pollution performances**



## 4.10.2 Maximized Service Life

**No moisture ingress**
The one-piece housing of the 3FL insulators, i.e. weathersheds and core rod sheath (coating) is one-piece, and has only one internal interface throughout the whole insulator, namely the boundary interface between the housing and the FRP core rod. This design eliminates all internal interfaces between weathersheds and the core rod coating. These kinds of longitudinal interfaces are normally very sensitive to tangential electrical field stress, which in worst case scenarios can easily lead to erosion damage of the polymer interfaces. In particular leading to erosion of the bonding between sheds and rod sheath, and thus damage to the insulator housing.

Furthermore, the junction point in the connection zone, where all three elements (FRP rod, metal end fitting, and silicone housing) meet each other, is absolutely water- and air-tight sealed during manufacturing by using an overmolding housing system. It totally encloses this junction point with the HTV silicone rubber of the housing itself. The highest bonding strength of the one-piece HTV silicone housing to the FRP core rod combined with the overmolding design system prevent moisture ingress at the connection zone of the insulator (fig. 4.10-4).

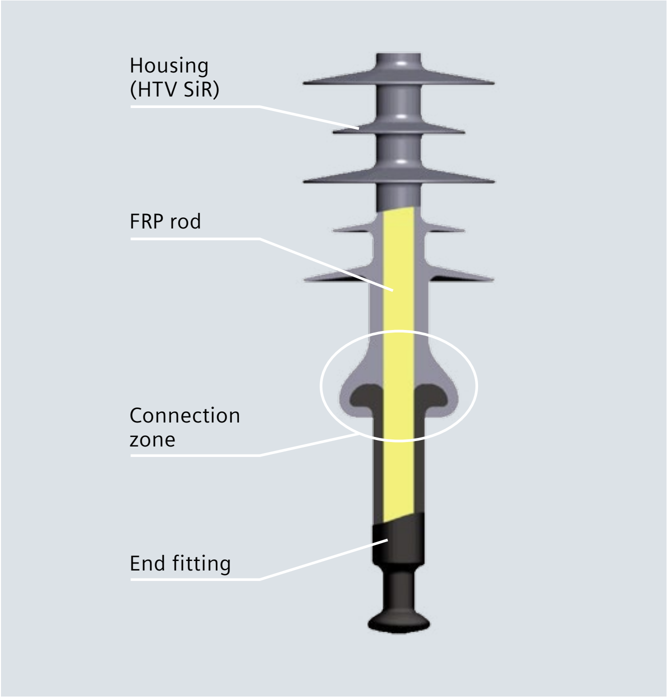



*Fig. 4.10-4:* **3FL cross-section**

**Minimized electrical field strength**
After numerous electrical calculations regarding E-field distribution along the insulator, and the connection zone on the high-voltage side in particular, the design of the 3FL insulator was optimized for maximum reduction of electrical field stress, reduced corona effect, and minimized RIV value. Two design keys ensure improved life expectancy by reducing electrical field stress in the triple point and on the silicone surface:

- The spherical-shaped rim of the end fitting inside the housing homogenizes the E-field distribution on the high-voltage side of the 3FL insulator with an integrated grading ring up to 170 kV (fig. 4.10-5, table 4.10-1).
- The overmolded design system and the silicone housing shape at the connection zone reduce the electrical field strength inside the housing, at the inner triple point in particular, as well as on the silicone surface directly. This by displacing the higher electrical field strength outside the housing (i.e. to the surrounding air area), and by taking advantage of the higher silicone relative permittivity (fig. 4.10-6).

In this way, 3FL insulators can be applied on 170 kV systems without the need for additional grading/corona rings.



**Standards and tests**
All 3FL long rod insulators are designed and tested in compliance with the latest IEC standards.

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.

| | |
|---|---|
| IEC 61109 | Insulators for overhead lines – Composite suspension and tension insulators for a.c. systems with a nominal voltage greater than 1,000 V |
| IEC 62217 | Polymeric insulators for indoor and outdoor use with a nominal voltage >1,000 V |
| IEC 60815 | Selection and dimensioning of high-voltage insulators intended for use in polluted conditions |
| IEC 61466-1, -2 | Composite string insulator units for overhead lines with a nominal voltage greater than 1,000 V |

*Table 4.10-1:* **Product standards**

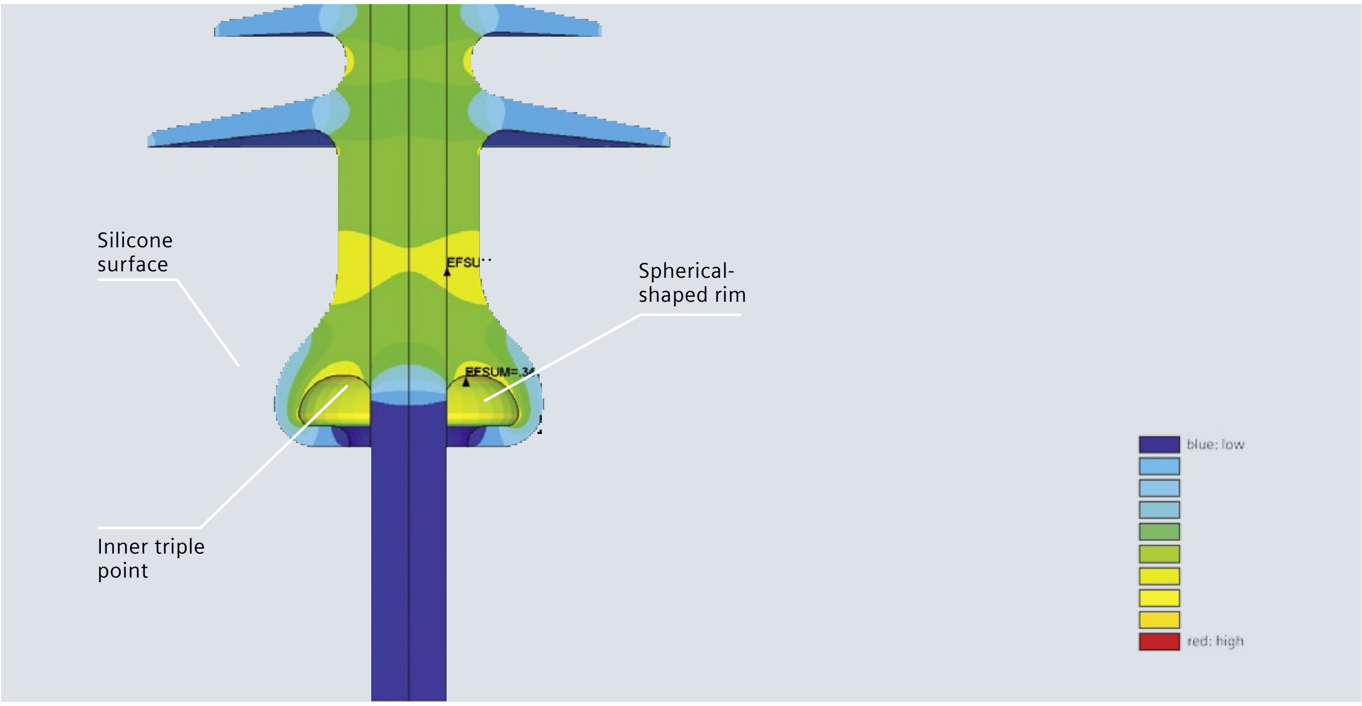



*Fig. 4.10-5:* **E-field distribution (%/mm) in silicone housing and in FRP core rod at 3FL insulator high-voltage end**

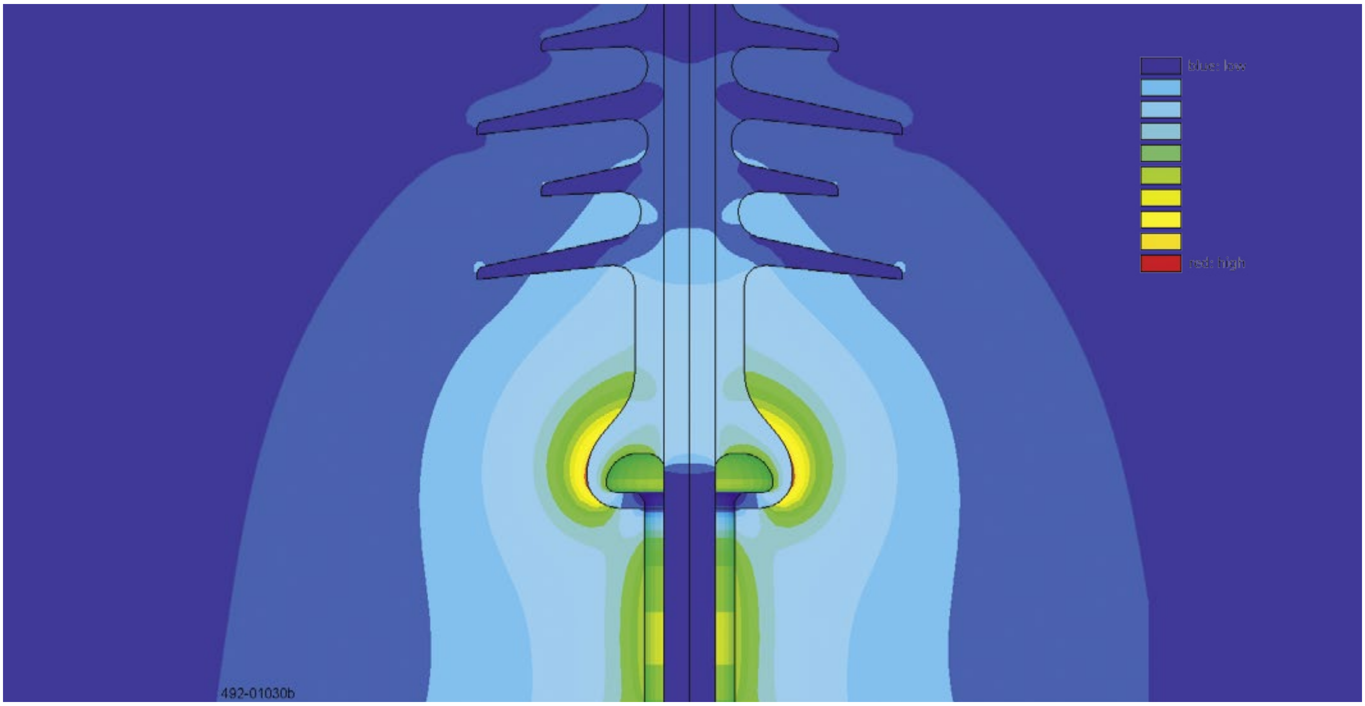
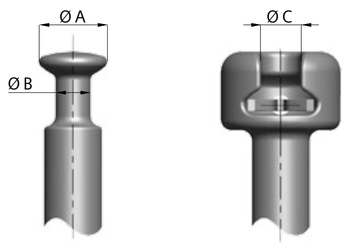
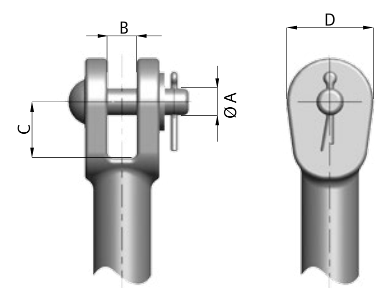


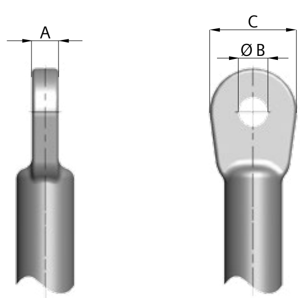

*Fig. 4.10-6:* **E-field distribution (%/mm) at 3FL insulator high-voltage end**



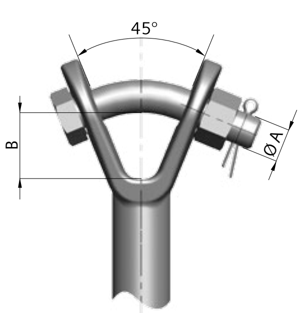

| Socket and Ball<br>acc. to IEC 60120 | | | | |
|---|---|---|---|---|
| Designation | SML | Dimensions in mm | | |
| | | A | B | C |
| 16 | 70 kN / 100 kN / 120 kN | 33 | 17 | 19 |
| 20 | 160 kN / 210 kN | 41 | 21 | 23 |



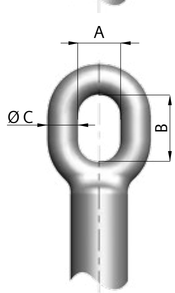

| Clevis<br>acc. to IEC 60471 and IEC 61466-1 | | | | | |
|---|---|---|---|---|---|
| Designation | SML | Dimensions in mm | | | |
| | | A | B | C | D |
| 13L | 70 kN | 13 | 14 | 17 | 42 |
| 16L | 100 / 120 kN | 16 | 18 | 32 | 46 |
| 16N | 100 / 120 kN | 16 | 18 | 32 | 46 |
| 19L | 160 kN | 19 | 20 | 37 | 56 |
| 19N | 160 kN | 19 | 22.5 | 26 | 56 |
| 22L | 210 kN | 22 | 20 | 43 | 60 |
| 22N | 210 kN | 22 | 26 | 30 | 60 |



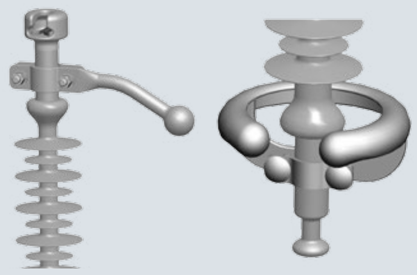

| Tongue<br>acc. to IEC 60471 and IEC 61466-1 | | | | |
|---|---|---|---|---|
| Designation | SML | Dimensions in mm | | |
| | | A | B | C |
| 13L | 70 kN | 13 | 14 | 42 |
| 16L | 100 kN / 120 kN | 16 | 17.5 | 46 |
| 16N | 100 kN / 120 kN | 12.7 | 17.5 | 46 |
| 19L | 160 kN | 19 | 20 | 56 |
| 19N | 160 kN | 19 | 20.6 | 46 |
| 22L | 210 kN | 19 | 24 | 60 |
| 22N | 210 kN | 22 | 23.8 | 52 |




| Y-Clevis<br>acc. to IEC 61466-1 | | | |
|---|---|---|---|
| Designation | SML | Dimensions in mm | |
| | | A | B |
| 16 | 70 kN | 16 | 32 |
| 19 | 100 / 120 kN | 19 | 34 |
| 22 | 160 / 210 kN | 22 | 41 |




| Eye<br>acc. to IEC 61466-1 | | | | |
|---|---|---|---|---|
| Designation | SML | Dimensions in mm | | |
| | | A | B | C |
| 17 | 70 kN | 20 | 32 | 15 |
| 24 | 100 kN / 120 kN | 24 | 48 | 19 |
| 25 | 160 kN / 210 kN | 25 | 50 | 22 |
| 30 | 160 kN / 210 kN | 30 | 60 | 25 |




| Recommended corona rings (diameter in mm) by line voltage | | |
|---|---|---|
| Line voltage (kV) | Ground end (top end fitting) | Line end (conductor end fitting) |
| ≤ 170 kV | None | None |
| 245 kV | None | Ø 210 |
| 300 kV | None | Ø 330 |
| 362 kV | None | Ø 330 |
| 420 kV | Ø 210 | Ø 330 |
| 550 kV | Ø 210 | Ø 420 |

**Accessories**
Arc protection devices such as arcing horns and corona rings for reduction of electrical field stress and corona effect are carefully designed based on numerous electrical simulations regarding electrical field distribution. For system voltages above 170 kV, corona rings are included in the 3FL insulator application as a standard feature. Customer-specific solutions as well as other connection and cable clamps are also available on request.

| Maximum values | | units | 3FL2 | 3FL3 | 3FL4 | 3FL5 | 3FL6 |
|---|---|---|---|---|---|---|---|
| Highest voltage for equipment, $U_m$ | from | kV | 12 | 72.5 | 72.5 | 72.5 | 72.5 |
| | to | kV | 72.5 | 550 | 550 | 550 | 550 |
| Nominal system voltage, $U_n$ | from | kV | 10 | 60 | 60 | 60 | 60 |
| | to | kV | 69 | 500 | 500 | 500 | 500 |
| Specified mechanical load, SML class | – | kN | 70 | 100 | 120 | 160 | 210 |
| Maximum section length, length increments 52 mm (with Socket and Ball) | from | mm | 332 | 821 | 821 | 871 | 871 |
| | to | mm | 782 | 6,125 | 6,125 | 6,125 | 6,125 |

4

**Long rod insulators type 3FL2, SML 70 kN**
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 (> 31 mm/kV). 3FL2 insulators are available with mechanical ratings up to SML = 70 kN.

| End fittings with SML = 70 kN | | |
|---|---|---|
| Designation as per standard | Standard | Connection length |
| Name/size | | V, mm |
| Ball 16 | IEC 60120 | 75 |
| Socket 16A | IEC 60120 | 79 |
| Clevis 13L | IEC 60471 | 87 |
| Tongue 13L | IEC 60741 | 87 |
| Y-clevis 16 | IEC 61466-1 | 94 |
| Eye 17 | IEC 61466-1 | 93 |

**Technical data 3FL2**

| Highest voltage for equip-ment | Typical nominal system voltages | Lightning impulse withstand voltage (1.2/50 µs, dry) | Power-frequency withstand voltage (50 Hz, 1min., wet) | Arcing distance | Creepage distance | Housing length | Section length* (with Socket and Ball) | Catalog number | Weight (with Socket and Ball) |
|---|---|---|---|---|---|---|---|---|---|
| $U_m$, kV | $U_n$, kV | LIWL $_{min}$, kV | PFWL $_{min}$, kV | S, mm | C, mm | H, mm | L, mm | | W, kg |
| 12.0 | 10, 11, 12 | 158 | 73 | 214 | 426 | 178 | 331 | 3FL2 018-4SB11-1XX1 | 1.6 |
| 24.0 | 15, 20, 22, 24 | 216 | 89 | 300 | 805 | 268 | 421 | 3FL2 027-4SB11-1XX1 | 2.0 |
| 36.0 | 30, 33, 35, 36 | 243 | 111 | 390 | 1,184 | 358 | 511 | 3FL2 036-4SB11-1XX1 | 2.4 |
| 72.5 | 60, 66, 69, 72 | 400 | 200 | 660 | 2,321 | 628 | 781 | 3FL2 063-4SB11-1XX1 | 3.6 |

*Reference value of the section length of an insulator for version with Socket and Ball end fittings of size 16 in accordance with IEC 60120. To obtain the section length of an insulator equipped with other end fittings, the housing length and connection lengths (see table "End fittings") of both end fittings must be added together.

4

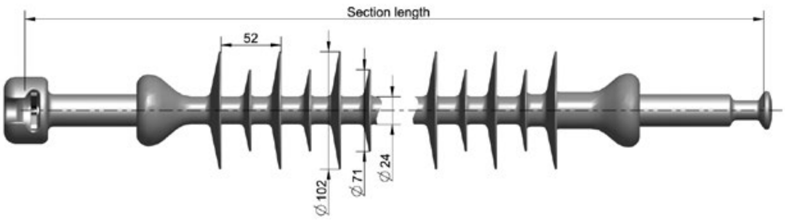
### Long rod insulators 3FL3 and 3FL4

3FL silicone long rod insulators for suspension and tension applications are available in lengths appropriate for 60 kV through 550 kV. Length increments are 52 mm. A few selected insulator lengths are listed in the following table. Intermediate, shorter, or longer lengths available on request.

| | | 3FL3 | 3FL4 |
|---|---|---|---|
| Specified mechanical load | SML: | 100 kN | 120 kN |
| Routine test load | RTL: | 50 kN | 60 kN |

**Technical data 3FL3 and 3FL4**

| Highest voltage for equipment based on 25 mm/kV | Lightning impulse withstand voltage (1.2/50 µs, dry) | Switching impulse withstand voltage (250/ 2,500 µs, positive, wet) | Power-frequency withstand voltage (50 Hz, 1 min, wet) | Arcing distance | Standard creepage distance catalog code: 3 | Extra-high creepage distance catalog code: 4 | Nominal housing length | Section length* with Socket and Ball | Catalog code | Grading ring diameter top/ bottom (earth-/ HV-side) | App. net weight for standard creepage distance |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $U_m$ kV | LIWV kV | SIWV min kV | PFWV kV | S mm | C mm | C mm | H mm | L mm | 3FL_[1]-____[2]-_[3]_[4]_[5]21-1_[6]_[7]1 | D mm | W kg |
| <72.5 | 449 | – | 160 | 644 | 1,706 | 2,291 | 614 | 821 | 3FLx - 061-3SB11-1XX1 | x / x | 3.2 |
| 72.5 | 476 | – | 180 | 696 | 1,868 | 2,516 | 666 | 873 | 3FLx - 067-3SB11-1XX1 | x / x | 3.3 |
| 72.5 | 503 | – | 200 | 748 | 2,031 | 2,740 | 718 | 925 | 3FLx - 072-3SB11-1XX1 | x / x | 3.4 |
| 72.5 | 530 | – | 220 | 800 | 2,194 | 2,964 | 770 | 977 | 3FLx - 077-3SB11-1XX1 | x / x | 3.5 |
| 72.5 | 556 | – | 240 | 852 | 2,356 | 3,189 | 822 | 1,029 | 3FLx - 082-3SB11-1XX1 | x / x | 3.6 |
| 72.5 | 583 | – | 260 | 904 | 2,519 | 3,413 | 874 | 1,081 | 3FLx - 087-3SB11-1XX1 | x / x | 3.7 |
| 72.5 | 610 | – | 280 | 956 | 2,681 | 3,637 | 926 | 1,133 | 3FLx - 093-3SB11-1XX1 | x / x | 3.8 |
| 72.5 | 637 | – | 300 | 1,008 | 2,844 | 3,862 | 978 | 1,185 | 3FLx - 098-3SB11-1XX1 | x / x | 3.9 |
| 72.5 | 664 | – | 320 | 1,060 | 3,007 | 4,086 | 1,030 | 1,237 | 3FLx - 103-3SB11-1XX1 | x / x | 4.0 |
| 123 | 690 | – | 340 | 1,112 | 3,169 | 4,310 | 1,082 | 1,289 | 3FLx - 108-3SB11-1XX1 | x / x | 4.1 |
| 123 | 717 | – | 360 | 1,164 | 3,332 | 4,535 | 1,134 | 1,341 | 3FLx - 113-3SB11-1XX1 | x / x | 4.2 |
| 123 | 744 | – | 380 | 1,216 | 3,494 | 4,759 | 1,186 | 1,393 | 3FLx - 119-3SB11-1XX1 | x / x | 4.3 |
| 145 | 771 | – | 400 | 1,268 | 3,657 | 4,983 | 1,238 | 1,445 | 3FLx - 124-3SB11-1XX1 | x / x | 4.4 |
| 145 | 797 | – | 420 | 1,320 | 3,820 | 5,208 | 1,290 | 1,497 | 3FLx - 129-3SB11-1XX1 | x / x | 4.5 |
| 145 | 824 | – | 440 | 1,372 | 3,982 | 5,432 | 1,342 | 1,549 | 3FLx - 134-3SB11-1XX1 | x / x | 4.6 |
| 145 | 851 | – | 460 | 1,424 | 4,145 | 5,656 | 1,394 | 1,601 | 3FLx - 139-3SB11-1XX1 | x / x | 4.7 |
| 170 | 882 | – | 469 | 1,476 | 4,307 | 5,881 | 1,446 | 1,653 | 3FLx - 145-3SB11-1XX1 | x / x | 4.8 |
| 170 | 913 | – | 478 | 1,528 | 4,470 | 6,105 | 1,498 | 1,705 | 3FLx - 150-3SB11-1XX1 | x / x | 4.9 |
| 170 | 943 | – | 488 | 1,580 | 4,633 | 6,329 | 1,550 | 1,757 | 3FLx - 155-3SB11-1XX1 | x / x | 5.0 |
| 170 | 974 | – | 497 | 1,632 | 4,795 | 6,554 | 1,602 | 1,809 | 3FLx - 160-3SB11-1XX1 | x / x | 5.1 |
| 170 | 1,005 | – | 506 | 1,684 | 4,958 | 6,778 | 1,654 | 1,861 | 3FLx - 165-3SB11-1XX1 | x / x | 5.2 |
| 170 | 1,036 | – | 515 | 1,736 | 5,120 | 7,002 | 1,706 | 1,913 | 3FLx - 171-3SB11-1XX1 | x / x | 5.3 |
| 170 | 1,066 | – | 525 | 1,788 | 5,283 | 7,227 | 1,758 | 1,965 | 3FLx - 176-3SB11-1XX1 | x / x | 5.4 |
| 170 | 1,097 | – | 534 | 1,840 | 5,446 | 7,451 | 1,810 | 2,017 | 3FLx - 181-3SB11-1XX1 | x / x | 5.5 |
| 170 | 1,128 | – | 543 | 1,892 | 5,608 | 7,675 | 1,862 | 2,069 | 3FLx - 186-3SB11-1XX1 | x / x | 5.6 |
| 170 | 1,159 | – | 552 | 1,944 | 5,771 | 7,900 | 1,914 | 2,121 | 3FLx - 191-3SB11-1XX1 | x / x | 5.7 |
| 170 | 1,189 | – | 562 | 1,996 | 5,933 | 8,124 | 1,966 | 2,173 | 3FLx - 197-3SB11-1XX1 | x / x | 5.8 |
| 245 | 1,220 | – | 571 | 2,003 | 6,096 | 8,348 | 2,018 | 2,225 | 3FLx - 202-3SB11-1XS1 | x / Ø210 | 6.8 |
| 245 | 1,251 | – | 580 | 2,055 | 6,259 | 8,573 | 2,070 | 2,277 | 3FLx - 207-3SB11-1XS1 | x / Ø210 | 6.9 |
| 245 | 1,282 | – | 586 | 2,107 | 6,421 | 8,797 | 2,122 | 2,329 | 3FLx - 212-3SB11-1XS1 | x / Ø210 | 7.0 |
| 245 | 1,313 | – | 593 | 2,159 | 6,584 | 9,021 | 2,174 | 2,381 | 3FLx - 217-3SB11-1XS1 | x / Ø210 | 7.1 |
| 245 | 1,344 | – | 599 | 2,211 | 6,747 | 9,246 | 2,226 | 2,433 | 3FLx - 223-3SB11-1XS1 | x / Ø210 | 7.2 |
| 245 | 1,375 | – | 605 | 2,263 | 6,909 | 9,470 | 2,278 | 2,485 | 3FLx - 228-3SB11-1XS1 | x / Ø210 | 7.3 |
| 245 | 1,406 | – | 612 | 2,315 | 7,072 | 9,694 | 2,330 | 2,537 | 3FLx - 233-3SB11-1XS1 | x / Ø210 | 7.4 |
| 245 | 1,437 | – | 618 | 2,367 | 7,234 | 9,919 | 2,382 | 2,589 | 3FLx - 238-3SB11-1XS1 | x / Ø210 | 7.5 |
| 245 | 1,468 | 1,032 | 625 | 2,419 | 7,397 | 10,143 | 2,434 | 2,641 | 3FLx - 243-3SB11-1XS1 | x / Ø210 | 8.4 |
| 300 | 1,499 | 1,042 | 631 | 2,456 | 7,560 | 10,367 | 2,486 | 2,693 | 3FLx - 249-3SB11-1XM1 | x / Ø330 | 8.5 |
| 300 | 1,530 | 1,052 | 637 | 2,508 | 7,722 | 10,592 | 2,538 | 2,745 | 3FLx - 254-3SB11-1XM1 | x / Ø330 | 8.6 |
| 300 | 1,561 | 1,062 | 644 | 2,560 | 7,885 | 10,816 | 2,590 | 2,797 | 3FLx - 259-3SB11-1XM1 | x / Ø330 | 8.7 |
| 300 | 1,623 | 1,081 | 656 | 2,664 | 8,210 | 11,265 | 2,694 | 2,901 | 3FLx - 269-3SB11-1XM1 | x / Ø330 | 8.9 |
| 300 | 1,654 | 1,091 | 663 | 2,716 | 8,373 | 11,489 | 2,746 | 2,953 | 3FLx - 275-3SB11-1XM1 | x / Ø330 | 9.0 |
| 300 | 1,716 | 1,111 | 676 | 2,820 | 8,698 | 11,938 | 2,850 | 3,057 | 3FLx - 285-3SB11-1XM1 | x / Ø330 | 9.2 |
| 362 | 1,778 | 1,130 | 688 | 2,924 | 9,023 | 12,386 | 2,954 | 3,161 | 3FLx - 295-3SB11-1XM1 | x / Ø330 | 9.4 |
| 362 | 1,809 | 1,140 | 695 | 2,976 | 9,186 | 12,611 | 3,006 | 3,213 | 3FLx - 301-3SB11-1XM1 | x / Ø330 | 9.5 |
| 362 | 1,840 | 1,150 | 701 | 3,028 | 9,348 | 12,835 | 3,058 | 3,265 | 3FLx - 306-3SB11-1XM1 | x / Ø330 | 9.6 |
| 362 | 1,873 | 1,170 | 709 | 3,132 | 9,673 | 13,284 | 3,162 | 3,369 | 3FLx - 316-3SB11-1XM1 | x / Ø330 | 9.8 |




[1] Specified mechanical load (SML): use »3« for 100 kN; use »4« for 120 kN.
[2] Nominal housing length in mm/10. [3] Standard creepage distance: »3«; Extra-high creepage distance: »4«.
[4] Upper end fitting (earth side) [5] Bottom end fitting (high-voltage side)
[6] Upper corona ring (earth side) [7] Bottom corona ring (high-voltage side). For all insulator types having no preinstalled corona rings and indicated by the code »X« optional corona rings can be added, if requested. For this, use the smallest corona ring available, i.e. catalog code »S«, please refer to page 10 for further catalog numbering information.

**Technical data 3FL3 and 3FL4**

| Highest voltage for equipment based on 25 mm/kV | Lightning impulse withstand voltage (1.2/ 50 µs, dry) | Switching impulse withstand voltage (250/ 2500 µs, positive, wet) | Power-frequency withstand voltage (50 Hz, 1 min., wet) | Arcing distance | Standard creepage distance catalog code: 3 | Extra-high creepage distance catalog code: 4 | Nominal housing length | Section length* with Socket and Ball | Catalog code | Grading ring diameter top/bottom (earth-/HV-side) | App. net weight for standard creepage distance |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $U_m$ kV | LIWV kV | SIWV min kV | PFWV kV | S mm | C mm | C mm | H mm | L mm | 3FL_[1]-___[2]-_[3]_[4]_[5]21-1_[6]_[7]1 | D mm | W kg |
| 362 | 1,889 | 1,179 | 713 | 3,184 | 9,836 | 13,508 | 3,214 | 3,421 | 3FLx - 321-3SB11-1XM1 | x / Ø330 | 9.9 |
| 362 | 1,922 | 1,199 | 720 | 3,288 | 10,161 | 13,957 | 3,318 | 3,525 | 3FLx - 332-3SB11-1XM1 | x / Ø330 | 10.1 |
| 362 | 1,939 | 1,209 | 724 | 3,340 | 10,324 | 14,181 | 3,370 | 3,577 | 3FLx - 337-3SB11-1XM1 | x / Ø330 | 10.2 |
| 420 | 1,971 | 1,229 | 732 | 3,399 | 10,649 | 14,629 | 3,474 | 3,681 | 3FLx - 347-3SB11-1SM1 | Ø210 / Ø330 | 11.3 |
| 420 | 2,004 | 1,248 | 740 | 3,503 | 10,974 | 15,078 | 3,578 | 3,785 | 3FLx - 358-3SB11-1SM1 | Ø210 / Ø330 | 11.5 |
| 420 | 2,037 | 1,268 | 748 | 3,607 | 11,300 | 15,527 | 3,682 | 3,889 | 3FLx - 368-3SB11-1SM1 | Ø210 / Ø330 | 11.7 |
| 420 | 2,054 | 1,278 | 752 | 3,659 | 11,462 | 15,751 | 3,734 | 3,941 | 3FLx - 373-3SB11-1SM1 | Ø210 / Ø330 | 11.8 |
| 420 | 2,070 | 1,288 | 756 | 3,711 | 11,625 | 15,975 | 3,786 | 3,993 | 3FLx - 379-3SB11-1SM1 | Ø210 / Ø330 | 11.9 |
| 420 | 2,103 | 1,307 | 763 | 3,815 | 11,950 | 16,424 | 3,890 | 4,097 | 3FLx - 389-3SB11-1SM1 | Ø210 / Ø330 | 12.1 |
| 420 | 2,136 | 1,327 | 771 | 3,919 | 12,275 | 16,873 | 3,994 | 4,201 | 3FLx - 399-3SB11-1SM1 | Ø210 / Ø330 | 12.3 |
| 420 | 2,169 | 1,346 | 779 | 4,023 | 12,600 | 17,321 | 4,098 | 4,305 | 3FLx - 410-3SB11-1SM1 | Ø210 / Ø330 | 12.5 |
| 420 | 2,185 | 1,356 | 783 | 4,075 | 12,763 | 17,546 | 4,150 | 4,357 | 3FLx - 415-3SB11-1SM1 | Ø210 / Ø330 | 12.6 |
| 420 | 2,201 | 1,366 | 787 | 4,127 | 12,926 | 17,770 | 4,202 | 4,409 | 3FLx - 420-3SB11-1SM1 | Ø210 / Ø330 | 12.7 |
| 420 | 2,218 | 1,376 | 791 | 4,179 | 13,088 | 17,994 | 4,254 | 4,461 | 3FLx - 425-3SB11-1SM1 | Ø210 / Ø330 | 12.8 |
| 420 | 2,251 | 1,396 | 798 | 4,283 | 13,413 | 18,443 | 4,358 | 4,565 | 3FLx - 436-3SB11-1SM1 | Ø210 / Ø330 | 13.0 |
| 550 | 2,284 | 1,415 | 806 | 4,362 | 13,739 | 18,892 | 4,462 | 4,669 | 3FLx - 446-3SB11-1SL1 | Ø210 / Ø420 | 14.8 |
| 550 | 2,300 | 1,425 | 810 | 4,466 | 14,064 | 19,340 | 4,566 | 4,773 | 3FLx - 457-3SB11-1SL1 | Ø210 / Ø420 | 15.0 |
| 550 | 2,300 | 1,425 | 810 | 4,674 | 14,714 | 20,238 | 4,774 | 4,981 | 3FLx - 477-3SB11-1SL1 | Ø210 / Ø420 | 15.4 |
| 550 | 2,300 | 1,425 | 810 | 4,778 | 15,040 | 20,686 | 4,878 | 5,085 | 3FLx - 488-3SB11-1SL1 | Ø210 / Ø420 | 15.6 |
| 550 | 2,300 | 1,425 | 810 | 4,882 | 15,365 | 21,135 | 4,982 | 5,189 | 3FLx - 498-3SB11-1SL1 | Ø210 / Ø420 | 15.8 |
| 550 | 2,300 | 1,425 | 810 | 4,986 | 15,690 | 21,584 | 5,086 | 5,293 | 3FLx - 509-3SB11-1SL1 | Ø210 / Ø420 | 16.0 |
| 550 | 2,300 | 1,425 | 810 | 5,090 | 16,015 | 22,032 | 5,190 | 5,397 | 3FLx - 519-3SB11-1SL1 | Ø210 / Ø420 | 16.2 |
| 550 | 2,300 | 1,425 | 810 | 5,194 | 16,340 | 22,481 | 5,294 | 5,501 | 3FLx - 529-3SB11-1SL1 | Ø210 / Ø420 | 16.4 |
| | 2,300 | 1,425 | 810 | 5,350 | 16,828 | 23,154 | 5,450 | 5,657 | 3FLx - 545-3SB11-1SL1 | Ø210 / Ø420 | 16.7 |
| | 2,300 | 1,425 | 810 | 5,454 | 17,153 | 23,603 | 5,554 | 5,761 | 3FLx - 555-3SB11-1SL1 | Ø210 / Ø420 | 16.9 |
| | 2,300 | 1,425 | 810 | 5,558 | 17,479 | 24,051 | 5,658 | 5,865 | 3FLx - 566-3SB11-1SL1 | Ø210 / Ø420 | 17.1 |
| | 2,300 | 1,425 | 810 | 5,662 | 17,804 | 24,500 | 5,762 | 5,969 | 3FLx - 576-3SB11-1SL1 | Ø210 / Ø420 | 17.4 |
| | 2,300 | 1,425 | 810 | 5,818 | 18,292 | 25,173 | 5,918 | 6,125 | 3FLx - 592-3SB11-1SL1 | Ø210 / Ø420 | 17.7 |

**End fittings types and standards**

| Type | Standard | Catalog code | Length V |
|---|---|---|---|
| Ball 16 | IEC 60120 | B | 108 mm |
| Socket 16A | IEC 60120 | S | 99 mm |
| Socket 16B | IEC 60120 | R | 103 mm |
| Clevis 16L | IEC 60471 | C | 119 mm |
| Tongue 16L | IEC 60741 | T | 118 mm |
| Y-clevis 19 | IEC 61466-1 | Y | 127 mm |
| Eye 24 | IEC 61466-1 | E | 128 mm |

**Section length adjustment table* for other end fittings combinations, Base end fittings: Socket and Ball (catalog code: SB)**

| Upper end fitting (earth side) | Bottom end fitting (high-voltage side) | Catalog code | Length change, mm |
|---|---|---|---|
| Clevis 16L | Tongue 16L | CT | +30 |
| Clevis 16L | Clevis 16L | CC | +31 |
| Clevis 16L | Eye 24 | CE | +40 |
| Clevis 16L | Ball 16 | CB | +20 |
| Tongue 16L | Tongue 16L | TT | +29 |
| Eye 24 | Ball 16 | EB | +29 |
| Eye 24 | Eye 24 | EE | +49 |
| Y-clevis 19 | Eye 24 | YE | +48 |
| Y-clevis 19 | Ball 16 | YB | +28 |

* To determine the section length of an insulator with a different end fitting combination than Socket and Ball, please add the appropriate adjustment section length shown in the table above. For all other configurations not shown in this table, contact your Siemens representative.

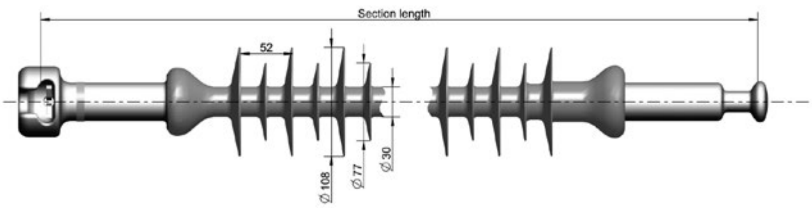
### Long rod insulators 3FL5 and 3FL6

3FL silicone long rod insulators for suspension and tension applications are available in lengths appropriate for 60 kV through 550 kV. Length increments are 52 mm. A few selected insulator lengths are listed in the following table. Intermediate, shorter, or longer lengths available on request.

| | | 3FL5 | 3FL6 |
|---|---|---|---|
| Specified mechanical load | SML: | 160 kN | 210 kN |
| Routine test load | RTL: | 80 kN | 105 kN |

**Technical data 3FL5 and 3FL6**

| Highest voltage for equipment based on 25 mm/kV | Lightning impulse withstand voltage (1.2/50 µs, dry) | Switching impulse withstand voltage (250/ 2,500 µs, positive, wet) | Power-frequency withstand voltage (50 Hz, 1 min, wet) | Arcing distance | Standard creepage distance catalog code: 3 | Extra-high creepage distance catalog code: 4 | Nominal housing length | Section length* with Socket and Ball | Catalog code | Grading ring diameter top/ bottom (earth-/ HV-side) | App. net weight for standard creepage distance |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $U_m$ kV | LIWV kV | SIWV min kV | PFWV kV | S mm | C mm | C mm | H mm | L mm | 3FL_[1]-___[2]-_[3]_[4]_[5]21-1_[6]_[7]1 | D mm | W kg |
| <72.5 | 449 | – | 160 | 643 | 1,702 | 2,288 | 614 | 878 | 3FLx - 061-3SB21-1XX1 | x / x | 5.2 |
| 72.5 | 476 | – | 180 | 695 | 1,865 | 2,512 | 666 | 930 | 3FLx - 067-3SB21-1XX1 | x / x | 5.3 |
| 72.5 | 503 | – | 200 | 747 | 2,027 | 2,736 | 718 | 982 | 3FLx - 072-3SB21-1XX1 | x / x | 5.4 |
| 72.5 | 530 | – | 220 | 799 | 2,190 | 2,961 | 770 | 1,034 | 3FLx - 077-3SB21-1XX1 | x / x | 5.6 |
| 72.5 | 556 | – | 240 | 851 | 2,352 | 3,185 | 822 | 1,086 | 3FLx - 082-3SB21-1XX1 | x / x | 5.7 |
| 72.5 | 583 | – | 260 | 903 | 2,515 | 3,409 | 874 | 1,138 | 3FLx - 087-3SB21-1XX1 | x / x | 5.9 |
| 72.5 | 610 | – | 280 | 955 | 2,678 | 3,634 | 926 | 1,190 | 3FLx - 093-3SB21-1XX1 | x / x | 6.0 |
| 72.5 | 637 | – | 300 | 1,007 | 2,840 | 3,858 | 978 | 1,242 | 3FLx - 098-3SB21-1XX1 | x / x | 6.1 |
| 123 | 664 | – | 320 | 1,059 | 3,003 | 4,082 | 1,030 | 1,294 | 3FLx - 103-3SB21-1XX1 | x / x | 6.3 |
| 123 | 690 | – | 340 | 1,111 | 3,166 | 4,307 | 1,082 | 1,346 | 3FLx - 108-3SB21-1XX1 | x / x | 6.4 |
| 123 | 717 | – | 360 | 1,163 | 3,328 | 4,531 | 1,134 | 1,398 | 3FLx - 113-3SB21-1XX1 | x / x | 6.5 |
| 123 | 744 | – | 380 | 1,215 | 3,491 | 4,755 | 1,186 | 1,450 | 3FLx - 119-3SB21-1XX1 | x / x | 6.7 |
| 145 | 771 | – | 400 | 1,267 | 3,653 | 4,980 | 1,238 | 1,502 | 3FLx - 124-3SB21-1XX1 | x / x | 6.8 |
| 145 | 797 | – | 420 | 1,319 | 3,816 | 5,204 | 1,290 | 1,554 | 3FLx - 129-3SB21-1XX1 | x / x | 6.9 |
| 145 | 824 | – | 440 | 1,371 | 3,979 | 5,428 | 1,342 | 1,606 | 3FLx - 134-3SB21-1XX1 | x / x | 7.1 |
| 145 | 851 | – | 460 | 1,423 | 4,141 | 5,652 | 1,394 | 1,658 | 3FLx - 139-3SB21-1XX1 | x / x | 7.2 |
| 170 | 882 | – | 469 | 1,475 | 4,304 | 5,877 | 1,446 | 1,710 | 3FLx - 145-3SB21-1XX1 | x / x | 7.3 |
| 170 | 913 | – | 478 | 1,527 | 4,466 | 6,101 | 1,498 | 1,762 | 3FLx - 150-3SB21-1XX1 | x / x | 7.5 |
| 170 | 943 | – | 488 | 1,579 | 4,629 | 6,325 | 1,550 | 1,814 | 3FLx - 155-3SB21-1XX1 | x / x | 7.6 |
| 170 | 974 | – | 497 | 1,631 | 4,792 | 6,550 | 1,602 | 1,866 | 3FLx - 160-3SB21-1XX1 | x / x | 7.7 |
| 170 | 1,005 | – | 506 | 1,683 | 4,954 | 6,774 | 1,654 | 1,918 | 3FLx - 165-3SB21-1XX1 | x / x | 7.9 |
| 170 | 1,036 | – | 515 | 1,735 | 5,117 | 6,998 | 1,706 | 1,970 | 3FLx - 171-3SB21-1XX1 | x / x | 8.0 |
| 170 | 1,066 | – | 525 | 1,787 | 5,279 | 7,223 | 1,758 | 2,022 | 3FLx - 176-3SB21-1XX1 | x / x | 8.1 |
| 170 | 1,097 | – | 534 | 1,839 | 5,442 | 7,447 | 1,810 | 2,074 | 3FLx - 181-3SB21-1XX1 | x / x | 8.3 |
| 170 | 1,128 | – | 543 | 1,891 | 5,605 | 7,671 | 1,862 | 2,126 | 3FLx - 186-3SB21-1XX1 | x / x | 8.4 |
| 170 | 1,159 | – | 552 | 1,943 | 5,767 | 7,896 | 1,914 | 2,178 | 3FLx - 191-3SB21-1XX1 | x / x | 8.5 |
| 170 | 1,189 | – | 562 | 1,995 | 5,930 | 8,120 | 1,966 | 2,230 | 3FLx - 197-3SB21-1XX1 | x / x | 8.7 |
| 245 | 1,220 | – | 571 | 2,002 | 6,092 | 8,344 | 2,018 | 2,282 | 3FLx - 202-3SB21-1XS1 | x / Ø210 | 9.7 |
| 245 | 1,251 | – | 580 | 2,054 | 6,255 | 8,569 | 2,070 | 2,334 | 3FLx - 207-3SB21-1XS1 | x / Ø210 | 9.8 |
| 245 | 1,282 | – | 586 | 2,106 | 6,418 | 8,793 | 2,122 | 2,386 | 3FLx - 212-3SB21-1XS1 | x / Ø210 | 10.0 |
| 245 | 1,313 | – | 593 | 2,158 | 6,580 | 9,017 | 2,174 | 2,438 | 3FLx - 217-3SB21-1XS1 | x / Ø210 | 10.1 |
| 245 | 1,344 | – | 599 | 2,210 | 6,743 | 9,242 | 2,226 | 2,490 | 3FLx - 223-3SB21-1XS1 | x / Ø210 | 10.2 |
| 245 | 1,375 | – | 605 | 2,262 | 6,906 | 9,466 | 2,278 | 2,542 | 3FLx - 228-3SB21-1XS1 | x / Ø210 | 10.4 |
| 245 | 1,406 | – | 612 | 2,314 | 7,068 | 9,690 | 2,330 | 2,594 | 3FLx - 233-3SB21-1XS1 | x / Ø210 | 10.5 |
| 245 | 1,437 | – | 618 | 2,366 | 7,231 | 9,915 | 2,382 | 2,646 | 3FLx - 238-3SB21-1XS1 | x / Ø210 | 10.6 |
| 245 | 1,468 | 1,032 | 625 | 2,403 | 7,393 | 10,139 | 2,434 | 2,698 | 3FLx - 243-3SB21-1XM1 | x / Ø210 | 11.5 |
| 300 | 1,499 | 1,042 | 631 | 2,455 | 7,556 | 10,363 | 2,486 | 2,750 | 3FLx - 249-3SB21-1XM1 | x / Ø330 | 11.7 |
| 300 | 1,530 | 1,052 | 637 | 2,507 | 7,719 | 10,588 | 2,538 | 2,802 | 3FLx - 254-3SB21-1XM1 | x / Ø330 | 11.8 |
| 300 | 1,561 | 1,062 | 644 | 2,559 | 7,881 | 10,812 | 2,590 | 2,854 | 3FLx - 259-3SB21-1XM1 | x / Ø330 | 11.9 |
| 300 | 1,623 | 1,081 | 656 | 2,663 | 8,206 | 11,261 | 2,694 | 2,958 | 3FLx - 269-3SB21-1XM1 | x / Ø330 | 12.2 |
| 300 | 1,654 | 1,091 | 663 | 2,715 | 8,369 | 11,485 | 2,746 | 3,010 | 3FLx - 275-3SB21-1XM1 | x / Ø330 | 12.3 |
| 300 | 1,716 | 1,111 | 676 | 2,819 | 8,694 | 11,934 | 2,850 | 3,114 | 3FLx - 285-3SB21-1XM1 | x / Ø330 | 12.6 |
| 362 | 1,778 | 1,130 | 688 | 2,923 | 9,019 | 12,382 | 2,954 | 3,218 | 3FLx - 295-3SB21-1XM1 | x / Ø330 | 12.9 |
| 362 | 1,809 | 1,140 | 695 | 2,975 | 9,182 | 12,607 | 3,006 | 3,270 | 3FLx - 301-3SB21-1XM1 | x / Ø330 | 13.0 |
| 362 | 1,840 | 1,150 | 701 | 3,027 | 9,345 | 12,831 | 3,058 | 3,322 | 3FLx - 306-3SB21-1XM1 | x / Ø330 | 13.1 |
| 362 | 1,873 | 1,170 | 709 | 3,131 | 9,670 | 13,280 | 3,162 | 3,426 | 3FLx - 316-3SB21-1XM1 | x / Ø330 | 13.4 |




[1] Specified mechanical load (SML): use »3« for 100 kN; use »4« for 120 kN.
[2] Nominal housing length in mm/10. [3] Standard creepage distance: »3«; Extra-high creepage distance: »4«.
[4] Upper end fitting (earth side) [5] Bottom end fitting (high-voltage side)
[6] Upper corona ring (earth side) [7] Bottom corona ring (high-voltage side). For all insulator types having no preinstalled corona rings and indicated by the code »X« optional corona rings can be added, if requested. For this, use the smallest corona ring available, i.e. catalog code »S«, please refer to page 10 for further catalog numbering information.

**Technical data 3FL5 and 3FL6**

| Highest voltage for equipment based on 25 mm/kV | Lightning impulse withstand voltage (1.2/ 50 µs, dry) | Switching impulse withstand voltage (250/ 2500 µs, positive, wet) | Power-frequency withstand voltage (50 Hz, 1 min., wet) | Arcing distance | Standard creepage distance catalog code: 3 | Extra-high creepage distance catalog code: 4 | Nominal housing length | Section length* with Socket and Ball | Catalog code | Grading ring diameter top/bottom (earth-/HV-side) | App. net weight for standard creepage distance |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $U_m$ kV | LIWV kV | SIWV min kV | PFWV kV | S mm | C mm | C mm | H mm | L mm | 3FL_[1]-____[2]-_[3]_[4]_[5]21-1_[6]_[7]1 | D mm | W kg |
| 362 | 1,889 | 1,179 | 713 | 3,183 | 9,832 | 13,504 | 3,214 | 3,478 | 3FLx - 321-3SB21-1XM1 | x / Ø330 | 13.6 |
| 362 | 1,922 | 1,199 | 720 | 3,287 | 10,158 | 13,953 | 3,318 | 3,582 | 3FLx - 332-3SB21-1XM1 | x / Ø330 | 13.8 |
| 362 | 1,939 | 1,209 | 724 | 3,339 | 10,320 | 14,177 | 3,370 | 3,634 | 3FLx - 337-3SB21-1XM1 | x / Ø330 | 14.0 |
| 420 | 1,971 | 1,229 | 732 | 3,398 | 10,645 | 14,625 | 3,474 | 3,738 | 3FLx - 347-3SB21-1SM1 | Ø210 / Ø330 | 15.1 |
| 420 | 2,004 | 1,248 | 740 | 3,502 | 10,971 | 15,074 | 3,578 | 3,842 | 3FLx - 358-3SB21-1SM1 | Ø210 / Ø330 | 15.4 |
| 420 | 2,037 | 1,268 | 748 | 3,606 | 11,296 | 15,523 | 3,682 | 3,946 | 3FLx - 368-3SB21-1SM1 | Ø210 / Ø330 | 15.6 |
| 420 | 2,054 | 1,278 | 752 | 3,658 | 11,459 | 15,747 | 3,734 | 3,998 | 3FLx - 373-3SB21-1SM1 | Ø210 / Ø330 | 15.8 |
| 420 | 2,070 | 1,288 | 756 | 3,710 | 11621 | 15,971 | 3,786 | 4,050 | 3FLx - 379-3SB21-1SM1 | Ø210 / Ø330 | 15.9 |
| 420 | 2,103 | 1,307 | 763 | 3,814 | 11,946 | 16,420 | 3,890 | 4,154 | 3FLx - 389-3SB21-1SM1 | Ø210 / Ø330 | 16.2 |
| 420 | 2,136 | 1,327 | 771 | 3,918 | 12,272 | 16,869 | 3,994 | 4,258 | 3FLx - 399-3SB21-1SM1 | Ø210 / Ø330 | 16.5 |
| 420 | 2,169 | 1,346 | 779 | 4,022 | 12,597 | 17,317 | 4,098 | 4,362 | 3FLx - 410-3SB21-1SM1 | Ø210 / Ø330 | 16.7 |
| 420 | 2,185 | 1,356 | 783 | 4,074 | 12,759 | 17,542 | 4,150 | 4,414 | 3FLx - 415-3SB21-1SM1 | Ø210 / Ø330 | 16.9 |
| 420 | 2,201 | 1,366 | 787 | 4,126 | 12,922 | 17,766 | 4,202 | 4,466 | 3FLx - 420-3SB21-1SM1 | Ø210 / Ø330 | 17.0 |
| 420 | 2,218 | 1,376 | 791 | 4,178 | 13,085 | 17,990 | 4,254 | 4,518 | 3FLx - 425-3SB21-1SM1 | Ø210 / Ø330 | 17.1 |
| 420 | 2,251 | 1,396 | 798 | 4,282 | 13,410 | 18,439 | 4,358 | 4,622 | 3FLx - 436-3SB21-1SM1 | Ø210 / Ø330 | 17.4 |
| 550 | 2,284 | 1,415 | 806 | 4,361 | 13,735 | 18,888 | 4,462 | 4,726 | 3FLx - 446-3SB21-1SL1 | Ø210 / Ø420 | 19.2 |
| 550 | 2,300 | 1,425 | 810 | 4,465 | 14,060 | 19,336 | 4,566 | 4,830 | 3FLx - 457-3SB21-1SL1 | Ø210 / Ø420 | 19.5 |
| 550 | 2,300 | 1,425 | 810 | 4,673 | 14,711 | 20,234 | 4,774 | 5,038 | 3FLx - 477-3SB21-1SL1 | Ø210 / Ø420 | 20.0 |
| 550 | 2,300 | 1,425 | 810 | 4,777 | 15,036 | 20,682 | 4,878 | 5,142 | 3FLx - 488-3SB21-1SL1 | Ø210 / Ø420 | 20.3 |
| 550 | 2,300 | 1,425 | 810 | 4,881 | 15,361 | 21,131 | 4,982 | 5,246 | 3FLx - 498-3SB21-1SL1 | Ø210 / Ø420 | 20.6 |
| 550 | 2,300 | 1,425 | 810 | 4,985 | 15,686 | 21,580 | 5,086 | 5,350 | 3FLx - 509-3SB21-1SL1 | Ø210 / Ø420 | 20.8 |
| 550 | 2,300 | 1,425 | 810 | 5,089 | 16,012 | 22,028 | 5,190 | 5,454 | 3FLx - 519-3SB21-1SL1 | Ø210 / Ø420 | 21.1 |
| 550 | 2,300 | 1,425 | 810 | 5,193 | 16,337 | 22,477 | 5,294 | 5,558 | 3FLx - 529-3SB21-1SL1 | Ø210 / Ø420 | 21.4 |
| | 2,300 | 1,425 | 810 | 5,349 | 16,825 | 23,150 | 5,450 | 5,714 | 3FLx - 545-3SB21-1SL1 | Ø210 / Ø420 | 21.8 |
| | 2,300 | 1,425 | 810 | 5,453 | 17,150 | 23,598 | 5,554 | 5,818 | 3FLx - 555-3SB21-1SL1 | Ø210 / Ø420 | 22.1 |
| | 2,300 | 1,425 | 810 | 5,557 | 17,475 | 24,047 | 5,658 | 5,922 | 3FLx - 566-3SB21-1SL1 | Ø210 / Ø420 | 22.3 |
| | 2,300 | 1,425 | 810 | 5,661 | 17,800 | 24,496 | 5,762 | 6,026 | 3FLx - 576-3SB21-1SL1 | Ø210 / Ø420 | 22.6 |
| | 2,300 | 1,425 | 810 | 5,817 | 18,288 | 25,169 | 5,918 | 6,182 | 3FLx - 592-3SB21-1SL1 | Ø210 / Ø420 | 23.0 |

**End fittings types and standards**

| Type | Standard | Catalog code | Length V |
|---|---|---|---|
| Ball 20 | IEC 60120 | B | 135 mm |
| Socket 20 | IEC 60120 | S | 129 mm |
| Clevis 19L | IEC 60471 | C | 145 mm |
| Clevis 22L | IEC 60471 | C | 154 mm |
| Tongue 19L | IEC 60741 | T | 144 mm |
| Tongue 22L | IEC 60741 | T | 153 mm |
| Y-clevis 22 | IEC 61466-1 | Y | 156 mm |
| Eye 25 | IEC 61466-1 | E | 153 mm |

**Section length adjustment table* for other end fittings combinations, Base end fittings: Socket and Ball (catalog code: SB)**

| Upper end fitting (earth side) | Bottom end fitting (high-voltage side) | Catalog code | Length change, mm |
|---|---|---|---|
| Clevis 19L | Tongue 19L | CT | +25 |
| Clevis 19L | Clevis 19L | CC | +26 |
| Clevis 19L | Eye 25 | CE | +34 |
| Clevis 19L | Ball 20 | CB | +16 |
| Tongue 19L | Tongue 19L | TT | +24 |
| Eye 25 | Ball 20 | EB | +24 |
| Eye 25 | Eye 25 | EE | +42 |
| Y-clevis 22 | Eye 25 | YE | +45 |
| Y-clevis 22 | Ball 20 | YB | +27 |

* To determine the section length of an insulator with a different end fitting combination than Socket and Ball, please add the appropriate adjustment section length shown in the table above. For all other configurations not shown in this table, contact your Siemens representative.