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4 Products and Devices

4.1 High Voltage Circuit Breakers

4.1.1 Circuit Breakers for 72.5 kV up to 800 kV

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.

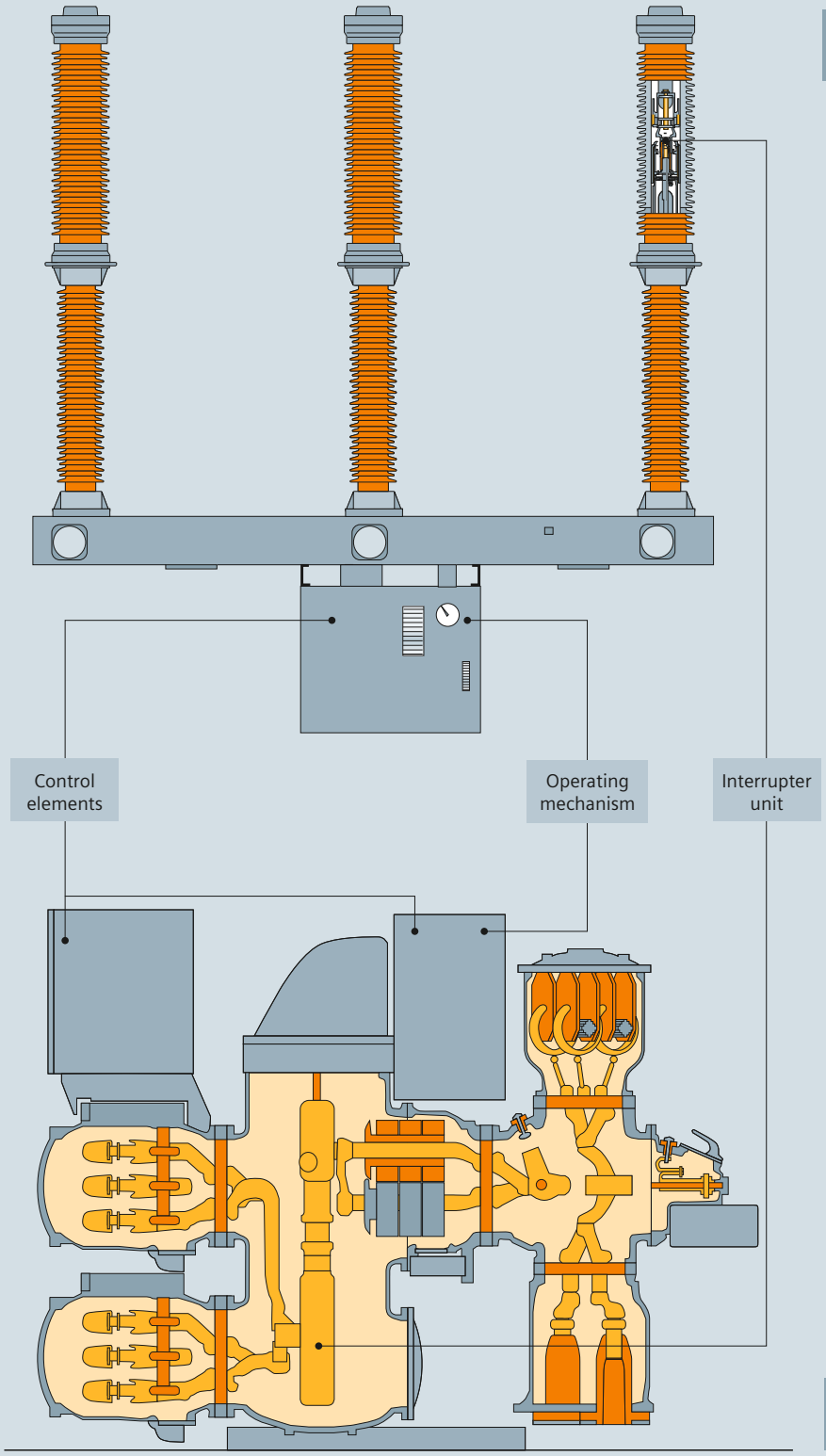


Fig. 4.1-1: **Circuit-breaker parts: circuit-breaker for air-insulated switchgear (top), circuit-breaker in SF_6-insulated switchgear (bottom)**

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.

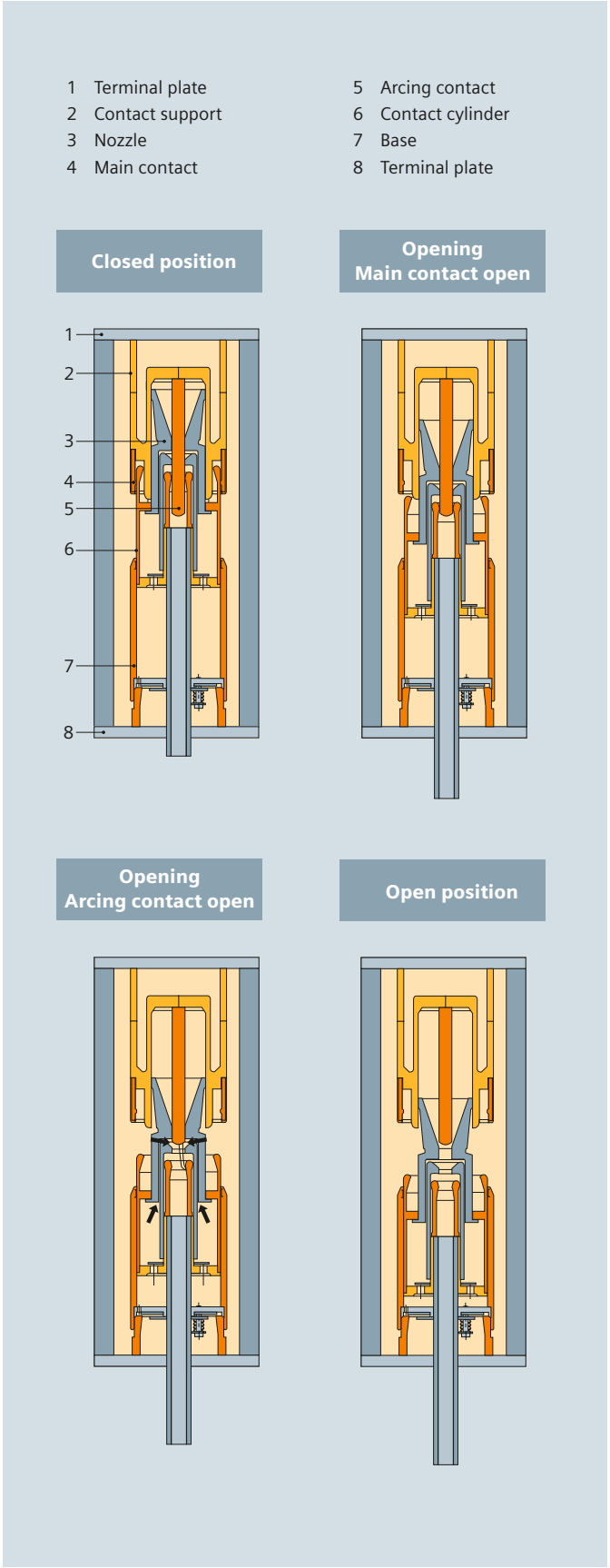
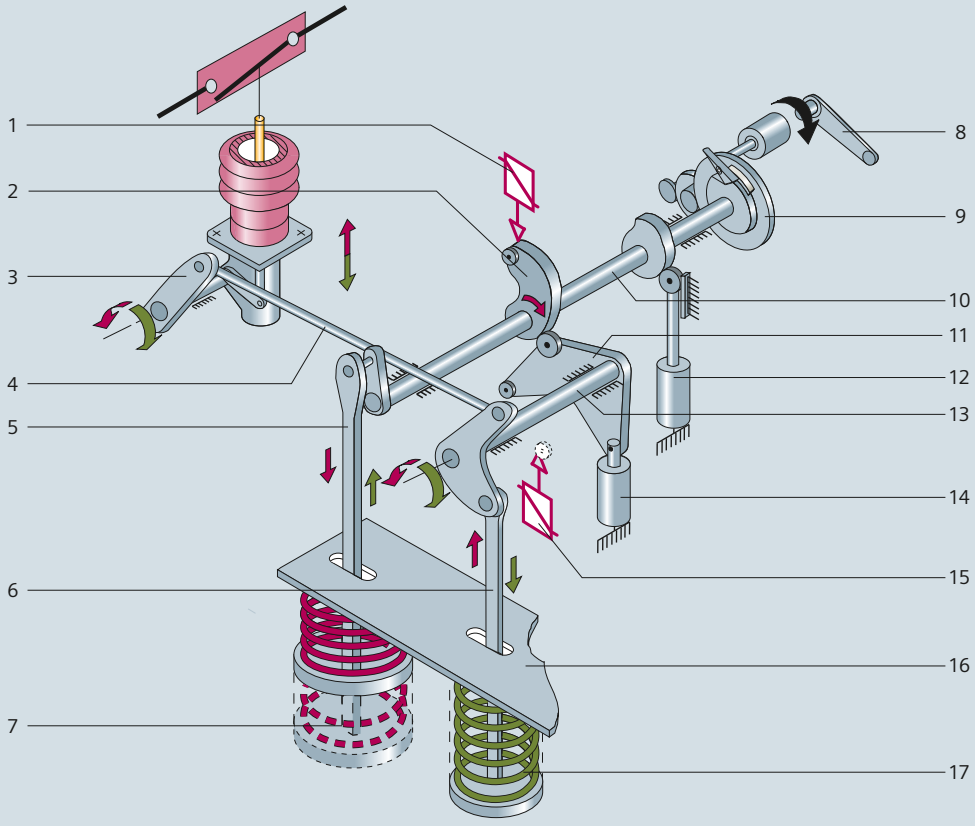


Fig. 4.1-2: **The interrupter unit**



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.

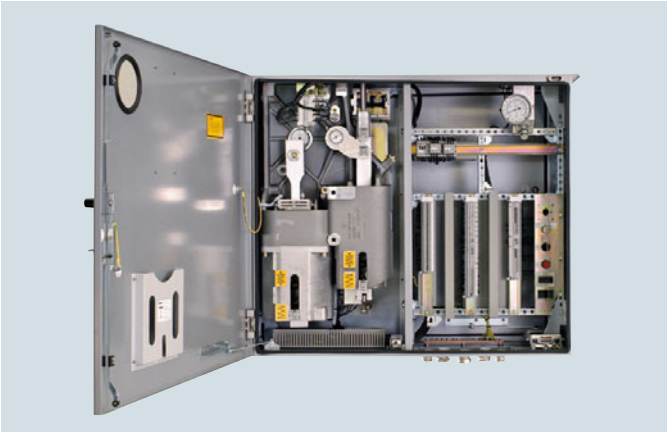


Fig. 4.1-4: **Control cubicle**

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

Live-tank circuit breakers for air-insulated switchgear
All live-tank circuit breakers are of the same general modular design, as shown in fig. 4.1-5 to fig. 4.1-9.

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

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

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

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

If desired, Siemens can provide appropriately qualified personnel for installation and commissioning.

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

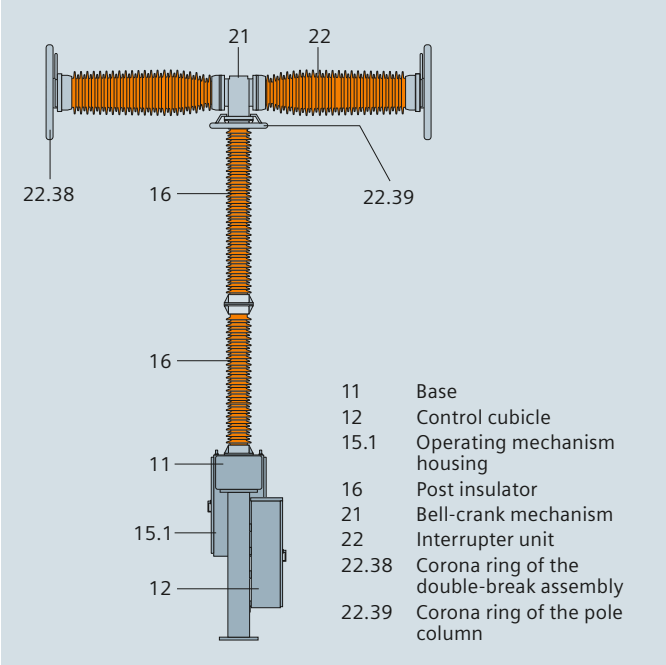


Fig. 4.1-6: **550 kV circuit breaker 3AP2FI**

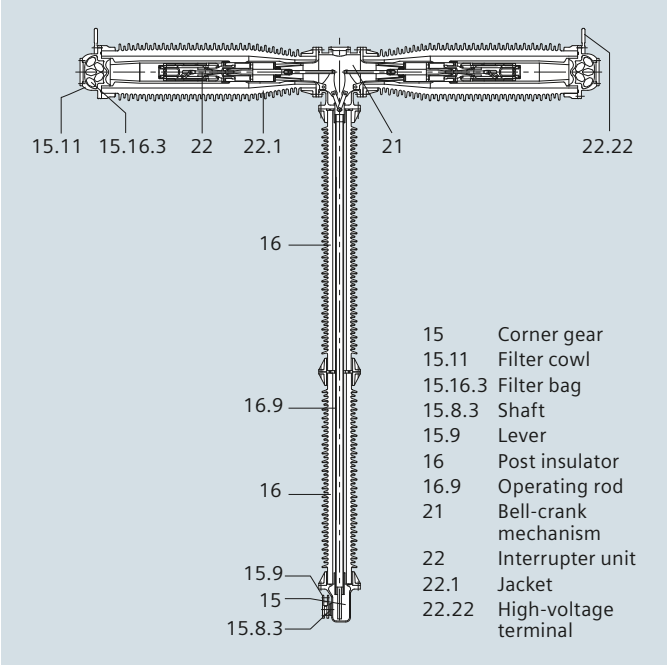


Fig. 4.1-7: **Sectional view of pole column**

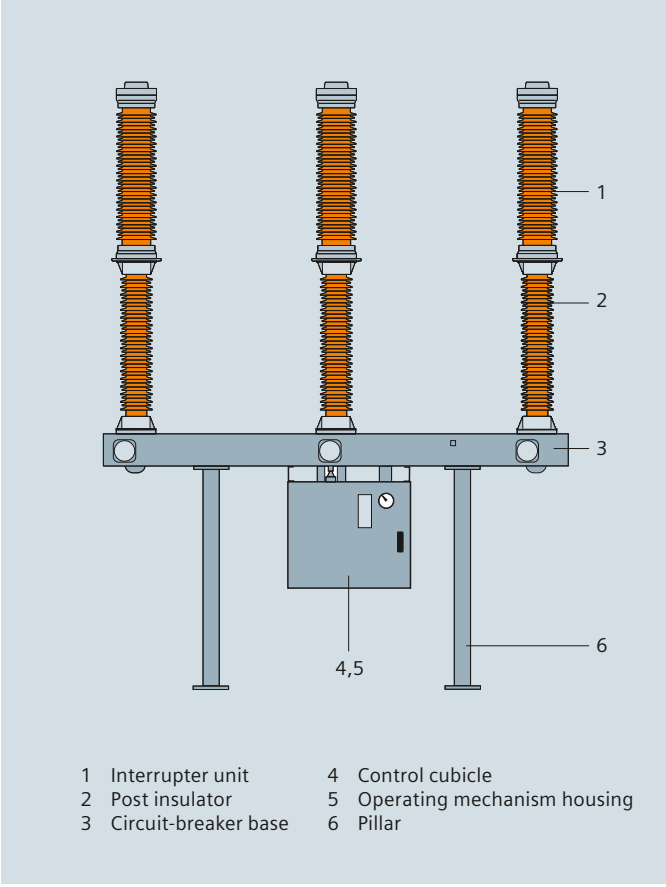


Fig. 4.1-8: **145 kV circuit breaker 3AP1FG with 3-pole stored-energy spring mechanism**

Fig. 4.1-9: **3AP1FG on site**

Type		3AP1					3AP2				3AP4
Rated voltage	[kV]	72.5	123	145	170	245	300	362	420	550	800
Number of interrupter units per pole		1					2				4
Rated power-frequency withstand voltage/min	[kV]	140	230	275	325	460	460	520	610	800	830
Rated lightning impulse withstand voltage/min	[kV]	325	550	650	750	1,050	1,050	1,175	1,425	1,550	2,100
Rated switching impulse withstand voltage/min	[kV]	–	–	–	–	–	850	950	1,050	1,175	1,425
Rated normal current, up to	[A]	4,000	4,000	4,000	4,000	4,000	4,000	5,000	5,000	5,000	5,000
Rated short-time withstand current (1 s – 3 s), up to	[kA $_{(rms)}$]	40	40	40	40	50	40	50	50	63	63
Rated peak withstand current, up to	[kA $_{(peak)}$]	108	108	108	108	135	108	170	170	170	170
Rated short-circuit breaking current, up to	[kA $_{(rms)}$]	40	40	40	40	50	40	63	63	63	63
Rated short-circuit making current, up to	[kA $_{(peak)}$]	108	108	108	108	135	108	170	170	170	170
Temperature range	[°C]	– 30 or – 40 ... + 40 or + 50									
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									50
Type of operating mechanism		Stored-energy spring mechanism									
Control voltage	[V, DC]	48 ... 250									
Motor voltage	[V, DC] [V, AC]	48/60/110/125/220/250 120 ... 240, 50 Hz; 120 ... 280, 60 Hz									
Flashover distance phase-to-earth	[mm]	700	1,250	1,250	1,500	1,900	2,200	3,400	3,400	3,800	5,850
Flashover distance across open circuit breaker	[mm]	1,200	1,200	1,200	1,400	1,900	2,200	3,200	3,200	3,800	7,600
Min. creepage distance phase-to-earth	[mm]	2,248	3,625	3,625	4,250	6,125	7,626	10,375	10,375	14,450	20,000
Min. creepage distance across open circuit breaker	[mm]	3,625	3,625	3,625	4,250	6,125	8,575	10,500	10,500	15,126	30,352
Dimensions height	[mm]	3,810	4,360	4,360	4,810	6,050	6,870	6,200	6,200	7,350	9,740
Dimensions width	[mm]	3,180	3,880	3,880	4,180	6,640	8,235	8,847	9,847	13,050	19,400
Dimensions depth	[mm]	660	660	660	660	880	880	4,380	4,380	5,050	10,470
Phase spacing (min.)	[mm]	1,350	1,700	1,700	1,850	2,800	3,600	4,000	4,500	6,000	9,000
Circuit breaker mass	[kg]	1,350	1,500	1,500	1,680	2,940	3,340	5,370	5,370	7,160	16,200
Maintenance after		25 years									
Values in accordance with IEC; other values available on request											

Table 4.1-1: **Technical data of circuit breakers 3AP1, 3AP2 and 3AP4**

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

Circuit breakers in dead-tank design
For certain substation designs, dead-tank circuit breakers might be required instead of the standard live-tank circuit breakers. The main feature of dead-tank technology is that the interrupter unit is accommodated in an earthed metal housing. The dead-tank circuit breaker offers particular advantages if the protection design requires the use of several current transformers per pole assembly. For this purpose, Siemens can offer dead-tank circuit breaker types (fig. 4.1-10, fig. 4.1-11).

Main features at a glance:
- Reliable opening and closing
  - Proven contact and self-compression arc-quenching system
  - Consistent quenching performance with rated and short-circuit currents – even after many switching operations
  - Similar uncomplicated design for all voltage levels
- High-performance, reliable operating mechanisms
  - Easy-to-actuate spring operating mechanisms
  - Low maintenance, economical and long service life
- Economy
  - Perfect finish
  - Simplified, quick installation process
  - Long maintenance intervals
  - High number of operating cycles
  - Long service life.
- Individual service
  - Close proximity to the customer
  - Order-specific documentation
  - Solutions tailored to specific problems
  - After-sales service available promptly worldwide
- The right qualifications
  - Expertise in all power supply matters
  - More than 40 years of experience with SF_6-insulated circuit breakers
  - A quality system certified to ISO 9001, covering development, manufacture, sales, installation and after-sales service
  - Our dead tank circuit breakers are developed according to the latest version of IEC 62271-1, IEC 62271-100 and ANSI C37.04, ANSI C37.06, C37.09
  - Test laboratories accredited to EN 45001 and PEHLA/STL.

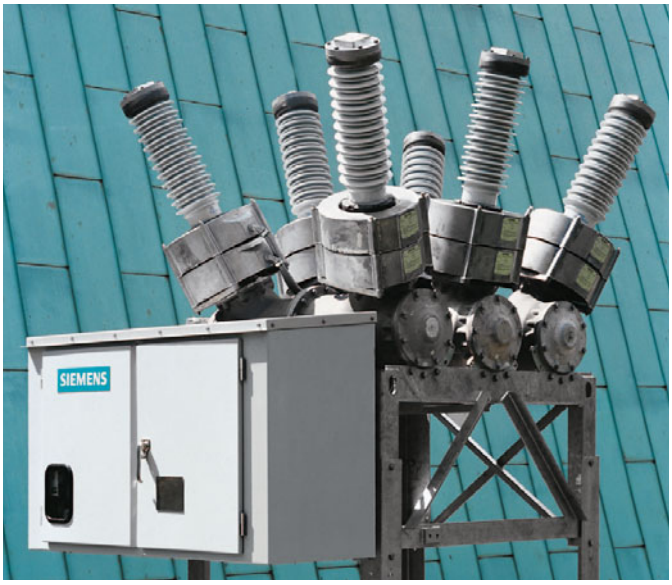


Fig. 4.1-10: **SPS2 circuit breaker 72.5 kV**

Fig. 4.1-11: **3AP1 dead-tank circuit breaker 145 kV**

Fig. 4.1-12: **SPS2/3AP1 dead-tank circuit breaker 362 kV (two-cycles)**

Dead-tank circuit breaker

Type SPS2 and 3AP DT
The type SPS2 power circuit breakers (table 4.1-2) are used for the US and ANSI markets, and the 3AP DT breaker types are offered in IEC markets. Both types are designed as general, definite-purpose circuit breakers for use at maximum rated voltages of 72.5 kV up to 550 kV.

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

The connection to the overhead lines and busbars is realized by 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. 4.1-13, fig. 4.1-14) 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.

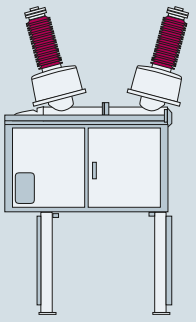
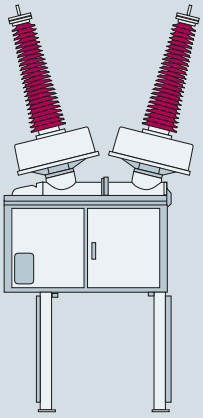
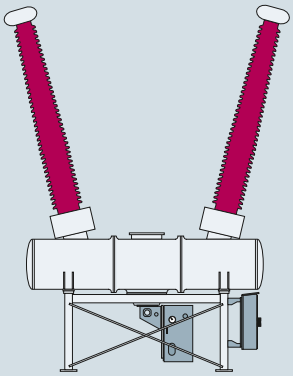
Technical data							
Type		**3AP1 DT / SPS2**					**3AP2/3 DT / SPS2**
Rated voltage	[kV]	72.5	123	145	245	362	550
Rated power-frequency withstand voltage	[kV]	140/160	230/260	275/310	460	520	800/860
Rated lighting impulse withstand voltage	[kV]	325/350	550	650	1,050	1,380	1,865/1,800
Rated switching 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**

Operating mechanism
The mechanically and electrically trip-free spring mechanism type FA is used on type SPS2 and 3AP1/2 DT circuit breakers. The closing and opening springs are loaded for "O-C-O" operations.

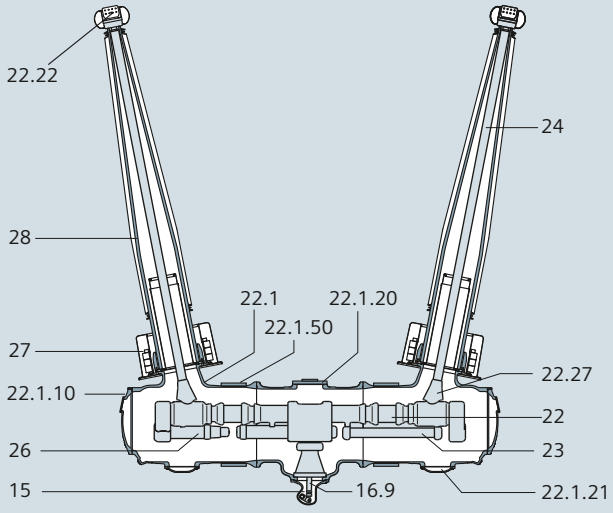
A weatherproofed control cubicle (degree of protection IP55) has a large door, sealed with rubber gaskets, for easy access during inspection and maintenance. Condensation is prevented by heaters that maintain a difference in inside/outside temperature, and by ventilation.

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

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

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

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



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

Fig. 4.1-13: **Sectional view of a 3AP2/3-DT circuit breaker pole**

Fig. 4.1-14: **3AP2 DT 550 kV**

For further information:
Fax: +49 30 386-20231
Email: support.energy@siemens.com
or circuit-breaker@siemens.com

4.1.4. The 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

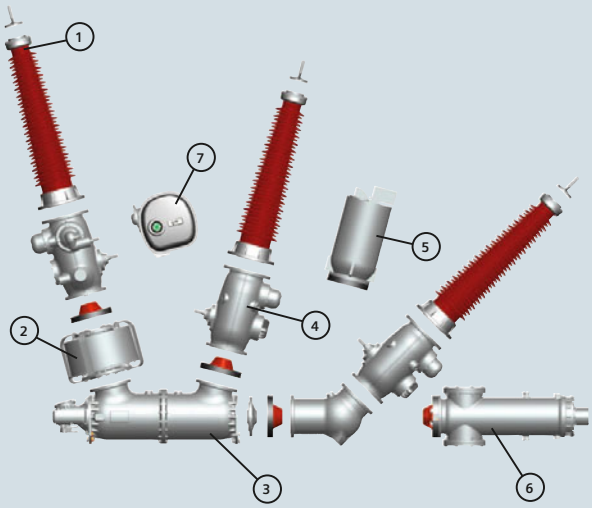
Based on the well-proven modular design, the core components of the main units are based on the same technology that is used in the well-established high-voltage circuit breakers, disconnectors and GIS product family of Siemens.

These components are:

- 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 (fig. 4.1-15 and fig. 4.1-16).

This allows for providing flexible solutions according to different substation configurations:

- Circuit breaker with single-pole or three-pole operating mechanism
- Disconnector, earthing switch, high-speed earthing switch
- Current transformer, voltage transformer and voltage detecting system
- Cable connections possible at various positions
- Bushings available as porcelain or composite insulators
- Additional separations of gas compartment, with 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 (fig. 4.1-17).



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. 4.1-15: **Possible components for the 3AP1 DTC**

Fig. 4.1-16: **3AP1 DTC 145 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. 4.1-18).

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.

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

Also other international testing laboratories (KEMA, CESI) certify our circuit breakers' high quality standards (fig. 4.1-19, table 4.1-3).

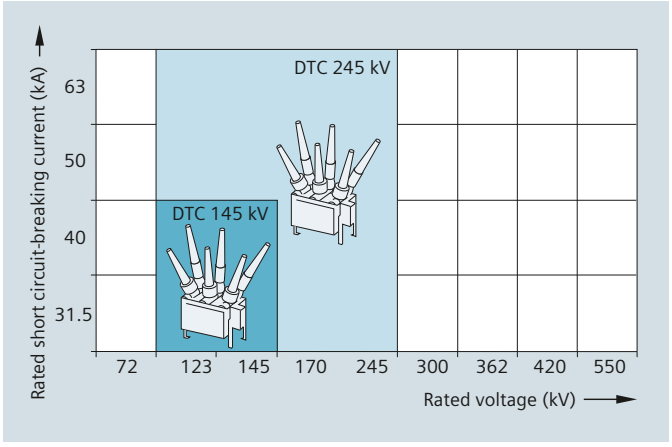


Fig. 4.1-18: **DTC product range, 1-pole or 3-pole operation**

Fig. 4.1-19: **3AP1 DTC 145 kV with voltage transformer and cable connection**

Fig. 4.1-17: **3AP1 DTC 245 kV**

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. 4.1-20, fig. 4.1-21).

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. The current status of the DCB can also be controlled electrically and is shown by well visible position indicators.

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

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

Combining the strengths of our well proven product portfolio, we can provide a new type of device which fulfills the system operator's needs for highest reliability and safety, while saving space and costs at the same time (table 4.1-4).

Fig. 4.1-20: **3AP1 DCB 145 kV**

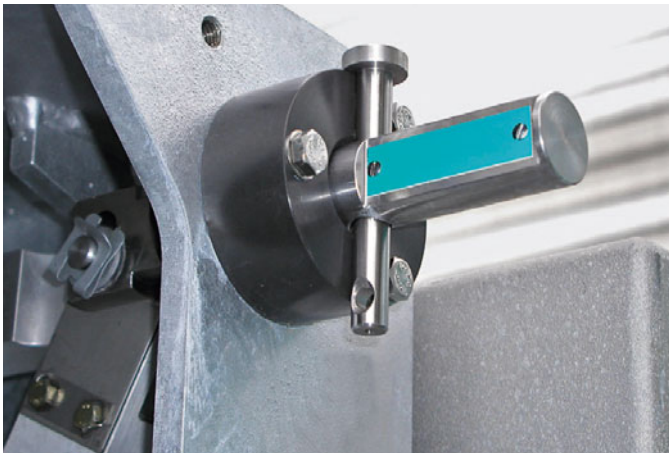


Fig. 4.1-21: **3AP2 DCB interlock indicator**

		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 *)	[°C]	–40 ... +40	–40 ... +40
Insulating medium		SF_6	SF_6
Classification CB		M2, C2	M2, C2
Classification DS		M2	M2
Insulators		composite **)	composite
Attached earthing switch (optional)		yes	no
Type-tested according to		IEC 62271-108	

*) Other ambient temperature values on request **) Or porcelain

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

Highlights and characteristics

- Maximum reliability by applying well-proven and established components from Siemens circuit breakers and Ruhrtal earthing switches
- Maximum availability due to longer maintenance intervals
- Economical, space-saving solution by combining the circuit breaker and the disconnector in one device
- Minimized costs for transportation, maintenance, installation and commissioning as well as civil works (foundation, steel, cable ducts, etc.)
- Compact and intelligent interlocking and position indicating device
- Optionally available without earthing switch
- Porcelain or composite insulators obtainable (fig. 4.1-20).

Fig. 4.1-22: **3AP2 DCB 420 kV**

4.2 High Voltage Disconnectors

4.2.1 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).

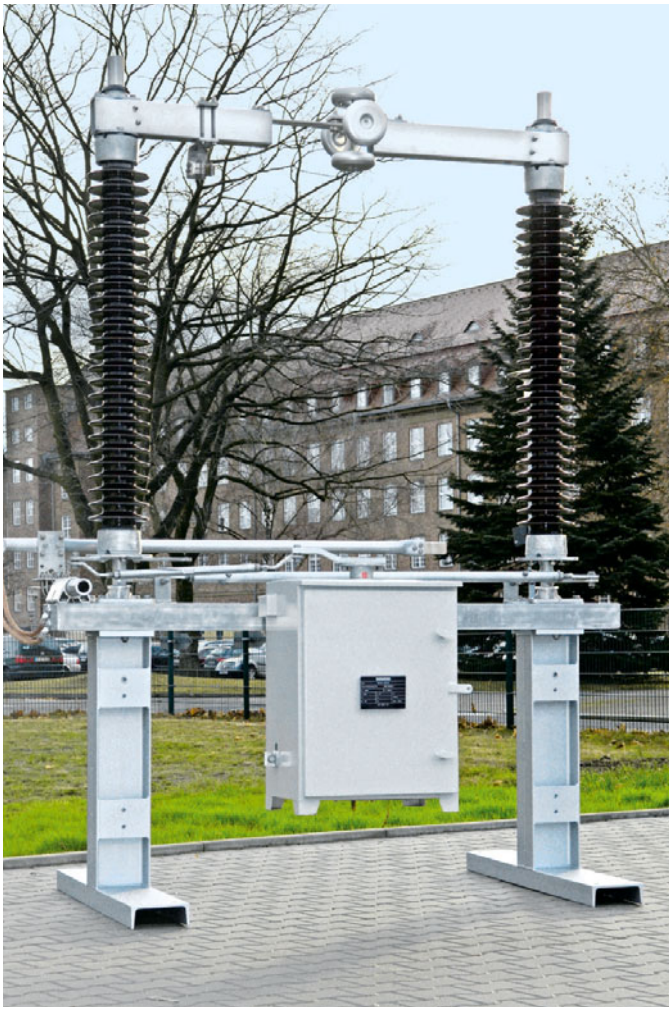


Fig. 4.2-1: **Center-break disconnector**

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

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

The main components of a pantograph disconnector are (fig. 4.2-3):
- Scissor arms (1)
- Bearing frame (2)
- Support insulator (3)
- Rotating insulator (4)
- Motor operating mechanism (5).

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

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

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

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

Vertical-break disconnectors
The current path of the vertical-break disconnector opens vertically and requires a minimum phase distance (fig. 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 movable part of the current path is one single subassembly which is pre-adjusted and routine-tested at the factory. This allows for easy and quick installation and commissioning on site.

Fig. 4.2-3: **Components of the pantograph disconnector**
1. *Scissor arms*
2. *Bearing frame*
3. *Support insulator*
4. *Rotating insulator*
5. *Motor operating mechanism*

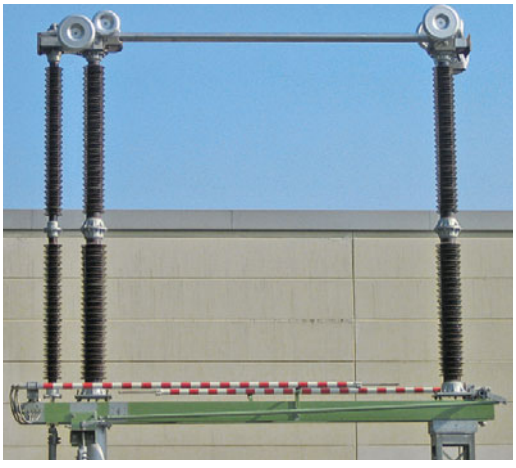


Fig. 4.2-4: **Vertical-break disconnector**

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).

Earthing switches

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

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

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.

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

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

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.

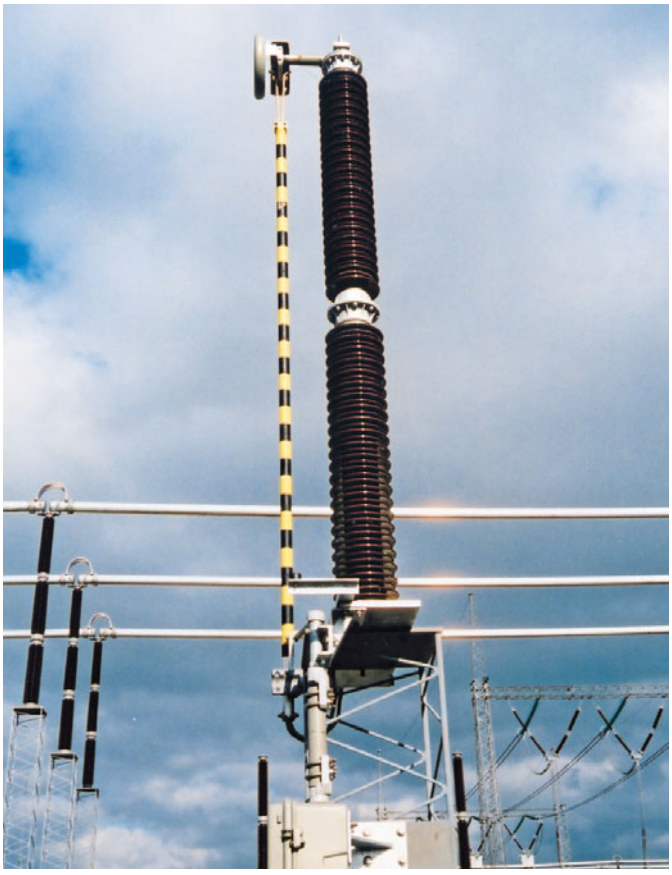


Fig. 4.2-7: **Free-standing earthing switch**

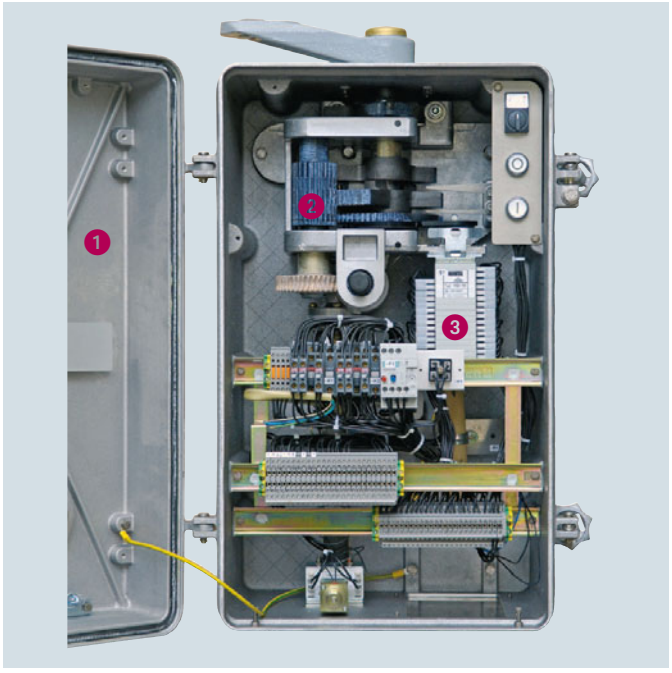


Fig. 4.2-8: **Motor operating mechanism: Cast-aluminum housing with door (1) – degree of protection IP55; gear unit (2) with motor; electrical equipment with auxiliary switch (3)**

4

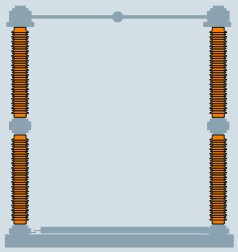
Technical data										
										
Design		Center break								
Rated voltage		72.5	123	145	170	245	300	362	420	550
Rated power-frequency withstand voltage 50 Hz/1 min										
To earth and between phases Across the isolating distance	[kV] [kV]	140 160	230 265	275 315	325 375	460 530	380 435	450 520	520 610	620 800
Rated lightning impulse withstand voltage 1.2/50 µs										
To earth and between phases Across the isolating distance	[kV] [kV]	325 375	550 630	650 750	750 860	1,050 1,200	1,050 1,050 (+170)	1,175 1,175 (+205)	1,425 1,425 (+240)	1,550 1,550 (+315)
Rated switching impulse withstand voltage 250/2,500 µs										
To earth and between phases Across the isolating distance	[kV] [kV]	– –	– –	– –	– –	– –	850 700 (+245)	950 800 (+295)	1,050 900 (+345)	1,175 900 (+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]	–50/+50								
Operating mechanism type		Motor operation/Manual operation								
Control voltage	[V, DC] [V, AC]	60/110/125/220 220...230, 1~, 50/60 Hz								
Motor voltage	[V, DC] [V, AC]	60/110/125/220 110/125/220, 1~, 50/60 Hz 220/380/415, 3~, 50/60 Hz								
Maintenance		25 years								

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

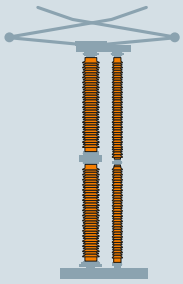
Technical data									
									
Design		Pantograph							
Rated voltage		123	145	170	245	300	362	420	550
Rated power-frequency withstand voltage 50 Hz/1 min									
To earth and between phases Across the isolating distance	[kV] [kV]	230 265	275 315	325 375	460 530	380 435	450 520	520 610	620 800
Rated lightning impulse withstand voltage 1.2/50 µs									
To earth and between phases Across the isolating distance	[kV] [kV]	550 630	650 750	750 860	1,050 1,200	1,050 1,050 (+170)	1,175 1,175 (+205)	1,425 1,425 (+240)	1,550 1,550 (+315)
Rated switching impulse withstand voltage 250/2,500 µs									
To earth and between phases Across the isolating distance	[kV] [kV]	– –	– –	– –	– –	850 700 (+245)	950 800 (+295)	1,050 900 (+345)	1,175 900 (+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]	–50/+50							
Operating mechanism type		Motor operation/Manual operation							
Control voltage	[V, DC]	60/110/125/220							
	[V, AC]	220...230, 1~, 50/60 Hz							
Motor voltage	[V, DC] [V, AC]	60/110/125/220 110/125/220, 1~, 50/60 Hz 220/380/415, 3~, 50/60 Hz							
Maintenance		25 years							

Table 4.2-2: **Pantograph disconnector**

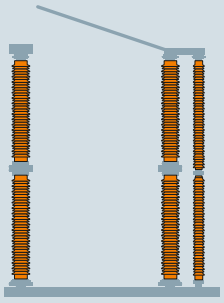
Technical data									
									
Design		Vertical break							
Rated voltage		123	145	170	245	300	362	420	550
Rated power-frequency withstand voltage 50 Hz/1 min									
To earth and between phases Across the isolating distance	[kV] [kV]	230 265	275 315	325 375	460 530	380 435	450 520	520 610	620 800
Rated lightning impulse withstand voltage 1.2/50 µs									
To earth and between phases Across the isolating distance	[kV] [kV]	550 630	650 750	750 860	1,050 1,200	1,050 1,050 (+170)	1,175 1,175 (+205)	1,425 1,425 (+240)	1,550 1,550 (+315)
Rated switching impulse withstand voltage 250/2,500 µs									
To earth and between phases Across the isolating distance	[kV] [kV]	– –	– –	– –	– –	850 700 (+245)	950 800 (+295)	1,050 900 (+345)	1,175 900 (+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]	–50/+50							
Operating mechanism type		Motor operation/Manual operation							
Control voltage	[V, DC] [V, AC]	60/110/125/220 220...230, 1~, 50/60 Hz							
Motor voltage	[V, DC] [V, AC]	60/110/125/220 110/125/230, 1~, 50/60 Hz 220/380/415, 3~, 50/60 Hz							
Maintenance		25 years							

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

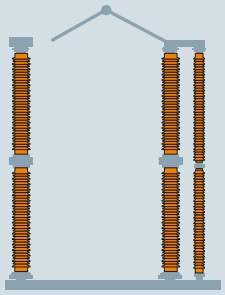
Technical data			
			
Design		Knee-type	
Rated voltage		123	550
Rated power-frequency withstand voltage 50 Hz/1 min			
To earth and between phases Across the isolating distance	[kV] [kV]	230 265	620 800
Rated lightning impulse withstand voltage 1.2/50 µs			
To earth and between phases Across the isolating distance	[kV] [kV]	550 630	1,550 1,550 (+315)
Rated switching impulse withstand voltage 250/2,500 µs			
To earth and between phases Across the isolating distance	[kV] [kV]	– –	1,175 900 (+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]	–50/+50	
Operating mechanism type		Motor operation/Manual operation	
Control voltage	[V, DC] [V, AC]	60/110/125/220 220...230, 1~, 50/60 Hz	
Motor voltage	[V, DC] [V, AC]	60/110/125/220 110/125/230, 1~, 50/60 Hz 220/380/415, 3~, 50/60 Hz	
Maintenance		25 years	

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

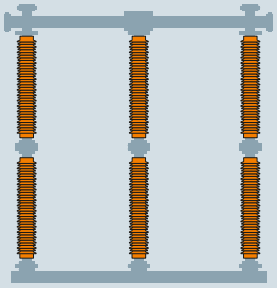
Technical data									
									
Design		Double-side break							
Rated voltage		123	145	170	245	300	420	550	800
Rated power-frequency withstand voltage 50 Hz/1 min									
To earth and between phases Across the isolating distance	[kV] [kV]	230 265	275 315	325 375	460 530	380 435	520 610	450 520	830 1,150
Rated lightning impulse withstand voltage 1.2/50 µs									
To earth and between phases Across the isolating distance	[kV] [kV]	550 630	650 750	750 860	1,050 120	1,050 1,050 (+170)	1,425 1,425 (+240)	1,550 1,550 (+315)	2,100 2,100 (+455)
Rated switching impulse withstand voltage 250/2,500 µs									
To earth and between phases Across the isolating distance	[kV] [kV]	– –	– –	– –	– –	850 700 (+245)	1,050 900 (+345)	1,175 900 (+450)	1,550 1,200 (+650)
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]	–50/+50							
Operating mechanism type		Motor operation/Manual operation							
Control voltage	[V, DC] [V, AC]	60/110/125/220 220...230, 1~, 50/60 Hz							
Motor voltage	[V, DC] [V, AC]	60/110/125/220 110/125/230, 1~, 50/60 Hz 220/380/415, 3~, 50/60 Hz							
Maintenance		25 years							

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

For further information, please contact:
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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.

Disconnectors
Disconnectors are used for no-load closing and opening operations. Their function is to "isolate" downstream equipment so they can be worked on.

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

Earthing switches
Earthing switches earth isolated circuits. Make-proof earthing switches earth circuits without danger, even if voltage is present, that is, also in the event that the circuit to be earthed was accidentally not isolated.

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.

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	■	■	■	–	■	–	■
Disconnector	■	–	■	■	–	–	–
Earthing switch	■	–	–	■	–	–	–
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 4.3-3). 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.

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
	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
	2,500 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								
63 kA	1,250 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								
72 kA	3,150 A								
	4,000 A								
	5,000 A								
	6,300 A								

Table 4.3-3: **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	
12.5 kA	800 A			SION					
	1,250 A			SION					
13.1 kA	800 A								
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
	2,000 A	3AH4	3AH47				3AH47	3AH3	3AH4
	2,500 A						3AH47	3AH3	3AH4
	3,150 A							3AH3	3AH4
	4,000 A							3AH3	3AH4
40 kA	1,250 A	3AH4						3AH3	
	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								
	2,500 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								
	2,500 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				

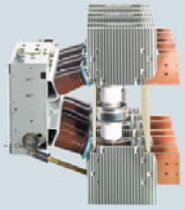
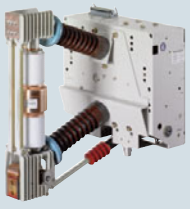
Portfolio of circuit-breakers		
SION	The standard circuit-breaker for variable application: ■ Available as standard circuit-breaker or complete slide-in module ■ Up to 30,000 operating cycles ■ Retrofit solution possible	
3AH5	The standard circuit-breaker for small switching capacities: ■ Up to 10,000 operating cycles.	
3AH3	The circuit-breaker for high switching capacities: ■ Rated short-circuit breaking currents of up to 63 kA ■ Rated normal currents of up to 4,000 A ■ Up to 10,000 operating cycles	
3AH4	The circuit-breaker for a high number of operating cycles, i.e. for arc furnace switching: ■ Up to 120,000 operating cycles ■ Rated normal currents of up to 4,000 A ■ Rated short-circuit breaking currents of up to 40 kA	
3AH37/3AH38	The circuit-breaker for high-current and generator applications ■ Rated short-circuit breaking currents of up to 72 kA (according to IEEE C37.013) ■ Rated normal currents up to 6,300 A ■ Up to 10,000 operating cycles ■ 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 ■ System frequency 16⅔, 25, 50 or 60 Hz ■ 1-pole or 2-pole ■ Up to 60,000 operating cycles	
3AK7	The compact, small circuit-breaker for high-current and generator applications ■ Rated short-circuit breaking currents of up to 40 kA (according to IEEE C37.013) ■ Rated normal currents up to 4,000 A	

Table 4.3-2: **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.

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

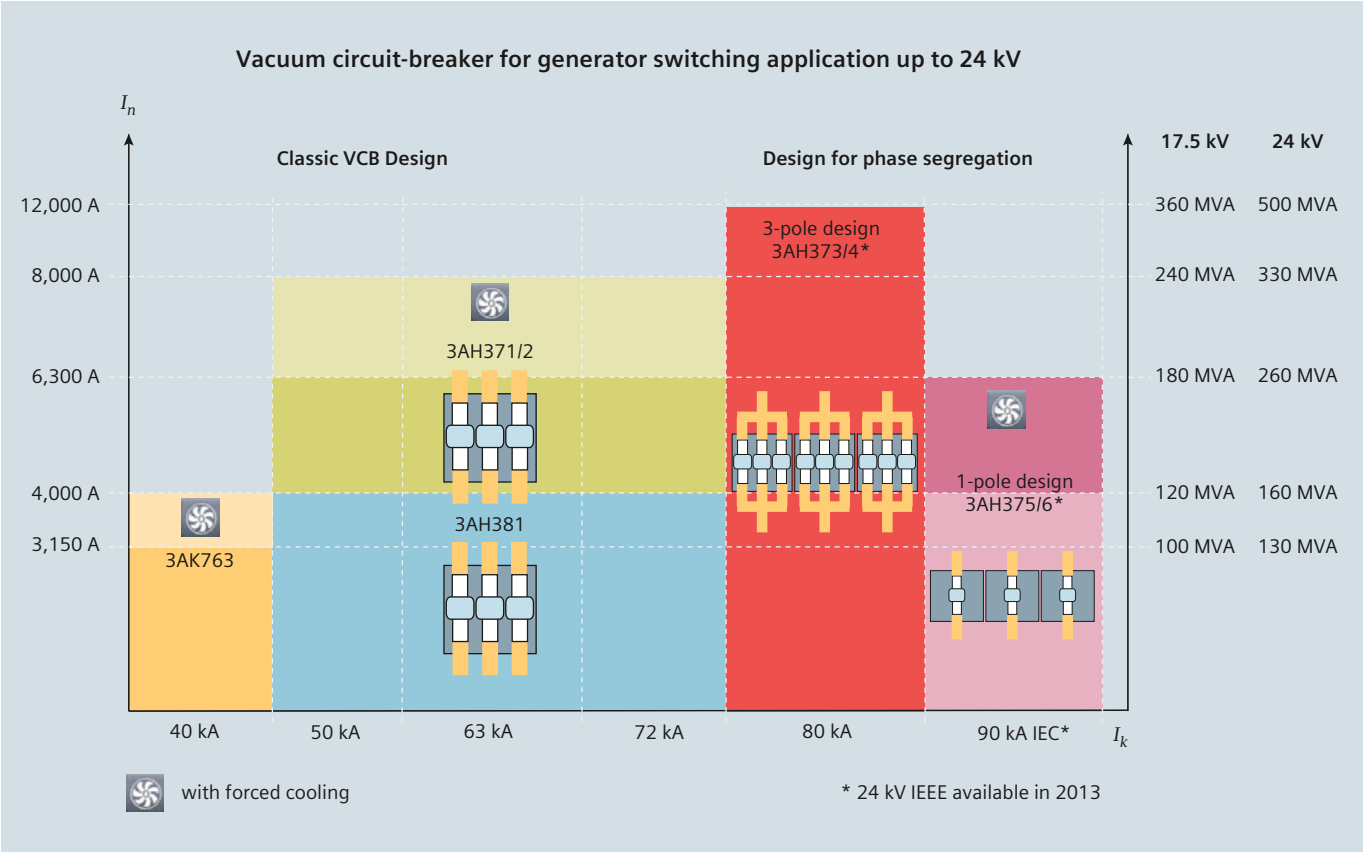


Fig. 4.3-2: **Vacuum circuit-breaker for generator switching application up to 24 kV**

4.3.5 Outdoor Vacuum Circuit-Breakers

Outdoor vacuum circuit-breakers perform the same functions as indoor circuit-breakers (table 4.3-3) 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. 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.

For switchover tasks in open ring networks (so called loop automation), reclosers with voltage sensors on both sides (source and load side) are available. In the open state, they are able to detect voltage on either side of the recloser individually. 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	400 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-tipple
Standards	ANSI C37.60; IEC 62271-111; IEC 60255; IEC 62271-100

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

4.3.7 Vacuum Contactors

3TL vacuum contactors (fig. 4.3-8 to fig. 4.3-10) 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 4.3-6.

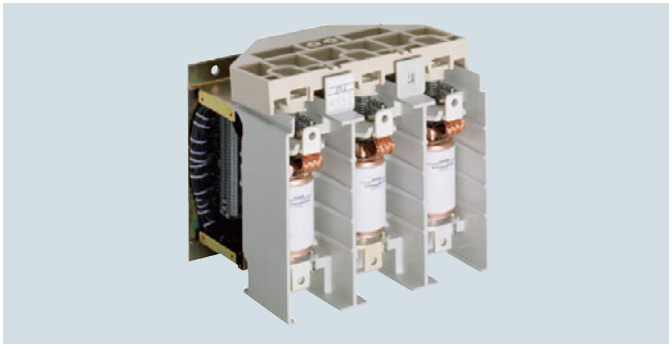


Fig. 4.3-8: **Vacuum contactor 3TL6**

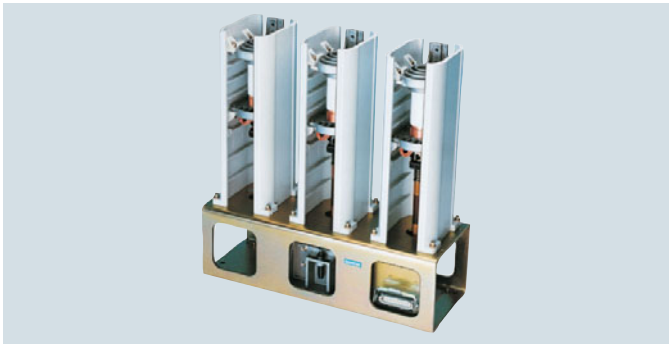


Fig. 4.3-9: **Vacuum contactor 3TL71**

Fig. 4.3-10: **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 4.3-6: **Portfolio of vacuum contactors**

4.3.8 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 4.3-7).

Construction
The contactor-fuse combination (fig. 4.3-11, fig. 4.3-12) 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).

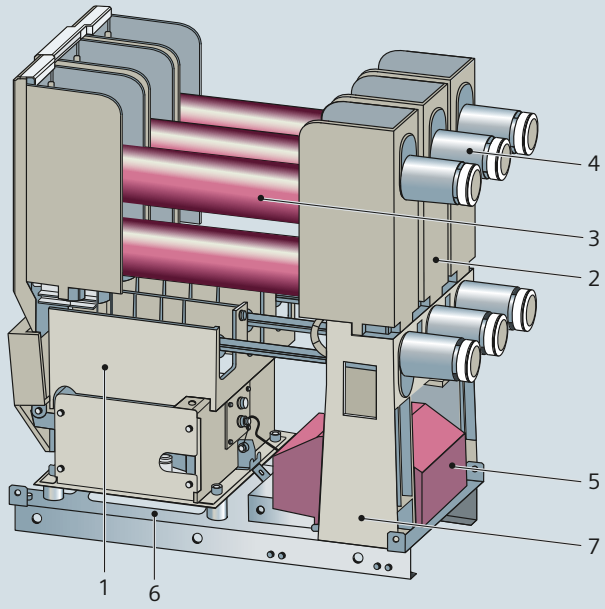
In normal operation, the vacuum contactor (1) breaks the corresponding currents reliably. To do this, the vacuum switching technology, proven for nearly 40 years, serves as arc-quenching principle by using vacuum interrupters. The vacuum interrupters are operated by the magnet system through an integral 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. 4.3-11: **Construction of the contactor-fuse combination 3TL6**

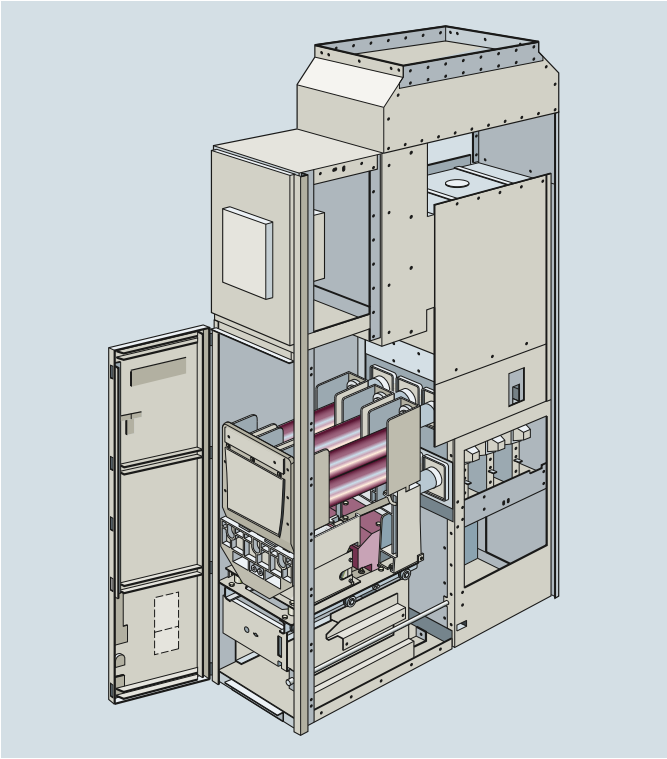


Fig. 4.3-12: **Installation of the contactor-fuse combination in the contactor panel**

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 in open construction, with degree of protection IP00, according to IEC 60470. They conform to the standards for high-voltage alternating current contactors above 1 kV to 12 kV:

IEC 62271-1	DIN EN 62271-1
IEC 60470 – Issue 2000	IDIN EN 60470
IEC 62271-1 – 106 CDV 01'2010	
IEC 60529	IDIN EN 60529
IEC 60721	DIN EN 60721
IEC 60282-1	IDIN EN 60282-1
Test voltage according to D/L 404, 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.

Type	3TL62	3TL63	3TL66
Rated voltage	7.2 kV	7.2 kV	12 kV
Standard	IEC 60470	IEC 60470/ High dielectric stength	IEC 60470
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 contractor (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 4.3-7: **Portfolio of contactor-fuse combination 3TL6**

4.3.9 Disconnectors and 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 (fig. 4.3-14). For this reason, stringent requirements are placed on the reliability, visibility and dielectric strength of the isolating distance.

The different disconnectors and their properties are shown in table 4.3-9.

Switch-disconnectors (table 4.3-9, fig. 4.3-13) 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.

Rated short-time withstand current	Rated normal current	Rated voltage		
		12 kV	24 kV	36 kV
20 kA	630 A	3DC	3DC/3DA	3DC
31.5 kA	630 A	3DC		
	1,250 A	3DC	3DC/3DA	3DC
	1,600 A	3DC	3DC/3DA	3DA
	2,500 A	3DC	3DC	3DC
	3,000 A			3DC
50 kA	1,250 A	3DC		
	1,600 A	3DC		
	2,500 A	3DC		
	3,000 A	3DC		
63 kA	1,250 A	3DC		
	1,600 A	3DC		
	2,500 A	3DC		
	3,000 A	3DC		

Table 4.3-8: **Portfolio of disconnectors**

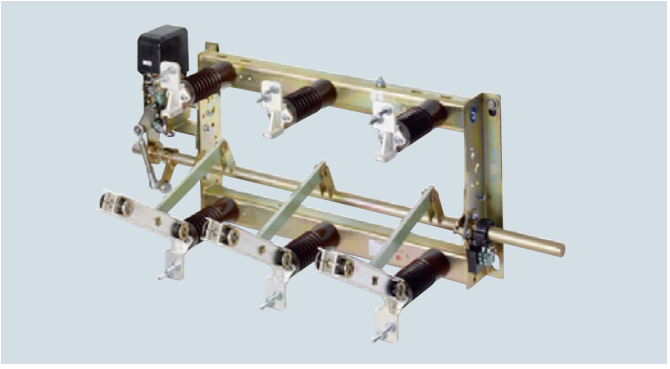


Fig. 4.3-13: **Disconnector in disconnected position**

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 4.3-9: **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. 4.3-15. During the opening movement, the contact blade, (2) in fig. 4.3-15, is separated first. Because the auxiliary blade, (3) in fig. 4.3-15, 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.

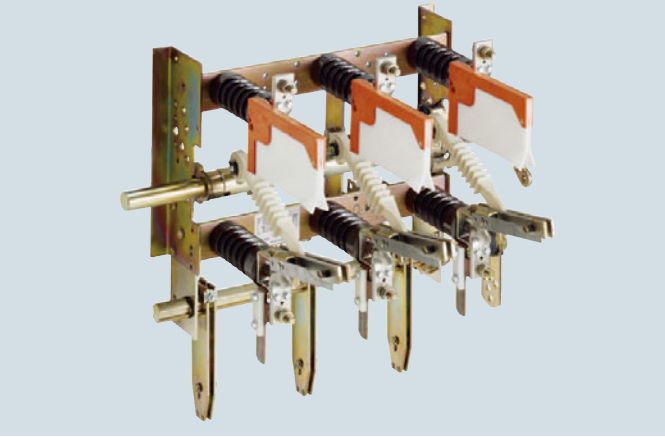


Fig. 4.3-14: **Switch-disconnector**

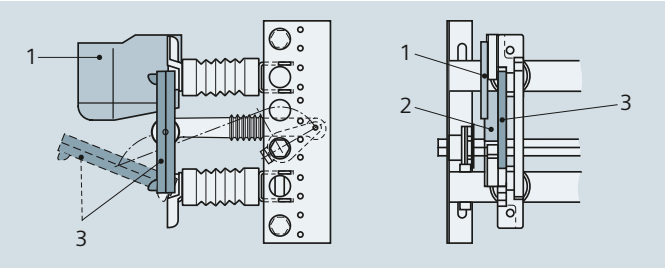


Fig. 4.3-15: **3CJ2 switch-disconnector: (1) flat hard-gas arcing chamber, (2) contact blade, (3) auxiliary blade**

4.3.10 Earthing Switches

Earthing switches (table 4.3-10) are used in order to earth and short-circuit switchgear parts, cables and overhead lines. They make it possible to work without danger on the previously earthed operational equipment. Their design is similar to that of vertical-break disconnectors. They are often mounted on disconnectors or switch-disconnectors and then interlocked with these devices in order to prevent earthing on applied voltages. If earthing switches with making capacity (make-proof earthing switches) are used instead of the normal earthing switches, earthing and short-circuiting presents no danger even if the circuit was accidentally not isolated before (fig. 4.3-16, fig. 4.3-17).

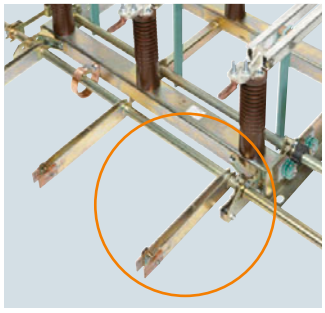


Fig. 4.3-16: **Earthing switch in OPEN position with closed disconnector**

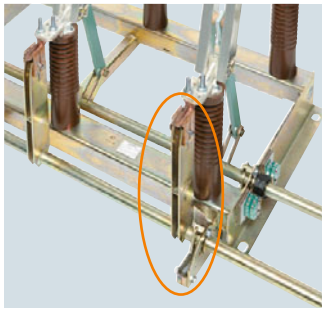


Fig. 4.3-17: **Earthing switch in CLOSED position with open disconnector**

Earthing switches		Rated voltage		
Rated short-time withstand current	Rated peak withstand current	12 kV	24 kV	36 kV
20 kA	50 kA	3DE	3DE/3DD	3DE
31.5 kA	80 kA	3DE	3DE/3DD	3DE
50 kA	125 kA	3DE		
63 kA	160 kA	3DE		

Make-proof earthing switches			Rated voltage			
Rated lightning impulse withstand voltage	Rated power-frequency withstand voltage	Rated short-circuit making current	7.2 kV	12 kV	15 kV	24 kV
60 kV	20 kV	63 kA	3CX50			
60 kV	28 kV	50 kA		3CX50		
75 kV	28 kV	50 kA		3CX50		
95 kV	38 kV	52 kA			3CX50	
95 kV	50 kV	40 kA				3CX50
125 kV	50 kV	40 kA				3CX50

Table 4.3-10: **Portfolio of earthing switches**

4.4 Low-Voltage Devices

4.4.1 Requirements on the Switchgear 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 x 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 $(n–1)\ x\ I_{k\ max}$ 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}). 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
  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. However for cost reasons, 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.

Fig. 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
	TM	–	Up to 630 A	Yes	Yes	Yes	
Tripping function	LI	Yes	Yes	Yes*	Yes*	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 *)	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 specifications
	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

* According to the fuse characteristic

Fig. 4.4-1: **Overview of the protective devices; *) with ETU: No limitation / with 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 that are used in the main power distribution circuits in commercial buildings and in industry.

Note:

All figures apply for low-voltage power systems or distribution boards in IEC applications. Different regulations and criteria apply for 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
(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-breaker protected switchgear (circuit-breaker)		
ACB	**Air circuit-breaker** – Air circuit-breaker – Non-current-limiting circuit-breaker – Current-zero cut-off circuit-breaker	
MCCB	**Molded-case circuit-breaker** – Molded-case circuit-breaker – Current-limiting circuit-breaker	
MCB	**Miniature circuit-breaker** – Miniature circuit-breaker	
MSP	**Motor starter protector**	
MPCB	**Motor protector circuit-breaker** – Circuit-breaker for motor protection	

Fig. 4.4-2: **Overview of circuit-breaker protected switchgear**

Fuse-protected switchgear (fuse switch-disconnector/switch-disconnector)		
SD	Switch-disconnector 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 (= switch-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 (= switch-disconnector without fuse)		

Fig. 4.4-3: **Overview of fuse-protected switchgear**

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

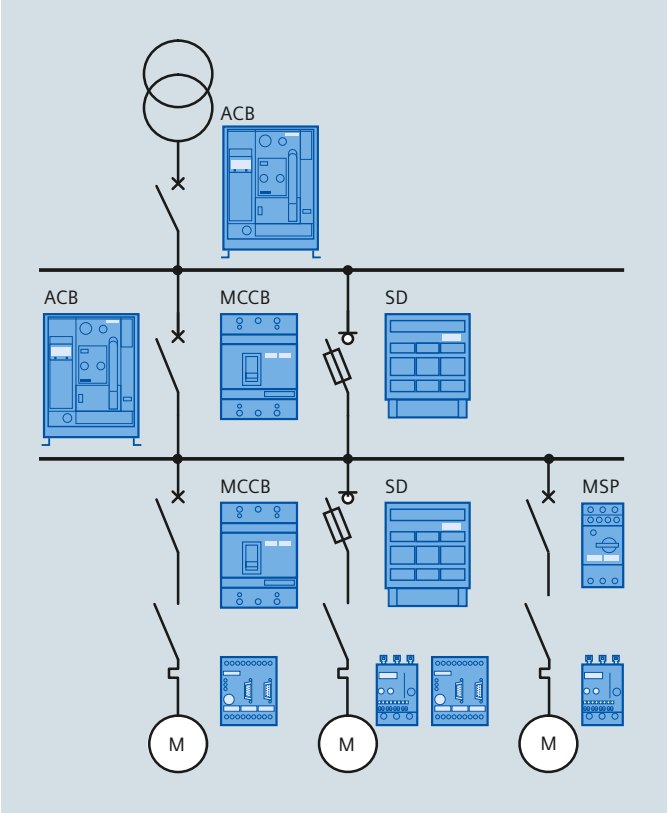
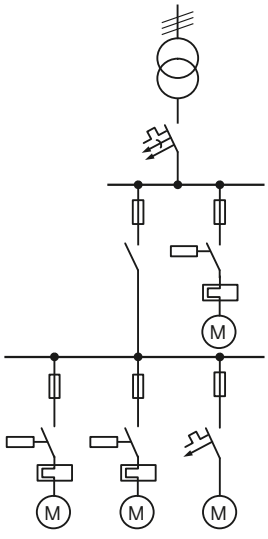


Fig. 4.4-4: **Core functions of the protective devices in the individual circuit types**

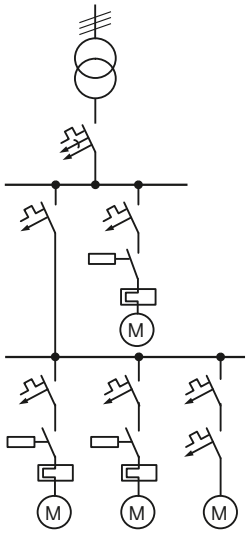
Criteria for device selection
A protective device is always part of a circuit and must satisfy the corresponding requirements (section 3.3.2 "Dimensioning of Power Distribution Systems"). The most important selection criteria are shown in the following.

Main selection criteria
Fig. 4.4-5 shows the seven most important selection criteria that must be at least taken into account for the device selection.



Fuse-protected

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



Circuit-breaker protected

Fig. 4.4-5: **Main selection criteria**

4.4.3 Busbar Trunking Systems, Cables and Wires

Busbar trunking systems

When a planning concept for power supply is developed, it is not only imperative to observe standards and regulations, it is also important to discuss and clarify economic and technical interrelations. The rating and selection of electric equipment, such as distribution boards and transformers, must be performed in such a way that an optimum result for the power system as whole is kept in mind rather than focusing on individual components.

All components must be sufficiently rated to withstand normal operating conditions as well as fault conditions. Further important aspects to be considered for the preparation of an energy concept are:

- Type, use and shape of the building (e.g., high-rise building, low-rise building, number of story levels)
- Load centers and possible power transmission routes and locations for transformers and main distribution boards
- Building-related connection details according to specific area loads that correspond to the type of use of the building
- Statutory provisions and conditions imposed by building authorities
- Requirements by the power supply system operator.

The result will never be a single solution. Several options have to be assessed in terms of their technical and economic impacts. The following requirements are of central importance:

- Easy and transparent planning
- High service life
- High availability
- Low fire load
- Flexible adaptation to changes in the building.

Most applications suggest the use of suitable busbar trunking systems to meet these requirements. For this reason, engineering companies increasingly prefer busbar trunking to cable installation for power transmission and distribution.
Siemens offers busbar trunking systems ranging from 25 A to 6,300 A:

- The CD-K busbar system from 25 to 40 A for the supply of light fixtures and micro-consumers
- The BD01 busbar system from 40 to 160 A for supplying workshops with tap-offs up to 63 A
- The BD2 busbar system from 160 to 1,250 A for supplying medium-size consumers in buildings and industry
- The ventilated LD system from 1,100 to 5,000 A for power transmission and power distribution an production sites with a high energy demand
- The LX sandwich system from 800 to 5,000 A (6,300 A on request), mainly for power transmission insensitive to position in buildings with the requirements of degree of protection IP54 and special conductor configurations such as double N or insulated PE
- The encapsulated LR system from 400 to 6,150 A for power transmission for extreme environmental conditions (IP68).

For the configuration of a busbar system, the following points are to be noted:
Calculation/dimensioning:

- Electrical parameters, such as rated current, voltage, given voltage drop and short-circuit strength at place of installation.

Technical parameters of the busbar systems:

- The conductor configuration depends on the mains system according to type of earth connection
- Reduction factors, e.g., for ambient air temperature, type of installation, (vertical) busbar position (horizontal on edge) and degree of protection
- Copper is required as conductor material; otherwise, aluminum has advantages such as weight, price, etc.
- How is the system supply to be carried out: as a TTA solution directly from the distribution board or by means of cables at the end or center of the busbar
- Max. cable connection options to infeed and tap-off units
- Power and size of the tap-off units including installation conditions
- Number of tapping points
- Use of bus systems possible
- Influence of a magnetic field (hospitals, broadcasting studios)
- Environmental conditions, especially ambient air temperature (e.g., where there are fire compartments in each floor of a vertical shaft).

Structural parameters and boundary conditions:
- Phase response (changes of direction in the busbar routing possible, differences in height, etc.)
- Functional sections (e.g., various environmental conditions or various uses)
- Check use in sprinkler-protected building sections
- Fire areas (provision of fire barriers –> what structural (e.g., type of walls) and fire fighting (local provisions) boundary conditions are there?
- Fire protection classes of the fire barriers (S90 and S120)
- Functional endurance classes (E60, E90, E120) and certifications of the busbar systems (observe relevant deratings)
- Fire loads/halogens (prescribed fire loads in certain functional sections, e.g., fire escape routes, must not be exceeded).

Fixing of the busbar systems to the structure:
- Maximum clearance from fixings taking into consideration location, weight of system and additional loads such as tap-off units, lighting, etc.
- Agreement on possible means of fixing with structural analyst
- Use of tested fixing accessories with busbar systems with functional endurance
- Observe derating for type of installation
- Dimensions of the distribution board, system supplies and tap-off units:
- Installation clearance from ceiling, wall and parallel systems for the purpose of heat dissipation and installation options
- Crossing with other installations (water, gas pipes, etc.)
- Swing angle for installing and operating the tap-off units
- Minimum dimensions for changes of direction in the busbar routing, fire protection compartmentalization, wall cutouts
- Space requirement for distribution connection
- Cutout planning (sizes and locations of the cutouts)
- Linear expansion (expansion units, if applicable).

More information:

Technical data, dimension drawings, components, etc. are included in the technical catalog LV 70 of Siemens AG:
- German: Order no. E86060-K1870-A101-A6
- English: Order no. E86060-K1870-A101-A6-7600

Manual:
Planning with SIVACON 8PS – Busbar Trunking Systems up to 6,300 A
- German: Order no. A5E 01541017-02
- English: Order no. A5E 01541117-02

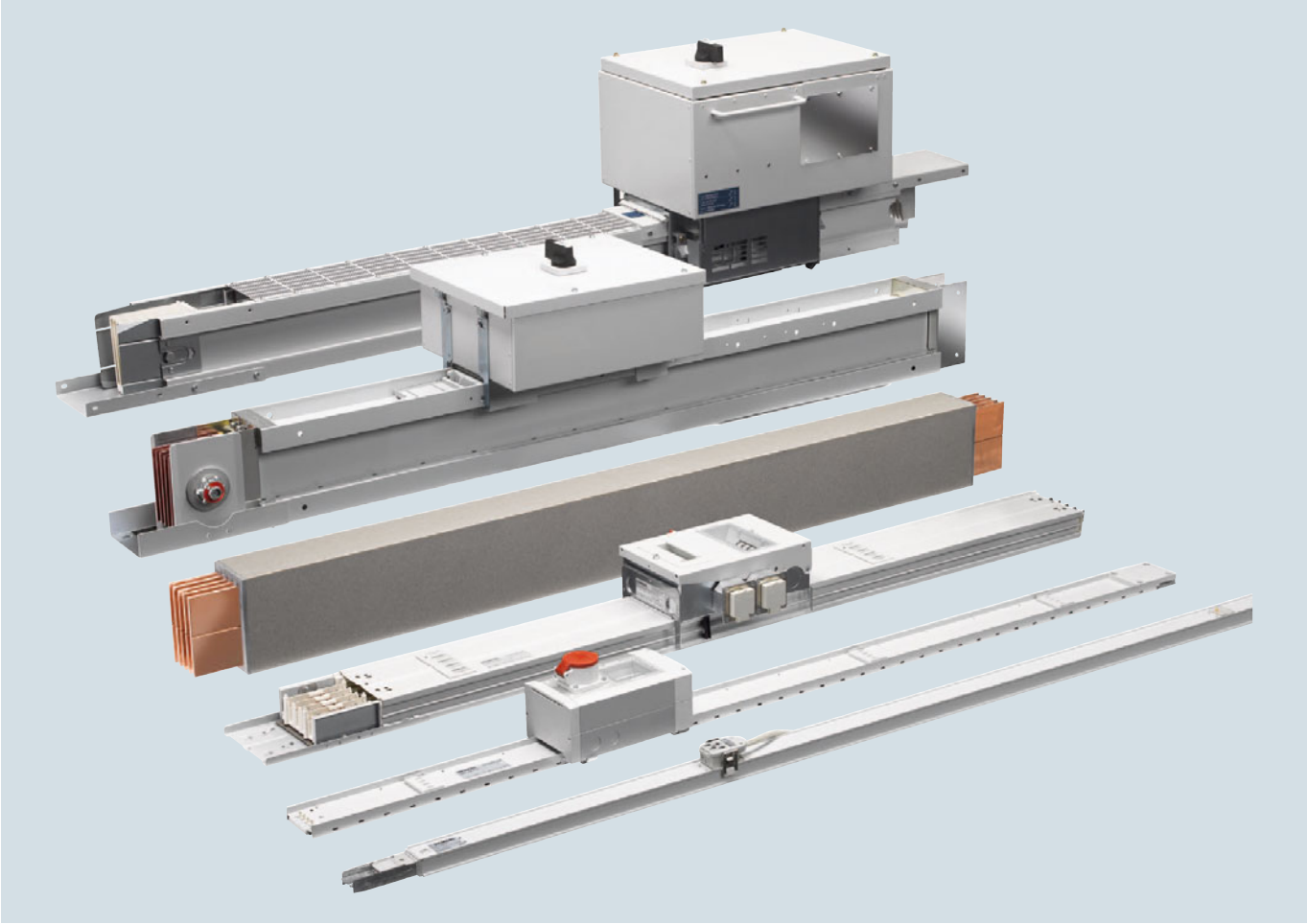


Fig. 4.4-6: **Busbar trunking systems**

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CD-K system 25 A – 40 A
The system is designed for applications of 25 to 40 A and serves to provide an economical and flexible power supply for lighting systems and low-consumption equipment. Typical areas of application are department stores, supermarkets, storerooms or clean room technology.

1. Trunking unit
- 2, 3, 4, 2 × 4, (1 × 4 + 1 x 2)-conductor (PE = casing)
- Degree of protection: IP54, IP55
- Standard lengths: 2 m and 3 m
- Rated current: 30 A, 40 A, 2 × 25 A, 2 × 40 A
- Spacing of the tapping points: 0.5 m and 1 m
- Rated operating voltage: 400 V AC

2. Feeding unit
- Cable entry: from three sides

3. Tap-off component
- Pluggable while energized
- 3-pole for 10 A and 16 A
- Equipped as L1, L2 or L3 with N and PE
- 5-pole for 10 A and 16 A
- Codable

4. End flange

5. Possible supplementary equipment
- Fixing clamp
- Suspension hook
- Hanger
- Cable fixing
- Coding set

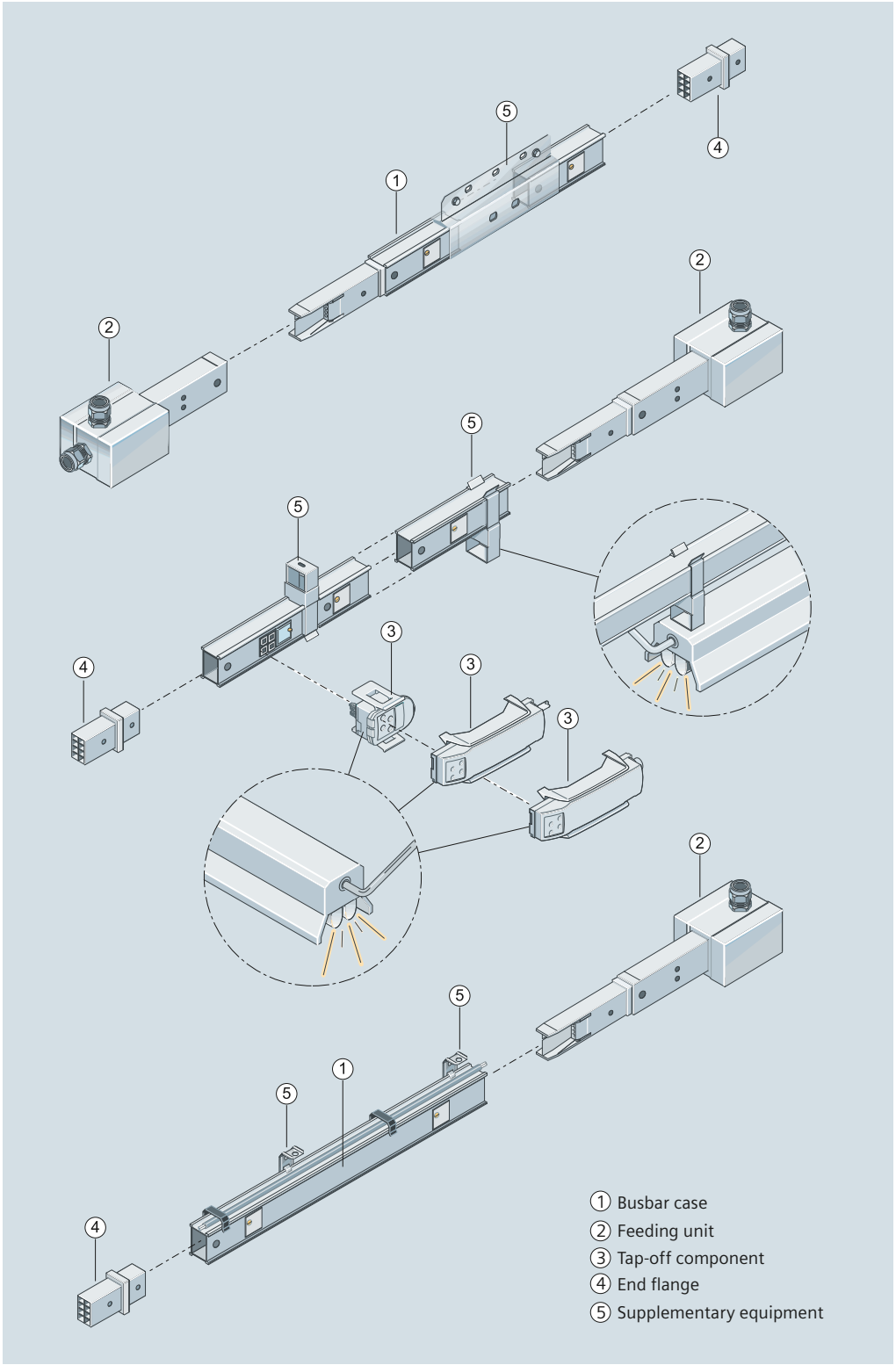

Fig. 4.4-7: **System components for CD-K system**

System BD01 40 A – 160 A
The BD01 busbar trunking system is designed for applications from 40 to 160 A. Five rated amperages are available for only one size, i.e., all other components can be used for all five rated currents irrespective of the power supply. The system is used primarily to supply smaller consumers, e.g., in workshops.

1. Trunking unit
- 4-conductor (L1, L2, L3, N, PE = casing)
- Degree of protection: IP50, IP54, IP55
- Standard lengths: 2 m and 3 m.
- Rated current: 40 A, 63 A, 100 A, 125 A, 160 A
- Spacing of the tapping points: 0.5 m and 1 m
- Rated operating voltage: 400 V AC

2. Directional change components
- Changes of direction in the busbar routing possible: flexible, length 0.5 m, 1 m

3. Feeding unit
- Universal system supply

4. Tap-off unit
- Up to 63 A, with fuses or miniature circuit-breaker (MCB) and with fused outlets
- With fittings or for customized assembly
- For 3, 4 or 8 modules (MW)
- With or without assembly unit

5. Device case
- For 4 or 8 modules (MW)
- With or without assembly unit
- With or without outlet installed

6. Possible supplementary equipment
- Installation sets for degree of protection IP55
- Fixing and suspension
- Coding set
- Fire barrier kit S90

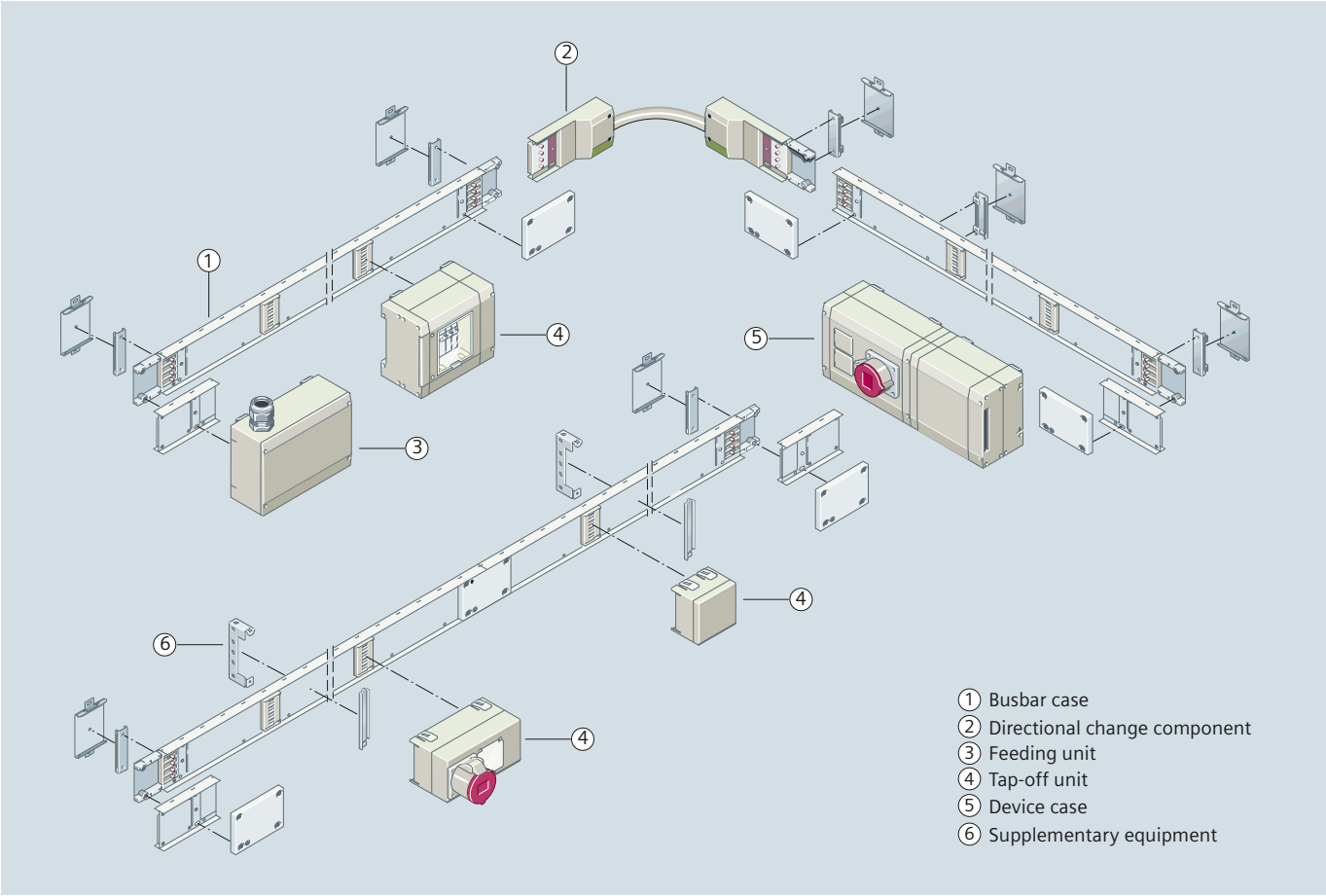

Fig. 4.4-8: **System components for BD01 system**

BD2 system 160 A – 1,250 A
The BD2A/BD2C busbar trunking system (aluminum/copper) is suitable for universal use. It has not only been designed to provide flexible power supply and distribution for consumers in trade and industry, but it can also be used for power transmission from one supply point to another. In addition, the BD2 busbar trunking system is used as rising mains in multi-storey buildings, and since a large number of changes of direction in the busbar routing are possible, it can be adapted to the building geometries perfectly.

1. Trunking unit
- 5-conductor (L1, L2, L3, N, PE or with half PE
- Degree of protection: IP52, IP54, IP55
- Busbar material: copper or aluminum
- Rated current: 160 A, 250 A, 400 A (68 mm x 167 mm) 630 A, 800 A, 1,000 A, 1,250 A (126 mm x 167 mm)
- Standard lengths: 3.25 m, 2.25 m and 1.25 m
- Lengths available: from 0.5 m to 3.24 m
- Tap-off points:
  - without
  - on both sides (0.25 or 0.5 m apart)
- Fire protection: fire safety class S90 and S120 in accordance with DIN 4102, sheet 2 to 4

2. Directional change components
- On edge or flat position
- With or without fire protection
- Horizontal angle unit with or without user-configurable bracket
- Z-unit
- T-unit
- Cross unit
- Flexible changes of direction in the busbar routing possible up to 800 A

3. Feeding unit
- Feeding from one end
- Center feeding
- Bolt terminal
- Cable entry from 1, 2 or 3 sides
- Distribution board feeding

4. Tap-off unit
- 25 A to 630 A
- With fuse, miniature circuit-breaker (MCB) or fused outlet installed

5. Device case
- For 8 modules (MW)
- With or without assembly unit

6. Possible supplementary equipment
- End flange
- For fixing:
- Universal fixing clamp for on edge or flat position
- Fixing elements for vertical phases, for fixing to walls or ceilings
- Terminal block

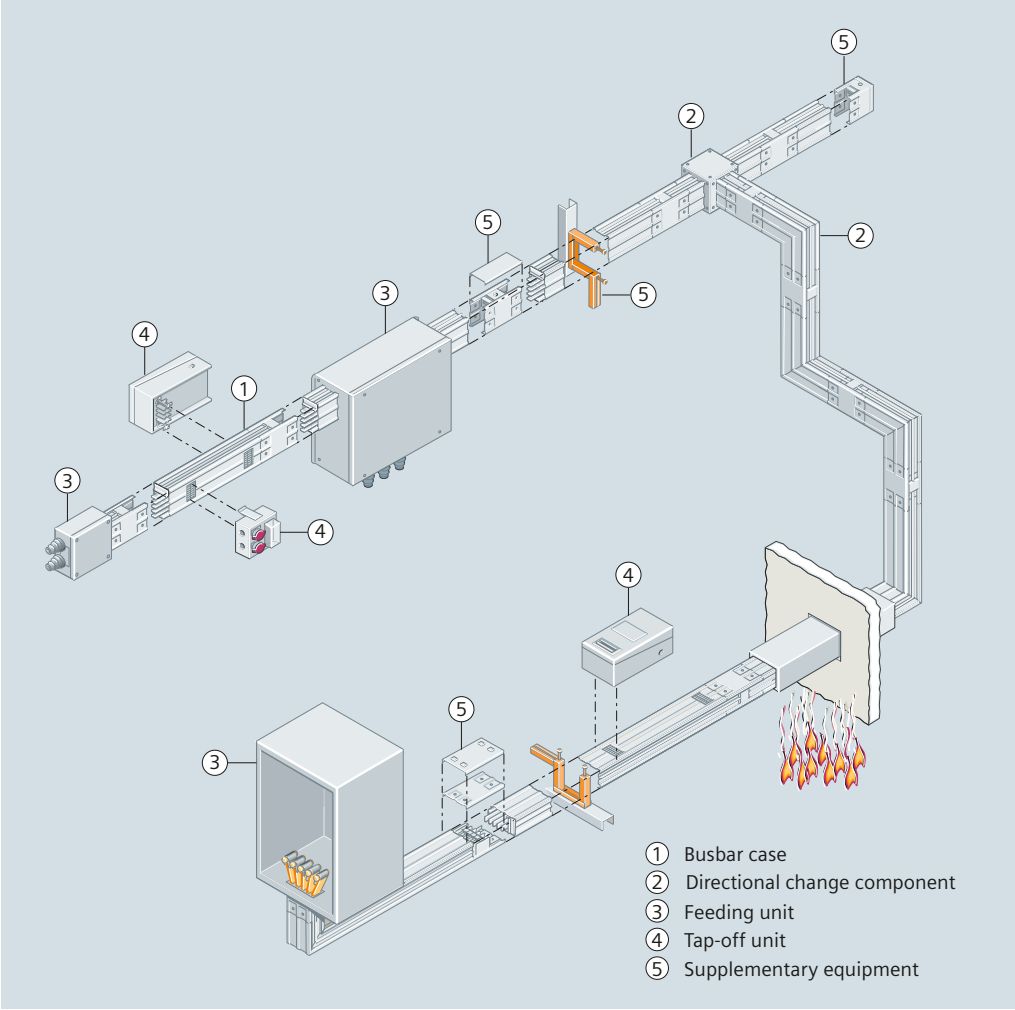

Fig. 4.4-9: **System components for BD2 system**

LD system
1,100 A – 5,000 A
The LDA/LDC busbar trunking system is used both for power transmission and power distribution. A special feature of the system is a high short-circuit strength and it is particularly suitable for connecting the transformer to the low-voltage main distribution and then to the subdistribution system. When there is a high power demand, conventional current conduction by cable means that parallel cables are frequently necessary. Here, the LD system allows optimal power distribution with horizontal and vertical phase responses. The system can be used in industry as well as for relevant infrastructure projects, such as hospitals, railroad stations, airports, trade fairs, office blocks, etc.

1. Trunking unit
- 4 and 5-conductor system
- Busbar material: copper or aluminum
- Rated current: 1,100 to 5,000 A
- LDA1 to LDC3 (180 mm x 180 mm)
- LDA4 to LDC8 (240 mm x 180 mm)
- Degree of protection: IP34 and IP54 (IP36 and IP56 upon request)
- Standard lengths: 1.6 m, 2.4 m and 3.2 m
- Lengths available: from 0.5 m to 3.19 m
- Tapping points:
- Without
- With user-configurable tapping points
- Fire protection partitions: fire resistance class S120 in accordance with DIN 4102-9

2. Directional change components
- With or without fire protection
- Horizontal angle unit with or without user-configurable bracket
- Z-unit
- U-unit
- T-unit

3. Tap-off unit
- Degree of protection IP30 and IP54
- With fuse switch-disconnector from 125 A to 630 A
- With circuit-breaker from 100 A to 1,250 A
- Leading PEN or PE connector
- Switching to load-free state following defined, forced-operation sequences
- Suspension and fixing bracket

4. Feeding unit
- Cable feeding unit
- Universal terminal for transformers

5. Terminal boxes for connection to distribution board
- TTA distribution connection to the SIVACON system from the top/bottom
- Terminals for external distribution boards

6. Possible supplementary equipment
- End flange
- Terminal block

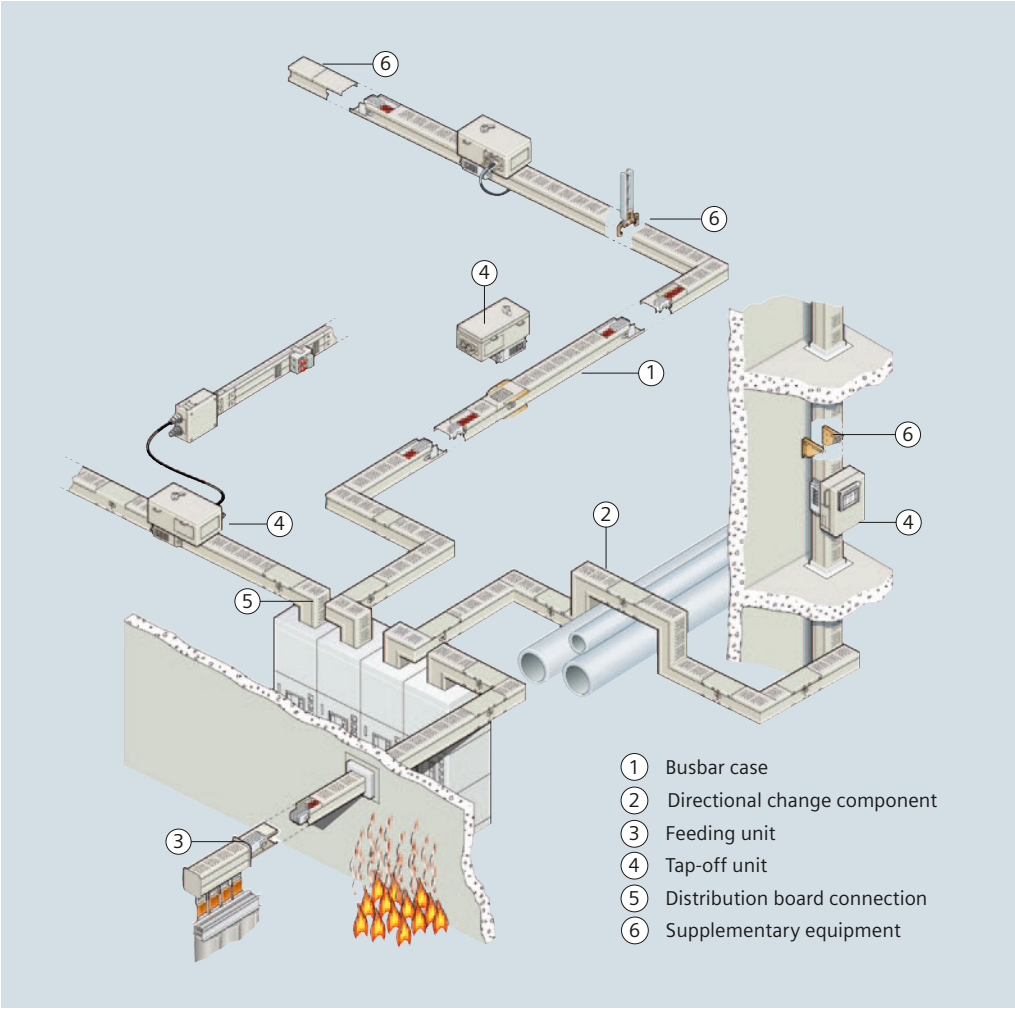

Fig. 4.4-10: **System components for LDA/LDC system**

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LX system
from 800 A – 6,300 A
The LXA/LXC busbar trunking system is used both for power transmission and power distribution. Special features of the system include high flexibility and position insensitivity, and it is particularly suitable for power distribution in multi-story buildings. The high degree of protection IP54, which is standard for this system, and tap-off units up to 1,250 A also guarantee a safe supply if there is a high energy demand. It can be used in industry as well as for relevant infrastructure projects such as hospitals, railroad stations, airports, data centers, office blocks, etc.

1. Trunking unit
- 4 and 5-conductor system in various conductor configurations, including separate PE or double N
- Busbar material: copper or aluminum
- Rated current:
  800 up to 5,000 A
  Size (mm) Aluminum Copper
  137 x 145 up to 1,000 A
  up to 1,250 A
  162 x 145 up to 1,250 A
  up to 1,600 A
  207 x 145 up to 1,600 A
  up to 2,000 A
  287 x 145 up to 2,500 A
  up to 3,200 A
  439 x 145 up to 3,200 A
  up to 4,000 A
  599 x 145 up to 4,500 A
  up to 5,000 A
  (up to 6,300 A on request)
- Degree of protection: IP54 (IP55 optional)
- Standard lengths: 1 m, 2 m and 3 m
- Lengths available: from 0.35 m to 2.99 m
- Layout: horizontal and vertical without derating
- Tap-off points:
  – On one side
  – On both sides
- Fire protection partitions: fire resistance class S120 in accordance with DIN 4102 Part 9

2. Directional change components
- With or without fire protection
- Horizontal angle unit with or without user-configurable bracket
- Z-unit
- Offset knee
- T-unit

3. Tap-off unit
- Degree of protection IP54 (IP55 upon request)
- With fuse switch-disconnector from 125 A to 630 A
- With circuit-breaker from 80 A to 1,250 A
- Pluggable while energized up to 630 A
- Fixed installation up to 1,250 A
  (on terminal block)
- Leading PEN or PE connector
- Switching to load-free state following defined, forced-operation sequences
- Suspension and fixing bracket

4. Feeding unit
- Cable feeding unit
- Universal terminal for transformers

5. Terminal boxes for connection to distribution board
- TTA distribution connection to the SIVACON system from the top/bottom
- Terminals for external distribution boards

6. Possible supplementary equipment
- End flange
- Flange for degree of protection increased from IP54 to IP55
- Terminal block

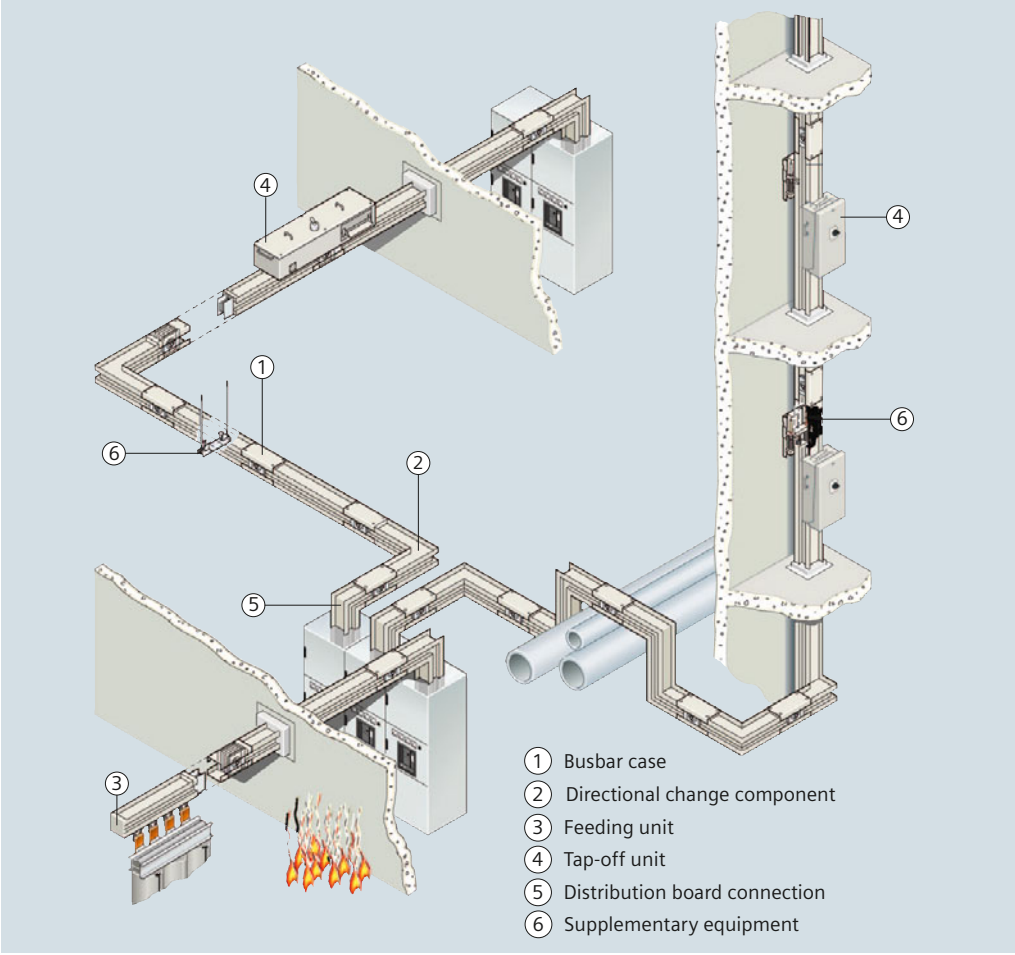


Fig. 4.4-11: **System components for LXA/LXC system**

LR system
from 400 A – 6,150 A
The LRA/LRC busbar trunking system is used for power transmission. A special feature of the system is high resistance to external influences of chemical and corrosive substances, and it is particularly suitable for use in the open air and in environments with high air humidity. The high degree of protection IP68 is guaranteed with the encapsulated epoxy cast-resin casing, and serves to provide reliable power transmission when there is a high energy demand. The system can be used in industry as well as for relevant infrastructure projects such as railroad stations, airports, office blocks, etc.

1. Trunking unit
- 4 and 5-conductor system
- Busbar material: copper or aluminium
- Degree of protection: IP68
- User-configurable lengths: from 0.30 m to 3.00 m
- Layout: horizontal and vertical without derating
- Fire barriers: fire resistance class S120 in accordance with DIN 4102 Part 9

2. Directional change components
- With or without fire protection
- Horizontal angle unit with or without offset
- Z-unit
- T-unit

3. Feeding unit and distributor units
- Universal terminals for transformers, external distributors and cable connection

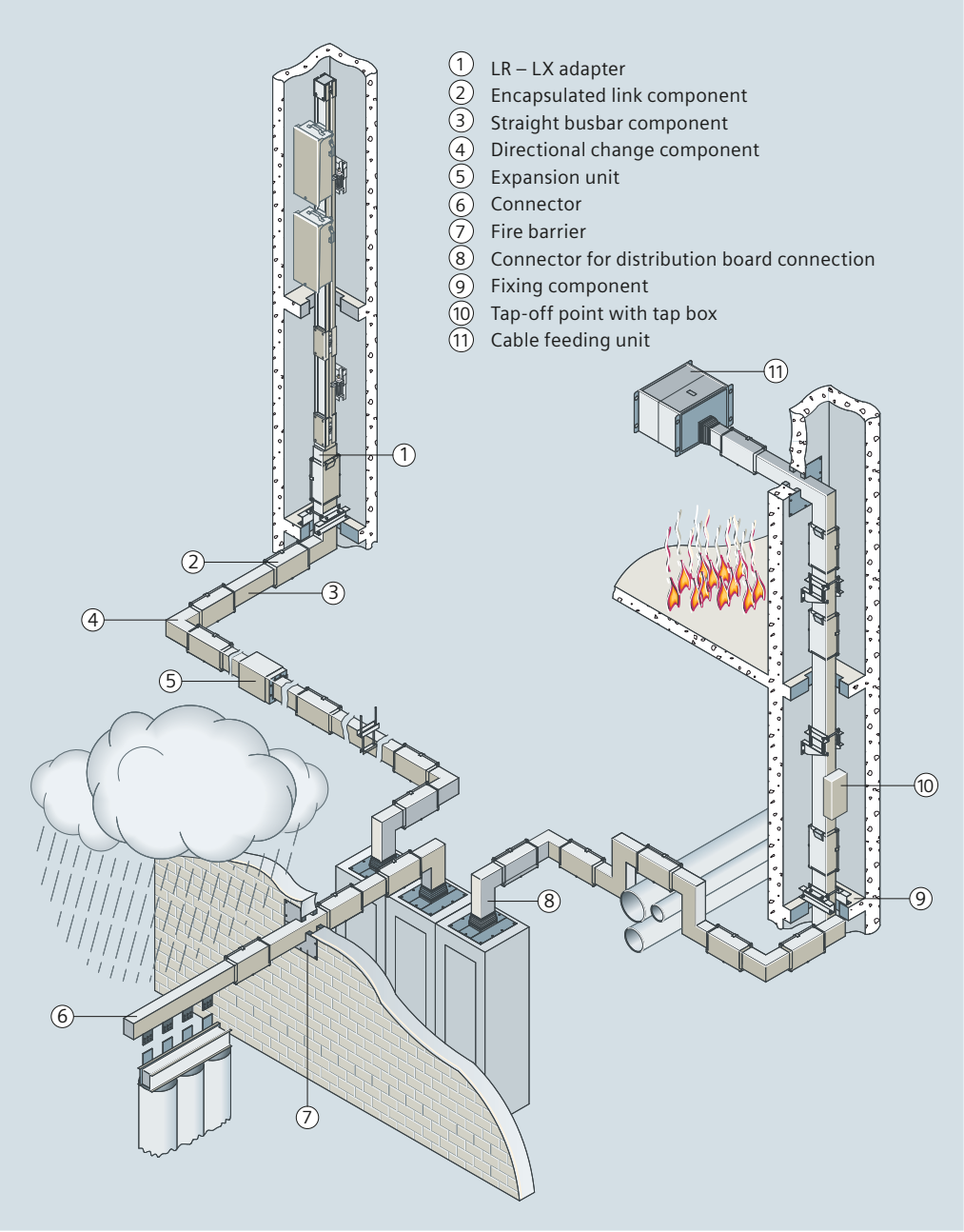


Fig. 4.4-12: **System components for LRA/LRC system**

4. Possible supplementary equipment
- End flange
- Terminal block
- Junction point every 1 m, on one side; junction box on request
- Adapters to the LX and LD systems

4.4.4 Subdistribution Systems

General
Subdistribution systems, as an essential component for the reliable power supply to all consumers of a building, are used for the distributed supply of circuits. From the subdistribution boards, cables either lead directly or via ground contact outlets to the consumer. Protective devices are located within the subdistribution systems.

These are:
- Fuses
- Miniature circuit-breakers
- RCD (residual current devices)
- Circuit-breakers
- Overvoltage protection

They provide protection against personal injury and protect:
- Against excessive heating caused by non-permissible currents
- Against the effects of short-circuit currents and the resulting mechanical damage.

In addition to the protective devices, a subdistribution system also contains devices for switching, measuring and monitoring. These are:
- Disconnectors
- KNX/EIB components
- Outlets
- Measuring instruments
- Switching devices
- Transformers for extra-low-voltages
- Components of the building control systems

Configuration
The local environmental conditions and all operating data have utmost importance for the configuration of the subdistribution systems. The dimensioning is made using the following criteria:

Ambient conditions
- Dimensions
- Mechanical stress
- Exposure to corrosion
- Notes concerning construction measures
- Wiring spaces
- Environmental conditions

Electrical data
- Rated currents of the busbars
- Rated currents of the supply circuits
- Rated currents of the branches
- Short-circuit strength of the busbars
- Rating factor for switchgear assemblies
- Heat loss

Protection and installation type
- Degree of protection
- Observance of the upper temperature limit
- Protective measures
- Installation type (free-standing, floor-mounted distribution board, wall-mounted distribution board)
- Accessibility, e.g., for installation, maintenance and operating

Type of construction
- Number of operating faces
- Space requirements for modular installation devices, busbars and terminals
- Supply conditions

The number of subdistribution boards in a building is determined using the following criteria:

Floors
A high-rise building normally has at least one floor distribution board for each floor. A residential building normally has one distribution system for each apartment.

Building sections
If a building consists of several sections, at least one subdistribution system is normally provided for each building section.

Departments
In a hospital, separate subdistribution systems are provided for the various departments, such as surgery, OP theater, etc.

Safety power supplies
Separate distribution boards for the safety power supply are required for supplying the required safety equipment. Depending on the type and use of the building or rooms, the relevant regulations and guidelines must be observed, such as IEC 60364-7-710 and -718, DIN VDE 0100-710 and -718 and the MLAR (Sample Directive on Fireproofing Requirements for Line Systems).

Standards to be observed for dimensioning
- IEC 60364-1, DIN VDE 0100-100 Low voltage electrical installations -Part 1: Fundamental principles, assessment of general characteristics, definitions
- IEC 60364-4-41, DIN VDE 0100-410 Protection against electric shock
- IEC 60364-4-43, DIN VDE 0100-430 Protection against overcurrent
- IEC 60364-5-51, DIN VDE 0100-510 Selection and erection of electrical equipment; common rules
- IEC 60364-5-52, DIN VDE 0100-520 Wiring systems
- DIN VDE 0298-4 Recommended values for the current carrying capacity of sheathed and non-sheathed cables
- DIN VDE 0606-1 Connecting materials up to 690 V; Part 1 – Installation boxes for accommodation of equipment and/or connecting terminals
- DIN 18015-1 Electrical systems in residential buildings, Part 1 planning principles

Selection of protective devices and connecting lines
The selection and setting of the protective devices to be used must satisfy the following three conditions:
- Protection against non-permissible contact voltage for indirect contact (electric shock)
- Overload protection
- Short-circuit protection

For detailed information on the three conditions, see section 3.3.2 “Dimensioning of Power Distribution Systems”.

An exact protective device selection and thus the dimensioning of subdistribution 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, DIN VDE 0100-710) and meeting rooms (IEC 60364-7-718, DIN VDE 0100-718) require the selection of protective devices in subareas. For other building types, such as computer 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 (chapter 6 “Protection, Substation Automation, Power Quality and Measurement”).

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.

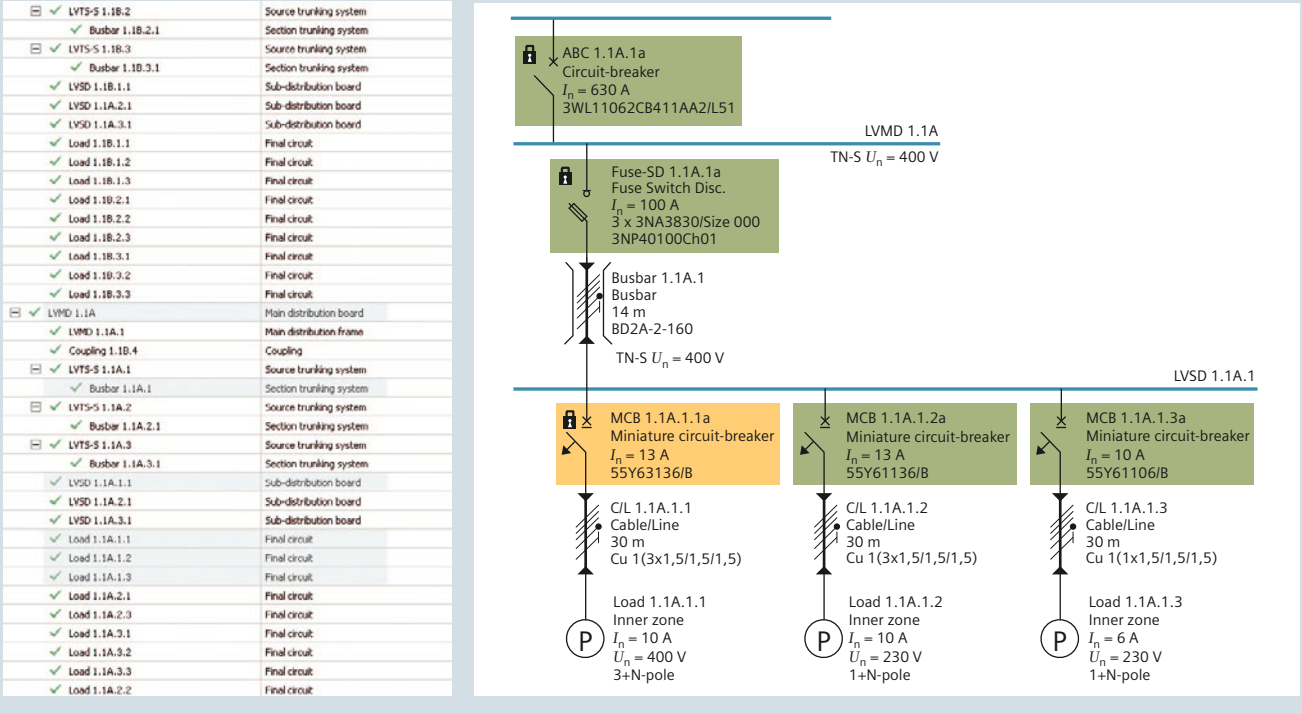


Fig. 4.4-13: **Subdistribution in a data center; display in SIMARIS design**

4

Selectivity and backup protection exemplified for a data center

Computer 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. 4.4-13 shows a subdistribution system in SIMARIS design. A SENTRON 3WL circuit-breaker as outgoing feeder switch of the main distribution is upstream to the subdistribution system shown here. The following figures show the selectivity diagrams for the considered subdistribution system automatically generated by SIMARIS design (fig. 4.4-14). 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. 4.4-15 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 for the 100 A group backup fuse.

The same subdistribution system also contains an example for backup protection. Fig. 4.4-16 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. 4.4-16 also shows up to which current ($I_{sel\text{-}short\text{-}circuit}$) the protective devices are selective to each other.

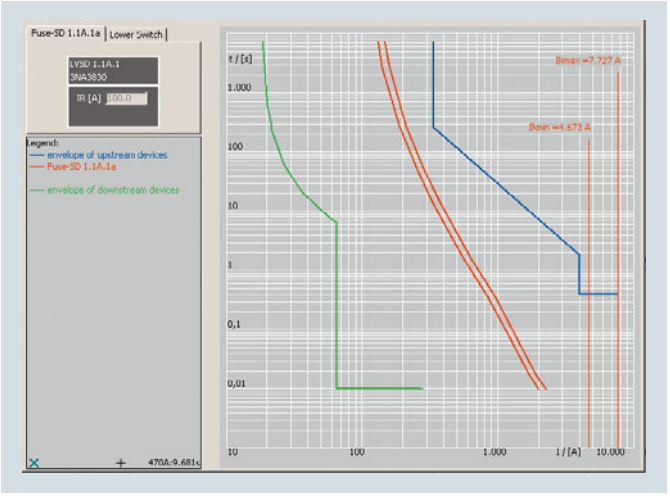


Fig. 4.4-14: **Selectivity of the group backup fuse to the upstream protective devices**

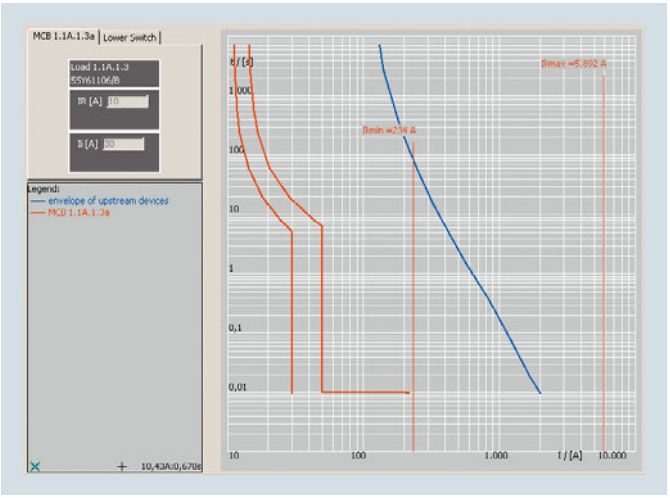


Fig. 4.4-15: **Selectivity of the group backup fuse/miniature circuit-diagram combination**

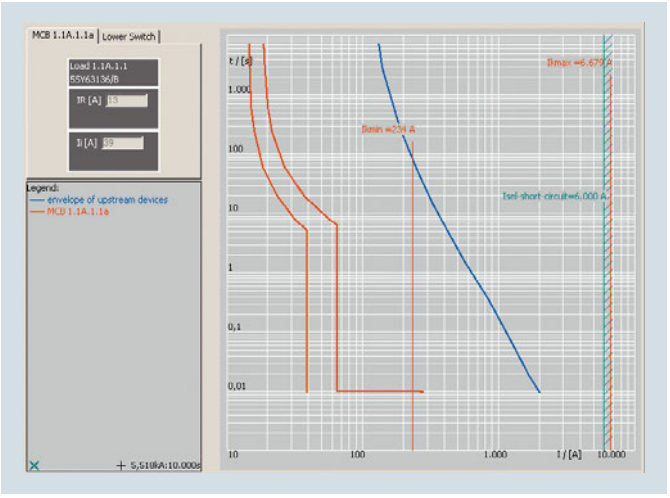


Fig. 4.4-16: **Backup protection of the group backup fuse/miniature circuit-breaker**

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.

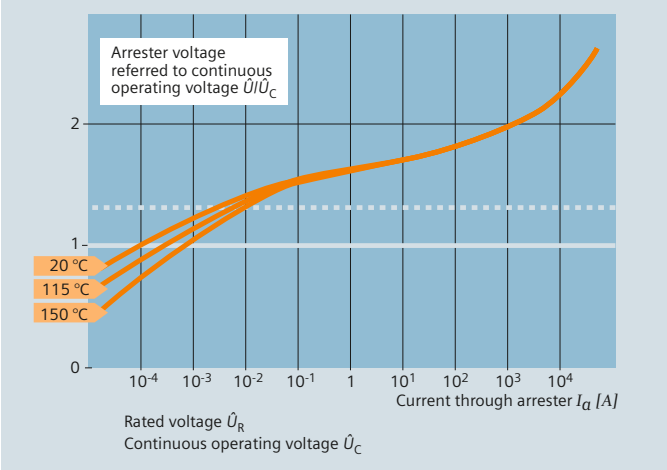


Fig. 4.5-1: **Current/voltage characteristics of a non-linear MO arrester**

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**

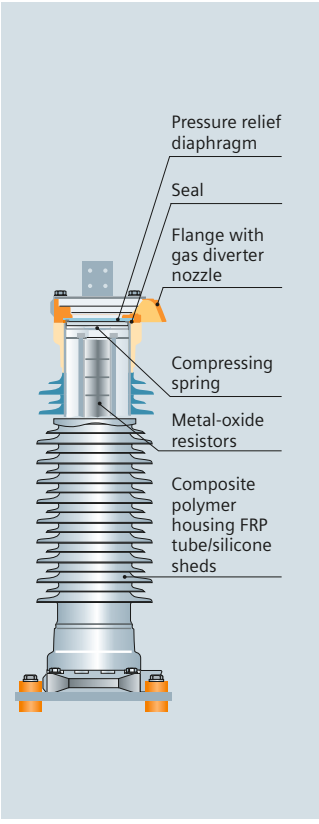


Fig. 4.5-3: **Cross-section of a polymer-housed arrester in tube design**

4

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. 4.5-7) is the heart of the future-proof (IEC 61850) monitoring product line.

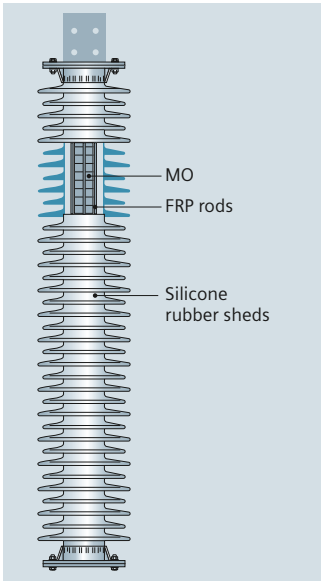


Fig. 4.5-4: **3EL-range surge arrester in cage design**

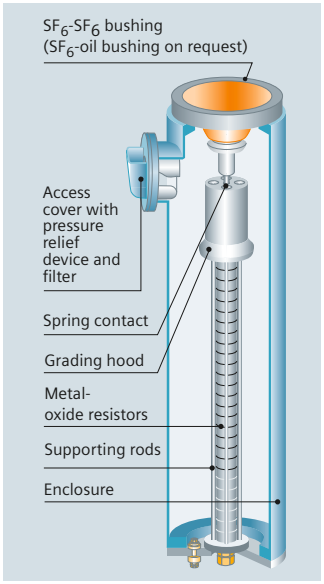


Fig. 4.5-5: **Gas-insulated metal-enclosed arrester (GIS arrester)**

Fig. 4.5-6: **Medium-voltage MO arrester for special applications**

Fig. 4.5-7: **Arrester condition monitor (ACM)**

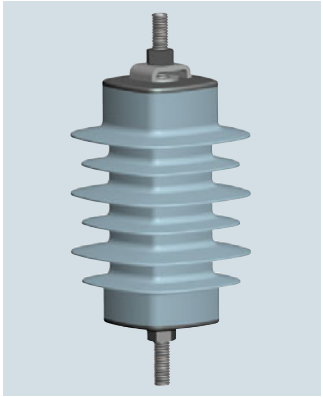


Fig. 4.5-8: **Medium-voltage arrester 3EK4 for distribution systems**

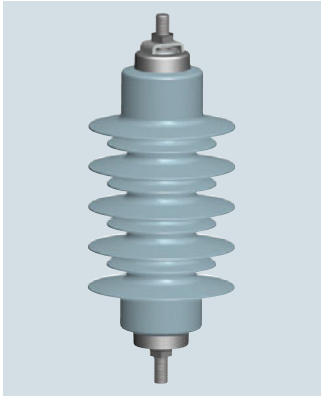
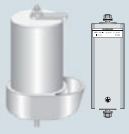
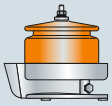
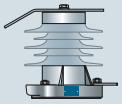
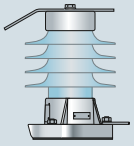
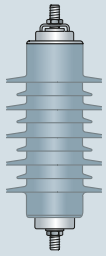


Fig. 4.5-9: **Medium-voltage arrester 3EK7 for distribution systems**

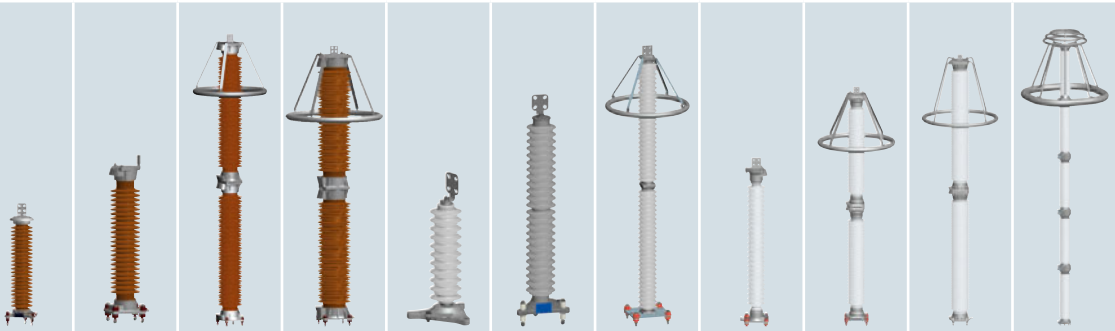
4.5.2 Low-Voltage and Medium-Voltage Surge Arresters and Limiters

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

	Special applications	Railway applications				Medium-voltage distribution class	
	3EF1; 3EF3; 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); 4 (DC)	37 (AC); 4 (DC)	36	60
Nominal discharge current kA	3EF1 1 3EF3 1 3EF4 10 3EF5 10	10	10	10	10	10	10
Maximum thermal energy absorption capability (per kV of U_r) kJ/kV	3EF1 0.8 3EF3 4 3EF4 12.5 3EF5 8	10	10	8 (AC); 10 (DC)	8 (AC); 10 (DC)	3.5[1)]	3.5[1)]
Maximum long-duration current impulse, 2 ms A	3EF4 1,600 3EF5 1,200	1,200	1,200	850 (AC); 1,200 (DC)	850 (AC); 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 – polyethylene 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

Tab. 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 installations	Medium and high-voltage systems, outdoor installations	High-voltage systems, outdoor installations	High-voltage systems, outdoor installations, HVDC, SC&SVC applications	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 installations	High-voltage systems, outdoor installations	High-voltage systems, outdoor installations, HVDC, SC&SVC applications	High-voltage systems, outdoor installations, HVDC applications
Highest voltage for equipment (U_m) kV	123	362	550	800	145	362	550	362	550	800	1,200
Maximum rated voltage kV	96	288	468	612	126	288	468	288	468	612	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	2	4	3	5	5	5
Maximum thermal energy absorption capability (per kV of U_r) kJ/kV	8	8	14	25	2	5	10	8	18	25	66
Maximum long-duration current impulse, 2 ms A	1,100	1,100	2,000	7,000	550	750	1,200	1,100	3,200	8,500	11,000
Rated short circuit current kA	40	65	65	100	20	65	65	50	80	80	80
Maximum permissible service load kNm	2.0 (SSL)[1)]	3 (SSL)[1)]	16.0 (SSL)[1)]	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

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

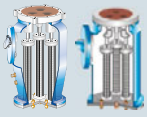
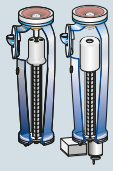
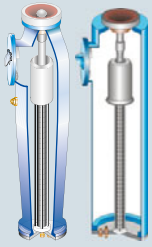
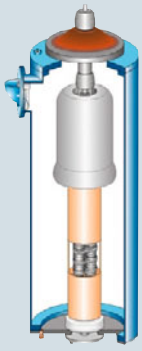
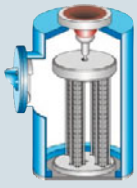
their original resistance value so that only a so-called leakage current of a few mA flows at operating voltage. Because this leakage current heats up the resistors, and thus the arrester, the device must be designed according to the neutral-point treatment of the system in order to prevent impermissible 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. 4.5-6).
- 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. 4.5-6).
- 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.

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					

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

For further information, please contact:
Fax: ++ 49 30 386-33222
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.

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

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

IEC standards for oil-immersed or gas-filled devices require a partial discharge value of less than 10 pC at U_{max}. Due to the demanding requirements of today's HV and UHV networks, the Trench Group has elected to adopt even more stringent internal requirements. As such, Trench instrument transformers typically perform much better than required by these standards with proven field experience with hundreds of thousands in operation over more than 50 years in almost every country worldwide. Typical designs are oil-immersed (fig. 4.6-2), 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. The transformer is based on state-of-the-art design and a secure failure mode approach. In the event of unexpected stresses from the network, secure failure is achieved through the use of a "barrier construction" design in the free oil section. This approach consists of inserting insulating barriers at critical points through the free oil space, thereby preventing the formation of fiber bridges.

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

If over pressure occurs, the protection is guaranteed by the:
- Welded elastic housing
- Stainless-steel bellows for the oil expansion.

Both the welded seam, which connects the upper and lower portions of the head housing, and the metallic bellows are designed to act as pressure relief points in the event of severe internal pressure buildup.

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

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

Gas-insulated instrument transformers
The reliability and security of Trench gas-insulated instrument transformers is based on:
- 50 years of experience as a manufacturer of instrument transformers covering epoxy resin and oil-paper
- Thousands of gas-insulated instrument transformers in service under a wide variety of different environmental conditions.

Explosion-proof design
The present Trench gas-insulated instrument transformers were initially designed in 1965 at the request of customers who sought to achieve explosion-proof operation. 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) or SF_6 gas dielectric systems (fig. 4.6-3).

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

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

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

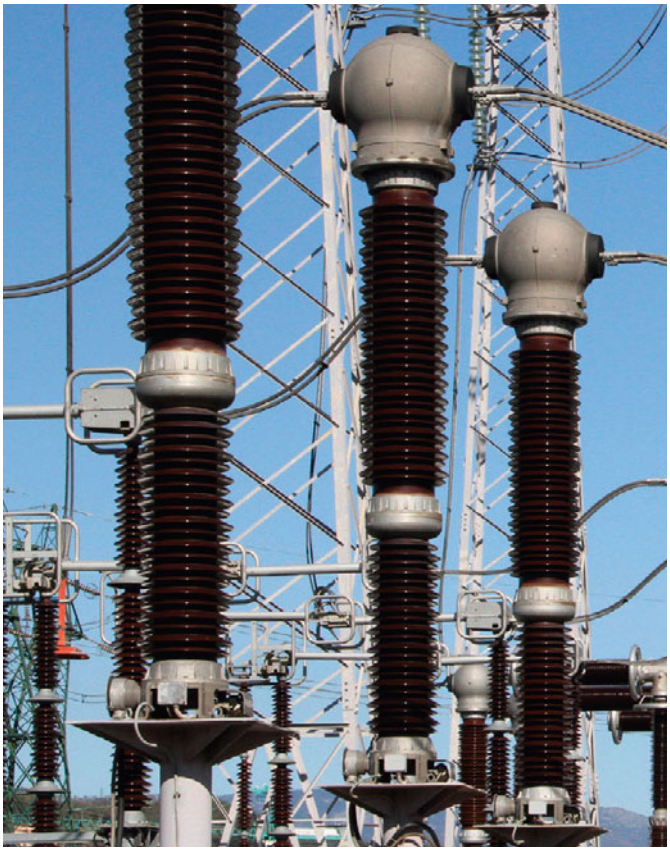


Fig. 4.6-3: **420 kV gas-insulated current transformers**

- 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. 4.6-4) or SF_6 gas dielectric systems (fig. 4.6-5).

Features of oil-immersed type
- Low weight and minimum oil volume
- Excellent seismic performance as a consequence of optimized designs of flanges, large choice of porcelain strengths and their interconnection and low weight
- Available for the full voltage range of 72.5 kV up to 550 kV
- Excellent control of internal and external insulation stresses through the use of a proprietary finely graded bushing system
- Optimized high-voltage coil ensures identical electric stresses under both transient and steady-state conditions
- Essentially unaffected by stray external magnetic fields
- Hermetically sealed stainless-steel metallic bellows for units rated 123 kV and above
- 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

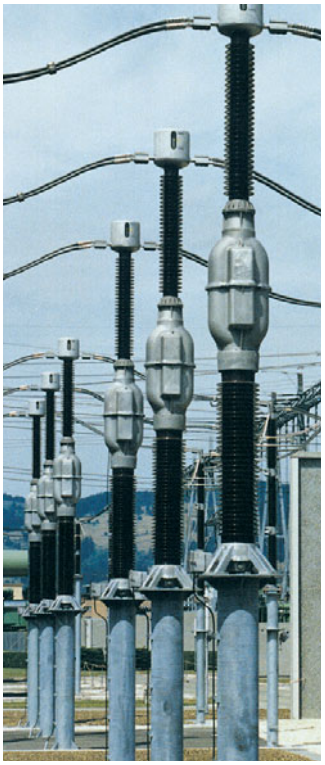


Fig. 4.6-4: **420 kV oil-paper insulated inductive voltage transformers**

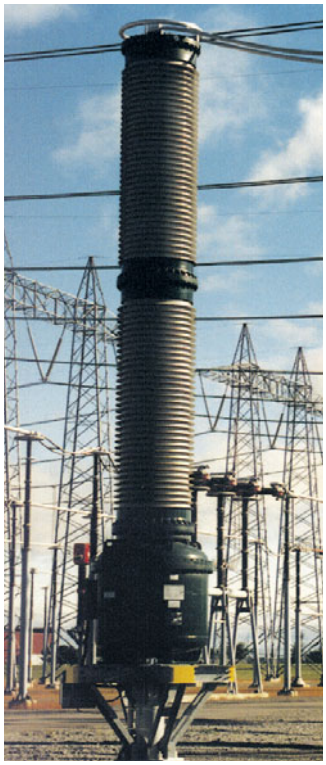


Fig. 4.6-5: **765 kV gas-insulated voltage transformer**

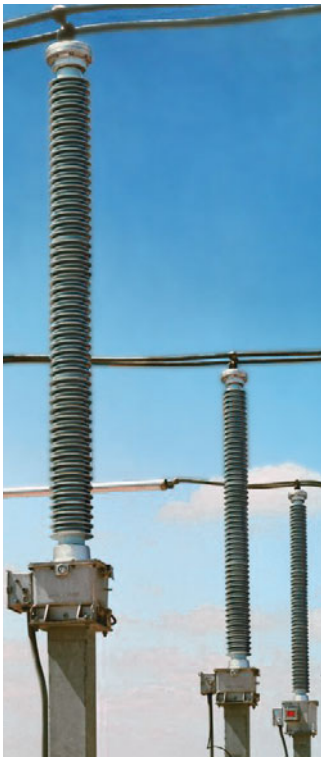


Fig. 4.6-6: **245 kV capacitor voltage transformers**

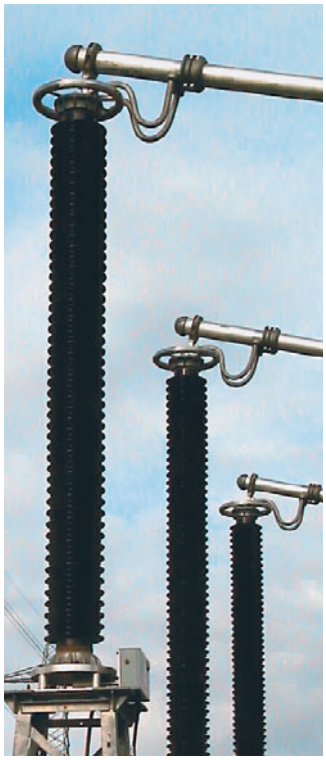


Fig. 4.6-7: **420 kV RC-dividers (AC) for AIS**

grading system especially developed for this application
- Wide range ferroresonance-free design without the use of an external damping device (please ask for details)
- Essentially unaffected by external stray magnetic fields
- Stable accuracy over a long period of time
- Suitable for line discharging
- Optimized high-voltage coil ensures identical electric stresses under both transient and steady state conditions
- Exclusive use of corrosion-resistant materials
- Applicable as a low-cost alternative to small power transformer.

Capacitor voltage transformer (oil-immersed)
Coupling capacitors (CC) are utilized to couple high-frequency carrier signals to the power line. A CC supplied with an electromagnetic unit is called a capacitor voltage transformer (CVT) and is used to provide voltage for metering and protection applications (fig. 4.6-6).

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.

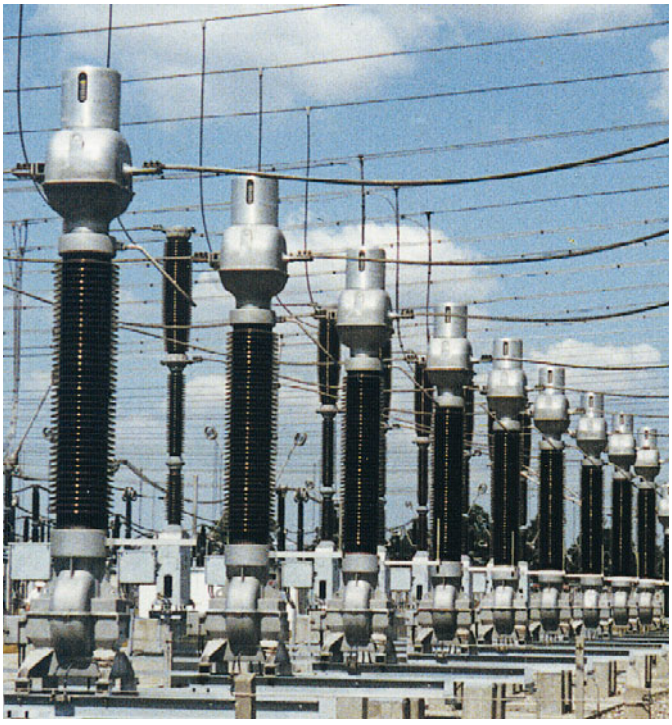


Fig. 4.6-8: **245 kV oil-immersed combined instrument transformers**

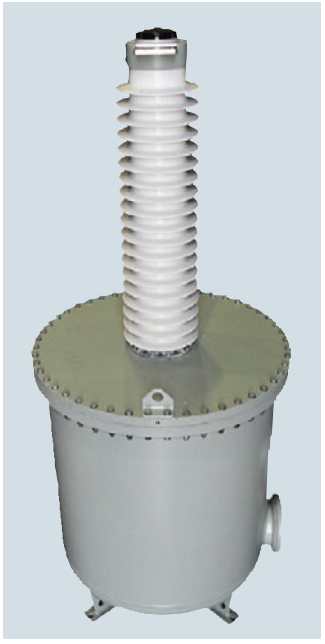


Fig. 4.6-9: **145 kV, 100 kVA gas-insulated Power VT for AIS**

Fig. 4.6-10: **420 kV gas-insulated 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. Compined ITs are available with either oil (fig. 4.6-8) or SF_6 gas dielectric systems (fig. 4.6-10, fig. 4.6-12).

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.

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. 4.6-13).

Fig. 4.6-11: **300 kV oil-immersed current transformers**

Fig. 4.6-12: **800 kV gas-insulated combined instrument transformer**

Fig. 4.6-13: **145 kV inductive voltage transformer for GIS**

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.

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. 4.6-7) or gas-insulated (GIS) switchgear (fig. 4.6-14). 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.

Fig. 4.6-14: **145 kV RC-divider for GIS**

Fig. 4.6-15: **145 kV Power VT for GIS**

Fig. 4.6-16: **300 kV core-in-air current transformer for GIS**

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

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

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

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. 4.6-17: **145 kV Siemens switchgear 8DN8 with Trench voltage- and current transformer**

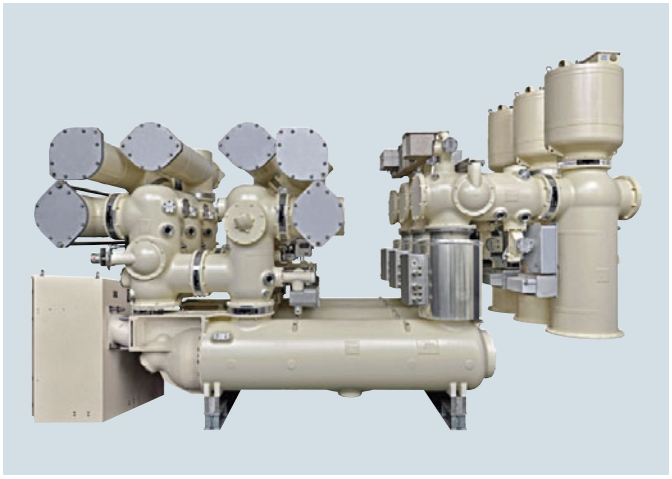


Fig. 4.6-18: **300 kV Siemens switchgear 8DN9 with Trench voltage transformer and Trench core-in-air current transformer**

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. 4.6-9.

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.

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. 4.6-15.

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.

Current Transformers for Gas Insulated Substations (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										

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

Voltage Transformers / RC-Dividers for Gas Insulated Substations (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											

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

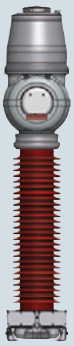
Current Transformers for Air Insulated Substations (AIS)											
Type		SAS			TAG			IOSK			
Voltage range	[kV]	72.5 – 800			72.5 – 550			72.5 – 550			
Insulation medium		SF_6			SF_6			Oil			
Composite insulator		×			×			×			
Porcelain insulator					×			×			
		Technical data									
Voltage level	[kV]	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											

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

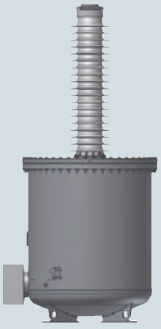
Voltage Transformers / RC-Dividers for Air Insulated Substations (AIS)											
Type		SVS		TVG		VEOT/VEOS	TCVT	AC RCD		DC RCD	
Voltage range	[kV]	72.5 – 800		72.5 – 420		72.5 – 550	72.5 – 1200	72.5 – 800		72.5 – 800	
Insulation medium		SF_6		SF_6		Oil	Oil	Oil		Oil / SF_6	
Composite insulator		×		×		×	×	×		×	
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											

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

4

Combined Instrument Transformers for Air Insulated Substations (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											

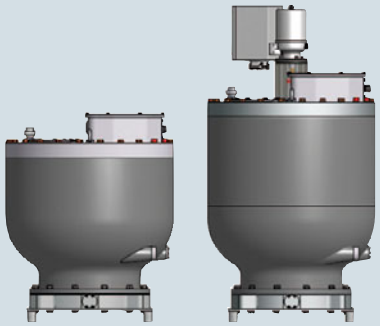
Tab 4.6-5: **Technical data of Trench combined instrument transformers for air-insulated substations (AIS)**

Power Voltage Transformers for Air Insulated Substations (AIS)									
									
Type		PSVS							
Technical data									
Voltage level	[kV]	123	145	170	245	300	362	420	550
Rated power frequency withstand voltage	[kV]	230	275	325	460	460	510	630	680
Rated lighting impulse withstand voltage	[kV]	550	650	750	1,050	1,050	1,175	1,425	1,550
Rated switching impulse withstand voltage	[kV]	–	–	–	–	850	950	1,050	1,175
Output power	[kVA]	100						75	65
		125 under development							
Output voltage	[V]	120 to 400 (values in between according to customer specification)							
Rated voltage factor		1.5 (30 s)							
Rated frequency	[Hz]	50 – 60							
Creepage distance	[mm/kV]	25 – 31 (higher upon request)							
Temperature range	[°C]	–25[1] – +40							
Insulation class		E							
Metering accuracy class		0.2[2] – 0.5[2] – 1.0[2] – 3.0							
Protection accuracy class		3P[2] – 6P							

Values in accordance with IEC; other values like ANSI are available [1] lower temperature upon request [2] not under load condition

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

4

Power Voltage Transformers for Gas Insulated Substations (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				

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

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

4.7 Coil Products (HV)

Introduction
With 50 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 the ISO 9001 quality standard. Trench's highly developed research and development program constantly addresses new technologies and their potential application in reactor products. Trench welcomes challenges for new applications for power reactors.

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

Construction
A Trench air-core dry-type reactor consists of a number of parallel-connected, individually insulated, aluminum (copper on request) conductors (fig. 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.

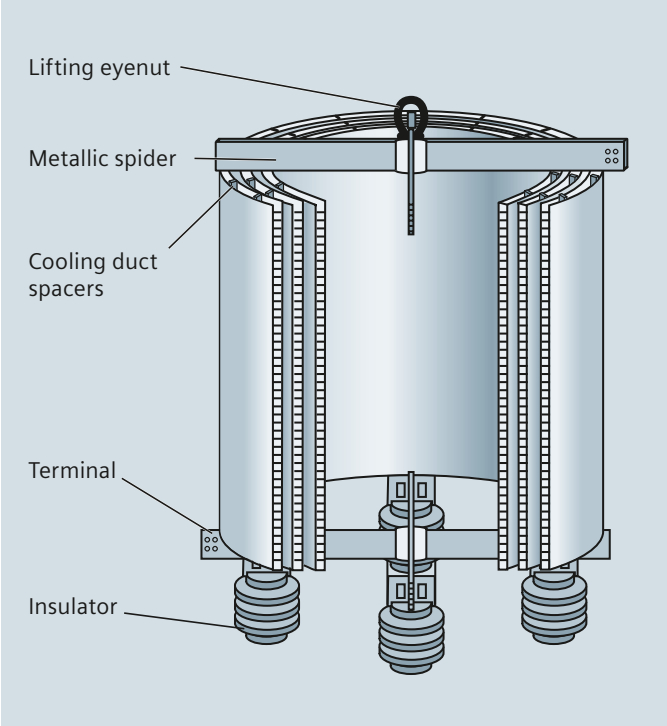


Fig. 4.7-1: **Typical Trench air-core dry-type reactor construction**

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 use of buffer reactors for electric arc furnaces (EAF) is achieved by operating the furnace at low electrode current and long arc length. This requires the use of a series reactor in the supply system of the arc furnace transformer for stabilizing the arc.

Duplex reactors
Duplex reactors are current limiting reactors that consist of two half coils, wound in opposition. These reactors provide a desirable low reactance under normal conditions and a high reactance under fault conditions.

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

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

Filter reactors
Filter reactors are used in conjunction with capacitor banks to form series tuned harmonic filter circuits, or in conjunction with capacitor banks and resistors to form broadband harmonic filter circuits. When specifying filter reactors, the magnitudes of fundamental and harmonic frequency 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.

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

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

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 detection system developed by Trench utilizes the plunger core coil (moveable-core design). Based on extensive experience in design, construction and application of ASCs, Trench products can meet the most stringent requirements for earth-fault compensating techniques.

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

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

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

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 up to 1,100 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), Toronto (Canada) and Shenyang (China).

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

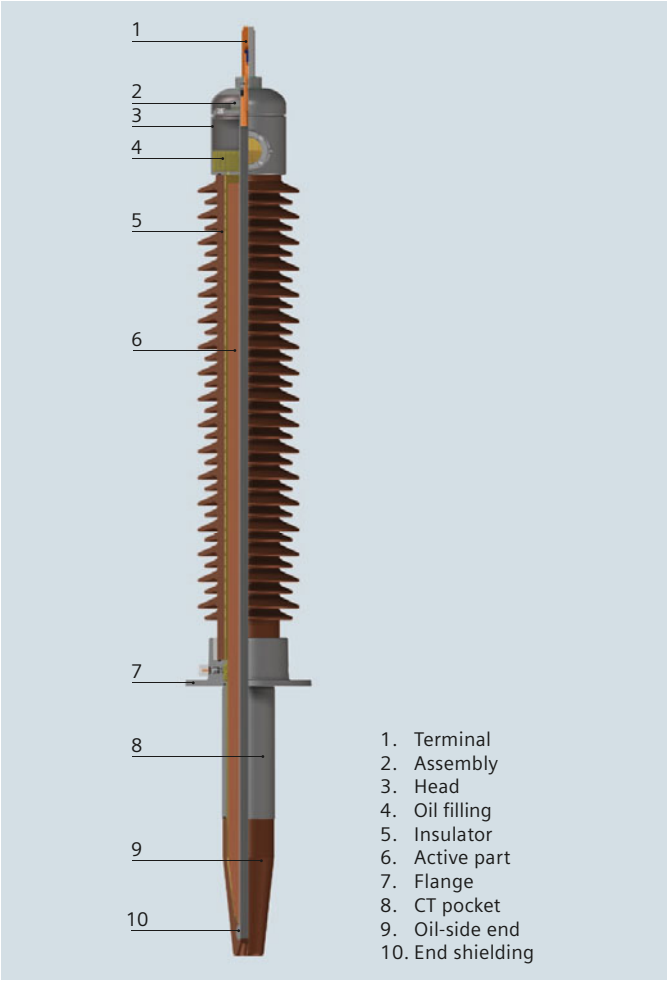


Fig. 4.8-1: **Transformer bushing – oil-impregnated paper (OIP) design – sectional view**

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.

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.

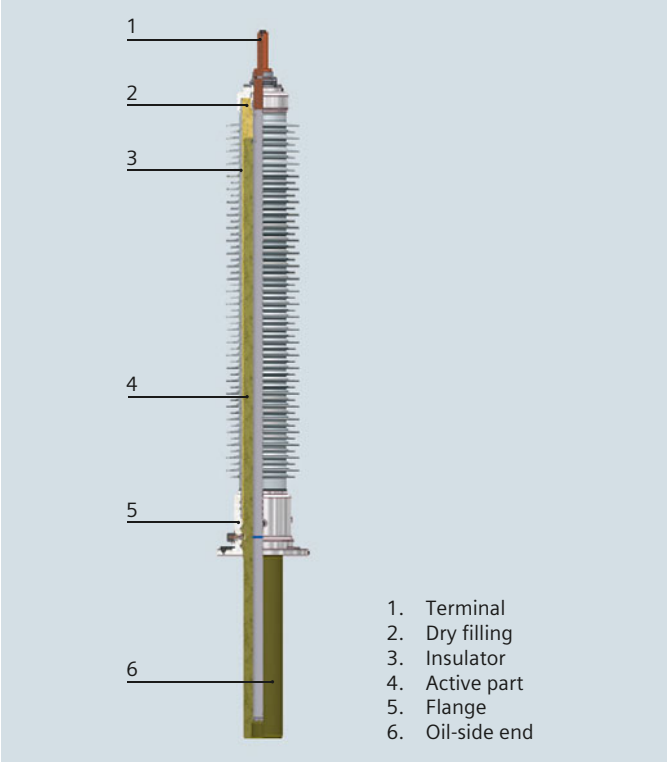


Fig. 4.8-2: **Transformer bushing – epoxy-resin-impregnated paper (RIP) design – sectional view**

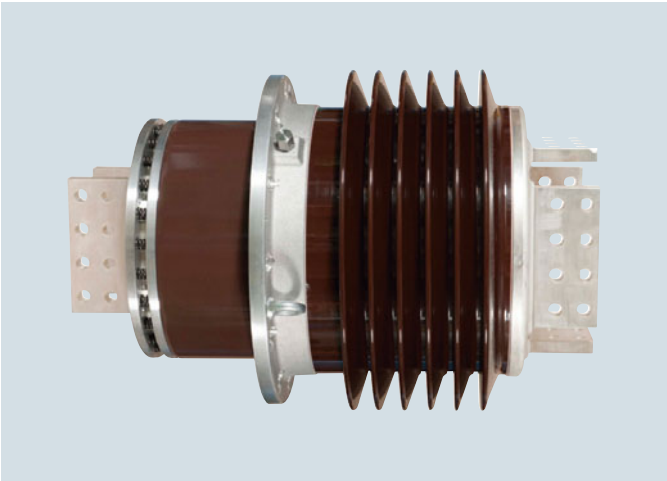


Fig. 4.8-3: **Transformer bushing – high current**

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.

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 36 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 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.

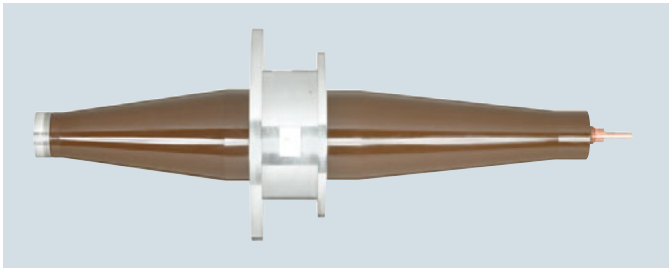


Fig. 4.8-4: **Transformer bushing – oil-to-gas**

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**

HVDC bushings: transformer and wall
The growing demand for HVDC transmission requires reliable and efficient transformer and wall bushings of up to 800 kV DC (fig. 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.

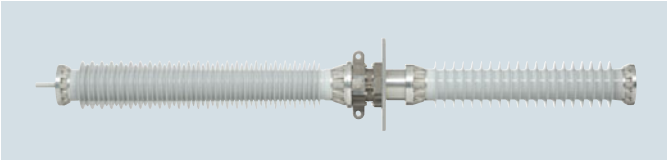


Fig. 4.8-7: **Wall bushing – air-to-air**

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

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**

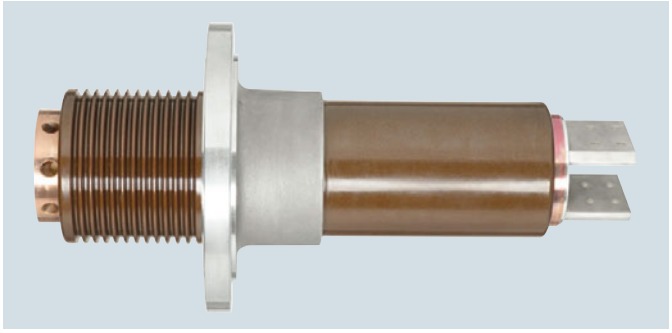


Fig. 4.8-10: **Generator bushing**

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**

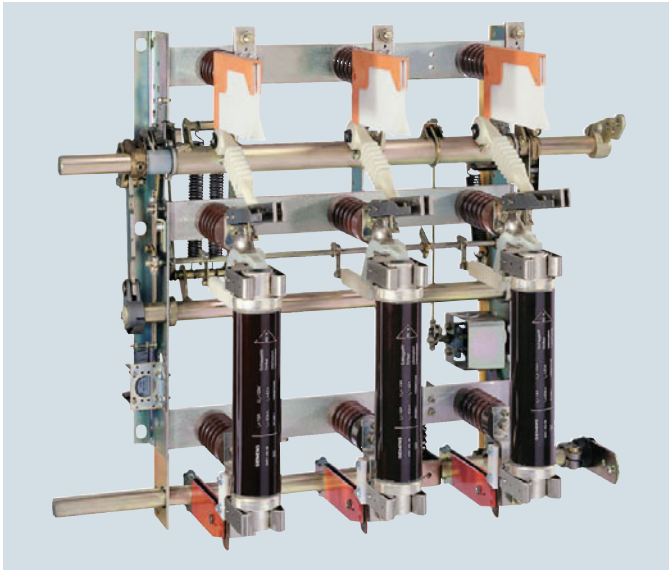


Fig. 4.9-3: **Switch-disconnector with fuse-links**

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

4.10.1 3FL Long Rod Insulators

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

Design
The 3FL insulator housing is a one-piece 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.

Core
The core rod is a boron-free, corrosionresistant 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 on 3FL insulators.

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

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

[1] *HTV: High-temperature vulcanizing*

[2] *ECR glass: Electrical- and corrosion-resistant glass*

Fig. 4.10-1: **HTV silicone rubber for best pollution performances**

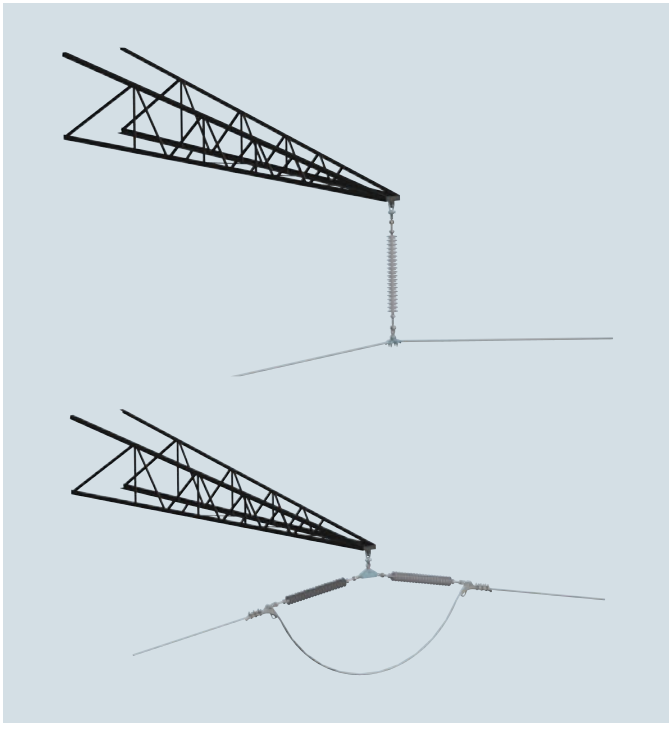


Fig. 4.10-2: **3FL long rod insulators can be used either as suspension or tension insulatorsrequirements**

4

3FL – HTV silicone rubber housing for best pollution performances

The excellent pollution layer characteristics of the HTV silicone rubber ensure maximum reliability of the 3FL insulator, even under extreme service conditions. The extremely hydrophobic housing prevents the formation of conductive film on its surface. Even the most severe ambient conditions, such as salt fog in coastal regions or dust-laden air in industrial areas, cannot impair the intrinsic hydrophobicity of the HTV silicone rubber. Surface currents and discharges are ruled out. Neither water nor dirt on the housing surface can cause insulator flashovers – a significant factor in insulator performance.

Quality from Siemens

According to long-established Siemens tradition and making use of the experience of producing high-voltage equipment for more than a century, each production step for the 3FL – beginning with numerous incoming raw material inspections through the assembly of the individual components to routine tests of the finished product – are rigorously monitored and well controlled.

Standards and tests

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

Accessories

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

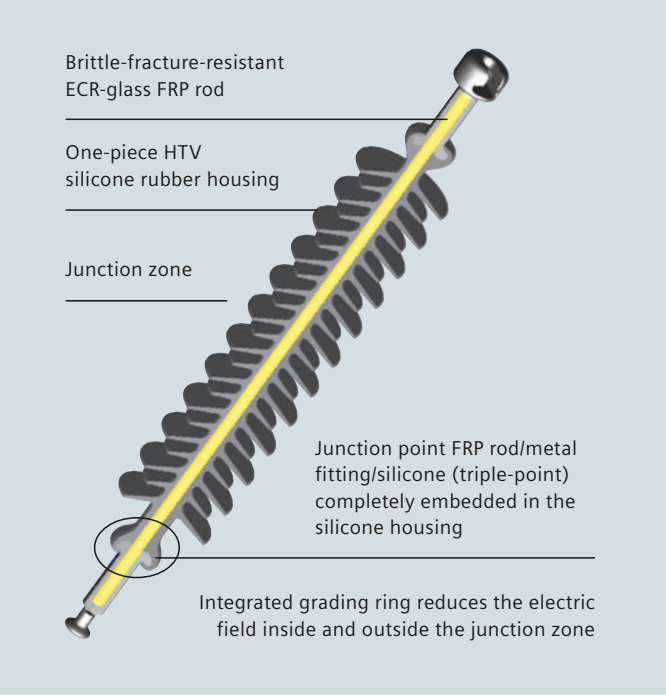


Fig. 4.10-3: **3FL – a superior design to meet the highest requirements**

Fig. 4.10-4: **Arcing horns**

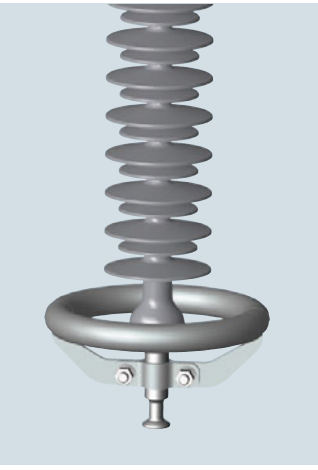


Fig. 4.10-5: **Corona ring**

Maximum values		3FL2	3FL4
Highest voltage for equipment U_m	kV	72.5	170
Nominal system voltage U_n	kV	69	154
Specified mechanical load (SML)	kN	70	120
Minimum unified specific creepage distance	mm /kV$_m$	31	31

Tab. 4.10-1: **Maximum values**

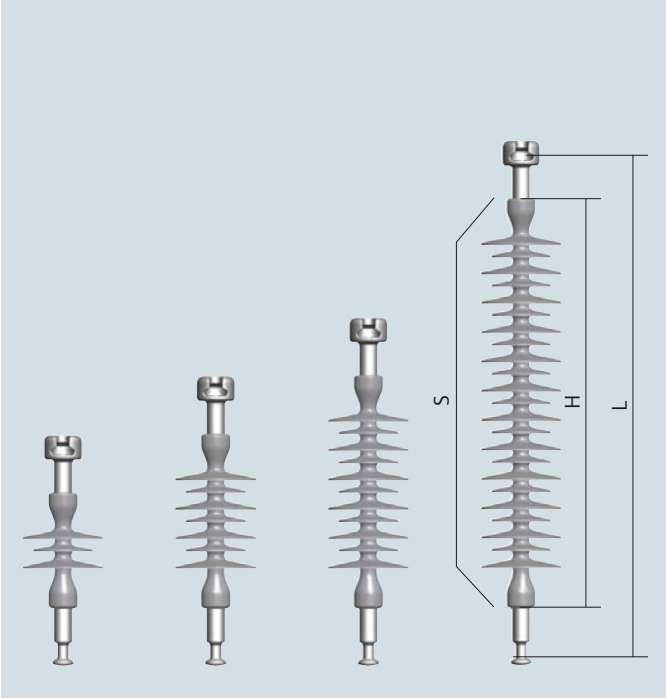


Fig. 4.10-6: **3FL2**

Fig. 4.10-7: **3FL2 end fittings**

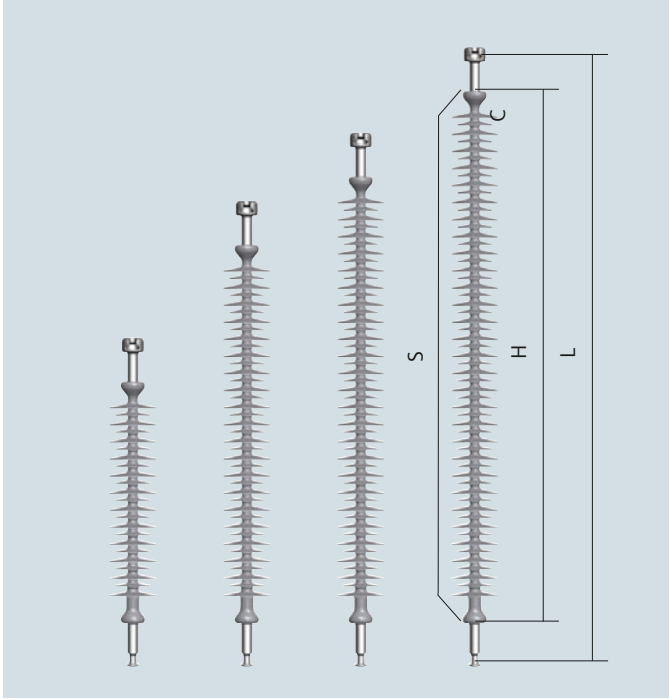


Fig. 4.10-8: **3FL4**

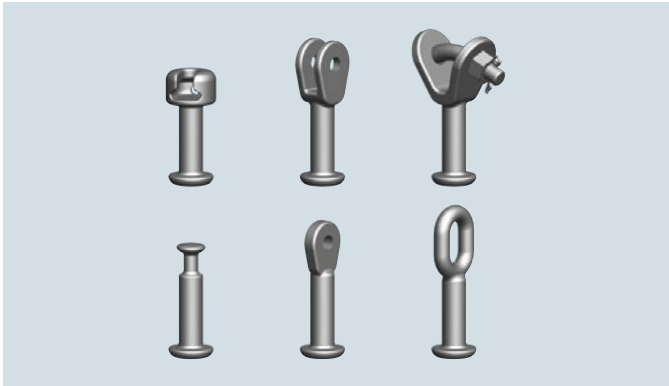


Fig. 4.10-9: **3FL4 end fittings**

3FL2 long rod insulators for distribution overhead power lines

3FL2 long rod insulators are designed to meet the highest requirements in distribution power systems up to 72 kV. They have high lightning impulse and power frequency withstand voltages and a long creepage class (> 31 mm/kV). 3FL2 insulators are available with mechanical ratings up to SML = 70 kN.

3FL4 long rod insulators for transmission overhead power lines

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

Technical data 3FL2

Highest voltage for equipment	Typical nominal system voltages	Rated* lightning impulse withstand voltage (1.2/50 µs, dry)	Rated* power frequency withstand voltage (50 Hz, 1 min, wet)	Flash-over distance	Creepage distance	Housing length	Section length** (with ball and socket)	Catalog number	Specified mechanical load	Routine test load	Corona ring diameter	Weight (with ball and socket)
Um kV	Un kV	LIWL min kV	PFWL min kV	S mm	C mm	H mm	L mm		SML kN	RTL kN	D mm	W kg
12.0	10, 11, 12	95	28	214	420	178	332	3FL2-009-4xx00-1xx1	70	35	–	1.6
24.0	15, 20, 22, 24	145	50	304	799	268	422	3FL2-014-4xx00-1xx1	70	35	–	2.0
36.0	30, 33, 35, 36	170	70	394	1178	358	512	3FL2-017-4xx00-1xx1	70	35	–	2.4
72.5	60, 66, 69, 72	325	140	664	2315	628	782	3FL2-032-4xx00-1xx1	70	35	–	3.55

* Rated lightning impulse withstand voltage and power frequency withstand voltage in accordance with IEC 60071. The physical value is higher.
** Reference value of the section length of the insulator for version with ball and socket end fittings of size 16 in accordance with IEC 60120. In order to obtain the section length of the insulator implemented with other end fittings, the housing length and connection lengths (see table "End fittings") of both end fittings must be added together. All electrical values refer to an insulator without arcing horns or corona rings.

Tab. 4.10-2: **Technical data 3FL2**

Technical data 3FL4

Highest voltage for equipment	Typical nominal system voltages	Rated* lightning impulse withstand voltage (1.2/50 µs, dry)	Rated* power frequency withstand voltage (50 Hz, 1 min, wet)	Flash-over distance	Creepage distance	Housing length	Section length** (with ball and socket)	Catalog number	Specified mechanical load	Routine test load	Corona ring diameter	Weight (with ball and socket)
Um kV	Un kV	LIWL min kV	PFWL min kV	S mm	C mm	H mm	L mm		SML kN	RTL kN	D mm	W kg
72.5	60, 66, 69, 72	325	140	674	2325	638	846	3FL4-032-4xx00-1xx1	120	60	–	3.8
123.0	110,115, 120	550	230	1034	3841	998	1206	3FL4-055-4xx00-1xx1	120	60	–	5.3
145.0	132, 138	650	275	1214	4599	1178	1386	3FL4-065-4xx00-1xx1	120	60	260	6.1
170.0	150, 154	750	325	1439	5546	1403	1611	3FL4-075-4xx00-1xx1	120	60	260	7.1

* Rated lightning impulse withstand voltage and power frequency withstand voltage in accordance with IEC 60071. The physical value is higher.
** Reference value of the section length of the insulator for version with ball-and-socket end fittings of size 16 in accordance with IEC 60120. In order to obtain the section length of the insulator implemented with other end fittings, the housing length and connection lengths (see table "End fittings") of both end fittings must be added together. All electrical values refer to an insulator without arcing horns or corona rings.

Tab. 4.10-3: **Technical data 3FL4**

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

Tab. 4.10-4: **Product standards**

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