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# 3 Switchgear and Substations

## 3.1 High-Voltage Substations

### 3.1.1 Turnkey Substations

#### Introduction

High-voltage substations are interconnection points within the power transmission and distribution grids between regions and countries. Different applications of substations lead to high-voltage substations with and without power transformers:

- Step up from a generator-voltage level to a high-voltage system (MV/HV)
  - Power plants (in load centers)
  - Renewable power plants (e.g., windfarms)
- Transform voltage levels within the high-voltage grid (HV/HV)
- Step down to a medium-voltage level of a distribution system (HV/MV)
- Interconnection in the same voltage level.

#### Scope

High-voltage substations comprise not only the high-voltage equipment which is relevant for the functionality in the power supply system. Siemens plans and constructs high-voltage substations comprising high-voltage switchgear, medium-voltage switchgear, major components such as high-voltage equipment and transformers, as well as all ancillary equipment such as auxiliaries, control systems, protective equipment and so on, on a turnkey basis or even as general contractor. The installations supplied worldwide range from basic substations with a single busbar to interconnection substations with multiple busbars, or a breaker-and-a-half arrangement for rated voltages up to 800 kV, rated currents up to 8,000 A and short-circuit currents up to 100 kA. The services offered range from system planning to commissioning and after-sales service, including training of customer personnel.

#### Project management

The process of handling such a turnkey installation starts with preparation of a quotation, and proceeds through clarification of the order, design, manufacture, supply and cost-accounting until the project is finally billed. Processing such an order hinges on methodical data processing that in turn contributes to systematic project handling.

#### Engineering

All these high-voltage installations have in common their high standard of engineering which covers all system aspects such as power systems, steel structures, civil engineering, fire precautions, environmental protection and control systems (fig. 3.1-1). Every aspect of technology and each work stage is handled by experienced engineers. With the aid of high-performance computer programs, e.g., the finite element method (FEM), installations can be reliably designed even for extreme stresses, such as those encountered in earthquake zones.

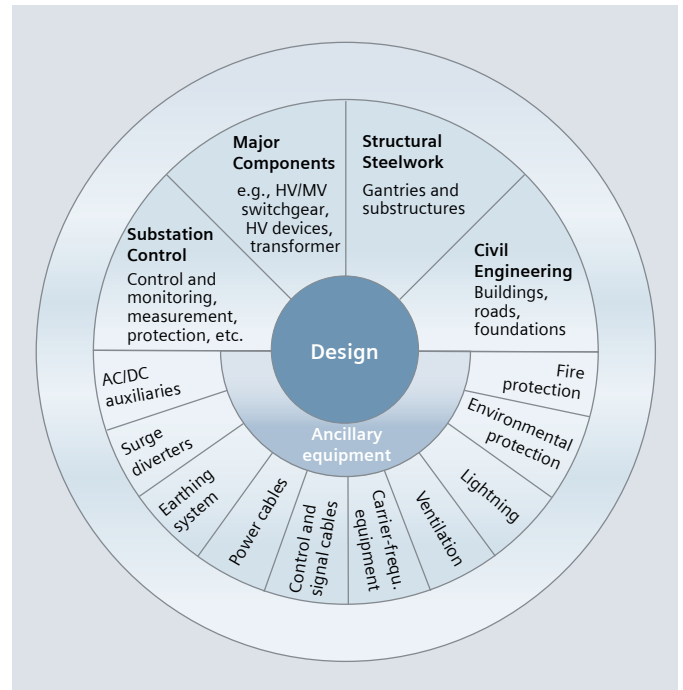


Fig. 3.1-1: Engineering of high-voltage switchgear

All planning documentation is produced on modern CAD/CAE systems; data exchange with other CAD systems is possible via interfaces. By virtue of their active involvement in national and international associations and standardization bodies, our engineers are always fully informed of the state of the art, even before a new standard or specification is published.

#### Certification of the integrated quality management system

At the beginning of the 1980s, a documented QM system was already introduced. The basis of the management system is the documentation of all processes relevant for quality, occupational safety and environmental protection.

The environment protection was implemented on the basis of the existing QM system and was certified in accordance with DIN ISO 14001 in 1996. Occupational safety and health have always played an important role for Siemens AG and for the respective Business Units. When the BS OHSAS 18001 standard was introduced, the conditions for a certification analogous to the existing management systems were created.

#### Know-how, experience and worldwide presence

A worldwide network of liaisons and sales offices, along with the specialist departments in Germany, support and advise system operators in all matters of high-voltage substations technology.



### 3.1.2 High-Voltage Switchgear – Overview

High-voltage substations comprising high-voltage switchgear and devices with different insulating systems: air or gas ( $\text{SF}_6$ ). When planning high-voltage substations, some basic questions have to be answered to define the type of high-voltage switchgear:

What is the function and location within the power supply system?  
What are the climatic and environmental conditions?  
Are there specific requirements regarding locations?  
Are there space/cost restrictions?

Depending on the answers, either AIS or GIS can be the right choice, or even a compact or hybrid solution.

#### Air-insulated switchgear (AIS)

AIS are favorably priced high-voltage substations for rated voltages up to 800 kV, which are popular wherever space restrictions and environmental circumstances are not severe. The individual electrical and mechanical components of an AIS installation are assembled on site. Air-insulated outdoor substations of open design are not completely safe to touch, and are directly exposed to the effects of the climate and the environment (fig. 3.1-2).

#### Gas-insulated switchgear (GIS)

The compact design and small dimensions of GIS make it possible to install substations of up to 550 kV right in the middle of load centers of urban or industrial areas. Each switchgear bay is factory-assembled and includes the full complement of disconnecting switches, earthing switches (regular or make-proof), instrument transformers, control and protection equipment, and interlocking and monitoring facilities commonly used for this type of installation. The earthed metal enclosures of GIS assure not only insensitivity to contamination but also safety from electric shock (fig. 3.1-3).

#### Mixed technology (compact/hybrid solutions)

Beside the two basic (conventional) designs, there are also compact solutions available that can be realized with air-insulated and/or gas-insulated components.



Fig. 3.1-2: Air-insulated outdoor switchgear



Fig. 3.1-3: GIS substations in metropolitan areas



### 3.1.3 Circuit Configuration

High-voltage substations are points in the power system where power can be pooled from generating sources, distributed and transformed, and delivered to the load points. Substations are interconnected with each other, so that the power system becomes a meshed network. This increases reliability of the power supply system by providing alternate paths for flow of power to take care of any contingency, so that power delivery to the loads is maintained and the generators do not face any outage. The high-voltage substation is a critical component in the power system, and the reliability of the power system depends upon the substation. Therefore, the circuit configuration of the high-voltage substation has to be selected carefully.

Busbars are the part of the substation where all the power is concentrated from the incoming feeders, and distributed to the outgoing feeders. That means that the reliability of any high-voltage substation depends on the reliability of the busbars present in the power system. An outage of any busbar can have dramatic effects on the power system. An outage of a busbar leads to the outage of the transmission lines connected to it. As a result, the power flow shifts to the surviving healthy lines that are now carrying more power than they are capable of. This leads to tripping of these lines, and the cascading effect goes on until there is a blackout or similar situation. The importance of busbar reliability should be kept in mind when taking a look at the different busbar systems that are prevalent.

#### Single-busbar scheme (1 BB)

The applications of this simple scheme are distribution and transformer substations, and feeding industrial areas (fig. 3.1-4). Because it has only one busbar and the minimum amount of equipment, this scheme is a low-cost solution that provides only limited availability. In the event of a busbar failure and during maintenance periods, there will be an outage of the complete substation. To increase the reliability, a second busbar has to be added.

#### Double-busbar scheme (2 BB)

The more complex scheme of a double-busbar system gives much more flexibility and reliability during operation of the substation (fig. 3.1-5). For this reason, this scheme is used for distribution and transformer substations at the nodes of the power supply system. It is possible to control the power flow by using the busbars independently, and by switching a feeder from one busbar to the other. Because the busbar disconnectors are not able to break the rated current of the feeder, there will be a short disruption in power flow.

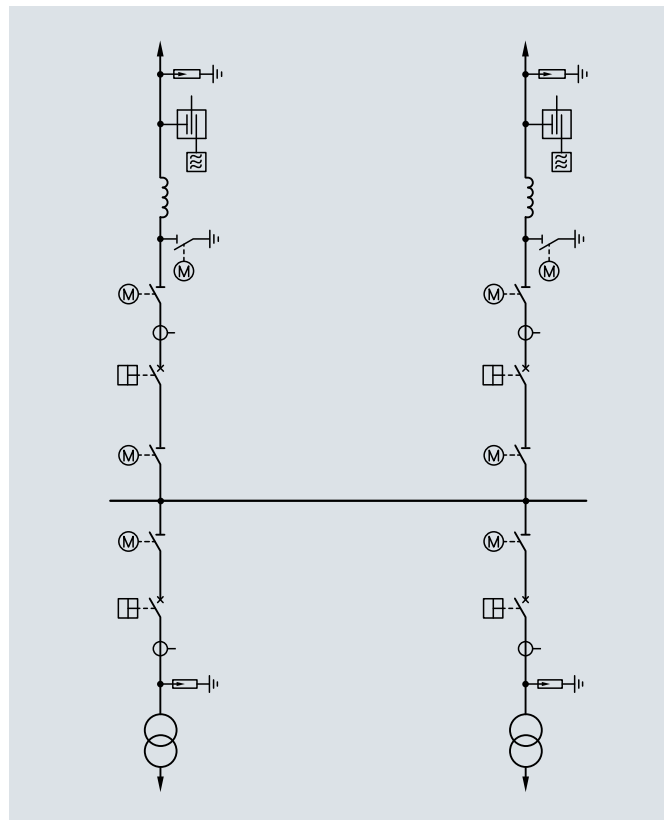


Fig. 3.1-4: Special single busbar, H-scheme (1 BB)

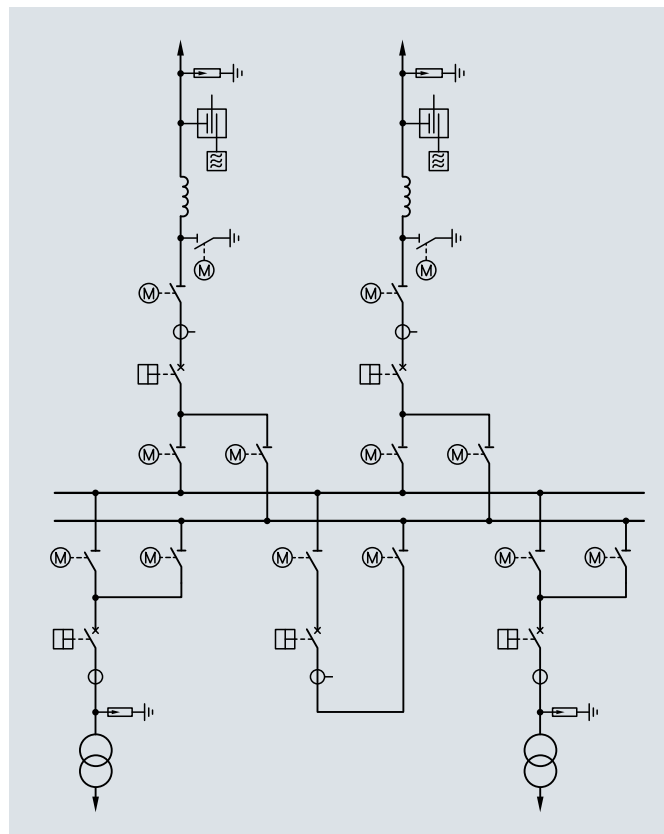


Fig. 3.1-5: Double-busbar scheme (2 BB)

### Double circuit-breaker scheme (2 CB)

To have a load change without disruption, a second circuit-breaker per feeder has to be used. This is the most expensive way to solve this problem. In very important feeders, the 2 CB solution will be used (fig. 3.1-6).

### One-breaker-and-a-half scheme (1.5 CB)

The one-breaker-and-a-half is a compromise between the 2 BB and the 2 CB scheme. This scheme improves the reliability and flexibility because, even in case of loss of a complete busbar, there is no disruption in the power supply of the feeders (fig. 3.1-7).

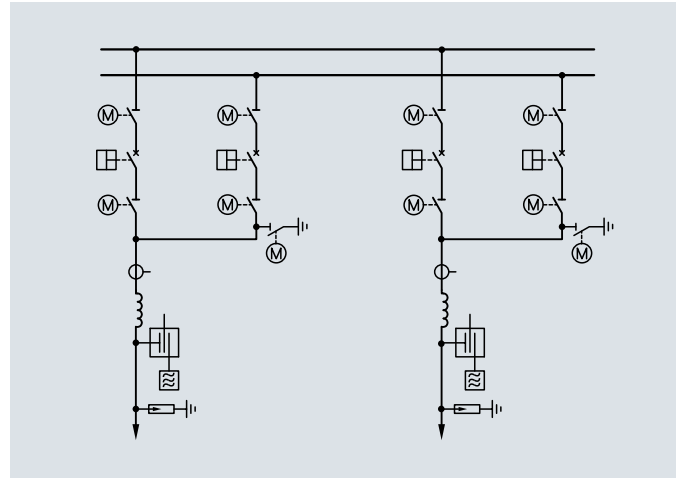


Fig. 3.1-6: Double circuit-breaker scheme (2 CB)

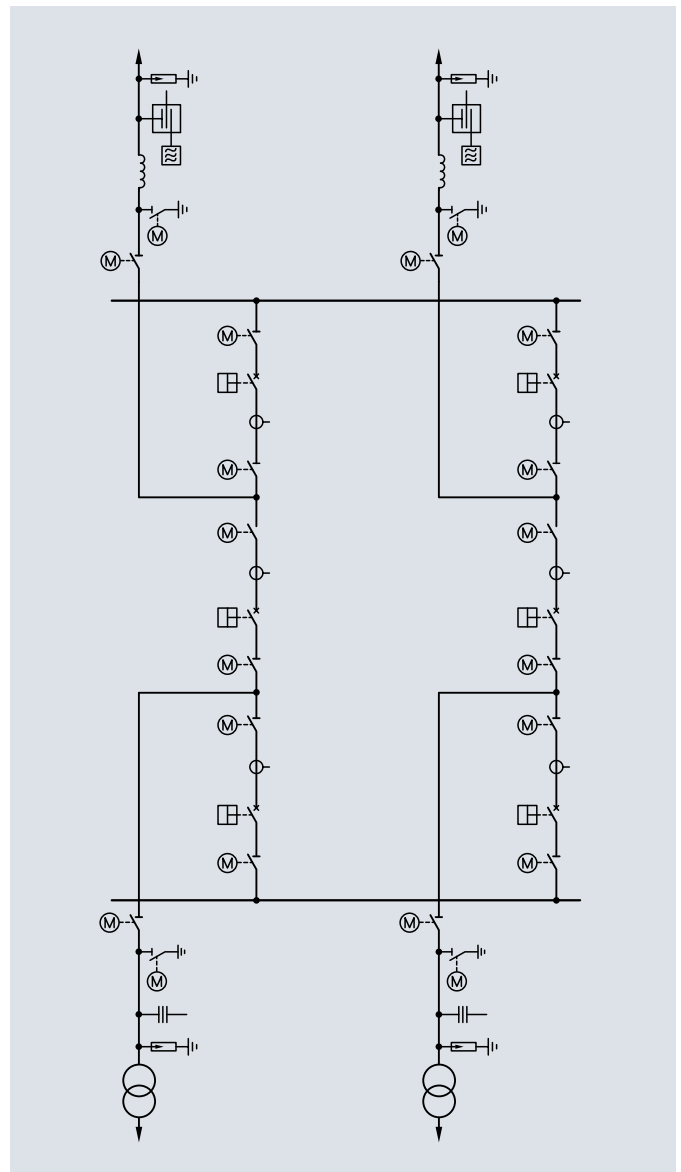


Fig. 3.1-7: One-breaker-and-a-half scheme (1.5 CB)



# Switchgear and Substations

## 3.1 High-Voltage Substations

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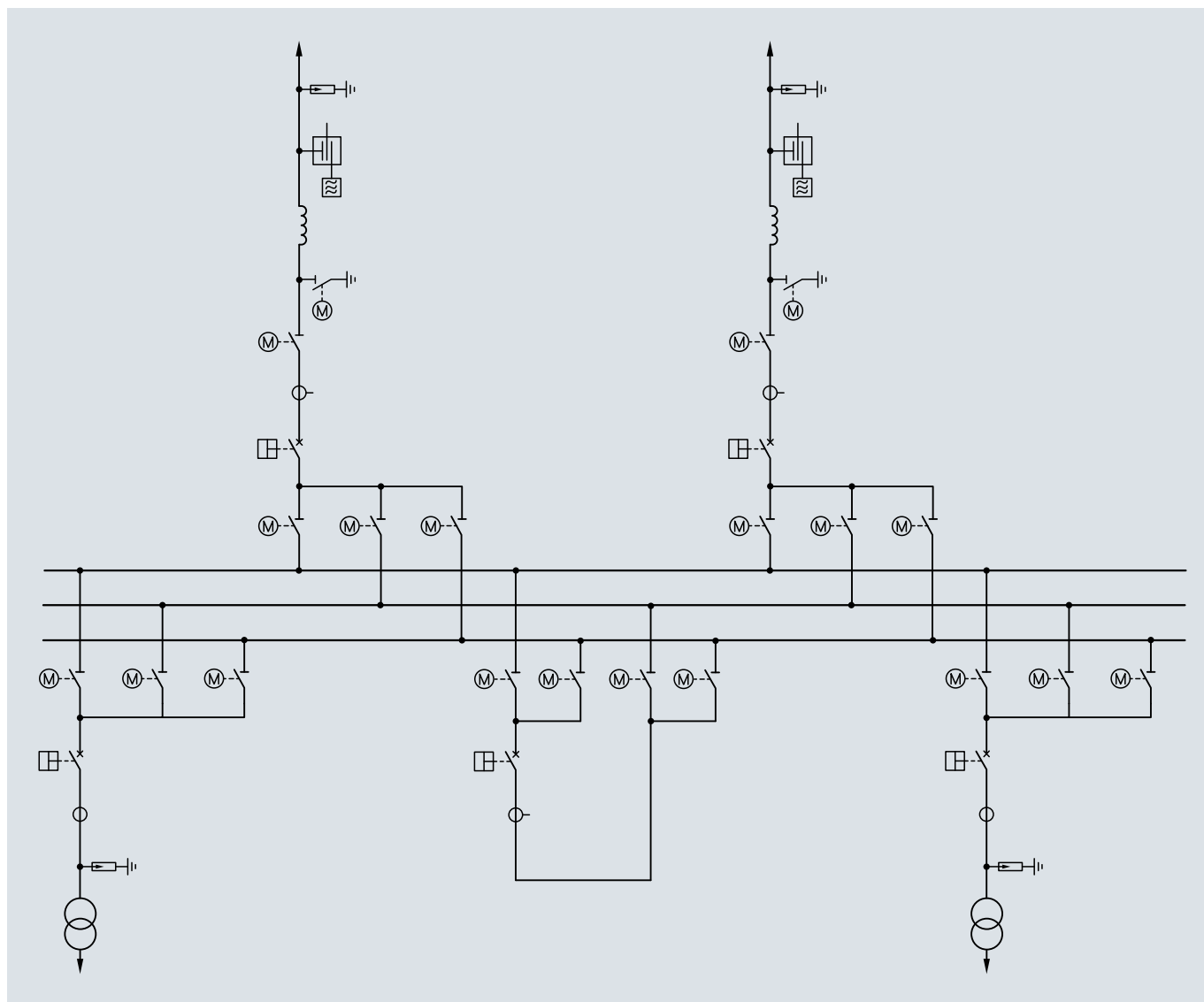


Fig. 3.1-8: Triple-busbar scheme (3 BB)

### Triple-busbar scheme (3 BB)

For important substations at the nodes of transmission systems for higher voltage levels, the triple-busbar scheme is used. It is a common scheme in Germany, utilized at the 380 kV level (fig. 3.1-8).

### 3.1.4 Air-Insulated Substations

In outdoor installations of open design, all live parts are insulated by air and not covered. Therefore, air-insulated substations (AIS) are always set up in a fenced area. Only authorized personnel have access to this operational area. Relevant national and international specifications that apply to outdoor substations and equipment have to be considered. The IEC 61936 standard is valid for European countries. Insulation coordination, including minimum phase-to-phase and phase-to-earth clearances, is effected in accordance with IEC 60071.

Outdoor switchgear is directly exposed to the effects of the environmental conditions. Therefore, they have to be designed both for electrical and environmental specifications. There is currently no common international standard covering the setup of air-insulated outdoor substations of open design. Siemens designs AIS in accordance with IEC standards, in addition to national standards or customer specifications. The standard IEC 61936-1, "Erection of power installations with rated voltages above 1 kV," demonstrates the typical protective measures and stresses that have to be taken into consideration for air-insulated switchyards.

#### Protective measures

The protective measures can be categorized as personal protection and functional protection of substations (S/S).

- Personal protection
  - Protective measures against direct contact, i. e., through appropriate covering, obstruction, through sufficient clearance, appropriately positioned protective devices, and minimum height
  - Protective measures against indirect touching by means of relevant earthing measures in accordance with IEC 61936/ DIN VDE 0101 or other required standards
  - Protective measures during work on equipment, i.e., installation must be planned so that the specifications of DIN EN 50110 (VDE 0105) (e.g., five safety rules) are observed
- Functional protection
  - Protective measures during operation, e.g., use of switchgear interlocking equipment
  - Protective measures against voltage surges and lightning strikes
  - Protective measures against fire, water and, if applicable, noise
- Stresses
  - Electrical stresses, e.g., rated current, short-circuit current, adequate creepage distances and clearances
  - Mechanical stresses (normal stressing), e.g., weight, static and dynamic loads, ice, wind
  - Mechanical stresses (exceptional stresses), e.g., weight and constant loads in simultaneous combination with maximum switching forces or short-circuit forces, etc.
  - Special stresses, e.g., caused by installation altitudes of more than 1,000 m above sea level, or by earthquakes.

#### Variables affecting switchgear installation

The switchyard design is significantly influenced by:

- Minimum clearances (depending on rated voltages) between various active parts and between active parts and earth
- Rated and short-circuit currents
- Clarity for operating staff
- Availability during maintenance work; redundancy
- Availability of land and topography
- Type and arrangement of the busbar disconnectors.

The design of a substation determines its accessibility, availability and clarity. It must therefore be coordinated in close cooperation with the system operator. The following basic principles apply: Accessibility and availability increase with the number of busbars. At the same time, however, clarity decreases. Installations involving single busbars require minimum investment, but they offer only limited flexibility for operation management and maintenance. Designs involving one-breaker-and-a-half and double-circuit-breaker arrangements ensure a high redundancy, but they also entail the highest costs.

Systems with auxiliary or bypass busbars have proved to be economical. The circuit-breaker of the coupling feeder for the auxiliary bus allows uninterrupted replacement of each feeder circuit-breaker. For busbars and feeder lines, mostly standard aluminum conductors are used. Bundle conductors are required where currents are high. Because of the additional short-circuit forces between the subconductors (the pinch effect), however, bundle conductors cause higher mechanical stresses at the terminal points. When conductors (particularly standard bundle conductors) are used, higher short-circuit currents cause a rise not only in the aforementioned pinch effect, also in further force maxima in the event of swinging and dropping of the conductor bundle (cable pull). This in turn results in higher mechanical stresses on the switchyard components. These effects can be calculated in an FEM (finite element method) simulation (fig. 3.1-9).

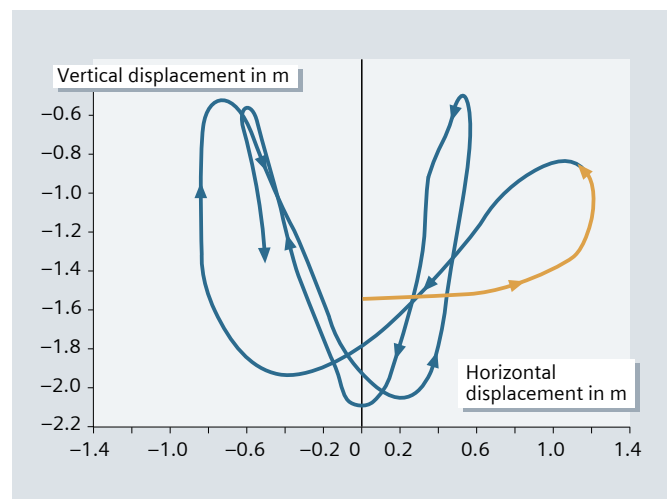


Fig. 3.1-9: FEM calculation of deflection of wire conductors in the event of short circuit



# Switchgear and Substations

## 3.1 High-Voltage Substations

### Computer-aided engineering/design (CAE/CAD)

A variety of items influence the design of air-insulated substations. In the daily engineering work, database-supported CAE tools are used for the primary and secondary engineering of the substations. The database speeds up all the engineering processes by using predefined solutions and improves the quality (fig. 3.1-10).

### Design of air-insulated substations

When rated and short-circuit currents are high, aluminum tubes are increasingly used to replace wire conductors for busbars and feeder lines. They can handle rated currents up to 8,000 A and short-circuit currents up to 80 kA without difficulty. Other influences on the switchyard design are the availability of land, the lie of the land, the accessibility and location of incoming and outgoing overhead-lines, and the number of transformers and voltage levels. A one-line or two-line arrangement, and possibly a U-arrangement, may be the proper solution. Each outdoor switchgear installation, especially for step-up substations in connection with power plants and large transformer substations in the extra-high-voltage transmission system, is therefore unique, depending on the local conditions. HV/MV transformer substations of the distribution system, with repeatedly used equipment and a scheme of one incoming and one outgoing line as well as two transformers together with medium-voltage switchgear and auxiliary equipment, are usually subject to a standardized design.

### Preferred designs

Conceivable designs include certain preferred versions that are often dependent on the type and arrangement of the busbar disconnectors.

#### *H-arrangement*

The H-arrangement is preferred for use in applications for feeding industrial consumers. Two overhead-lines are connected with two transformers and interlinked by a double-bus sectionalizer. Thus, each feeder of the switchyard can be maintained without disturbance of the other feeders (fig. 3.1-11, fig. 3.1-12).

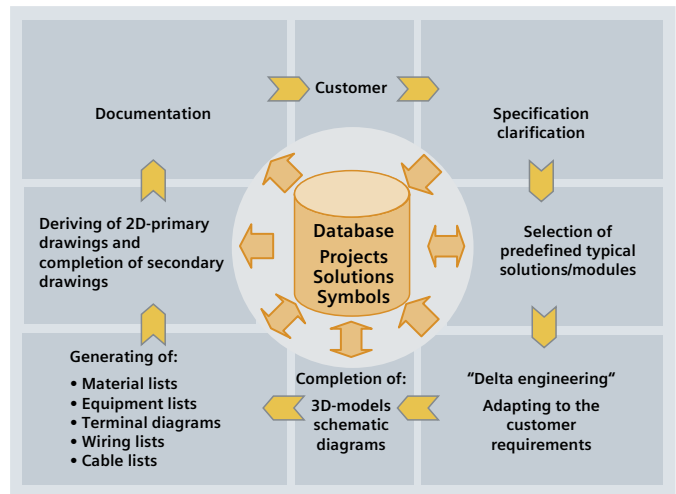


Fig. 3.1-10: Database-supported engineering

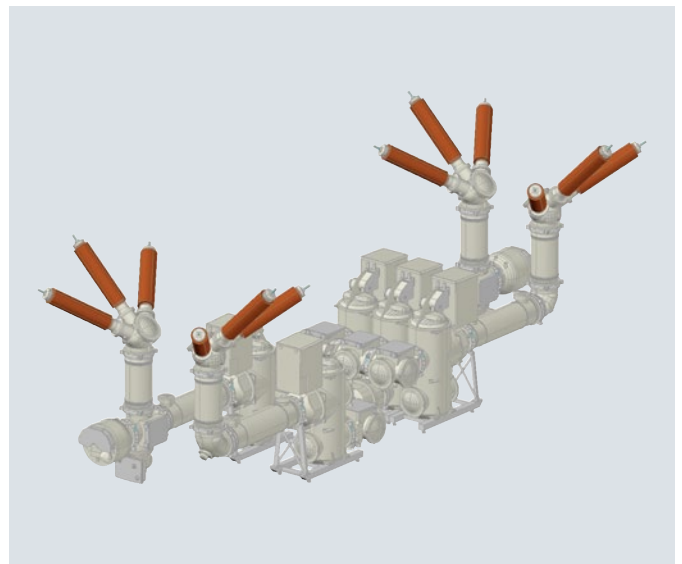


Fig. 3.1-11: H-arrangement 123 kV, GIS (3D view – HIS)

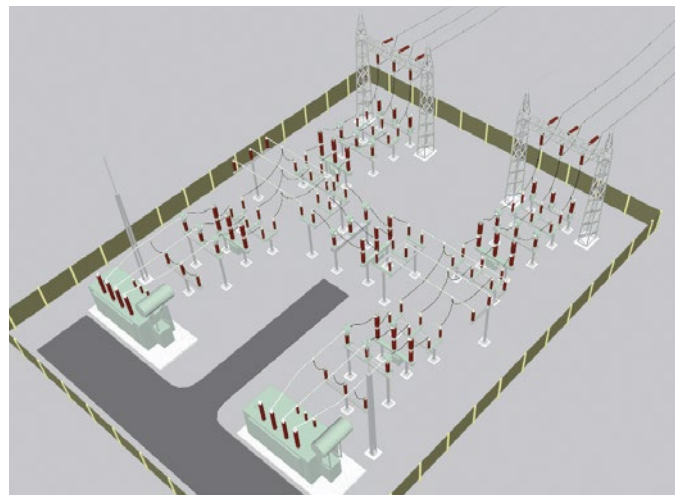


Fig. 3.1-12: 110 kV H-arrangement, conventional AIS (3D view)

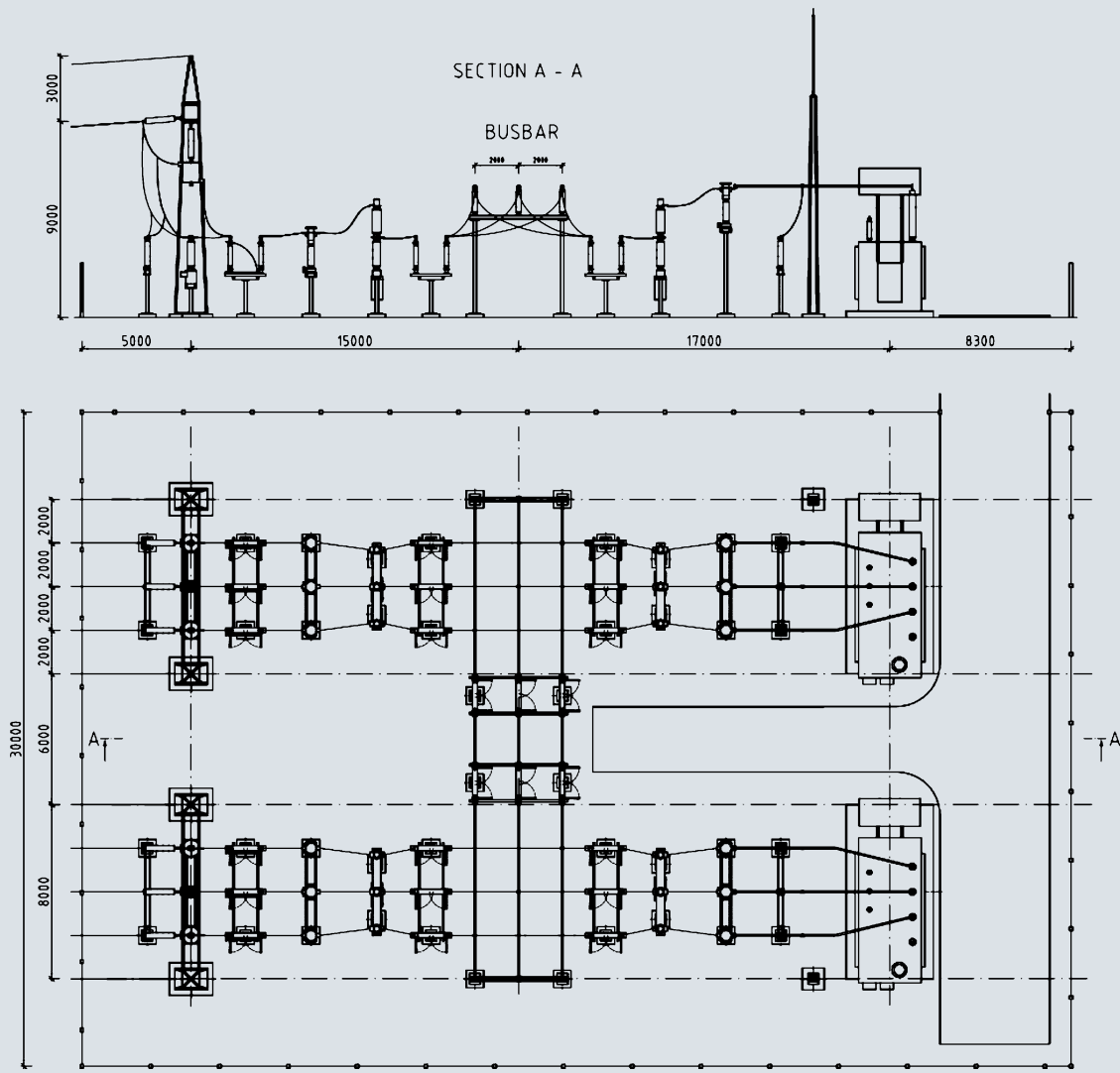


Fig. 3.1-13: H-arrangement 110 kV

### H-arrangement

The H-arrangement is preferred for use in applications for feeding industrial consumers. Two overhead-lines are connected with two transformers and interlinked by a double-bus sectionalizer. Thus, each feeder of the switchyard can be maintained without disturbance of the other feeders (fig. 3.1-13, fig. 3.1-14).



Fig. 3.1-14: H-arrangement, 110 kV, Germany



# Switchgear and Substations

## 3.1 High-Voltage Substations

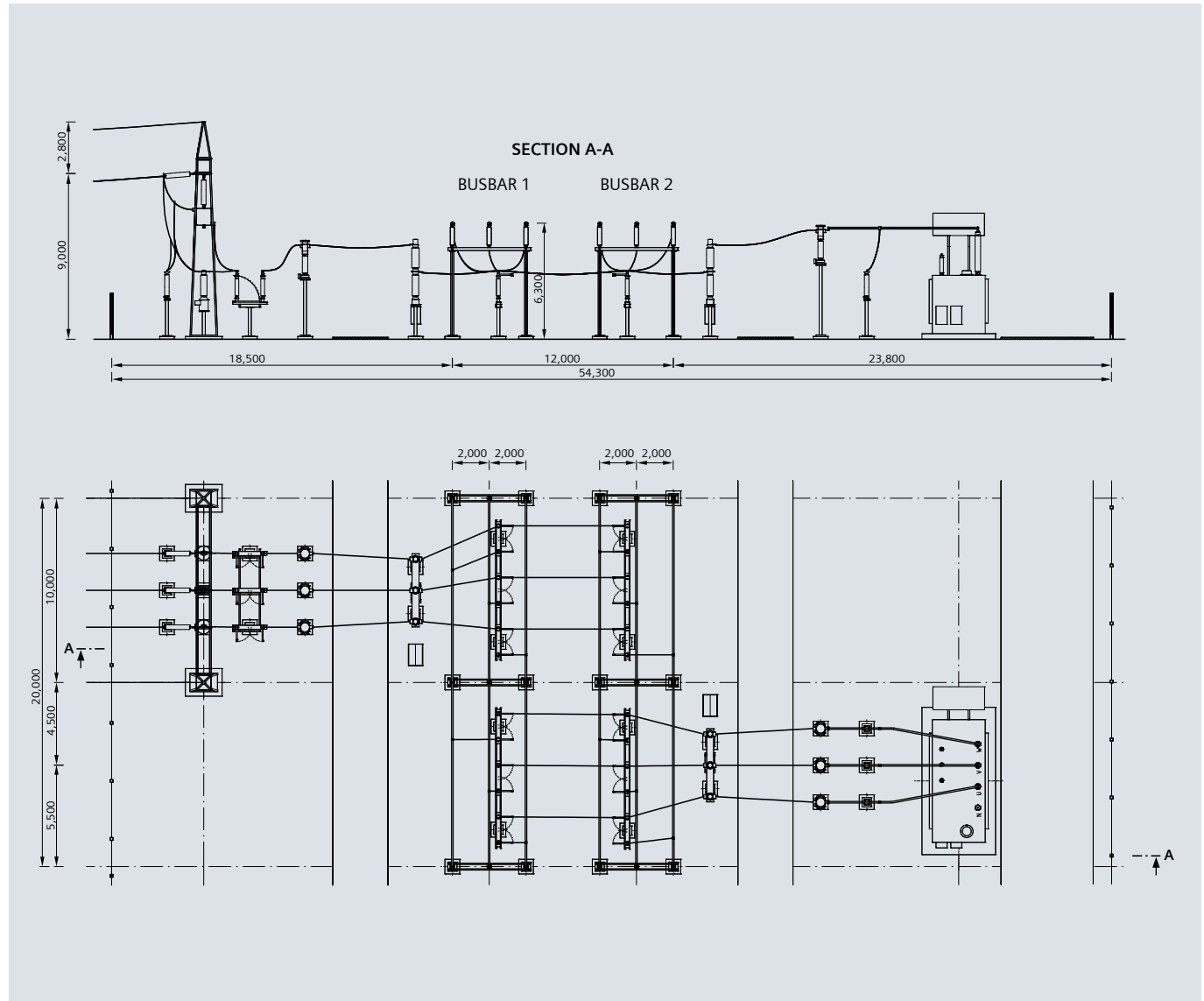


Fig. 3.1-15: In-line arrangement, 110 kV

*In-line longitudinal arrangement (Kiellinie®), with center-break disconnectors, preferably 110 to 220 kV*

The busbar disconnectors are lined up one behind the other and parallel to the longitudinal axis of the busbar. It is preferable to have either wire-type or tubular busbars. Where tubular busbars are used, gantries are required for the outgoing overhead lines only. The system design requires only two conductor levels and is therefore clear. The bay width is quite large (in-line arrangement of disconnectors), but the bay length is small (fig. 3.1-15, fig. 3.1-16).



Fig. 3.1-16: Busbar disconnectors "in line", 110 kV, Germany

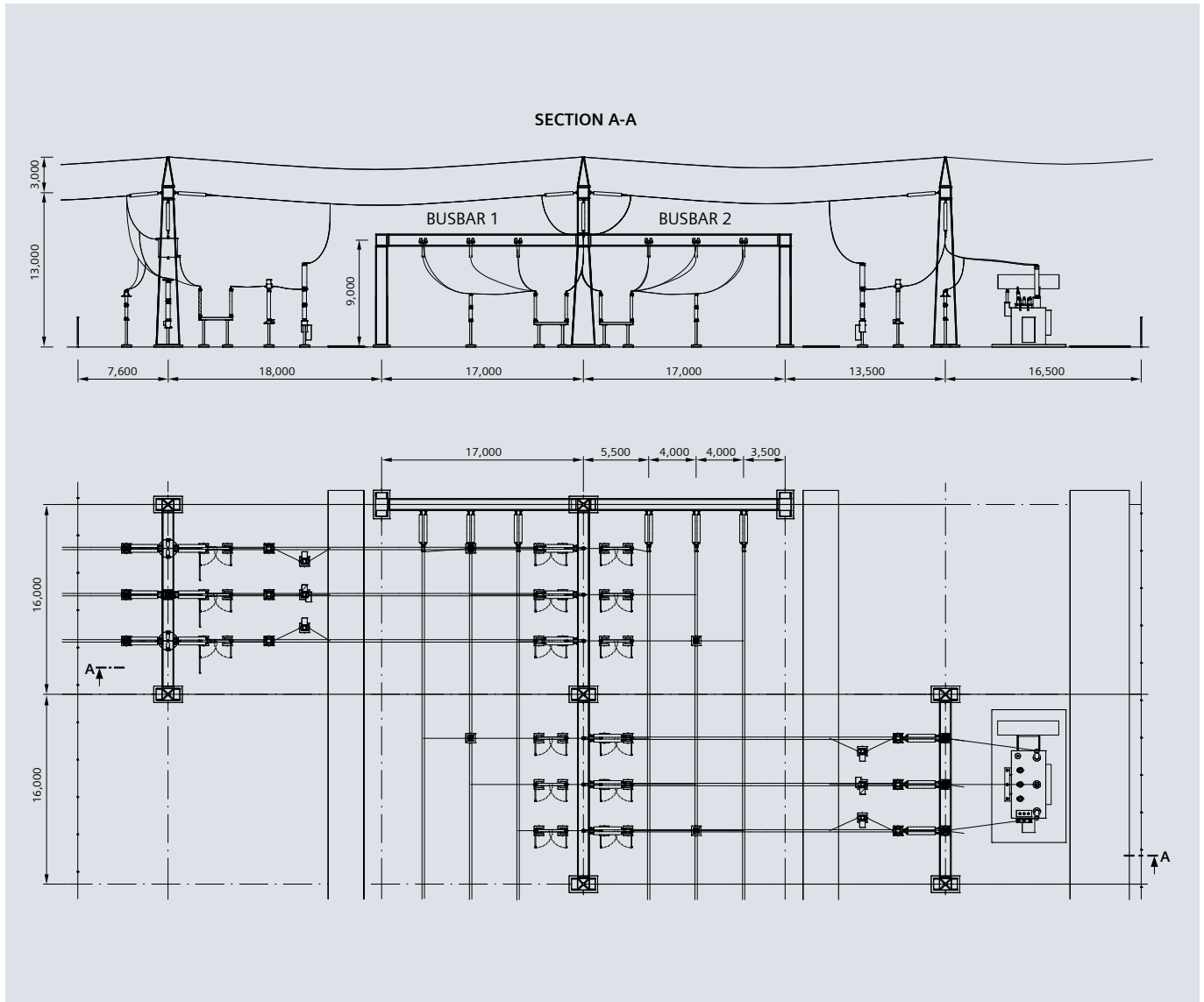


Fig. 3.1-17: Central/center tower arrangement, 220 kV

*Central/center arrangement (classical arrangement) layout with center-break disconnectors, normally only for 245 kV*  
 The busbar disconnectors are arranged side-by-side and parallel to the longitudinal axis of the feeder. Wire-type busbars located at the top are commonly used; tubular busbars are also possible. This arrangement enables the conductors to be easily jumped over the circuit-breakers, and the bay width to be made smaller than that of in-line designs. With three conductor levels, the system is relatively clear, but the cost of the gantries is high (fig. 3.1-17, fig. 3.1-18).



Fig. 3.1-18: Central/center tower arrangement, 220 kV, Egypt

# Switchgear and Substations

## 3.1 High-Voltage Substations

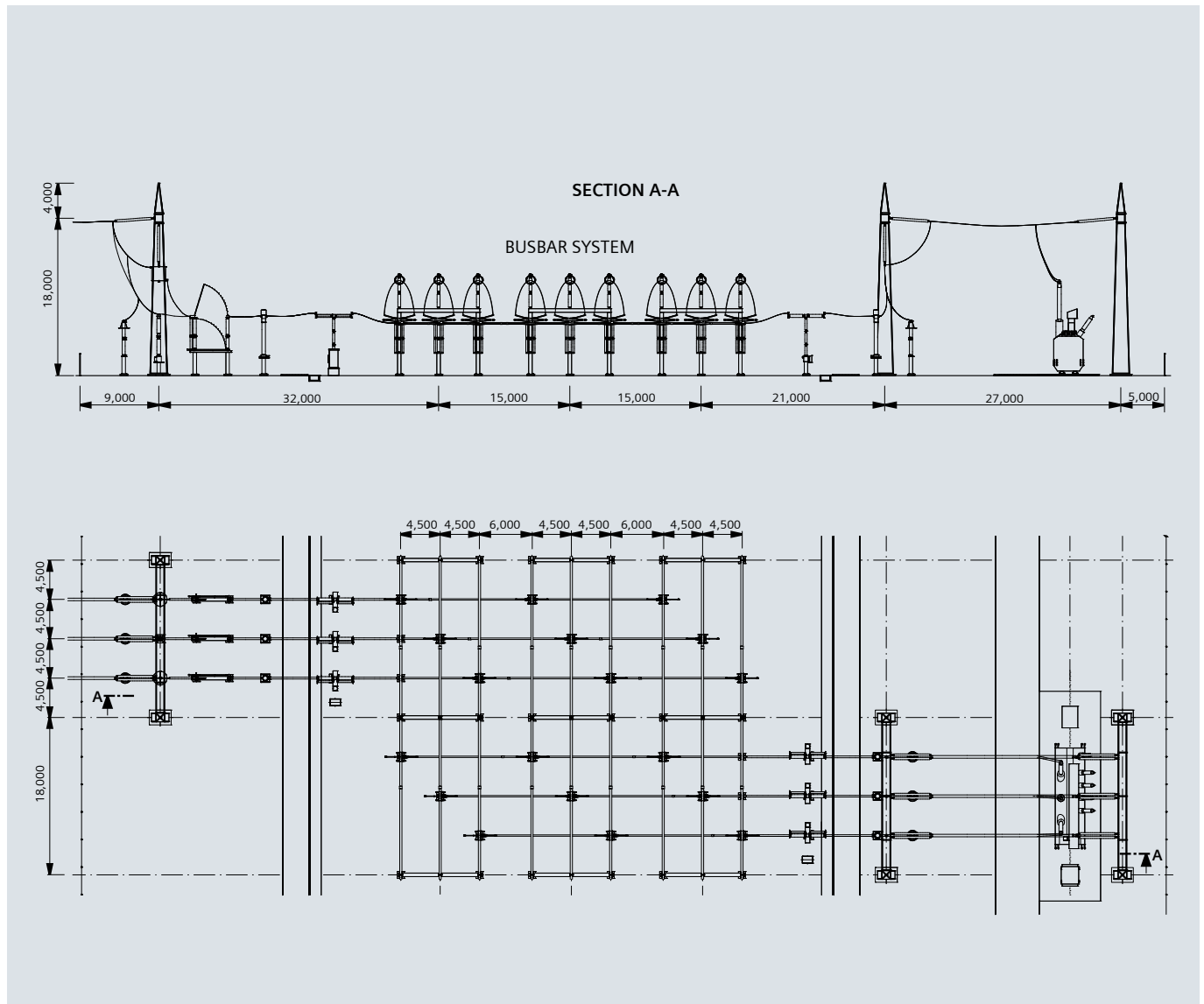


Fig. 3.1-19: Diagonal arrangement, 380 kV

*Diagonal layout with pantograph disconnectors, preferably 110 to 420 kV*

The pantograph disconnectors are placed diagonally to the axis of the busbars and feeder. This results in a very clear and most space-saving arrangement. Wire and tubular conductors are customary. The busbars can be located above or below the feeder conductors (fig. 3.1-19, fig. 3.1-20).



Fig. 3.1-20: Busbar disconnectors in diagonal arrangement, 380 kV, Germany



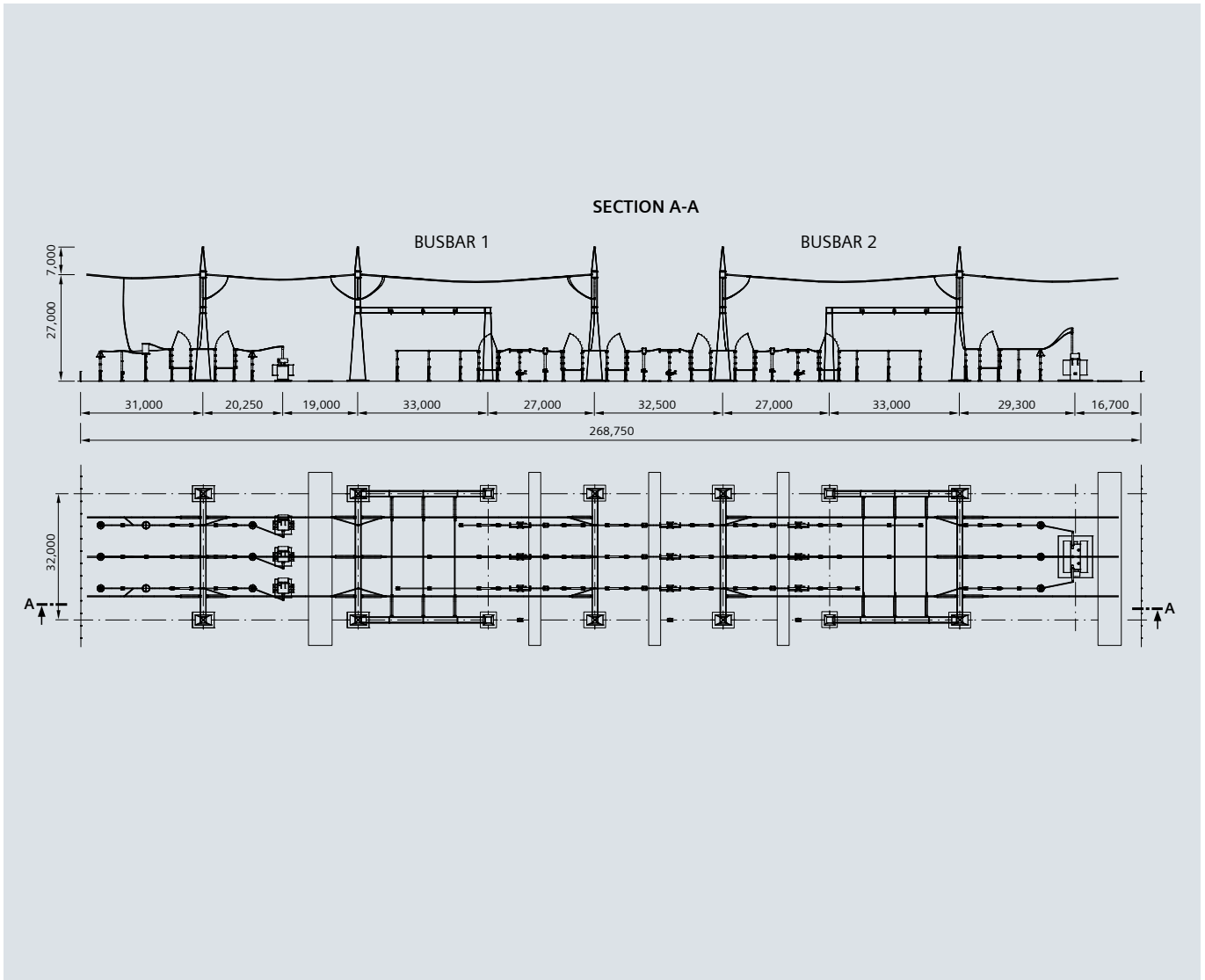


Fig. 3.1-21: One-breaker-and-a-half arrangement, 500 kV

*One-breaker-and-a-half layout, preferably up to 220 to 800 kV*  
 The one-breaker-and-a-half arrangement ensures high supply reliability; however, the expenditure for equipment is high as well. The busbar disconnectors are of the pantograph, rotary or vertical-break type. Vertical-break disconnectors are preferred for the feeders. The busbars located at the top can be either the wire or tubular type. Two arrangements are customary:

- Internal busbar, feeders in H-arrangement with two conductor levels
- External busbar, feeders in-line with three conductor levels (fig. 3.1-21, fig. 3.1-22)



Fig. 3.1-22: One-breaker-and-a-half arrangement, 500 kV, Pakistan

# Switchgear and Substations

## 3.1 High-Voltage Substations

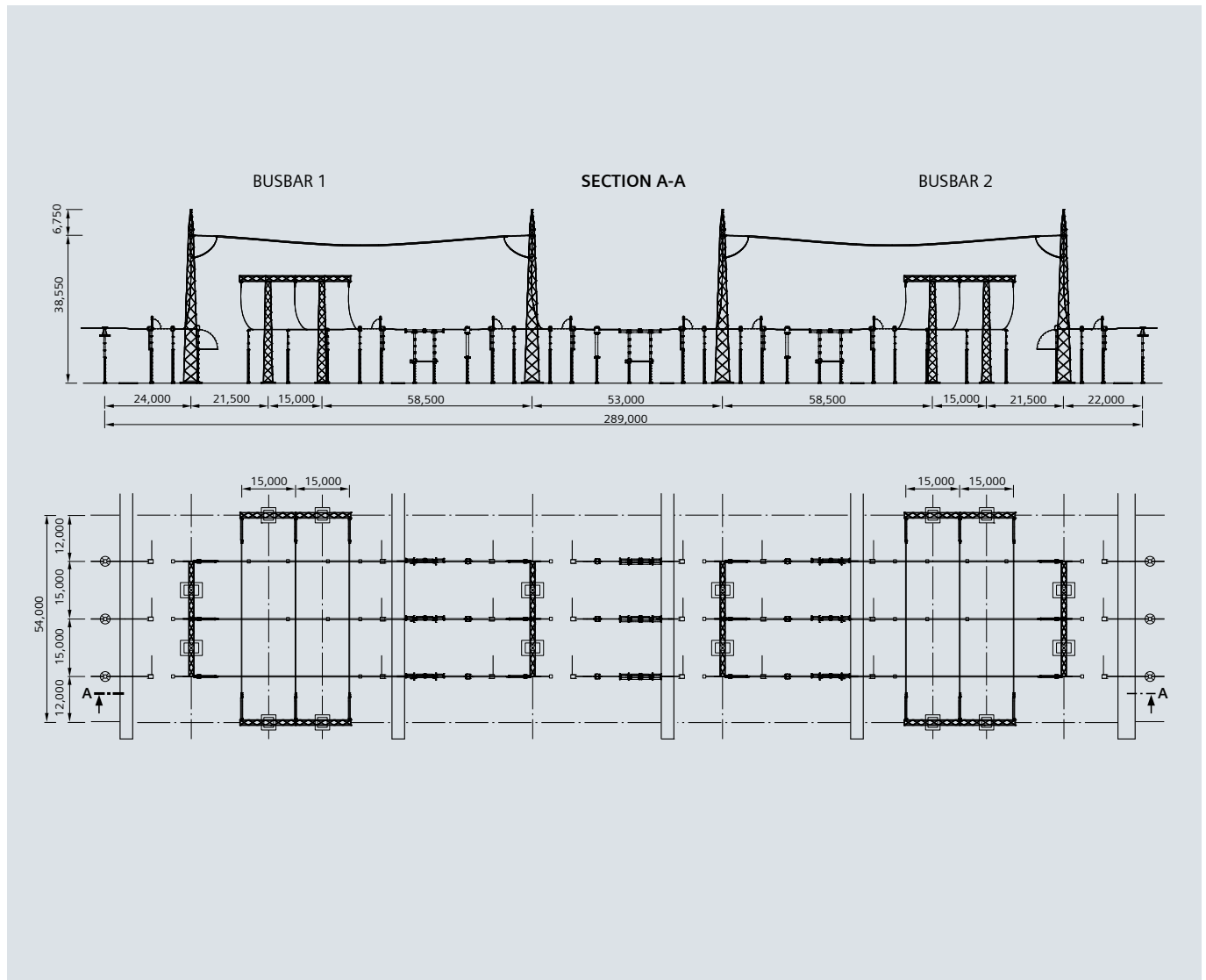


Fig. 3.1-23: One-breaker-and-a-half arrangement, 800 kV

*One-breaker-and-a-half layout, preferably 220 to 800 kV*

The one-breaker-and-a-half arrangement ensures high supply reliability; however, the expenditure for equipment is high as well. The busbar disconnectors are of the pantograph, rotary or vertical-break type. Vertical-break disconnectors are preferred for the feeders. The busbars located at the top can be either the wire or tubular type. Two arrangements are customary:

- Internal busbar, feeders in H-arrangement with two conductor levels
- External busbar, feeders in-line with three conductor (fig. 3.1-23, fig. 3.1-24)



Fig. 3.1-24: One-breaker-and-a-half arrangement, 800 kV, India

### 3.1.5 Mixed Technology (Compact/Hybrid Solutions)

Wherever there is a lack of space, system operators have to rely on space-saving outdoor switchgear, especially in regions where smaller-scale transformer substations prevail and in industrial plants. For rated voltages from 72.5 to 170 kV, Siemens Energy offers two different conventional switchgear versions for a reliable and cost-effective power supply:

- SIMOBREAKER, outdoor switchyard featuring a side-break disconnector
- SIMOVER, outdoor switchyard featuring a pivoting circuit-breaker
- HIS, highly integrated switchgear
- DTC, dead-tank compact

#### **SIMOBREAKER – Substation with rotary disconnector**

The design principle of SIMOBREAKER provides for the side-break disconnector blade to be located on the rotating post insulator, which establishes the connection between the circuit-breaker and the transformer. Because the circuit-breaker, the disconnector, the earthing switch and the instrument transformer are integrated into SIMOBREAKER, there is no need for a complex connection with cables and pipes, or for separate foundations, steel, or earthing terminals for each individual device. This means that the system operator gets a cost-effective and standardized overall setup from one source and has no need to provide any items. Coordination work is substantially reduced, and interface problems do not even arise.

SIMOBREAKER can also be used as indoor switchgear. Installation inside a building ensures protection against the elements. This can be an enormous advantage, particularly in regions with extreme climates, but it is also relevant in industrial installations exposed to excessive pollution, e.g., in many industrial plants (fig. 3.1-25, fig. 3.1-26).



Fig. 3.1-25: SIMOBREAKER module

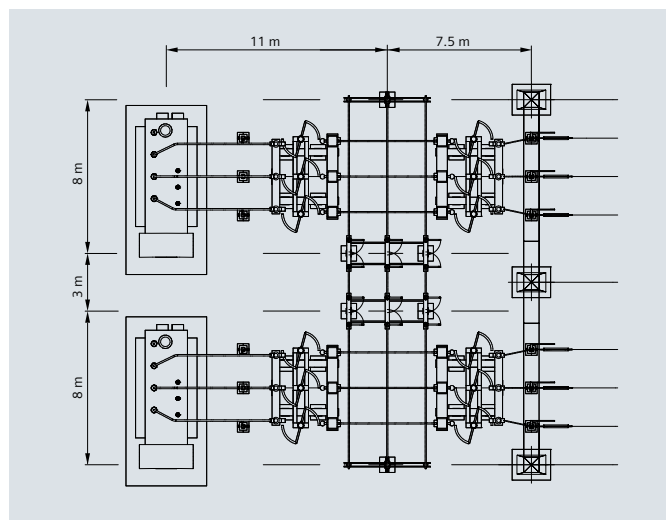


Fig. 3.1-26: SIMOBREAKER (schematic)



# Switchgear and Substations

## 3.1 High-Voltage Substations

### SIMOVER – Switchgear with withdrawable circuit-breaker

The compact SIMOVER switchgear, specially conceived for substations with single busbars, features a pivoting circuit-breaker. It is excellent for use in small transformer substations or any plants where space is restricted. It integrates all components of a high-voltage bay. There are no busbar and outgoing disconnectors for the feeders. The cabling is simple, and the switching status is clear. Drive technology is improved and the drive unit is weatherproofed. Pre-assembled components reduce installation times. In SIMOVER, all components of a high-voltage outdoor switchgear bay, including the isolating distances, are integrated in one unit. The instrument transformers and the local control cubicle are part of this substation design.

The concept behind SIMOVER is based on customary type-tested standard components. This ensures high reliability. Thanks to economizing on the disconnectors, and to the integration of the instrument transformers and the local control cubicle, implementation costs are considerably reduced. All components needed for the full scope of functioning of the movable circuit-breaker can be obtained from a single source, so there is no need for customer-provided items, coordination work is greatly reduced and interface problems do not even arise (fig. 3.1-27, fig. 3.1-28).

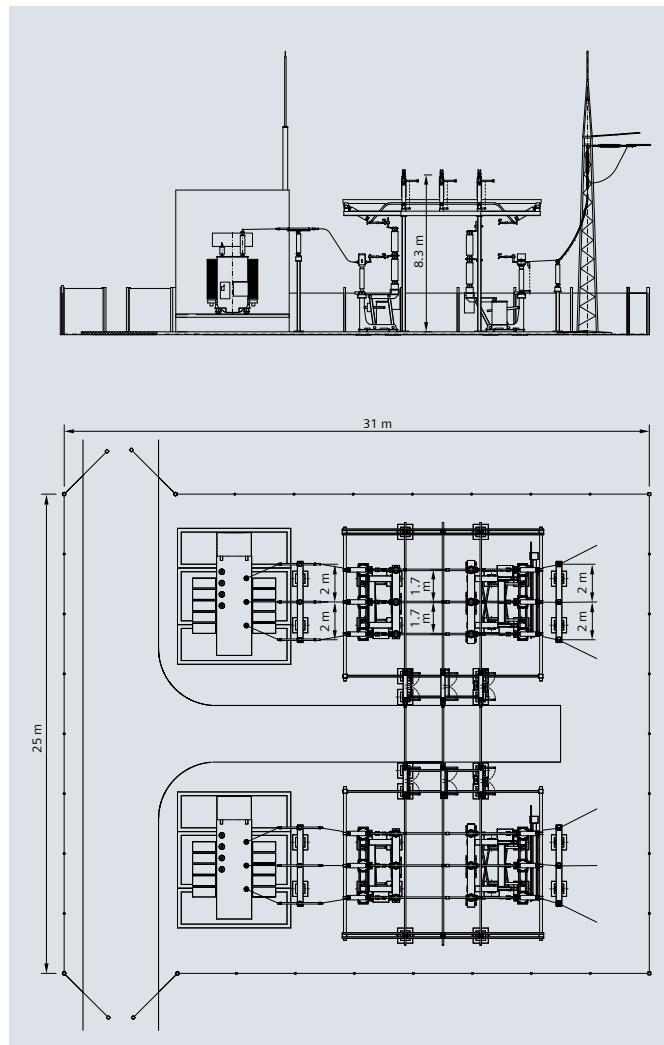


Fig. 3.1-27: SIMOVER H-arrangement (schematic)



Fig. 3.1-28: H-arrangement with SIMOVER, 145 kV, Czech Republic

### Dead-tank compact (DTC)

The dead-tank compact is another compact solution for the 145 kV voltage level: a dead-tank circuit-breaker together with GIS modules for disconnectors (fig 3.1-29, fig. 3.1-30). For more information, please refer to section 4.1.4.



Fig 3.1-29: Dead Tank Compact (DTC)

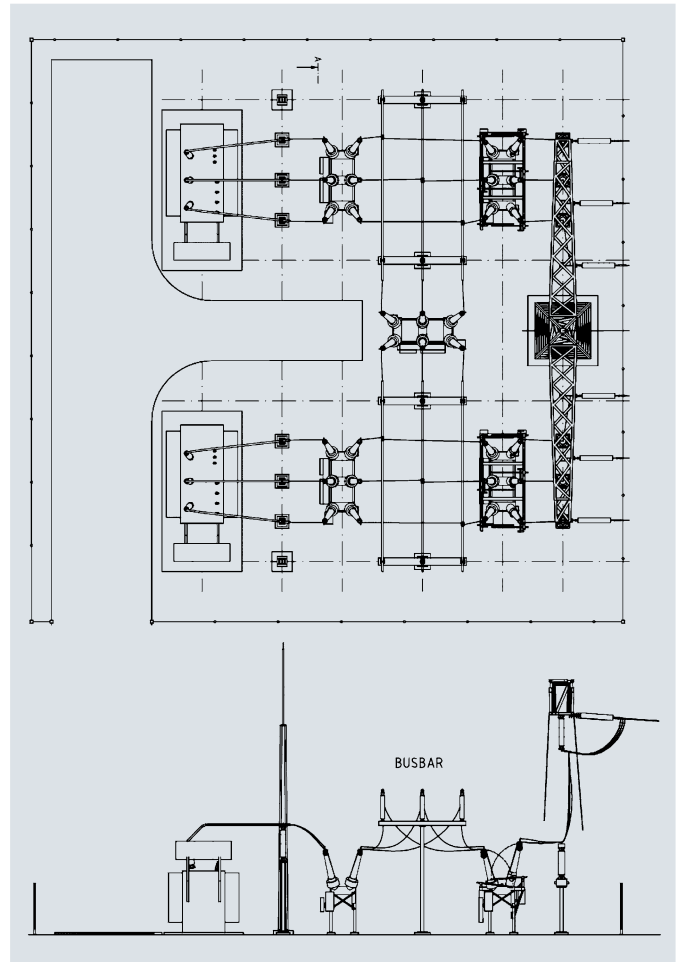


Fig. 3.1-30: DTC solution (schematic)

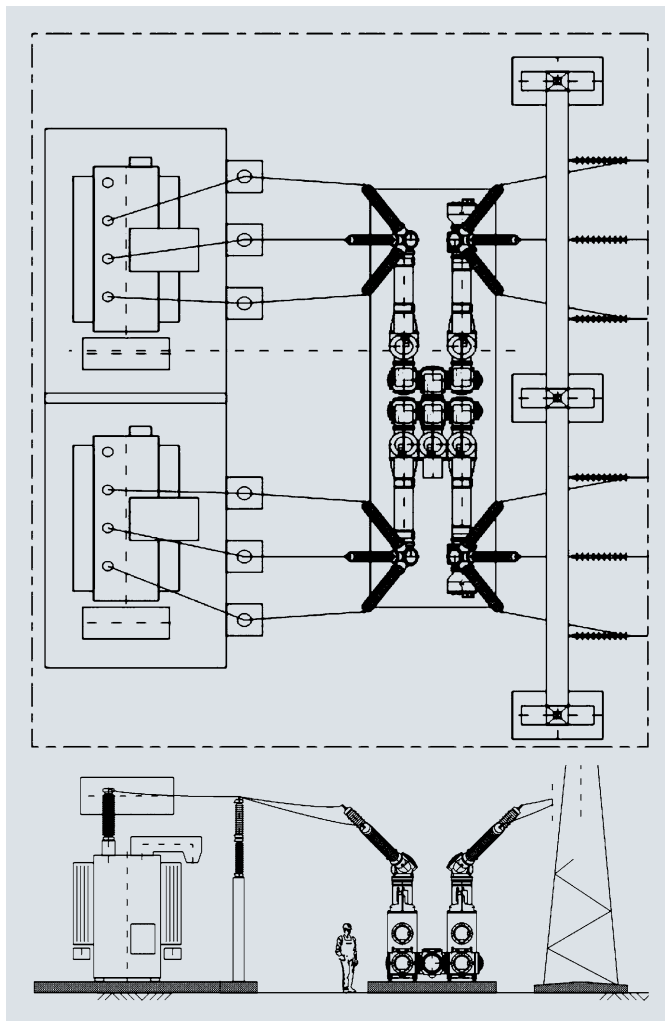


Fig. 3.1-31: H-arrangement outdoor GIS

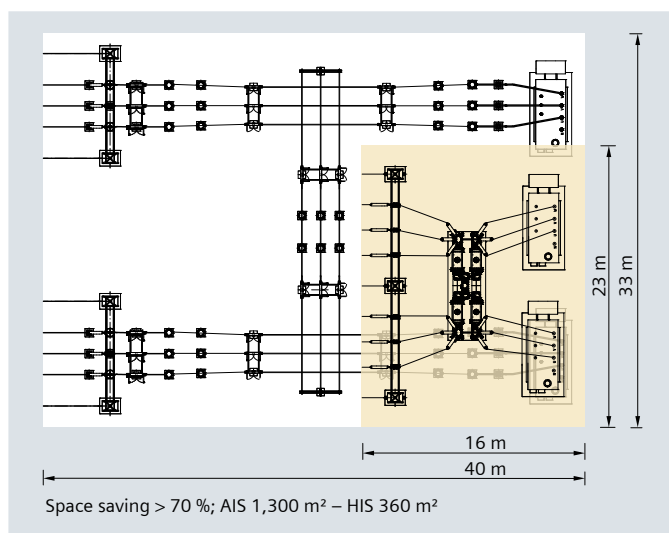


Fig. 3.1-32: HIS for renewal of AIS space relations

### Highly integrated switchgear (HIS)

Highly integrated switchgear (HIS), fig. 3.1-31 and fig. 3.1-32 combines the advantages of air-insulated installations with those of gas-insulated switchgear technology. HIS switchgear is available up to 550 kV. The compact HIS switchgear is especially suited

- for new substations in a limited space
- where real estate prices are high
- where environmental conditions are extreme
- where the costs of maintenance are high.

HIS arrangements are compact solutions used mainly for renewal or expansion of air-insulated outdoor and indoor substations, particularly if the operator wants to carry out modifications while the switchgear is in service. In new construction projects, high site prices and increasingly complex approval procedures mean that the space requirement is the prime factor in costing. With the HIS solution, the circuit-breakers, disconnectors, earthing switches and transformers are accommodated in compressed gastight enclosures, thus rendering the switchgear extremely compact.

### Planning principles

For air-insulated outdoor substations of open design, the following planning principles must be taken into account:

- High reliability
  - Reliable mastering of normal and exceptional stresses
  - Protection against surges and lightning strikes
  - Protection against surges directly on the equipment concerned (e.g., transformer, HV cable)
- Good clarity and accessibility
  - Clear conductor routing with few conductor levels
  - Free accessibility to all areas (no equipment located at inaccessible depth)
  - Adequate protective clearances for installation, maintenance and transportation work
  - Adequately dimensioned transport routes
- Positive incorporation into surroundings
  - As few overhead conductors as possible
  - Tubular instead of wire-type busbars
  - Unobtrusive steel structures
  - Minimal noise and disturbance level
  - EMC earthing system for modern control and protection
- Fire precautions and environmental protection
  - Adherence to fire protection specifications and use of flame-retardant and non-flammable materials
  - Use of environmentally compatible technology and products.



### 3.1.6 Gas-Insulated Switchgear for Substations

#### Characteristic features of switchgear installations

Since 1968, the concept of Siemens gas-insulated metal-enclosed high-voltage switchgear has proved itself in more than 29,000 bay installations in all regions of the world (table 3.1-1). Gas-insulated metal-enclosed high-voltage switchgear (GIS) (fig. 3.1-33) is constantly gaining on other types of switchgear because it offers the following outstanding advantages:

- **Minimum space requirements:**  
Where the availability of land is low and/or prices are high, e.g., in urban centers, industrial conurbations, mountainous regions with narrow valleys, or in underground power plants, gas-insulated switchgear is replacing conventional switchgear because of its very small space requirements.
- **Full protection against contact with live parts:**  
The surrounding metal enclosure affords maximum safety for personnel under all operating and fault conditions.
- **Protection against pollution:**  
Its metal enclosure fully protects the switchgear interior against environmental effects such as salt deposits in coastal regions, industrial vapors and precipitates, and sandstorms. The compact switchgear can be installed as an indoor as well as an outdoor solution.
- **Free choice of installation site:**  
The small site area required for gas-insulated switchgear saves expensive grading and foundation work, e.g., in permafrost zones. Another advantage is the rapid on-site installation and commissioning because of the short erection time and the use of prefabricated and factory tested bay units.
- **Protection of the environment:**  
The necessity to protect the environment often makes it difficult to install outdoor switchgear of conventional design. Gas-insulated switchgear, however, can almost always be designed to blend well with the surroundings. Gas-insulated metal-enclosed switchgear is, because of the modular design, very flexible, and meets all requirements for configuration that exist in the network design and operating conditions.

Each circuit-breaker bay includes the full complement of disconnecting and earthing switches (regular or make-proof), instrument transformers, control and protection equipment, and interlocking and monitoring facilities commonly used for this type of installation.

Besides the traditional circuit-breaker bay, other circuits, such as single busbar, single-busbar arrangement with bypass busbar, coupler and bay for double and triple busbar, can be supplied.

#### (Main) product range of GIS for substations

The Siemens product range covers GIS from 72.5 up to 800 kV rated voltage – the main range covers GIS up to 550 kV (table 3.1-2). Furthermore, in 2014 the portfolio was extended by gas-insulated solutions for DC voltage with the  $\pm 320$  kV DC CS (see chapter 2.2.5).

#### More than 50 years of experience with gas-insulated switchgear

1960	Start of fundamental studies in research and development of SF <sub>6</sub> technology
1964	Delivery of first SF <sub>6</sub> circuit-breaker
1968	Delivery of first GIS
1974	Delivery of first GIL (420 kV)
1997	Introduction of intelligent, bay integrated control, monitoring and diagnostic
1999	Introduction of newest GIS generation: self-compression interrupter unit and spring-operated mechanism
2000	Introduction of the trendsetting switchgear concept HIS (Highly Integrated Switchgear) for extension, retrofit and new compact AIS substations
2005	First GIS with electrical endurance capability (class E2)
2007	Introduction of 72.5 kV GIS – a new dimension in compactness
2009	New generation of 145 kV 40 kA GIS
2010	New generation of 420 kV 63 kA GIS
2011	New 170 kV 63 kA GIS
2012	New 420 kV 80 kA GIS
2013	New 245 kV 80/90 kA GIS
2014	New $\pm 320$ kV DC CS

Table 3.1-1: Siemens experience with gas-insulated switchgear



Fig. 3.1-33: 8DN8 GIS for a rated voltage of 110 kV

# Switchgear and Substations

## 3.1 High-Voltage Substations

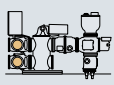
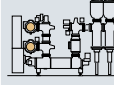
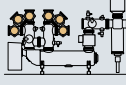
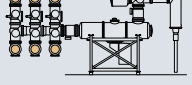
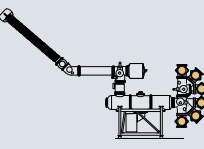
							
Switchgear type			8DN8	8DN9	8DQ1		
Rated voltage	kV	up to	170	245	420	420	550
Rated frequency	Hz		50/60				
Rated power-frequency withstand voltage (1 min)	kV	up to	325	460	650	650	740
Rated lightning impulse withstand voltage (1.2 / 50 µs)	kV	up to	750	1,050	1,425	1,425	1,550
Rated switching impulse withstand voltage (250 / 2,500 µs)	A	up to	–	–	1,050	1,050	1,175
Rated normal current for busbar	A	up to	4,000	4,000	5,000	6,300	5,000
Rated normal current for feeder	kA	up to	4,000	4,000	5,000	5,000	5,000
Rated short-circuit breaking current	kA	up to	63	50	63 / 80* / 90*	80	63
Rated peak withstand current	kA	up to	170	135	170 / 216* / 243*	216	170
Rated short-time withstand current (3 s)	kA	up to	63	50	63 / 80*	80	63
Rated short-time withstand current (1 s)	kA	up to	–	–	90*	–	–
Leakage rate per year and gas compartment (type-tested)	%		< 0.1				
Operating mechanism of circuit-breaker			stored-energy spring (common or single pole drive)	stored-energy spring (single pole drive)			
Rated operating sequence			O-0.3 s-CO-3 min-CO CO-15 s-CO				
Installation			indoor/outdoor				
Standards			IEC/IEEE/GOST				
Bay width	mm		800 / 1,000	1,500	2,200	3,600	
First major inspection	years		> 25				
Expected lifetime	years		> 50				
Other values on request – * these values apply to 245 kV rated voltage							

Table 3.1-2: Main product range of GIS

The development of this switchgear has been based on two overall production concepts: meeting the high technical standards required of high-voltage switchgear, and providing maximum customer benefit.

This objective is attained only by incorporating all processes in the quality management system, which has been introduced and certified according to EN 29001/DIN EN ISO 9001.

Siemens GIS switchgear meets all performance, quality and reliability demands, including:

- Compact and low-weight design:  
Small building dimensions and low floor loads, a wide range of options in the utilization of space, and less space taken up by the switchgear.

- Safe encapsulation:  
An outstanding level of safety based on new manufacturing methods and optimized shape of enclosures.
- Environmental compatibility:  
No restrictions on choice of location due to minimum space requirement; extremely low noise and EMC emission, as well as effective gas sealing system (leakage < 0.1 % per year per gas compartment). Modern spring mechanisms that are currently available for the whole GIS 8D product spectrum eliminate the need for hydraulic oil.
- Economical transport:  
Simplified fast transport and reduced costs, because of a minimum of shipping units.

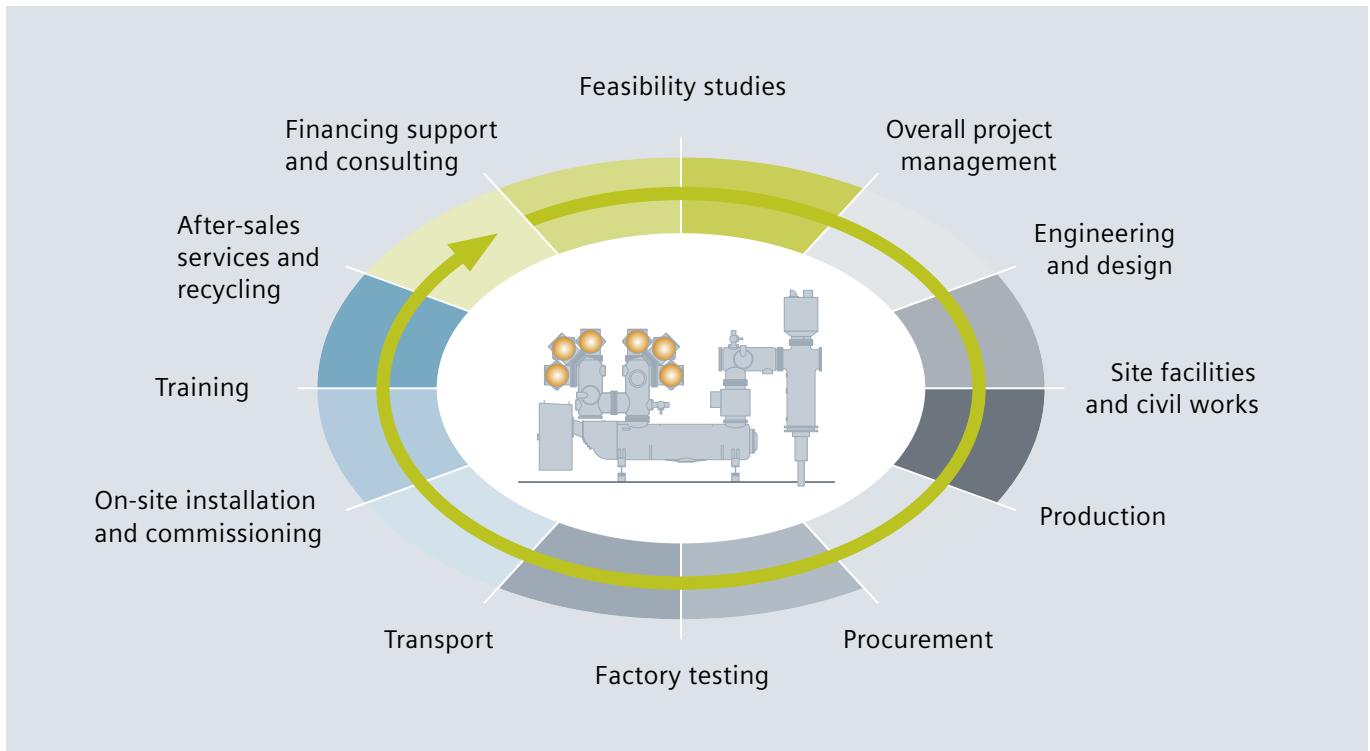


Fig. 3.1-34: GIS for your full value chain offers

- **Low operating costs:**  
The switchgear is practically maintenance-free, e.g., contacts of circuit-breakers and disconnectors are designed for extremely long endurance, motor operating mechanisms are lubricated for life, the enclosure is corrosion-free. This ensures that the first inspection is required only after 25 years of operation.
- **High reliability:**  
The longstanding experience of Siemens in design, production and commissioning – more than 330,000 bay operating years in over 29,000 bay installations worldwide – is testament to the fact that the Siemens products are highly reliable. The mean time between failures (MTBF) is more than 950 bay years for major faults. A quality management system certified according to ISO 9001, which is supported by highly qualified employees, ensures high quality throughout the whole process chain. Our services provide value added through constant project-related support and consulting right from the start – and throughout the entire life cycle of our switchgear all the way to disposal and recycling of old switchgear (fig. 3.1-34).
- **Smooth and efficient installation and commissioning:**  
Transport units are fully assembled, tested at the factory and filled with SF<sub>6</sub> gas at reduced pressure. Coded plug connectors are used to cut installation time and minimize the risk of cabling failures.
- **Routine tests:**  
All measurements are automatically documented and stored in the electronic information system, which provides quick access to measured data for years.



Fig. 3.1-35: 8DN8 GIS for a rated voltage of 145 kV

3-phase enclosures are used for SF<sub>6</sub>-insulated switchgear type 8DN8 up to 170 kV in order to achieve small and compact component dimensions. The low bay weight ensures low floor loading, and helps to reduce the cost of civil works and minimize the footprint. The compact low-weight design allows installation almost anywhere. Capital cost is reduced by using smaller buildings or existing ones, e.g., when replacing medium-voltage switchyards with the 145 kV GIS (fig. 3.1-35).



# Switchgear and Substations

## 3.1 High-Voltage Substations

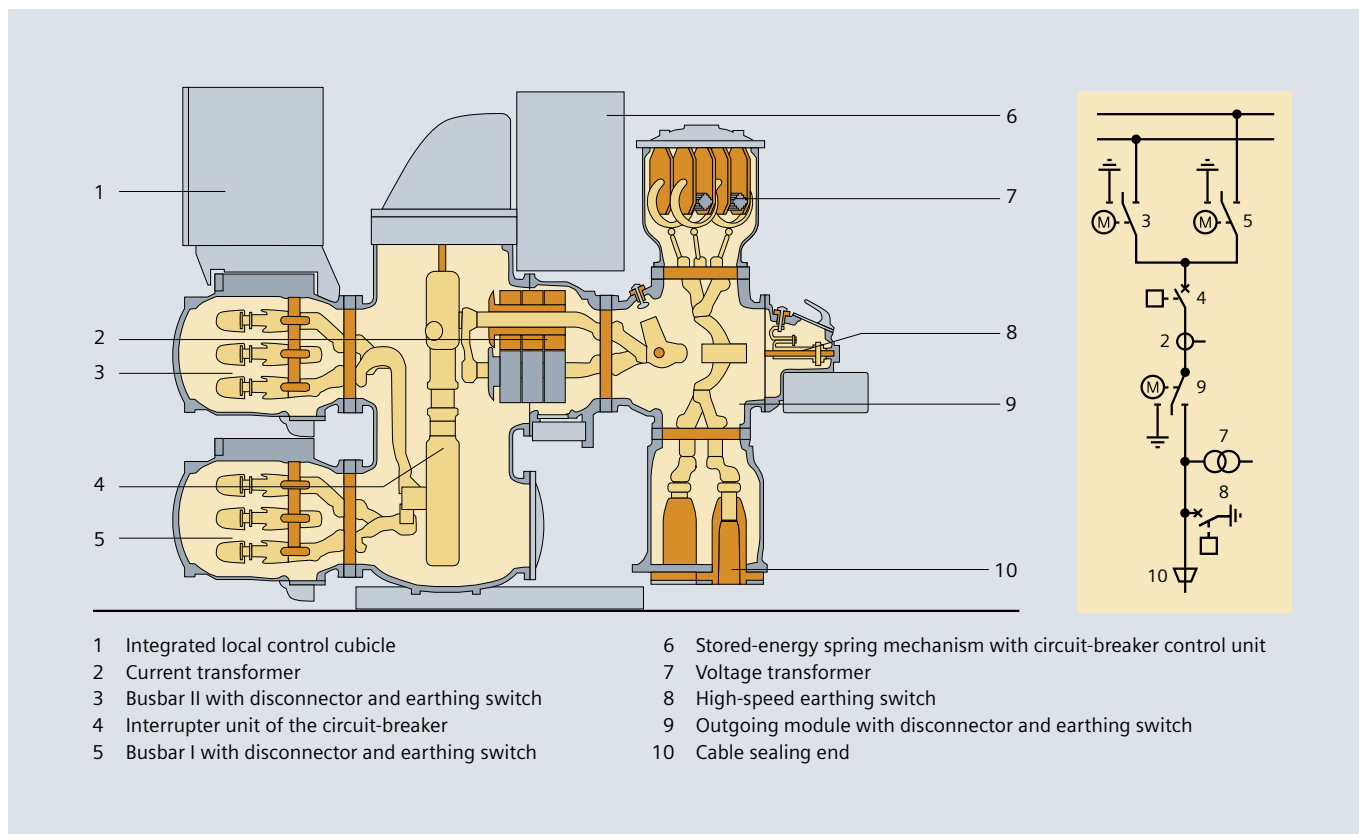


Fig. 3.1-36: 8DN8 switchgear bay up to 145 kV

The bay is based on a circuit-breaker mounted on a supporting frame (fig. 3.1-36). A special multifunctional cross-coupling module combines the functions of the disconnector and earthing switch in a 3-position switching device. It can be used as:

- An active busbar with an integrated disconnector and work-in-progress earthing switch (fig. 3.1-36, pos. 3 and 5)
- An outgoing feeder module with an integrated disconnector and work-in-progress earthing switch (fig. 3.1-36, pos. 9)
- A busbar sectionalizer with busbar earthing.

Cable termination modules can be equipped with either conventional sealing ends or the latest plug-in connectors (fig. 3.1-36, pos. 10). Flexible 1-pole modules are used to connect overhead lines and transformers with a splitting module that links the 3-phase enclosed switchgear to the 1-pole connections.

Thanks to their compact design, the completely assembled and factory-tested bays can be shipped as a single transport unit. Fast erection and commissioning on site ensure the highest possible quality.

The feeder control and protection can be installed in a bay-integrated local control cubicle mounted to the front of each bay (fig. 3.1-36, pos. 1). Moreover, state-of-the-art monitoring devices are available at the system operator's request, e.g., for partial discharge online monitoring.



Fig. 3.1-37: 8DN9 switchgear for a rated voltage of 245 kV, with a 3-phase enclosed passive busbar

The clear bay configuration of the lightweight and compact 8DN9 switchgear is evident at first glance. Control and monitoring facilities are easily accessible despite the switchgear's compact design.

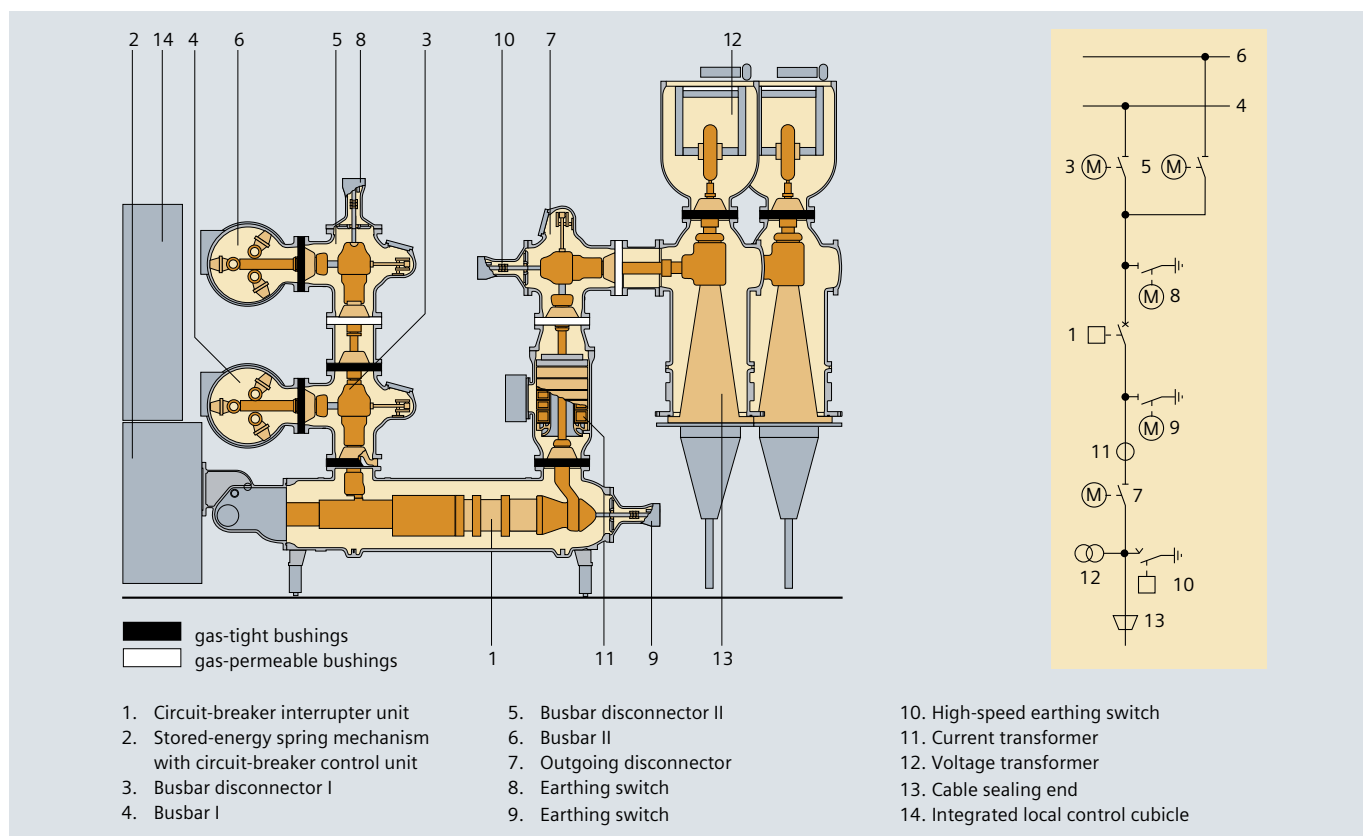


Fig. 3.1-38: 8DN9 switchgear bay up to 245 kV

The horizontally arranged circuit-breaker forms the basis of every bay configuration. The operating mechanism is easily accessible from the operator area. The other bay modules – of 1-phase enclosed switchgear design, like the circuit-breaker module – are located on top of the circuit-breaker. The 3-phase enclosed passive busbar is partitioned off from the active equipment (fig. 3.1-37, fig. 3.1-38).

Thanks to “single-function” assemblies (assignment of just one task to each module) and the versatile modular structure, even unconventional arrangements can be set up from a pool of only 20 different modules. The modules are connected to each other with a standard interface that allows implementing an extensive range of bay structures. Switchgear design with standardized modules, and the scope of services ensure that all types of bay structures can be set up in a small area. The compact design allows supplying of complete bays that are fully assembled and tested at the factory, providing smooth and efficient installation and commissioning.



Fig. 3.1-39: 8DQ1 switchgear for a rated voltage of 550 kV

SF<sub>6</sub>-insulated switchgear for up to 550 kV, type 8DQ1 is a 1-phase enclosed switchgear system for high-power switching stations with individual enclosure of all modules.

# Switchgear and Substations

## 3.1 High-Voltage Substations

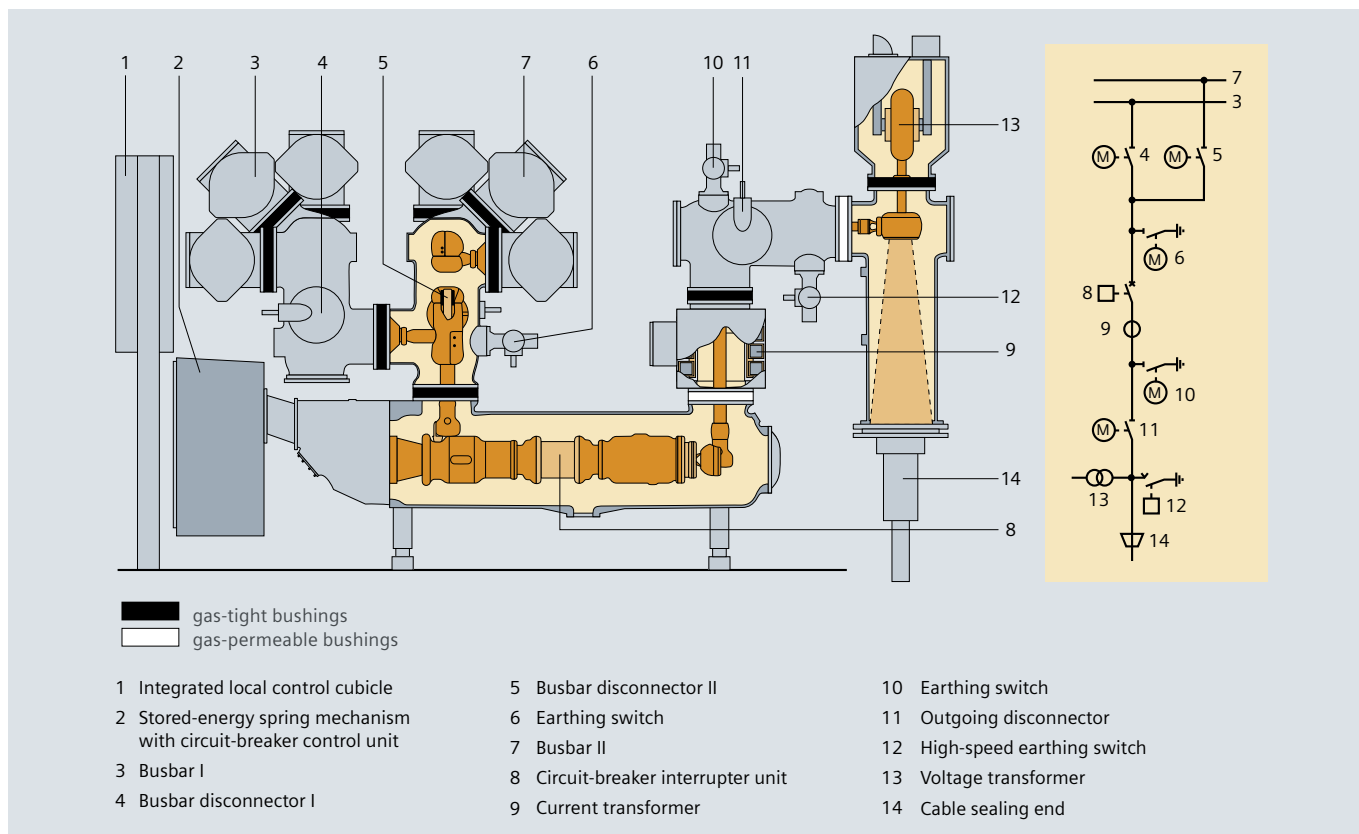


Fig. 3.1-40: 8DQ1 switchgear bay up to 420 kV

The base unit for the switchgear is a horizontally arranged circuit-breaker on top of which the housing containing the disconnectors, earthing switches, current transformers and so on are mounted. The busbar modules are partitioned off from the active equipment (fig. 3.1-39, fig. 3.1-40, fig. 3.1-41).

Some other characteristic features of switchgear installation are:

- Circuit-breakers with single interrupter unit up to operating voltages of 420 kV (fig. 3.1-40, fig. 3.1-41), with two interrupter units up to operating voltages of 550 kV (fig. 3.1-39)
- Short-circuit breaking currents up to 63 kA within 2 cycles for 50 Hz/ 60 Hz and 80 kA up to 420 kV
- Horizontal arrangement of the circuit-breakers in the lower section provides low center of gravity for the switchgear
- Utilization of the circuit-breaker transport frame as a supporting device for the entire bay
- Reduced length of sealing surfaces, and thus, decreased risk of leakage through use of only a few modules and equipment combinations in one enclosure.



Fig. 3.1-41: 8DQ1 switchgear for a rated voltage of 420 kV

### Specification guide for metal-enclosed SF<sub>6</sub>-insulated switchgear

Note: The points below are not considered exhaustive, but are a selection of the important. These specifications cover the technical data applicable to metal-enclosed SF<sub>6</sub>-insulated switchgear for switching and distributing power in cable and/or overhead-line systems and transformers. Key technical data are contained in the data sheet and the single-line diagram (SLD) attached to the inquiry.

A general SLD and a sketch showing the general arrangement of the substation will be part of a proposal. Any switchgear quoted will be complete and will form a functional, safe and reliable system after installation, even if certain parts required to achieve this have not been specifically included in the inquiry.

#### • Applicable standards

All equipment is designed, built, tested and installed according to the latest issues of the applicable

IEC standards, which are:

- IEC 62271-1 "High-voltage switchgear and controlgear: Common specifications"
- IEC 62271-203 "High-voltage switchgear and controlgear: Gas-insulated metal-enclosed switchgear for rated voltages above 52 kV"
- IEC 62271-100 "High-voltage switchgear and controlgear: Alternating-current circuit-breakers"
- IEC 62271-102 "High-voltage switchgear and controlgear: Alternating current disconnectors and earthing switches"
- IEC 60044 "Instrument transformers: Current transformers"
- National standards on request.

#### Local conditions

The equipment is tested for indoor and outdoor applications. All the buyer has to provide is a flat concrete floor with the cutouts for cable installation – if this is required. The switchgear comes equipped with adjustable supports (feet). If steel support structures are required for the switchgear, Siemens will provide these as well. For design purposes, the indoor temperatures should be between –5 °C and +40 °C, and outdoor temperatures should be between –30 °C and +40 °C (+50 °C). For parts to be installed outdoors (overhead-line connections), the conditions described in IEC 62271-203 will be observed. For the enclosures, aluminum or aluminum alloys are preferred.

A minimum of one-site installation will ensure maximum reliability. Up to six single or three double switchgear bays, completely assembled and tested, come as a single transport unit. Subassembly size is restricted only by transport requirements. Siemens will provide the enclosure in a material and thickness suited to withstand an internal arc and prevent burn-throughs or punctures within the first stage of protection, referred to the rated short-circuit current of the given GIS type.

All assemblies are designed to allow absorption of thermal expansion and contraction caused by varying temperatures. Adjustable metal bellow compensators are installed for this

purpose. Density monitors with electrical contacts for at least two pressure levels are installed to allow monitoring the gas in the enclosures. The circuit-breakers can be monitored with density gauges that are fitted in the circuit-breaker control units.

Siemens can assure that the pressure loss for each individual gas compartment – i.e., not just for the complete switchgear installation – will not exceed 0.1 % per year and gas compartment. Each gas-filled compartment comes equipped with static filters that are capable of absorbing any water vapor that penetrates into the switchgear installation for a period of at least 25 years. Intervals between required inspections are long, which keeps maintenance costs to a minimum. The first minor inspection is due after ten years. The first major inspection is usually required after more than 25 years of operation unless the permissible number of operations is reached before that date.

### Arrangement and modules

#### Arrangement

The system is of the enclosed 1-phase or 3-phase type. The assembly consists of completely separate pressurized sections, and is thus designed to minimize any danger to the operating staff and risk of damage to adjacent sections, even if there should be trouble with the equipment. Rupture diaphragms are provided to prevent the enclosures from bursting in an uncontrolled manner. Suitable deflectors provide protection for the operating personnel. For maximum operating reliability, internal relief devices are not installed, because these would affect adjacent compartments. The modular design, complete segregation, arc-proof bushing and plug-in connections allow speedy removal and replacement of any section with only minimal effects on the remaining pressurized switchgear.

#### Busbar module

The busbar modules of adjacent bays are connected with expansion joints which absorb constructional tolerances and temperature-related movements in longitudinal as well as transverse direction to the busbar. Axially guided sliding contacts between the conductors compensate temperature-related expansions in conductor length (fig. 3.1-42).

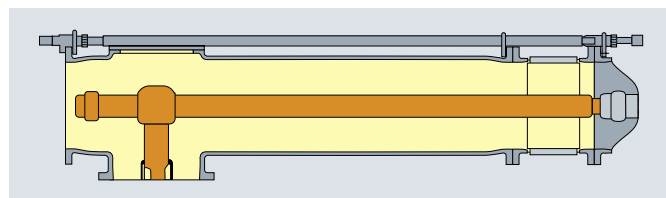


Fig. 3.1-42: All busbars of the enclosed 3-phase or the 1-phase (fig.) type are connected with plugs from one bay to the next



# Switchgear and Substations

## 3.1 High-Voltage Substations

### Circuit-breakers

(see chapter 4.1.1 Circuit-Breakers for 72.5 kV up to 800 kV)

The circuit-breakers operate according to the dynamic self-compression principle. The number of interrupting units per phase depends on the circuit-breaker's performance. The arcing chambers and circuit-breaker contacts are freely accessible. The circuit-breaker is suitable for out-of-phase switching and designed to minimize overvoltages. The specified arc interruption performance has to be consistent across the entire operating range, from line-charging currents to full short-circuit currents.

The circuit-breaker is designed to withstand at least 10 operations (depending on the voltage level) at full short-circuit rating. Opening the circuit-breaker for service or maintenance is not necessary. The maximum tolerance for phase displacement is 3 ms, that is, the time between the first and the last pole's opening or closing. A standard station battery that is required for control and tripping may also be used for recharging the operating mechanism. The drive and the energy storage system are provided by a stored-energy spring mechanism that holds sufficient energy for all standard IEC close-open duty cycles. The control system provides alarm signals and internal interlocks but inhibits tripping or closing of the circuit-breaker when the energy capacity in the energy storage system is insufficient or the SF<sub>6</sub> density within the circuit-breaker drops below the minimum permissible level.

### Disconnectors

All disconnectors (isolators) are of the single-break type. DC motor operation (110, 125, 220 or 250 V), which is fully suited to remote operation, and a manual emergency operating mechanism are provided. Each motor operating mechanism is self-contained and equipped with auxiliary switches in addition to the mechanical indicators. The bearings are lubricated for life (fig. 3.1-43).

### Earthing switches

Work-in-progress earthing switches are generally provided on either side of the circuit-breaker. Additional earthing switches may be used to earth busbar sections or other groups of the assembly. DC motor operation (110, 125, 220 or 250 V) that is fully suited for remote operation and a manual emergency operating mechanism are provided. Each motor operating mechanism is self-contained and equipped with auxiliary position switches in addition to the mechanical indicators. The bearings are lubricated for life. Make-proof high-speed earthing switches are generally installed at the cable and overhead-line terminals. They are equipped with a rapid closing mechanism to provide short-circuit making capacity (fig. 3.1-44).

### Instrument transformers

Current transformers (CTs) are of the dry-type design. Epoxy resin is not used for insulation purposes. The cores have the accuracies and burdens that are shown on the SLD. Voltage transformers are of the inductive type, with ratings of up to 200 VA.

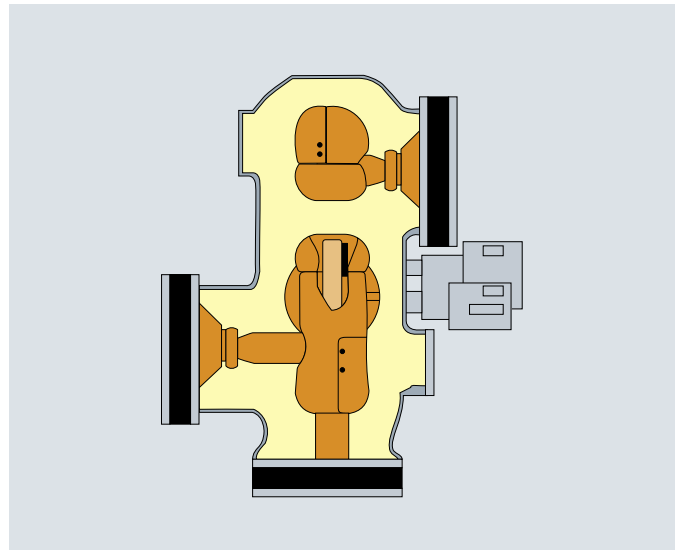


Fig. 3.1-43: Disconnectors: In the open position, disconnectors assure a dielectrically safe gap between system parts at different potentials; for example, busbar disconnector isolates the feeders from the busbar. Cast-resin bushings keep the contact system in place, and the pressurized gas serves as the high-voltage insulating medium between live parts and the metal housing. The conductor terminals vary for different types of adjacent modules. Up to two earthing switches can be installed simultaneously

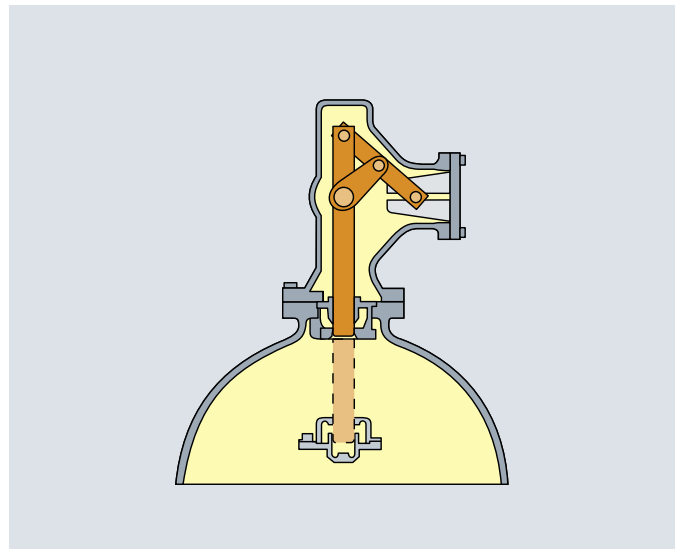


Fig. 3.1-44: Earthing switches: Earthing switches (work-in-progress earthing switches or busbar earthing switches, for example) are used for properly connecting de-energized live parts of the high-voltage system to the earthing system. On the outgoing side of the feeders, a make-proof version (high-speed) is frequently used to dissipate inductive and capacitive currents from parallel cables or overhead lines or to reduce the risk to the GIS system in case of faulty connections. In the insulated design they are also used for measuring purposes and for testing protection relays

### Cable terminations

1-phase or 3-phase, SF<sub>6</sub> gas-insulated, metal-enclosed cable end housings are provided. The cable manufacturer has to supply the stress cone and suitable sealings to prevent oil or gas from leaking into the SF<sub>6</sub> switchgear. Siemens will supply a mating connection piece to be fitted to the cable end. The cable end housing is suitable for oil-type, gas-pressure-type cables with plastic insulation (PE, PVC, etc.) as specified on the SLD or the data sheets. Additionally, devices for safely isolating a feeder cable and connecting a high-voltage test cable to the switchgear or cable will be provided (fig. 3.1-45).

### Overhead-line terminations

The terminations for connecting overhead-lines come complete with SF<sub>6</sub>-to-air bushings but without line clamps (fig. 3.1-46).

### Transformer/reactor termination module

These terminations form the direct connection between the GIS and oil-insulated transformers or reactance coils. Standardized modules provide an economical way of matching them to various transformer dimensions (fig. 3.1-47).

### Control and monitoring

As a standard, an electromechanical or solid-state interlocking control board is supplied for each switchgear bay. This fault-tolerant interlocking system prevents all operating malfunctions. Mimic diagrams and position indicators provide the operating personnel with clear operating instructions. Provisions for remote control are included. Gas compartments are constantly monitored by density monitors that provide alarm and blocking signals via contacts.

### Required tests

#### Partial discharge tests

All solid insulators fitted in the switchgear are subjected to a routine partial discharge test prior to installation. At 1.2 times the line-to-line voltage, no measurable discharge is allowed. This test ensures maximum safety with regard to insulator failure, good long-term performance and thus a very high degree of reliability.

#### Pressure tests

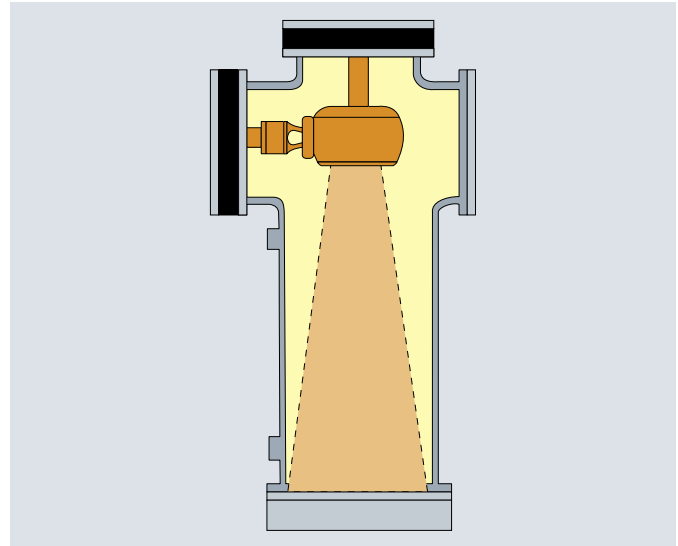
Each cast-aluminum enclosure of the switchgear is pressure-tested for at least twice the service pressure.

#### Leakage tests

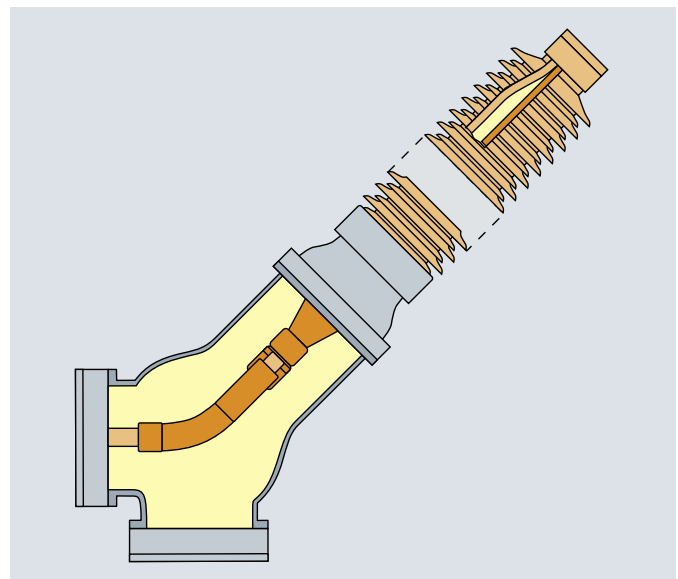
Leakage tests performed on the subassemblies ensure that the flanges and cover faces are clean, and that the guaranteed leakage rate is not exceeded.

#### Power frequency tests

Each assembly is subjected to power-frequency withstand tests, including sensitive partial discharge detection, to verify correct installation of the conductors, and to make sure that the insulator surfaces are clean and the switchgear as a whole is not subject to internal faults.



**Fig. 3.1-45: Example for 1-phase cable termination:**  
Cable termination modules conforming to IEC are available for connecting the switchgear to high-voltage cables. The standardized construction of these modules allows connection of various cross-sections and insulation types. Parallel cable connections for higher rated currents are also possible with the same module



**Fig. 3.1-46: Overhead-line terminations:** High-voltage bushings are used for the SF<sub>6</sub>-to-air transition. The bushings can be matched to specific requirements with regard to clearance and creepage distances. They are connected to the switchgear by means of angular-type modules of variable design

### Additional technical data

Siemens will point out any dimensions, weights or other switchgear data that may affect local conditions and handling of the equipment. Any quotation includes drawings showing the switchgear assembly.

### Instructions

Detailed instruction manuals on the installation, operation and maintenance of the equipment are supplied with all equipment delivered by Siemens.

### Scope of supply

Siemens supplies the following items for all GIS types and interfaces as specified:

- The switchgear bay, including circuit-breakers, disconnectors and earthing switches, instrument transformers and busbar housings, as specified. For the different feeder types, the following limits apply:
  - Cable feeder:  
According to IEC 60859, the termination housing, conductor coupling and connecting plate are part of the GIS delivery, while the cable stress cone with the matching flange is part of the cable supply (fig. 3.1-45).
  - Overhead-line feeder:  
The connecting stud at the SF<sub>6</sub>-to-air bushing is supplied without the line clamp (fig. 3.1-46).
- Transformer feeder:  
Siemens supplies the connecting flange at the switchgear bay and the connecting bus ducts to the transformer, including any expansion joints. The SF<sub>6</sub>-to-oil bushings plus terminal enclosures are part of the transformer delivery unless otherwise agreed (fig. 3.1-47).  
Note: This point always requires close coordination between the switchgear manufacturer and the transformer supplier.
- Each feeder bay is equipped with earthing pads. The local earthing network and the connections to the switchgear are included in the installation contractor's scope.
- Initial SF<sub>6</sub> gas filling for the entire switchgear supplied by Siemens is included. Siemens will also supply all gas interconnections from the switchgear bay to the integral gas service and monitoring panel.
- Terminals and circuit protection for auxiliary drives and control power are provided with the equipment. Feeder circuits and cables as well as the pertaining installation material will be supplied by the installation contractor.
- The local control, monitoring and interlocking panels are supplied for each circuit-breaker bay to form completely operational systems. Terminals for remote monitoring and control are also provided.
- Siemens will supply the above-ground mechanical support structures; embedded steel and foundation work are part of the installation contractor's scope.



Fig. 3.1-47: Transformer termination

**For further information:**  
Fax +49 (9131) 7-34662  
[www.energy.siemens.com/hq/en/power-transmission](http://www.energy.siemens.com/hq/en/power-transmission)

## 3.2 Medium-Voltage Switchgear

### 3.2.1 Introduction

According to international rules, there are only two voltage levels:

- Low voltage: up to and including 1 kV AC (or 1,500 V DC)
- High voltage: above 1 kV AC (or 1,500 V DC)

Most electrical appliances used in household, commercial and industrial applications work with low-voltage. High-voltage is used not only to transmit electrical energy over very large distances, but also for regional distribution to the load centers via fine branches. However, because different high-voltage levels are used for transmission and regional distribution, and because the tasks and requirements of the switchgear and substations are also very different, the term “medium-voltage” has come to be used for the voltages required for regional power distribution that are part of the high-voltage range from 1 kV AC up to and including 52 kV AC (fig. 3.2-1). Most operating voltages in medium-voltage systems are in the 3 kV AC to 40.5 kV AC range.

The electrical transmission and distribution systems not only connect power plants and electricity consumers, but also, with their “meshed systems,” form a supraregional backbone with reserves for reliable supply and for the compensation of load differences. High operating voltages (and therefore low cur-

rents) are preferred for power transmission in order to minimize losses. The voltage is not transformed to the usual values of the low-voltage system until it reaches the load centers close to the consumer.

In public power supplies, the majority of medium-voltage systems are operated in the 10 kV to 30 kV range (operating voltage). The values vary greatly from country to country, depending on the historical development of technology and the local conditions.

#### Medium-voltage equipment

Apart from the public supply, there are still other voltages fulfilling the needs of consumers in industrial plants with medium-voltage systems; in most cases, the operating voltages of the motors installed are decisive. Operating voltages between 3 kV and 15 kV are frequently found in industrial supply systems.

In power supply and distribution systems, medium-voltage equipment is available in:

- Power plants, for generators and station supply systems
- Transformer substations of the primary distribution level (public supply systems or systems of large industrial companies), in which power supplied from the high-voltage system is transformed to medium-voltage
- Local supply, transformer or customer transfer substations for large consumers (secondary distribution level), in which the power is transformed from medium to low-voltage and distributed to the consumer.

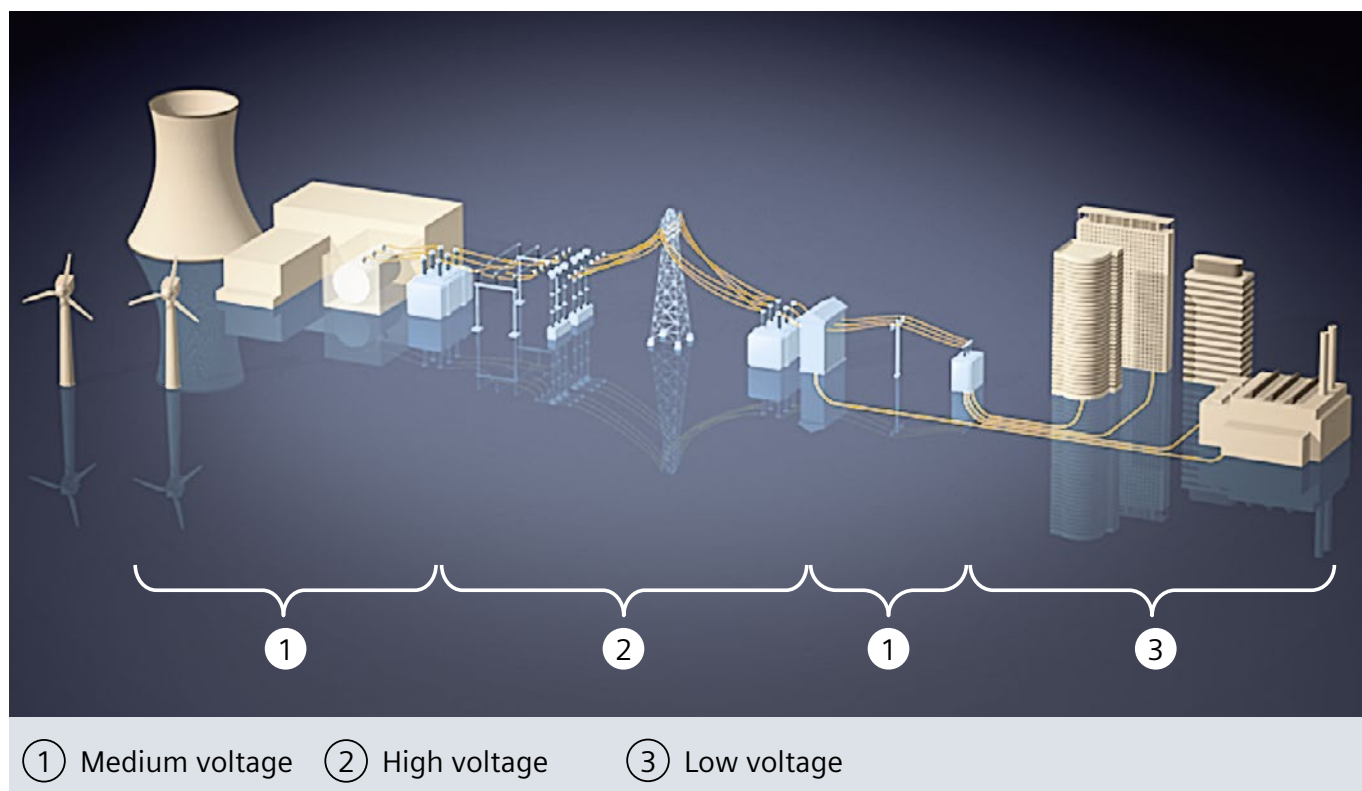


Fig. 3.2-1: Voltage levels from the power plant to the consumer



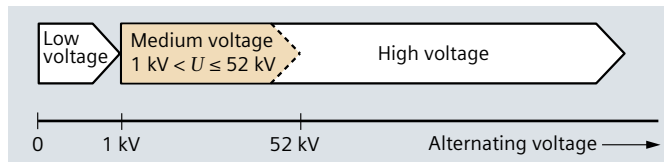


Fig. 3.2-2: Voltage definitions

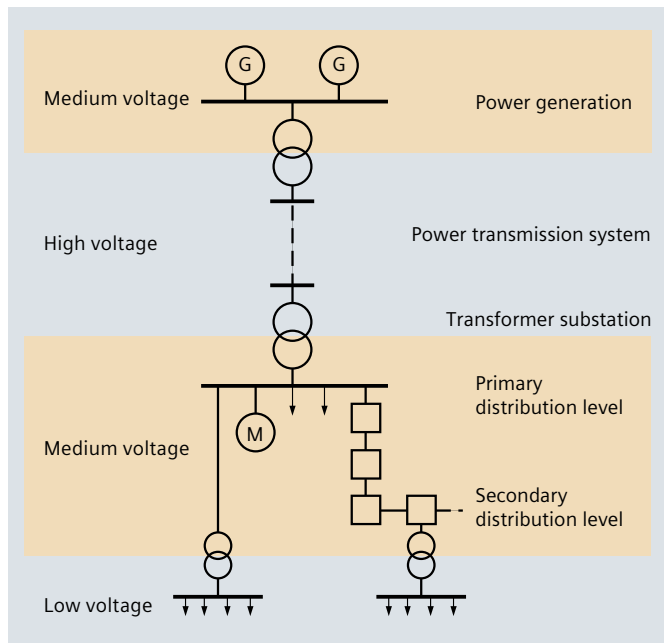


Fig. 3.2-3: Medium voltage in the power supply and distribution system

- **Three-position disconnectors:** Combine the functions of disconnecting and earthing in one device. Three-position disconnectors are typical for gas-insulated switchgear.
- **Switch-disconnectors (load-break switches):** The combination of a switch and a disconnector, or a switch with isolating distance.
- **Contactors:** Load breaking devices with a limited short-circuit making or breaking capacity. They are used for high switching rates.
- **Earthing switches:** To earth isolated circuits.
- **Make-proof earthing switches (earthing switches with making capacity):** Are used for the safe earthing of circuits, even if voltage is present, that is, also in the event that the circuit to be earthed was accidentally not isolated.
- **Fuses:** Consist of a fuse-base and a fuse-link. With the fuse-base, an isolating distance can be established when the fuse-link is pulled out in de-energized condition (like in a disconnector). The fuse-link is used for one single breaking of a short-circuit current.
- **Surge arresters:** To discharge loads caused by lightning strikes (external overvoltages) or switching operations and earth faults (internal overvoltages). They protect the connected equipment against impermissibly high-voltages.

### Selection of switching devices

Switching devices are selected both according to their ratings and according to the switching duties to be performed, which also includes the switching rates. The following tables illustrate these selection criteria: table 3.2-1, next page, shows the selection according to ratings. Table 3.2-2 through table 3.2-5 show the endurance classes for the devices.

### Selection according to ratings

The system conditions, that is, the properties of the primary circuit, determine the required parameters. The most important of these are:

- **Rated voltage:** The upper limit of the 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 insulation level:** 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  $\mu$ s and a power-frequency withstand voltage test (50 Hz/1 min).

## 3.2.2 Basics of Switching Devices

### What are switching devices?

Switching devices are devices used to close (make) or open (break) electrical circuits. The following stress can occur during making and breaking:

- No-load switching
- Breaking of operating currents
- Breaking of short-circuit currents

### What can the different switching devices do?

- **Circuit-breakers:** Make and break all currents within the scope of their ratings, from small inductive and capacitive load currents up to the full short-circuit current, and this under all fault conditions in the power supply system, such as earth faults, phase opposition, and so on.
- **Switches:** Switch currents up to their rated normal current and make on existing short-circuits (up to their rated short-circuit making current).
- **Disconnectors (isolators):** Used for no-load closing and opening operations. Their function is to “isolate” downstream devices so they can be worked on.

Device	Withstand capability, rated ...				Switching capacity, rated ...		
	insulation level	voltage	normal current	peak withstand current	breaking current	short-circuit breaking current	short-circuit making current
Circuit-breaker	x	x	x			x	x
Switch(-disconnector)	x	x	x		x		x
Disconnecter	x		x	x			
Earthing switch	x			x			
Make-proof earthing switch	x	x					x
Contactor	x	x	x	x		x <sup>1)</sup>	x <sup>1)</sup>
Fuse-link		x	x			x	
Fuse-base	x		x				
Surge arrester*	x <sup>2)</sup>	x <sup>3)</sup>		x <sup>4)</sup>		x <sup>5)</sup>	
Current limiting reactor	x		x	x			
Bushing	x		x	x <sup>6)</sup>			
Post insulator (insulator)	x			x <sup>6)</sup>			

<sup>x</sup> Selection parameter  
<sup>1)</sup> Limited short-circuit making and breaking capacity  
<sup>2)</sup> Applicable as selection parameter in special cases only, e.g., for exceptional pollution layer  
<sup>3)</sup> For surge arresters with spark gap: rated voltage  
<sup>4)</sup> Rated discharge current for surge arresters  
<sup>5)</sup> For surge arresters: short-circuit strength in case of overload  
<sup>6)</sup> For bushings and insulators:  
 Minimum failing loads for tension, bending and torsion  
 \* See also section 3.3

(Parameters of the secondary equipment for operating mechanisms, control and monitoring are not taken into consideration in this table.)

Table 3.2-1: Device selection according to data of the primary circuit

Class	Operating cycles	Description
M	M1	1,000 Mechanical endurance
	M2	5,000 Increased mechanical endurance
E	E1	$10 \times I_{load}$ $10 \times I_{load}$ $2 \times I_{ma}$ $20 \times 0.05 \times I_{load}$ $10 \times I_{cc}$ $10 \times 0.2$ $20 \times 0.4 \times I_{cc}$ $10 \times I_{lc}$ $10 \times I_{ef1}$ $10 \times I_{ef2}$
	E2	$30 \times I_{load}$ $20 \times I_{load}$ $3 \times I_{ma}$ $10 \times I_{cc}$ $10 \times I_{lc}$ $10 \times I_{ef1}$ $10 \times I_{ef2}$
	E3	$100 \times I_{load}$ $20 \times I_{load}$ $5 \times I_{ma}$ $10 \times I_{cc}$ $10 \times I_{lc}$ $10 \times I_{sc}$ $10 \times I_{bb}$
C	C1	$10 \times I_{cc}$ $10 \times I_{lc}$ $10 \times I_{sc}$ $10 \times I_{bb}$ Restrikes permitted (number not defined)
	C2	additionally each $10 \times 0.1 \dots$ $0.4 \times I_{cc'}$ $I_{sb'}$ $I_{bb}$ No restrikes

Test currents: (old)  
 $I_{load}$  active load-breaking current  $I_1$   
 $I_{loo}$  closed-loop breaking current  $I_{2a}$   
 $I_{cc}$  cable-charging breaking current  $I_{4a}$   
 $I_{lc}$  line-charging breaking current  $I_{4b}$   
 $I_{sb}$  capacitor bank breaking current  $I_{4c}$   
 $I_{bb}$  back-to-back capacitor bank breaking current  $I_{4d}$   
 $I_{ef1}$  earth fault breaking current  $I_{6a}$   
 $I_{ef2}$  cable- and line-charging breaking current under earth fault conditions  $I_{6b}$   
 $I_{ma}$  short-circuit making current  $I_{ma}$

Table 3.2-2: Classes for switches

Class	Description			
M	M1 2,000 operating cycles Normal mechanical endurance			
	M2 10,000 operating cycles Extended mechanical endurance, low maintenance			
E	E1 2 × C and 3 × O with 10 %, 30 %, 60 % and 100 % $I_{sc}$ Normal electrical endurance (not covered by E2)			
	E2 2 × C and 3 × O with 10 %, 30 %, 60 % and 100 % $I_{sc}$ <table> <tr> <td>Without auto-reclosing duty</td> <td>Extended electrical endurance without maintenance of interrupting parts of the main circuit</td> </tr> <tr> <td>With auto-reclosing duty</td> <td></td> </tr> </table>	Without auto-reclosing duty	Extended electrical endurance without maintenance of interrupting parts of the main circuit	With auto-reclosing duty
Without auto-reclosing duty	Extended electrical endurance without maintenance of interrupting parts of the main circuit			
With auto-reclosing duty				
C	C1 24 × O per 10...40% $I_{lc'}$ $I_{cc'}$ $I_{bc}$ 24 × CO per 10...40% $I_{lc'}$ $I_{cc'}$ $I_{bc}$ Low probability of restrikes* Restrike-free breaking operations at 2 of 3 test duties			
	C2 24 × O per 10...40% $I_{lc'}$ $I_{cc'}$ 128 × CO per 10...40% $I_{lc'}$ $I_{cc'}$ Very low probability of restrikes**			
S	S1 Circuit-breaker used in a cable system			
	S2 Circuit-breaker used in a line system or in a cable system with direct connection (without cable) to overhead lines			

\* Class C1 is recommendable for infrequent switching of transmission lines and cables  
 \*\* Class C2 is recommended for capacitor banks and frequent switching of transmission lines and cables

Table 3.2-3: Classes for circuit-breakers

# Switchgear and Substations

## 3.2 Medium-Voltage Switchgear

Class	Operating cycles	Description
M	M0 1,000	For general requirements
	M1 2,000	Extended mechanical endurance
	M2 10,000	

Table 3.2-4: Endurance classes for disconnectors

Class	Operating cycles	Description
E	E0 $0 \times I_{ma}$	No short-circuit making capacity
	E1 $2 \times I_{ma}$	Short-circuit making capacity
	E2 $5 \times I_{ma}$	Short-circuit making capacity

Table 3.2-5: Endurance classes for earthing switches

Class	Description
C	C0 $24 \times O$ per 10...40% $I_{IC}$ , $I_{CC}$ , $I_{bc}$
	C1 $24 \times CO$ per 10...40% $I_{IC}$ , $I_{CC}$ , $I_{bc}$
	C2 $24 \times O$ per 10...40% $I_{IC}$ , $I_{CC}$ , $I_{bc}$

\* Class C2 is recommended for capacitor banks

Table 3.2-6: Classes for contactors

- **Rated normal current:**  
The current that the main circuit of a device can continuously carry under defined conditions. The temperature increase of components – especially contacts – must not exceed defined values. Permissible temperature increases always refer to the ambient air temperature. If a device is mounted in an enclosure, it may be advisable to load it below its full rated current, depending on the quality of heat dissipation.
- **Rated peak withstand current:**  
The peak value of the major loop of the short-circuit current during a compensation process after the beginning of the current flow, which 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 next item in this list).

- **Rated short-circuit making current:**  
The peak value of the making current in case 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.
- **Rated breaking current:**  
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 previous item in this list).
- **Rated short-circuit breaking current:**  
The root-mean-square value of the breaking current in case of short circuit at the terminals of the switching device.

### Selection according to endurance and switching rates

If several devices satisfy the electrical requirements and no additional criteria have to be taken into account, the required switching rate can be used as an additional selection criterion. Table 3.2-1 through table 3.2-5 show the endurance of the switching devices, providing a recommendation for their appropriate use. The respective device standards distinguish between classes of mechanical (M) and electrical (E) endurance, whereby they can also be used together on the same switching device; for example, a switching device can have both mechanical class M1 and electrical class E3.

### Switches:

Standard IEC 62271-103 / VDE 0671-103 only specifies classes for the so-called general-purpose switches. There are also "special switches" and "switches for limited applications."

#### – General-purpose switches:

General-purpose switches must be able to break different types of operating currents (load currents, ring currents, currents of unloaded transformers, charging currents of unloaded cables and overhead-lines), as well as to make on short-circuit currents.

General-purpose switches that are intended for use in systems with isolated neutral or with earth earth-fault compensation, must also be able to switch under earth-fault conditions. The versatility is mirrored in the very exact specifications for the E classes.

#### – SF<sub>6</sub> switches:

SF<sub>6</sub> switches are appropriate when the switching rate is not more than once a month. These switches are usually classified as E3 with regard to their electrical endurance.

#### – Air-break or hard-gas switches:

Air-break or hard-gas switches are appropriate when the switching rate is not more than once a year. These switches are simpler and usually belong to the E1 class. There are also E2 versions available.

#### – Vacuum switches:

The switching capacity of vacuum switches is significantly higher than that of the M2/E3 classes. They are used for special tasks – mostly in industrial power supply systems – or when the switching rate is at least once a week.

\* Disconnectors up to 52 kV may only switch negligible currents up to 500 mA (e.g., voltage transformer), or larger currents only when there is an insignificant voltage difference (e.g., during busbar transfer when the bus coupler is closed).

- **Circuit-breakers:**

Whereas the number of mechanical operating cycles is specifically stated in the M classes, the circuit-breaker standard IEC 62271-100/VDE 0671-100 does not define the electrical endurance of the E classes by specific numbers of operating cycles; the standard remains very vague on this.

The test duties of the short-circuit type tests provide an orientation as to what is meant by "normal electrical endurance" and "extended electrical endurance." The number of make and break operations (**C**lose, **O**pen) is specified in table 3.2-3.

Modern vacuum circuit-breakers can generally make and break the rated normal current up to the number of mechanical operating cycles.

The switching rate is not a determining selection criterion, because circuit-breakers are always used where short-circuit breaking capacity is required to protect equipment.

- **Disconnectors:**

Disconnectors do not have any switching capacity (switches for limited applications must only control some of the switching duties of a general-purpose switch). Switches for special applications are provided for switching duties such as switching of single capacitor banks, paralleling of capacitor banks, switching of ring circuits formed by transformers connected in parallel, or switching of motors in normal and locked condition. Therefore, classes are only specified for the number of mechanical operating cycles.

- **Earthing switches:**

With earthing switches, the E classes designate the short-circuit making capacity (earthing on applied voltage). E0 corresponds to a normal earthing switch; switches of the E1 and E2 classes are also-called make-proof or high-speed earthing switches.

The standard does not specify how often an earthing switch can be actuated purely mechanically; there are no M classes for these switches.

- **Contactors:**

The standard has not specified any endurance classes for contactors yet. Commonly used contactors today have a mechanical and electrical endurance in the range of 250,000 to 1,000,000 operating cycles. They are used wherever switching operations are performed very frequently, e.g., more than once per hour.

Regarding capacitor applications IEC 62271-106 introduced classes for capacitive current breaking. If contactors are used for capacitor banks it is recommended to only install class C2 contactors.



### 3.2.3 Requirements of Medium-Voltage Switchgear

The major influences and stress values that a switchgear assembly is subjected to result from the task and its rank in the distribution system. These influencing factors and stresses determine the selection parameters and ratings of the switchgear (fig. 3.2-4).

#### Influences and stress values

##### System voltage

The system voltage determines the rated voltage of the switchgear, switching devices and other installed components. The maximum system voltage at the upper tolerance limit is the deciding factor.

##### Assigned configuration criteria for switchgear

- Rated voltage  $U_r$
- Rated insulation level  $U_d$ ;  $U_p$
- Rated primary voltage of voltage transformers  $U_{pr}$

##### Short-circuit current

The short-circuit current is characterized by the electrical values of peak withstand current  $I_p$  (peak value of the initial symmetrical short-circuit current) and sustained short-circuit current  $I_k$ . The required short-circuit current level in the system is predetermined by the dynamic response of the loads and the power quality to be maintained, and determines the making and breaking capacity and the withstand capability of the switching devices and the switchgear (table 3.2-7).

**Important note:** The ratio of peak current to sustained short-circuit current in the system can be significantly larger than the standardized factor  $I_p/I_k = 2.5$  (50 Hz) used for the construction of the switching devices and the switchgear. A possible cause, for example, are motors that feed power back to the system when a short circuit occurs, thus increasing the peak current significantly.

##### Normal current and load flow

The normal current refers to current paths of the incoming feeders, busbar(s) and outgoing consumer feeders. Because of the spatial arrangement of the panels, the current is also distributed, and therefore there may be different rated current values next to one another along a conducting path; different values for busbars and feeders are typical.

Reserves must be planned when dimensioning the switchgear:

- In accordance with the ambient air temperature
- For planned overload
- For temporary overload during faults.

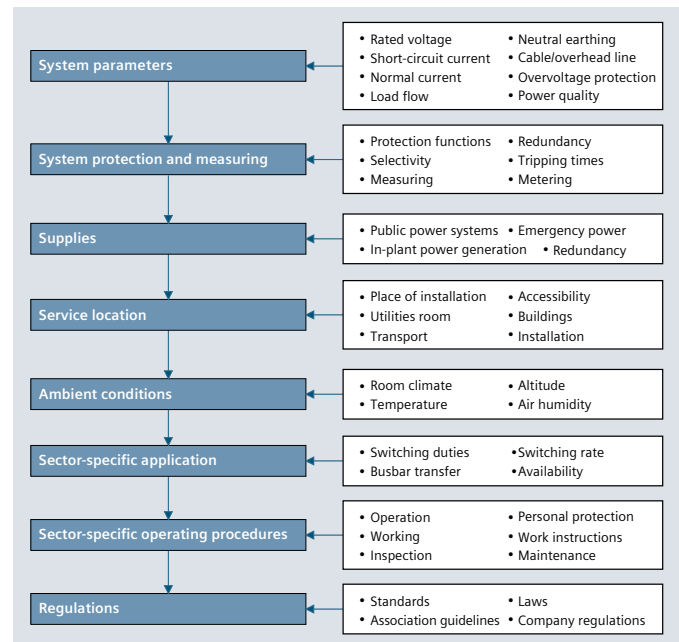


Fig. 3.2-4: Influencing factors and stresses on the switchgear

Assigned configuration criteria for switchgear	
Main and earthing circuits	<ul style="list-style-type: none"> <li>– Rated peak withstand current <math>I_p</math></li> <li>– Rated short-time withstand current <math>I_k</math></li> </ul>
Switching devices	<ul style="list-style-type: none"> <li>– Rated short-circuit making current <math>I_{ma}</math></li> <li>– Rated short-circuit breaking current <math>I_{sc}</math></li> </ul>
Current transformers	<ul style="list-style-type: none"> <li>– Rated peak withstand current <math>I_{k-dyn}</math></li> <li>– Rated short-time thermal current <math>I_{th}</math></li> </ul>

Table 3.2-7: Configuration criteria for short-circuit current

Large cable cross-sections or several parallel cables must be connected for high normal currents; the panel connection must be designed accordingly.

##### Assigned configuration criteria for switchgear

- Rated current of busbar(s) and feeders
- Number of cables per phase in the panel (parallel cables)
- Current transformer ratings.

Category		When an accessible compartment in a panel is opened, ...
LSC 1		other panels must be shut down, i.e. at least one more
LSC 2	LSC 2	only the connection compartment is accessible, while busbar and other panels remain energized
	LSC 2A	any accessible compartment – except the busbar – can be open while busbar and other panels remain energized
	LSC 2B	the connection (cable) compartment can remain energized while any other accessible compartment can be open – except busbar and connections – and busbar and other panels remain energized

Table 3.2-8: Loss of service continuity categories

Type of accessibility to a compartment	Access features	Type of construction
Interlock-controlled	Opening for normal operation and maintenance, e.g., fuse replacement	Access is controlled by the construction of the switchgear, i.e., integrated interlocks prevent impermissible opening.
Procedure-based	Opening for normal operation or maintenance, e.g., fuse replacement	Access control via a suitable procedure (work instruction of the operator) combined with a locking device (lock).
Tool-based	Opening not for normal operation and maintenance, e.g., cable testing	Access only with tool for opening; special access procedure (instruction of the operator).
Not accessible	Opening not possible or not intended for operator; opening can destroy the compartment. This applies generally to the gas-filled compartments of gas-insulated switchgear. As the switchgear is maintenance-free and climate-independent, access is neither required nor possible.	

Table 3.2-9: Accessibility of compartments

The notation IAC A FLR, and contains the abbreviations for the following values:	
IAC	Internal Arc Classification
A	Distance between the indicators 300 mm, i.e., installation in rooms with access for authorized personnel; closed electrical service location.
FLR	Access from the front (F), from the sides (L = Lateral) and from the rear (R).
I	Test current = Rated short-circuit breaking current (in kA)
t	Arc duration (in s)

Table 3.2-10: Internal arc classification according to IEC 62271-200

### 3.2.4 Medium-Voltage Switchgear

Distribution level	Insulation	Type of construction	Loss of service continuity	Partition class	Internal arc classification*	
Primary	Gas-insulated	Extendable	LSC 2	PM	IAC A FLR 31.5 kA, 1 s	
			LSC 2	PM	IAC A FLR 25 kA, 1 s	
			LSC 2	PM	IAC A FL 25 kA, 1 s ** IAC A FLR 25 kA, 1 s ****	
			LSC 2	PM	IAC A FLR 31.5 kA, 1 s	
			LSC 2	PM	IAC A FLR 31.5 kA, 1 s	
			LSC 2	PM	IAC A FLR 40 kA, 1 s	
			LSC 2	PM	IAC A FLR 40 kA, 1 s	
	Air-insulated	Extendable	LSC 2B	PM	IAC A FLR 50 kA, 1 s	
					IAC A FLR 25 kA, 1 s	
			LSC 2B	PM	IAC A FLR 31.5 kA, 1 s	
			LSC 2A	PM	IAC A FLR 25 kA, 1 s	
			LSC 2B	PM	IAC A FLR 31.5 kA, 1 s	
Secondary	Gas-insulated	Non-extendable	LSC 2	PM	IAC A FL 21 kA, 1 s ** IAC A FLR 21 kA, 1 s ****	
		Extendable	LSC 2	PM	IAC A FL 21 kA, 1 s ** IAC A FLR 21 kA, 1 s ****	
		Extendable	LSC 2	PM	IAC A FL 20 kA, 1 s ** IAC A FLR 20 kA, 1 s ****	
	Air-insulated	Extendable	LSC 2	PM	IAC A FLR 21 kA, 1 s	

\* Maximum possible IAC classification \*\* Wall-standing arrangement \*\*\* Free-standing arrangement \*\*\*\* Depending on HV HRC fuse-link

Table 3.2-11: Overview of Siemens medium-voltage switchgear

	Switchgear type	Busbar system	Rated voltage (kV)	Rated short-time withstand current (kA)		Rated current, busbar (A)	Rated current, feeder (A)
				1 s	3 s		
	NXPLUS C	Single	15	31.5	31.5	2,500	2,500
			24.0	25	25	2,500	2,000
	NXPLUS C	Double	24	25	25	2,500	1,250
	NXPLUS C Wind	Single	36	25	20	1,000	630/1,000
	NXPLUS	Single	40.5	31.5	31.5	2,500	2,500
	NXPLUS	Double	36	31.5	31.5	2,500	2,500
	8DA10	Single	40.5	40	40	5,000	2,500
	8DB10	Double	40.5	40	40	5,000	2,500
	NXAIR	Single	17.5	50	50	4,000	4,000
		Double	17.5	50	50	4,000	4,000
		Single	24	25	25	2,500	2,500
		Double	24	25	25	2,500	2,500
	NXAIR S	Single	40.5	31.5	31.5	3,150	2,500
	8BT1	Single	24	25	25	2,000	2,000
	8BT2	Single	36	31.5	31.5	3,150	3,150
	8DJH Compact (panel blocks)	Single	17.5	25	20	630	200 **** / 250/400/630
			24	20	20	630	200 **** / 250/400/630
	8DJH (single panel/ block type)	Single	17.5	25	20	630	200 **** / 250/400/630
			24	20	20	630	200 **** / 250/400/630
	8DJH 36	Single	36	20	20	630	200 **** / 630
	SIMOSEC	Single	17.5	25	21	1,250	1,250
			24	20	20	1,250	1,250



### NXAIR ≤ 17.5 kV

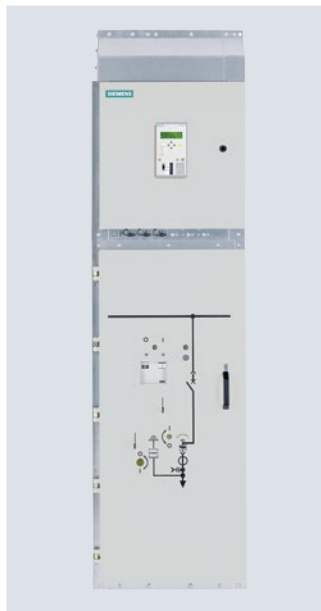
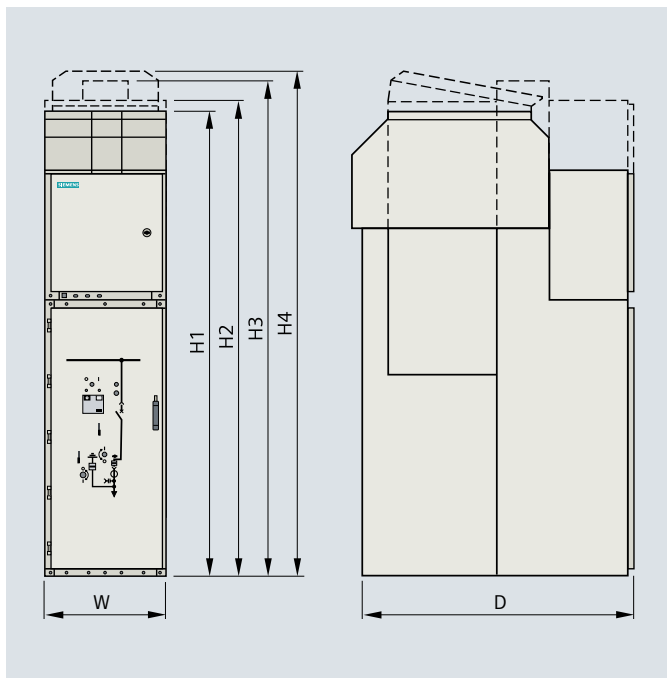


Fig. 3.2-5: NXAIR panel

Rated				
Voltage	kV	7.2	12	17.5
Frequency	Hz	50/60	50/60	50/60
Short-duration power-frequency withstand voltage (phase/phase, phase/earth)	kV	20*	28*	38
Lightning impulse withstand voltage (phase/phase, phase/earth)	kV	60	75	95
Short-circuit breaking current	max. kA	50	50	50
Short-time withstand current, 3 s	max. kA	50	50	50
Short-circuit making current	max. kA	125/130**	125/130**	125/130**
Peak withstand current	max. kA	125/130**	125/130**	125/130**
Normal current for busbar	max. A	4,000	4,000	4,000
Normal current for feeders:				
Circuit-breaker panel	max. A	4,000	4,000	4,000
Contactor panel	max. A	400***	400***	–
Disconnecting panel	max. A	4,000	4,000	4,000
Bus sectionalizer	max. A	4,000	4,000	4,000
Busbar connection panel	max. A	4,000	4,000	4,000

\* 32 kV at 7.2 kV and 42 kV at 12 kV optional for GOST standard.  
 \*\* Values for 50 Hz: 125 kA; for 60 Hz: 130 kA.  
 \*\*\* Current values dependent on HV HRC fuses. Lightning impulse withstand voltage across open contact gap of contactor: 40 kV at 7.2 kV, 60 kV at 12 kV.

Table 3.2-12: Technical data of NXAIR



Dimensions			in mm
Width	W	Circuit-breaker panel ≤ 1,000 A	600*
		1,250/2,500/3,150 A	800
		2,500 A/3,150 A/4,000 A	1,000
		Contactor panel ≤ 400 A	435/600
		Disconnecting panel 1,250 A	800
		2,500 A/3,150 A/4,000 A	1,000
		Bus sectionalizer 1,250 A	2 × 800
		2,500 A/3,150 A/4,000 A	2 × 1,000
		Metering panel	800
		Busbar connection panel ≤ 4,000 A	800/1,000
Height	H1	With standard low-voltage compartment, natural ventilation	2,300
Height	H2	With high low-voltage compartment or additional compartment for busbar components	2,350
Height	H3	With forced ventilation for 4,000 A	2,450
Height	H4	With optional internal arc absorber	2,500
Depth	D	Single busbar, all panel types ≤ 31.5 kA (except contactor panel)	1,350
		40 kA	1,500
		Contactor panel ≤ 40 kA	1,400*/1,500

\* ≤ 31.5 kA

Fig. 3.2-6: Dimensions of NXAIR

#### Performance features

The air-insulated, metal-clad switchgear type NXAIR is an innovation in the switchgear field for the distribution and process level up to 17.5 kV, 50 kA, 4,000 A.

- Type-tested, IEC 62271-200, metal-clad, loss of service continuity category: LSC 2B; partition class: PM; internal arc classification: IAC A FLR ≤ 50 kA 1 s
- Evidence of the making and breaking capacity for the circuit-breakers and the make-proof earthing switches inside the panel

- Insulating medium air is always available
- Single busbar, double busbar (back-to-back, face-to-face)
- Withdrawable vacuum circuit-breaker
- Withdrawable vacuum contactor
- Platform concept worldwide, local manufacturing presence
- Use of standardized devices
- Maximum security of operation by self-explaining operating logic
- Maintenance interval ≥ 10 years

### NXAIR 24 kV

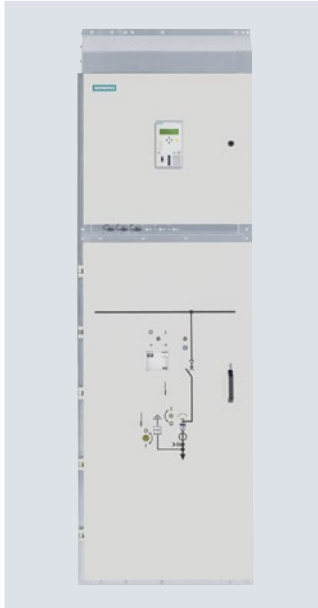
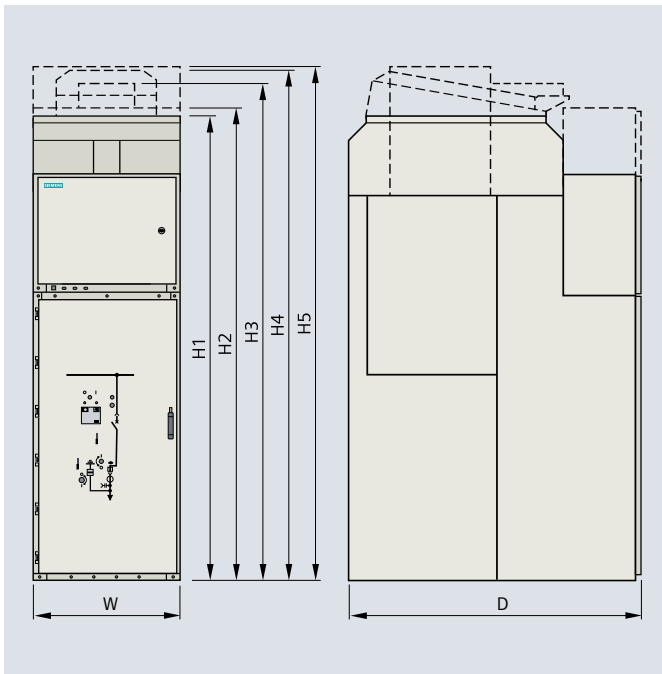


Fig. 3.2-7: NXAIR, 24 kV panel

Rated		
Voltage	kV	24
Frequency	Hz	50/60
Short-duration power-frequency withstand voltage (phase/phase, phase/earth)	kV	50 *
Lightning impulse withstand voltage (phase/phase, phase/earth)	kV	125
Short-circuit breaking current	max. kA	25
Short-time withstand current, 3 s	max. kA	25
Short-circuit making current	max. kA	63/65 **
Peak withstand current	max. kA	63/65 **
Normal current for busbar	max. A	2,500
Normal current for feeders:		
Circuit-breaker panel	max. A	2,500
Disconnecting panel	max. A	2,500
Bus sectionalizer	max. A	2,500
* 65 kV optional for GOST standard ** Values for 50 Hz: 63 kA; for 60 Hz: 65 kA.		

Table 3.2-13: Technical data of NXAIR, 24 kV



Dimensions				in mm
Width	W	Circuit-breaker panel	≤ 1,250 A 2,500 A	800 1,000
		Disconnecting panel	≤ 1,250 A 2,500 A	800 1,000
		Bus sectionalizer	≤ 1,250 A 1,600 A / 2,000 A / 2,500 A	2 × 800 2 × 1,000
		Metering panel		800
Height	H1	With standard low-voltage compartment		2,510
Height	H2	With high low-voltage compartment		2,550
Height	H3	With natural ventilation		2,680
Height	H4	With optional internal arc absorber		2,750
Height	H5	With additional compartment for busbar components		2,770
Depth	D	Single busbar		1,600
		Double busbar (back-to-back)		3,350

Fig. 3.2-8: Dimensions of NXAIR, 24 kV

#### Performance features

The air-insulated, metal-clad switchgear type NXAIR, 24 kV is the resulting further development of the NXAIR family for use in the distribution and process level up to 24 kV, 25 kA, 2,500 A.

- Type-tested, IEC 62271-200, metal-clad, loss of service continuity category: LSC 2B; partition class: PM; internal arc classification: IAC A FLR ≤ 25 kA 1s
- Evidence of the making and breaking capacity for the circuit-breakers and the make-proof earthing switches inside the panel

- Single busbar, double busbar (back-to-back, face-to-face)
- Insulating medium air is always available
- Withdrawable vacuum circuit-breaker
- Platform concept worldwide, local manufacturing presence
- Use of standardized devices
- Maximum security of operation by self-explaining operating logic
- Maintenance interval ≥ 10 years

# Switchgear and Substations

## 3.2 Medium-Voltage Switchgear

### NXAIR S



Fig. 3.2-9: NXAIR S panel

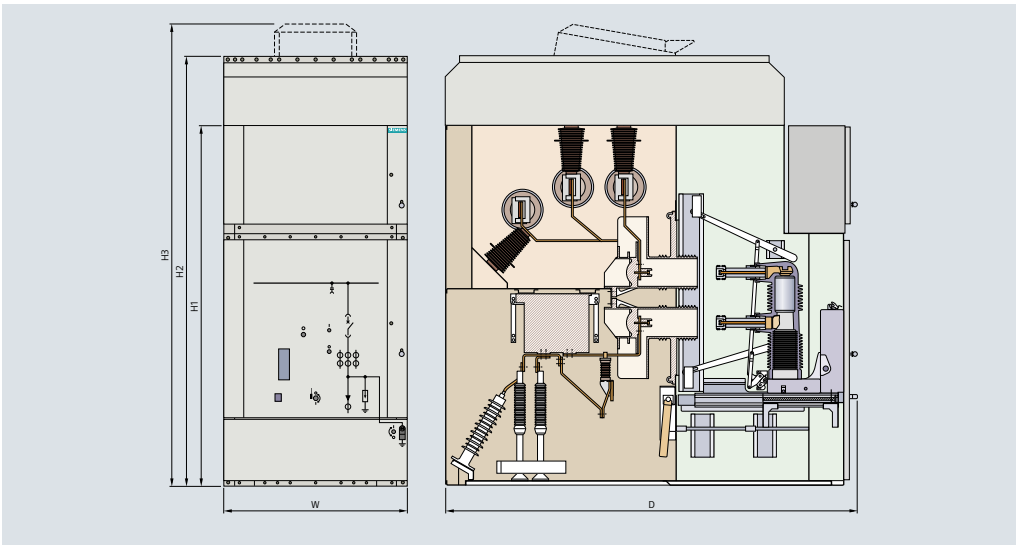
#### Performance features

The air-insulated, metal-clad switchgear type NXAIR S is based on the construction principles of the NXAIR family and designed for use in the distribution and process level up to 40.5 kV, 31.5 kA, 3,150 A.

- Type-tested, IEC 62271-200, metal-clad, loss of service continuity category: LSC 2B; partition class: PM; internal arc classification: IAC A FLR  $\leq 31.5$  kA 1 s
- Insulating medium air is always available
- Evidence of the making and breaking capacity for the circuit-breakers and the make-proof earthing switches inside the panel
- Withdrawable vacuum circuit-breaker
- Maximum availability due to modular design
- Maximum security of operation by self-explaining operating logic
- Maintenance interval  $\geq 10$  years

Rated		
Voltage	kV	40.5
Frequency	Hz	50/60
Short-duration power-frequency withstand voltage (phase/phase, phase/earth)	kV	185
Lightning impulse withstand voltage (phase/phase, phase/earth)	kV	95
Short-circuit breaking current	max. kA	31.5
Short-time withstand current, 4 s	max. kA	31.5
Short-circuit making current	max. kA	80/82
Peak withstand current	max. kA	80/82
Normal current for busbar	max. A	3,150
Normal current for feeders:		
	Circuit-breaker panel	max. A 2,500
	Disconnecting panel	max. A 2,500
	Bus sectionalizer	max. A 2,500

Table 3.2-14: Technical data of NXAIR S



Dimensions		in mm	
Width	W	Circuit-breaker panel	1,200
		Disconnecting panel	1,200
		Switch-fuse panel including auxiliary transformer	1,400
		Bus sectionalizer	2 × 1,200
		Metering panel	1,200
Height	H1	With standard low-voltage compartment	2,650
Height	H2	Standard panel	2,800
Height	H3	Optionally with internal arc absorber	3,010
Depth	D	Single busbar	2,650

Fig. 3.2-10: Dimensions of NXAIR S

### 8BT1



Fig. 3.2-11: 8BT1 panel

#### Performance features

The air-insulated, cubicle-type switchgear type 8BT1 is a factory-assembled, type-tested indoor switchgear for lower ratings in the distribution and process level up to 24 kV, 25 kA, 2,000 A.

- Type-tested, IEC 62271-200, cubicle-type, loss of service continuity category: LSC 2A; partition class: PM; internal arc classification: IAC A FLR ≤ 25 kA 1 s
- Insulating medium air is always available
- Evidence of the making and breaking capacity for the circuit-breakers and the make-proof earthing switches inside the panel
- Single busbar
- Withdrawable vacuum circuit-breaker
- All switching operations with door closed

Rated			
Voltage	kV	12	24
Frequency	Hz	50	50
Short-duration power-frequency withstand voltage (phase/phase, phase/earth)	kV	28	50
Lightning impulse withstand voltage (phase/phase, phase/earth)	kV	75	125
Short-circuit breaking current	max. kA	25	25
Short-time withstand current, 3 s	max. kA	25	25
Short-circuit making current	max. kA	63	63
Peak withstand current	max. kA	63	63
Normal current for busbar	max. A	2,000	2,000
Normal current for feeders with circuit-breaker with switch-disconnector and fuses	max. A	2,000	2,000
	max. A	630	630
	max. A	200 A*	200 A*

\* Depending on rated current of the HV HRC fuses used.

Table 3.2-15: Technical data of 8BT1

All panel types			Dimensions in mm
<b>7.2/12 kV</b>			
Width	W	For circuit-breaker max. 1,250 A For circuit-breaker 2,000 A For switch-disconnector	600 800 600
Height	H1 H2 H2	With standard low-voltage compartment With pressure relief system With lead-off duct	2,050 2,300* 2,350*
Depth	D1 D2	Without low-voltage compartment With low-voltage compartment	1,200 1,410
<b>24 kV</b>			
Width	W	For circuit-breaker max. 1,250 A For circuit-breaker 2,000 A For switch-disconnector	800 1,000 800
Height	H1 H2 H2	With standard low-voltage compartment With pressure relief system With lead-off duct	2,050 2,300* 2,350*
Depth	D1 D2	Without low-voltage compartment With low-voltage compartment	1,200 1,410

\* For 1 s arc duration.

Fig. 3.2-12: Dimensions of 8BT1

# Switchgear and Substations

## 3.2 Medium-Voltage Switchgear

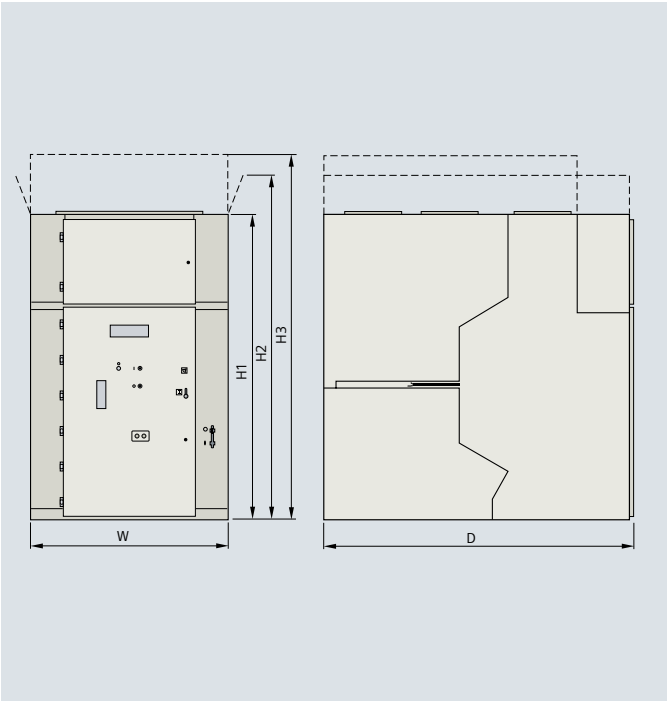
### 8BT2



Rated		
Voltage	kV	36
Frequency	Hz	50/60
Short-duration power-frequency withstand voltage (phase/phase, phase/earth)	kV	70
Lightning impulse withstand voltage (phase/phase, phase/earth)	kV	170
Short-circuit breaking current	max. kA	31.5
Short-time withstand current, 3 s	max. kA	31.5
Short-circuit making current	max. kA	80/82*
Peak withstand current	max. kA	80/82*
Normal current for busbar	max. A	3,150
Normal current for feeders with circuit-breaker	max. A	3,150
* Values for 50 Hz: 80 kA; for 60 Hz: 82 kA.		

Fig. 3.2-13: 8BT2 switchgear

Table 3.2-16: Technical data of 8BT2



Dimensions			in mm
Width	W	≤ 3,150 A feeder current	1,200
Height	H1	Intermediate panel	2,400
Height	H2	End panel with side baffles	2,750 / 2,800*
Height	H3	Panel with closed duct	2,900**
Depth	D	Wall-standing, IAC A FL	2,450
		Free-standing, IAC A FLR	2,700
* H2 indicates side baffles for internal arc protection			
** Closed duct for IAC-classification A FLR			

Fig. 3.2-14: Dimensions of 8BT2

#### Performance features

The air-insulated, metal-clad switchgear type 8BT2 is a factory-assembled, type-tested indoor switchgear for use in the distribution and process level up to 36 kV, 31.5 kA, 3,150 A.

- Type-tested, IEC 62271-200, metal-clad, loss of service continuity category: LSC 2B; partition class: PM; internal arc classification: IAC A FLR ≤ 31.5 kA 1 s
- Insulating medium air is always available

- Evidence of the making and breaking capacity for the circuit-breakers and the make-proof earthing switches inside the panel
- Single busbar
- Withdrawable vacuum circuit-breaker
- All switching operations with door closed



### 8DA/8DB



Fig. 3.2-15: 8DA switchgear for single-busbar applications (on the left), 8DB switchgear for double-busbar applications (on the right)

8DA/8DB are gas-insulated medium-voltage circuit-breaker switchgear assemblies up to 40.5 kV with the advantages of the vacuum switching technology – for a high degree of independence in all applications. 8DA/8DB are suitable for primary distribution systems up to 40.5 kV, 40 kA, up to 5,000 A.

#### Performance features

- Type-tested according to IEC 62271-200
- Enclosure with modular standardized housings made from corrosion-resistant aluminum alloy
- Safe-to-touch enclosure and standardized connections for plug-in cable terminations
- Operating mechanisms and transformers are easily accessible outside the enclosure
- Metal-enclosed, partition class PM
- Loss of service continuity category for switchgear: LSC 2
- Internal arc classification: IAC A FLR 40 kA 1 s

Rated					
Voltage	kV	12	24	36	40.5
Frequency	Hz	50/60	50/60	50/60	50/60
Short-duration power-frequency withstand voltage	kV	28	50	70	85
Lightning impulse withstand voltage	kV	75	125	170	185
Short-circuit breaking current	max. kA	40	40	40	40
Short-time withstand current, 3 s	max. kA	40	40	40	40
Short-circuit making current	max. kA	100	100	100	100
Peak withstand current	max. kA	100	100	100	100
Normal current for busbar	max. A	5,000	5,000	5,000	5,000
Normal current for feeders	max. A	2,500	2,500	2,500	2,500

Table 3.2-17: Technical data of 8DA/8DB

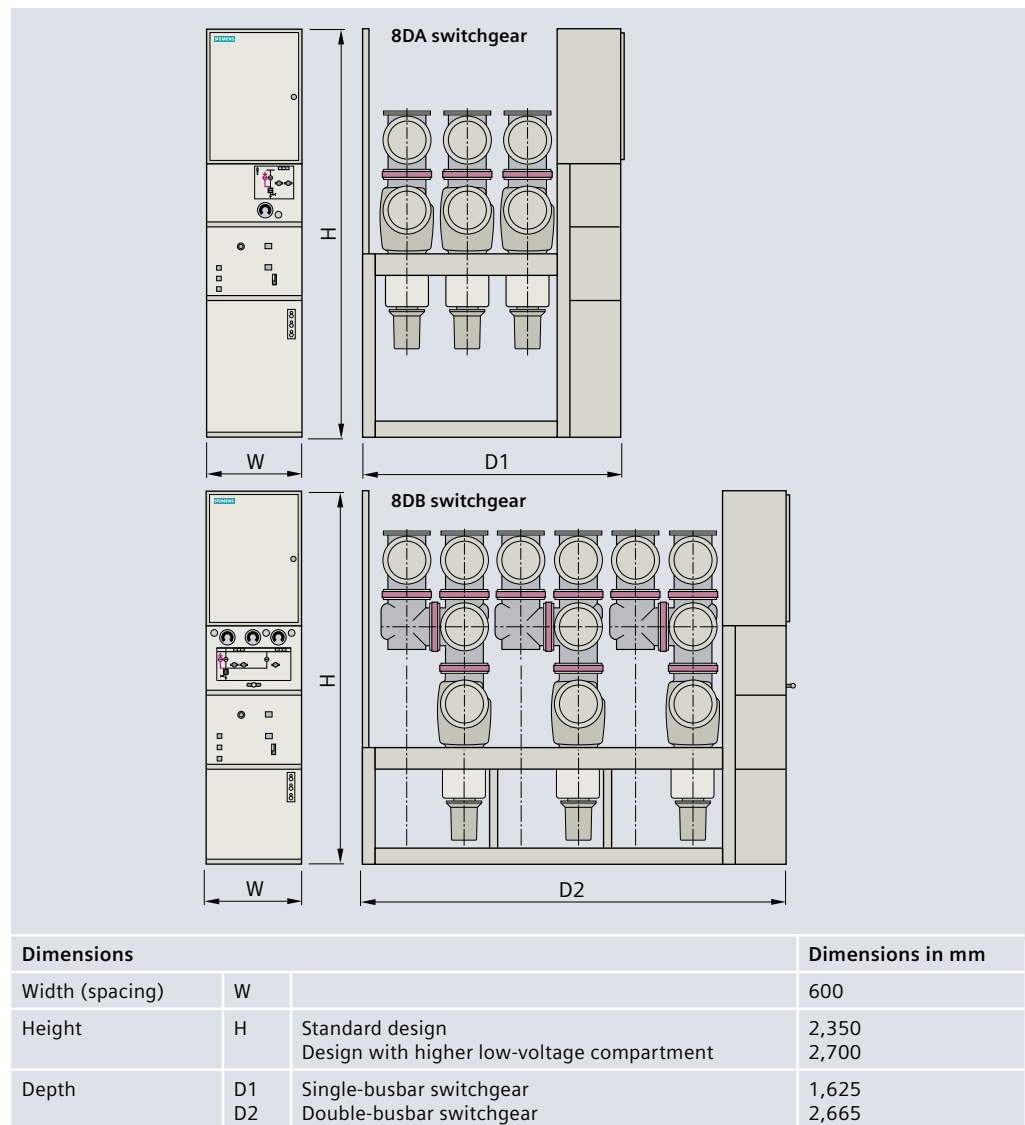


Fig. 3.2-16: Dimensions of 8DA/8DB

#### Advantages

- Independent of environment and climate
- Compact
- Maintenance-free
- Personal safety
- Operational reliability
- Environmentally compatible
- Cost-efficient

# Switchgear and Substations

## 3.2 Medium-Voltage Switchgear

### 8DJH Compact



Fig. 3.2-17: 8DJH Compact

The gas-insulated medium-voltage switchgear type 8DJH Compact is used for power distribution in secondary distribution systems up to 24 kV. Ring-main feeders and transformer feeders are all part of a comprehensive product range to satisfy all requirements with the highest level of operational reliability – also for extreme ambient conditions.

#### Performance features

- Type-tested according to IEC 62271-200
- Sealed pressure system with SF<sub>6</sub> filling for the entire service life
- Safe-to-touch enclosure and standardized connections for plug-in cable terminations
- 3-pole, gas-insulated switchgear vessel for switching devices and busbar
- Panel blocks
- Switching devices: three-position switch-disconnector (OPEN – CLOSED – EARTHED), switch-fuse combination for distribution transformer protection
- Earthing function of switching devices generally make-proof

Rated						
Voltage	kV	7.2	12	15	17.5	24
Frequency	Hz	50/60	50/60	50/60	50/60	50/60
Short-duration power-frequency withstand voltage	kV	20	28	36	38	50
Lightning impulse withstand voltage	kV	60	75	95	95	125
Normal current for ring-main feeders	A	400 or 630				
Normal current for busbar	max. A	630				
Normal current for transformer feeders	A	200*				
Short-time withstand current, 1 s	50 Hz	max. kA	25	25	25	20
Short-time withstand current, 3 s		max. kA	20	20	20	20
Peak withstand current		max. kA	63	63	63	50
Short-circuit making current for ring-main feeders	60 Hz	max. kA	63	63	63	50
Short-circuit making current for transformer feeders		max. kA	63	63	63	50
Short-time withstand current, 1 s		max. kA	21	21	21	20
Short-time withstand current, 3 s		max. kA	21	21	21	20
Peak withstand current		max. kA	55	55	55	52
Short-circuit making current for ring-main feeders		max. kA	55	55	55	52
Short-circuit making current for transformer feeders		max. kA	55	55	55	52

\* Depending on HV HRC fuse-link

Table 3.2-18: Technical data of 8DJH Compact

Dimensions			Dimensions in mm
Width	W	Number of feeders (in extracts) 3 feeders (RRT) 4 feeders (RRT-R) 6 feeders (RRT-RRT)	620** / 700*** 930** / 1,010*** 1,240** / 1,400***
Height	H		1,400 / 1,700
Depth	D	Standard switchgear	775

\*\* Internal arc classification IAC A F, \*\*\* Internal arc classification IAC A FLR

Fig. 3.2-18: Dimensions of 8DJH Compact

### 8DJH



Fig. 3.2-19: 8DJH block type

The gas-insulated medium-voltage switchgear type 8DJH is used for power distribution in secondary distribution systems up to 24 kV. Ring-main feeders, circuit-breaker feeders and transformer feeders are all part of a comprehensive product range to satisfy all requirements with the highest level of operational reliability – also for extreme ambient conditions.

#### Performance features

- Type-tested according to IEC 62271-200
- Sealed pressure system with SF<sub>6</sub> filling for the entire service life
- Safe-to-touch enclosure and standardized connections for plug-in cable terminations
- 3-pole, gas-insulated switchgear vessel for switching devices and busbar
- Panel blocks and single panels available
- Switching devices: three-position switch-disconnector (ON – OFF – EARTH), switch-fuse combination for distribution transformer protection, vacuum circuit-breaker with three-position disconnector, earthing switch
- Earthing function of switching devices generally make-proof

Rated			kV 7.2	12	15	17.5	24
Voltage		kV	7.2	12	15	17.5	24
Frequency		Hz	50/60	50/60	50/60	50/60	50/60
Short-duration power-frequency withstand voltage		kV	20	28*	36	38	50
Lightning impulse withstand voltage		kV	60	75	95	95	125
Normal current for ring-main feeders		A	400 or 630				
Normal current for busbar		max. A	630				
Normal current for circuit-breaker feeders		A	250 or 630				
Normal current for transformer feeders		A	200**				
Short-time withstand current, 1 s	50 Hz	max. kA	25	25	25	25	20
Short-time withstand current, 3 s		max. kA	20	20	20	20	20
Peak withstand current		max. kA	63	63	63	63	50
Short-circuit making current for ring-main feeders	50 Hz	max. kA	63	63	63	63	50
Short-circuit making current for circuit-breaker feeders		max. kA	63	63	63	63	50
Short-circuit making current for transformer feeders		max. kA	63	63	63	63	50
Short-time withstand current, 1 s	60 Hz	max. kA	25	25	25	25	21
Short-time withstand current, 3 s		max. kA	21	21	21	21	20
Peak current		max. kA	65	65	65	65	55
Short-circuit making current for ring-main feeders	60 Hz	max. kA	65	65	65	65	55
Short-circuit making current for circuit-breaker feeders		max. kA	65	65	65	65	55
Short-circuit making current for transformer feeders		max. kA	65	65	65	65	55

\* 42 kV according to some national requirements \*\* Depending on HV HRC fuse-link

Table 3.2-19: Technical data of 8DJH

Dimensions			Dimensions in mm
Width	W	Number of feeders (in extracts) 2 feeders (e.g., RR) 3 feeders (e.g., RRT) 4 feeders (e.g., 3R + 1T)	620 1,050 1,360
Height	H	Panels without low-voltage compartment Panels with low-voltage compartment (option) Switchgear with pressure absorber (option)	1,200/1,400/1,700 1,400–2,600 1,800–2,600
Depth	D	Standard switchgear Switchgear with pressure absorber (option)	775 890

Fig. 3.2-20: Dimensions of 8DJH block types

### 8DJH



Fig. 3.2-21: 8DJH single panel

- Metal-enclosed, partition class PM
- Loss of service continuity category for switchgear: LSC 2
- Internal arc classification (option):
  - IAC A FL 21 kA, 1 s
  - IAC A FLR 21 kA, 1 s

#### Advantages

- No gas work during installation
- Compact
- Independent of environment and climate
- Maintenance-free
- High operating and personal safety
- Switchgear interlocking system with logical mechanical interlocks
- Operational reliability and security of investment
- Environmentally compatible
- Cost-efficient

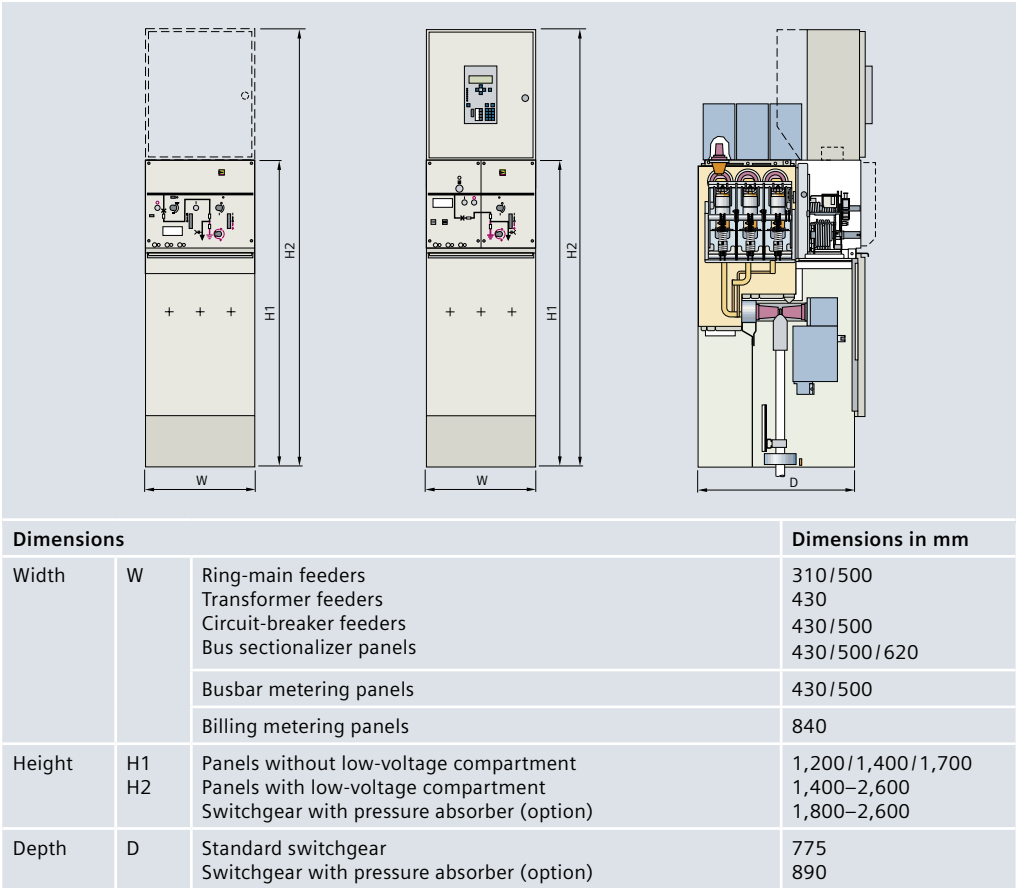


Fig. 3.2-22: Dimensions of 8DJH single panels

#### Typical uses

8DJH switchgear is used for power distribution in secondary distribution systems, such as

- Public energy distribution
  - Transformer substations
  - Customer transfer substations
  - High-rise buildings
- Infrastructure facilities
  - Airports & ports
  - Railway & underground railway stations
  - Water & wastewater treatment
- Industrial plants
  - Automotive industry
  - Chemical industry
  - Open-cast mines
- Renewable power generation
  - Wind power plants
  - Solar power plants
  - Biomass power plants

### 8DJH 36



Fig. 3.2-23: 8DJH 36 block type

The gas-insulated medium voltage switchgear type 8DJH 36 is used for power distribution in secondary distribution systems up to 36 kV. Ring-main feeders, circuit-breaker feeders and transformer feeders are all part of a comprehensive product range to satisfy all requirements with the highest level of operational reliability – also for extreme conditions.

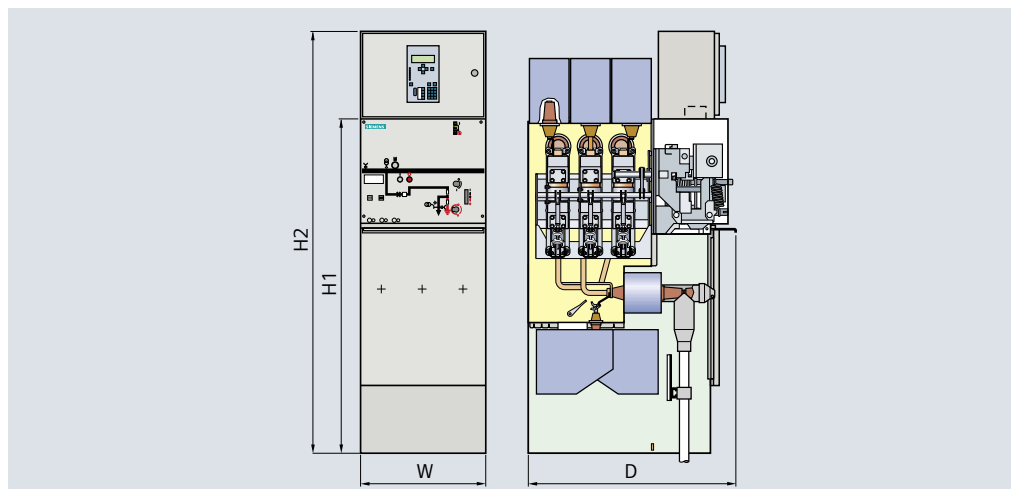
#### Performance features

- Type-tested according to IEC 62271-200
- Sealed pressure system with SF<sub>6</sub> filling for the entire service life
- Safe-to-touch enclosure and standardized connections for plug-in terminations
- 3-pole, gas-insulated switchgear vessel for switching devices and busbar
- Panel blocks and single panels available
- Switching devices: three-position switch-disconnector (OPEN – CLOSED – EARTHED), switch-fuse combination for distribution transformer protection, vacuum circuit-breaker with three-position disconnector
- Earthing function of switching devices generally make-proof

- Metal-enclosed, partition class PM
- Loss of service continuity category for switchgear: LSC 2
- Internal arc classification (option):
  - IAC A FL 20 kA, 1 s
  - IAC A FLR 20 kA, 1 s

#### Advantages

- No gas work during installation
- Compact
- Independent of environment and climate
- Maintenance-free
- High operating and personal safety
- Switchgear interlocking system with logical mechanical interlocks
- Operational reliability and security of investment
- Environmentally compatible
- Cost-efficient



Dimensions			Dimensions in mm
Width	W	Ring-main feeders	430
		Transformer feeders	500
		Circuit-breaker feeders	590
		RRT block	1,360
		RRL block	1,450
		Billing metering panels	1,100
Height	H1	Panels without low-voltage compartment	1,600
	H2	Panels with low-voltage compartment	1,800–2,200
Depth	D	Standard switchgear	920
		Switchgear with pressure absorber (option)	1,035

Fig. 3.2-24: Dimensions of 8DJH 36

Rated			
Voltage	kV	36	
Frequency	Hz	50/60	
Short-duration power-frequency withstand voltage	kV	70	
Lightning impulse withstand voltage	kV	170	
Normal current for ring-main feeders	A	630	
Normal current for busbar	max. A	630	
Normal current for circuit-breaker feeders	A	630	
Normal current for transformer feeders	A	200*	
Short-time withstand current, 1 s	50 Hz	max. kA	20
Short-time withstand current, 3 s		max. kA	20
Peak withstand current		max. kA	50
Short-circuit making current for ring-main feeders	60 Hz	max. kA	50
Short-circuit making current for circuit-breaker feeders		max. kA	50
Short-circuit making current for transformer feeders		max. kA	50
Short-time withstand current, 1 s		max. kA	20
Short-time withstand current, 3 s		max. kA	20
Peak withstand current		max. kA	52
Short-circuit making current for ring-main feeders	60 Hz	max. kA	52
Short-circuit making current for circuit-breaker feeders		max. kA	52
Short-circuit making current for transformer feeders		max. kA	52

\* Depending on HV HRC fuse-link

Table 3.2-20: Technical data of 8DJH



# Switchgear and Substations

## 3.2 Medium-Voltage Switchgear

### NXPLUS



Fig. 3.2-25: **NXPLUS** switchgear for single-busbar applications (on the left), **NXPLUS** switchgear for double-busbar applications (on the right)

NXPLUS is a gas-insulated medium-voltage circuit-breaker switchgear up to 40.5 kV with the advantages of the vacuum switching technology – for a high degree of independence in all applications. NXPLUS can be used for primary distribution systems up to 40.5 kV, up to 31.5 kA, up to 2,000 A (for double-busbar switchgear up to 2,500 A).

#### Performance features

- Type-tested according to IEC 62271-200
- Sealed pressure system with SF<sub>6</sub> filling for the entire service life
- Safe-to-touch enclosure and standardized connections for plug-in cable terminations
- Separate 3-pole gas-insulated modules for busbar with three-position disconnector, and for circuit-breaker
- Interconnection of modules with 1-pole insulated and screened module couplings
- Operating mechanisms and

Rated	Busbar system		Single double	Single double	Single double	Single
Voltage		kV	12	24	36	40.5
Frequency		Hz	50/60	50/60	50/60	50/60
Short-duration power-frequency withstand voltage		kV	28	50	70	85
Lightning impulse withstand voltage		kV	75	125	170	185
Short-circuit breaking current		max. kA	31.5	31.5	31.5	31.5
Short-time withstand current, 3 s		max. kA	31.5	31.5	31.5	31.5
Short-circuit making current		max. kA	80	80	80	80
Peak withstand current		max. kA	80	80	80	80
Normal current for busbar		max. A	2,500	2,500	2,500	2,000
Normal current for feeders		max. A	2,500	2,500	2,500	2,000

Table 3.2-21: **Technical data of NXPLUS**

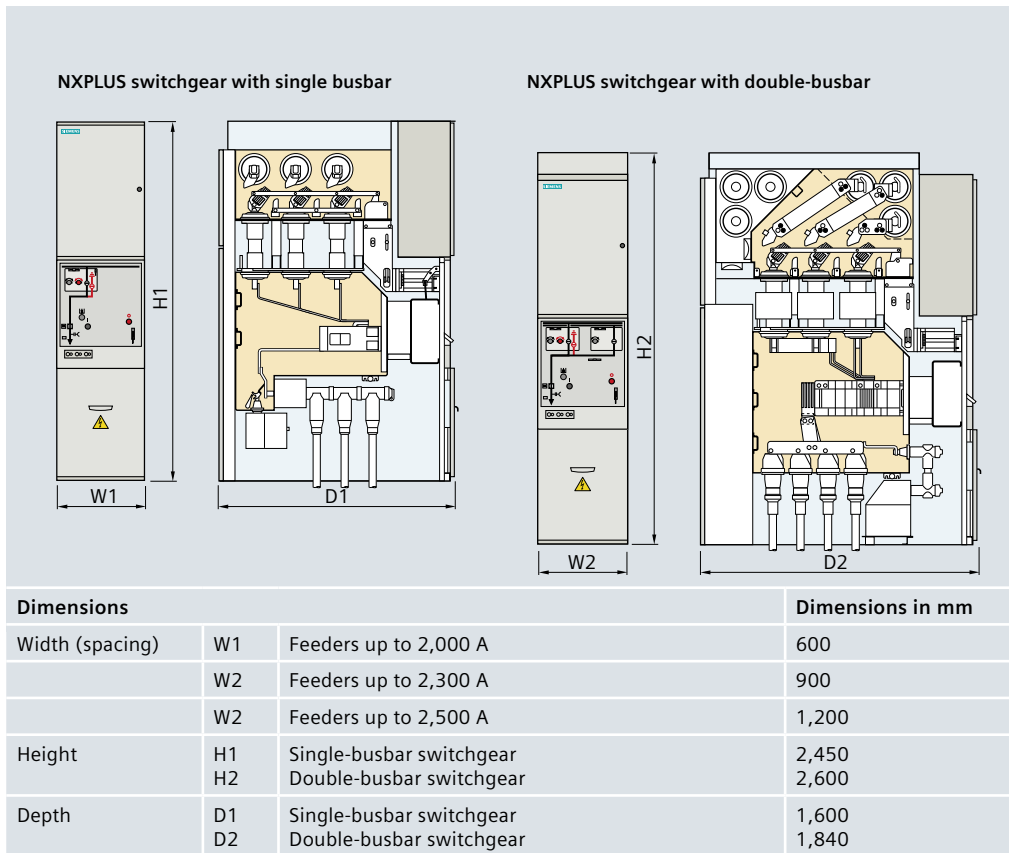


Fig. 3.2-26: **Dimensions of NXPLUS**

transformers are arranged outside the switchgear vessels and are easily accessible

- Metal-enclosed, partition class PM
- Loss of service continuity category for switchgear: LSC 2

- Internal arc classification: IAC A FLR 31.5 kA, 1 s
- No gas work during installation or extension

#### Advantages

- Independent of environment and climate
- Compact

- Maintenance-free
- Personal safety
- Operational reliability
- Environmentally compatible
- Cost-efficient

### NXPLUS C



Fig. 3.2-27: NXPLUS C panel

The compact NXPLUS C is the medium-voltage circuit-breaker switchgear that made gas insulation with the proven vacuum switching technology economical in its class. The NXPLUS C is used for secondary and primary distribution systems up to 24 kV, up to 31.5 kA and up to 2,500 A. It can also be supplied as double-busbar switchgear in a back-to-back arrangement (see catalog HA35.41).

#### Performance features

- Type-tested according to IEC 62271-200
- Sealed pressure system with SF<sub>6</sub> filling for the entire service life
- Safe-to-touch enclosure and standardized connections for plug-in cable terminations
- Loss of service continuity category for switchgear:
  - Without HV HRC fuses: LSC 2
- 1-pole insulated and screened busbar
- 3-pole gas-insulated switchgear vessels with three-position switch and circuit-breaker
- Operating mechanisms and transformers are located outside the switchgear vessel and are easily accessible
- Metal-enclosed, partition class PM

Rated						
Voltage	kV	7.2	12	15	17.5	24
Frequency	Hz	50/60	50/60	50/60	50/60	50/60
Short-duration power-frequency withstand voltage	kV	20	28*	36	38	50
Lightning impulse withstand voltage	kV	60	75	95	95	125
Short-circuit breaking current	max. kA	31.5	31.5	31.5	25	25
Short-time withstand current, 3 s	max. kA	31.5	31.5	31.5	25	25
Short-circuit making current	max. kA	80	80	80	63	63
Peak withstand current	max. kA	80	80	80	63	63
Normal current for busbar	max. A	2,500	2,500	2,500	2,500	2,500
Normal current for feeders	max. A	2,500	2,500	2,500	2,000	2,000

\* 42 kV according to some national requirements

Table 3.2-22: Technical data of NXPLUS C

Dimensions			Dimensions in mm
Width	W	630 A/1,000 A/1,250 A 2,000 A/2,500 A	600 900
Height	H1	Standard design	2,250 (W = 600); 2,550 (W = 900)
	H2	With horizontal pressure relief duct	2,640 (W = 600); 2,640 (W = 900)
	H3	With higher low-voltage compartment	2,650
Depth	D	Wall-standing arrangement	1,250
		Free-standing arrangement	1,250

Fig. 3.2-28: Dimensions of NXPLUS C

- With horizontal pressure relief duct
- Extended number of operating cycles (up to 15 kV, up to 31.5 kV, up to 1,250 A)
  - DISCONNECTING function: 5,000 ×, 10,000 ×
  - READY-TO-EARTH function: 5,000 ×, 10,000 ×
  - CIRCUIT-BREAKER function: 30,000 ×
- Type-approved by LR, DNV, GL, ABS, RMR
- Internal arc classification for:
  - Wall-standing arrangement: IAC A FL 31.5 kA, 1 s
  - Free-standing arrangement: IAC A FLR 31.5 kA, 1 s

#### Advantages

- No gas work during installation or extension
- Compact
- Independent of environment and climate
- Maintenance-free
- Personal safety
- Operational reliability
- Environmentally compatible
- Cost-efficient

### NXPLUS C Wind



Fig. 3.2-29: NXPLUS C Wind

The compact medium voltage circuit-breaker switchgear NXPLUS C Wind is especially designed for wind turbines. Due to the small dimensions it fits into wind turbines where limited space is available. The NXPLUS C Wind is available for 36 kV, up to 25 kA and busbar currents up to 1,000 A. NXPLUS C Wind offers a circuit-breaker, a disconnector and a switch-disconnector (ring-main) panel.

#### Performance features

- Type-tested according to IEC 62271-200
- Sealed pressure system with SF<sub>6</sub> filling for the entire service life
- Safe-to-touch enclosure and standardized connections for plug-in cable terminations
- 1-pole insulated and screened busbar
- 3-pole gas-insulated switchgear vessels with three-position switch and

Rated		
Voltage	kV	36
Frequency	Hz	50/60
Short-duration power-frequency withstand voltage	kV	70
Lightning impulse withstand voltage	kV	170
Short-circuit breaking current	max. kA	25
Short-time withstand current, 1 s	max. kA	25
Short-time withstand current, 3 s	max. kA	20
Short-circuit making current	max. kA	63
Peak withstand current	max. kA	63
Normal current for busbar	max. A	1,000
Normal current for circuit-breaker panel	max. A	630
Normal current for disconnector panel	max. A	1,000

Table 3.2-23: Technical data of NXPLUS C Wind

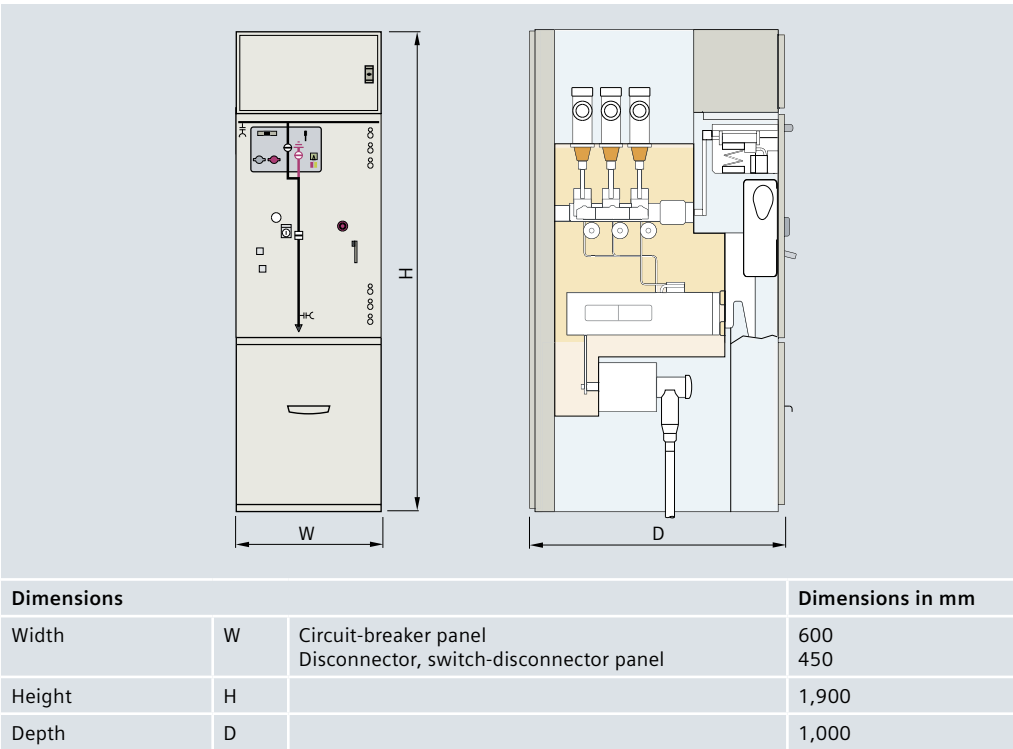


Fig. 3.2-30: Dimensions of NXPLUS C Wind

- circuit-breaker
- Operating mechanism and transformers are located outside the vessel and are easily accessible
- Metal-enclosed, partition class PM
- Loss of service continuity category LSC 2B

- Internal arc classification for:
  - Wall-standing arrangement: IAC FL A 25 kA, 1 s
  - Free-standing arrangement: IAC FLR A 25 kA, 1 s

- #### Advantages
- No gas work during installation or extension
  - Compact
  - Independent of environment and climate
  - Maintenance-free
  - Personal safety
  - Operational reliability
  - Environmentally compatible
  - Cost efficient

### SIMOSEC



Fig. 3.2-31: SIMOSEC switchgear

The air-insulated medium-voltage switchgear type SIMOSEC is used for power distribution in secondary and primary distribution systems up to 24 kV and up to 1,250 A. The modular product range includes individual panels such as ring-main, transformer and circuit-breaker panels, or metering panels to fully satisfy all requirements for power supply companies and industrial applications.

#### Performance features

- Type-tested according to IEC 62271-200
- Phases for busbar and cable connection are arranged one behind the other
- 3-pole gas-insulated switchgear vessel with three-position disconnecter, circuit-breaker and earthing switch as a sealed pressure system with SF<sub>6</sub> filling for the entire service life
- Air-insulated busbar system
- Air-insulated cable connection system, for conventional cable sealing ends
- Metal-enclosed, partition class PM
- Loss of service continuity category for switchgear: LSC 2

Rated		7.2 kV	12 kV	15 kV o.r.	17.5 kV	24 kV
Voltage		50/60	50/60	50/60	50/60	50/60
Frequency	Hz	50/60	50/60	50/60	50/60	50/60
Short-duration power-frequency withstand voltage	kV	20	28*	36	38	50
Lightning impulse withstand voltage	kV	60	75	95	95	125
Short-circuit breaking current	max. kA	25	25	25	25	20
Short-time withstand current, 1 s	max. kA	25	25	25	25	20
Short-time withstand current, 3 s	max. kA	–	21	21	21	20
Short-circuit making current	max. kA	25	25	25	25	20
Peak withstand current	max. kA	63	63	63	63	50
Normal current for busbar	A	630 or 1,250				
Normal current for feeders	max. A	1,250	1,250	1,250	1,250	1,250

\* 42 kV/75 kV, according to some national requirements

Table 3.2-24: Technical data of SIMOSEC

Dimensions			Dimensions in mm
Width (spacing)	W	Ring-main feeders, transformer feeders	375 or 500
		Circuit-breaker feeders, bus sectionalizer	750 or 875
		Metering panels	500/750/875
Height	H1	Panels without low-voltage compartment	1,760
	H2	Panels with low-voltage compartment	2,100 or 2,300
Depth	D	Standard	1,170 and 1,230

Fig. 3.2-32: Dimensions of SIMOSEC

- Internal arc classification for:
  - Wall-standing arrangement: IAC A FL 21 kA, 1 s
  - Free-standing arrangement: IAC A FLR 21 kA, 1 s
  - Can be mounted side-by-side and extended as desired

#### Advantages

- Compact modular design
- High operating and personal safety
- Environmentally compatible
- Cost-efficient

### 3.2.5 High-Current and Generator Switchgear

As central components, high-current and generator switchgear provides the link between the generator and the transformer (feeding into the transmission and distribution grids). Siemens offers various generator switchgear types with rated voltages up to 17.5 kV, rated currents up to 10,000 A and rated short-circuit breaking currents up to 72 kA for indoor and outdoor installations.

The heart of the generator switchgear is the circuit-breaker. Its primary function is to withstand very high currents and to switch

off extremely high short-circuit currents. Siemens generator circuit-breakers, designed using environmentally friendly vacuum switching technology, are designed to withstand maximum normal currents and meet the demanding requirements of the generator circuit-breaker standard IEEE C37.013-1997.

#### Performance features

- High mechanical stability
- Low fire load
- High operational safety.

#### HIGS (highly integrated generator switchgear)

HIGS is an air-insulated, metal-enclosed generator switchgear for voltages and currents up to 13.8 kV, 63 kA, 3,150 A for indoor and outdoor installation. For the first time, the neutral treatment of the generator as well as the auxiliary feeder are integrated in a single generator switchgear (fig. 3.2-33).

#### Performance features

- Generator circuit-breaker according to IEEE C37.013 in the main transformer feeder
- Earthing switch on generator and transformer side
- Current and voltage transformers
- Surge arresters
- Surge capacitors
- Integrated auxiliary feeder with disconnector and generator circuit-breaker or with switch-disconnector and fuses.

The technical data of HIGS and generator switchgear is shown in the table 3.2-25.



Fig. 3.2-33: HIGS

Type		HIGS	8BK40	HB1	HB1 Outdoor	HB3
Installation		IR, FL	IR	IR	FL	IR, FL
Dimensions L × W × H	mm	3,430 × 1,200 × 2,500	2,300 × 1,100 × 2,500	4,000 × 1,900 × 2,500*	6,300 × 1,900 × 2,600*	2,900 × 4,040 × 2,400*
Rated voltage	kV	13.8	max. 17.5	17.5	17.5	17.5
Rated lightning impulse withstand voltage	kV	110	95	110	110	110
Rated short-duration power-frequency withstand voltage	kV	50	38	50	50	50
Rated short-circuit breaking current	kA	31.5–63	50/63	50/63/72	50/63/72	50/63/72
Rated normal current:	A	2,000–3,150		max. 6,100	max. 5,400	max 10,000
for busbar			5,000			
for feeder			5,000			

\* Measurements may vary according to type

Table 3.2-25: Technical data of HIGS and generator switchgear



### 8BK40

8BK40 is an air-insulated, metal-enclosed generator switchgear with truck-type circuit-breaker for indoor installation up to 17.5 kV; 63 kA; 5,000 A (fig. 3.2-34).

#### Performance features

- Generator circuit-breaker according to IEEE C37.013, or circuit-breaker according to IEC 62271-100
- Disconnecting function by means of truck-type circuit-breaker
- Earthing switch on generator and transformer side
- Current and voltage transformers
- Surge arresters
- Surge capacitors.

### HB1, HB1 Outdoor and HB3

This is an air-insulated, metal-enclosed horizontal busbar switchgear, non-phase-segregated (HB1, HB1 Outdoor, fig. 3.2-35, fig. 3.2-36) or phase-segregated (HB3, fig. 3.2-37).

#### Performance features

- Generator circuit-breaker according to IEEE C37.013
- Disconnecter
- Earthing switch on generator and transformer side
- Current and voltage transformers
- Surge arresters
- Surge capacitors
- Further options
  - Integrated SFC starter
  - Integrated auxiliary feeder, with generator circuit-breaker or with switch-disconnector and fuses
  - Integrated excitation feeder
  - Brake switch.



Fig. 3.2-34: 8BK40



Fig. 3.2-35: HB1



Fig. 3.2-36: HB1 Outdoor



Fig. 3.2-37: HB3

### 3.2.6 Industrial Load Center Substation

#### Introduction

Industrial power supply systems call for a maximum level of personal safety, operational reliability, economic efficiency, and flexibility. And they likewise necessitate an integral approach that includes “before” and “after” sales service, that can cope with the specific load requirements and, above all, that is tailored to each individually occurring situation. With SITRABLOC® (fig. 3.2-38), such an approach can be easily turned into reality.

#### General

SITRABLOC is an acronym for Siemens TRANSformer BLOC-type. SITRABLOC is supplied with power from a medium-voltage substation via a fuse/switch-disconnector combination and a radial cable. In the load center, where SITRABLOC is installed, several SITRABLOCs are connected together by means of cables or bars (fig. 3.2-39).

#### Features

- Due to the fuse/switch-disconnector combination, the short-circuit current is limited, which means that the radial cable can be dimensioned according to the size of the transformer.
- In the event of cable faults, only one SITRABLOC fails.
- The short-circuit strength is increased due to the connection of several stations in the load center. The effect of this is that, in the event of a fault, large loads are selectively disconnected in a very short time.
- The transmission losses are optimized because only short connections to the loads are necessary.
- SITRABLOC has, in principle, two transformer outputs:
  - 1,250 kVA during AN operation (ambient air temperature up to 40 °C)
  - 1,750 kVA during AF operation (140% with forced cooling).

These features ensure that, if one station fails, for whatever reason, supply of the loads is maintained without interruption.

The SITRABLOC components are:

- Transformer housing with roof-mounted ventilation for AN/AF operating mode
- GEAFOIL transformer
  - (Cast-resin insulated) with make-proof earthing switch
  - AN operating mode: 100% load up to an ambient air temperature of 40 °C
  - AF operating mode: 140% load
- LV circuit-breaker as per transformer AF load
- Automatic power factor correction equipment (tuned/detuned)
- Control and metering panel as well as central monitoring interface
- Universal connection to the LV distribution busway system (fig. 3.2-40).

Whether in the automobile or food industry, in paint shops or bottling lines, putting SITRABLOC to work in the right place considerably reduces transmission losses. The energy is transformed in the production area itself, as close as possible to the loads. For installation of the system itself, no special building or fire-protection measures are necessary.

#### Available with any level of output

SITRABLOC can be supplied with any level of power output, the latter being controlled and protected by a fuse/switch-disconnector combination.

A high-current busbar system into which up to four transformers can feed power ensures that even large loads can be brought onto load without any loss of energy. Due to the interconnection of units, it is also ensured that large loads are switched off selectively in the event of a fault.



Fig. 3.2-38: SITRABLOC system

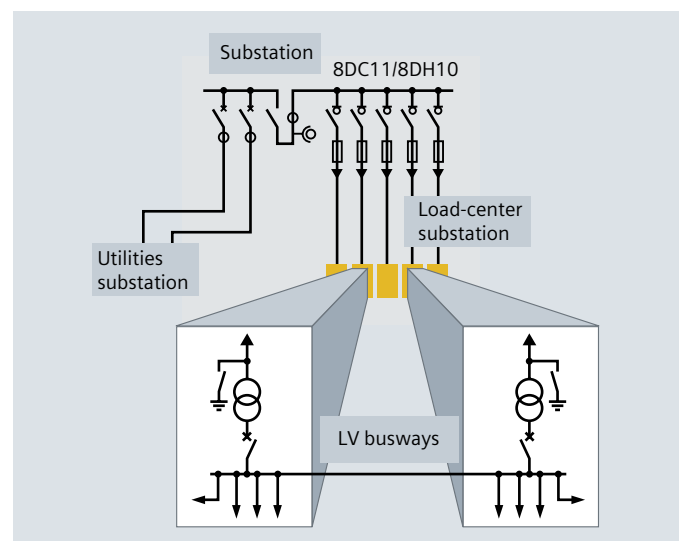


Fig. 3.2-39: Example of a schematic diagram

### Integrated automatic power factor correction

With SITRABLOC, power factor correction is integrated from the very beginning. Unavoidable energy losses – e.g., due to magnetization in the case of motors and transformers – are balanced out with power capacitors directly in the low-voltage network. The advantages are that the level of active power transmitted increases and energy costs are reduced (fig. 3.2-41).

### Reliability of supply

With the correctly designed transformer output, the n-1 criterion is no longer a problem. Even if one module fails (e.g., a medium-voltage switching device or a cable or transformer), power continues to be supplied without the slightest interruption. None of the drives comes to a standstill, and the whole manufacturing plant continues to run reliably. With SITRABLOC, the power is where it is needed – and it is safe, reliable and economical.

### n-1 operating mode

#### n-1 criteria

With the respective design of a factory grid on the MV side as well as on the LV side, the so-called n-1 criteria is fulfilled. In case one component fails on the line side of the transformer (e.g., circuit-breaker or transformer or cable to transformer) no interruption of the supply on the LV side will occur (fig. 3.2-42).

Load required 5,000 kVA =  $4 \times 1,250$  kVA. In case one load center (SITRABLOC) is disconnected from the MV network, the missing load will be supplied via the remaining three (n-1) load centers. SITRABLOC is a combination of everything that present-day technology has to offer. The GEAFO<sup>®</sup> cast-resin transformers are just one example of this.

Their output is 100 % load without fans plus reserves of up to 140 % with fans. The safety of operational staff is ensured – even in the direct vicinity of the installation.

Another example is the SENTRON high-current busbar system. It can be laid out in any arrangement, is easy to install and conducts the current wherever you like – With almost no losses. The most important thing, however, is the uniformity of SITRABLOC throughout, regardless of the layout of the modules.

### The technology at a glance

(table 3.2-26, fig. 3.2-44, next page)

SITRABLOC can cope with any requirements. Its features include:

- A transformer cubicle with or without fans (AN/AF operation)
- GEAFO<sup>®</sup> cast-resin transformers with make-proof earthing switch – AN operation 1,250 kVA, AF operation 1,750 kVA (fig. 3.2-43, next page)
- External medium-voltage switchgear with fuse/switch-disconnectors
- Low-voltage circuit-breakers
- Automatic reactive-power compensation: up to 500 kVAr unrestricted, up to 300 kVAr restricted
- The SENTRON high-current busbar system: connection to high-current busbar systems from all directions
- SIMATIC ET 200/PROFIBUS interface for central monitoring system (if required).

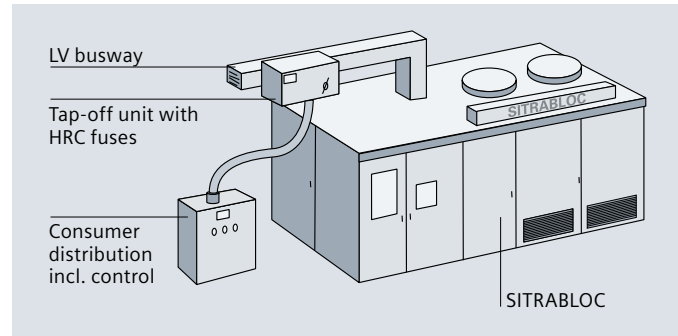


Fig. 3.2-40: Location sketch

Rated voltage	12 kV and 24 kV
Transformer rating AN/AF	1,250 kVA/1,750 kVA
Transformer operating mode	100 % AN up to 40 °C 140 % AF
Power factor correction	up to 500 kVAr without reactors up to 300 kVAr with reactors
Busway system	1,250 A; 1,600 A; 2,500 A
Degree of protection	IP23 for transformer housing IP43 for LV cubicles
Dimensions (min) (LxHxD)	3,600 mm × 2,560 mm × 1,400 mm
Weight approx.	6,000 kg

Table 3.2-26: Technical data of SITRABLOC

# Switchgear and Substations

## 3.2 Medium-Voltage Switchgear

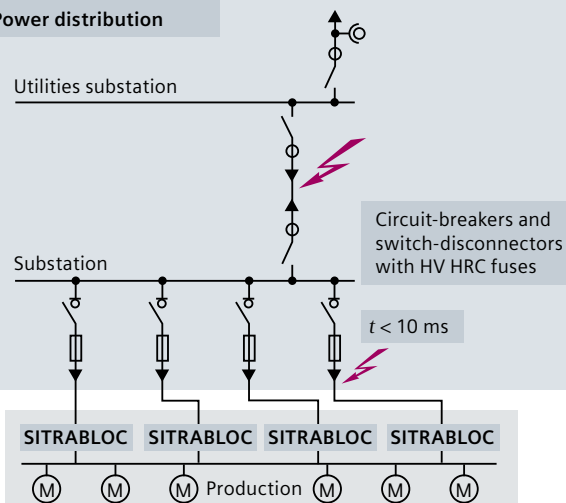


Fig. 3.2-41: Capacitor banks

### How to understand this mode:

- Normal operating mode:  $4 \times 1,250 \text{ kVA}$   
→ AN operating mode (100 %)
- n-1 operating mode:  $3 \times 1,750 \text{ kVA}$   
→ AF operating mode (140 %)

### Power distribution



- Personal safety
- Reduced costs
- Low system losses

Fig. 3.2-42: n-1 operating mode



Fig. 3.2-43: Transformer and earthing switch, LV bloc

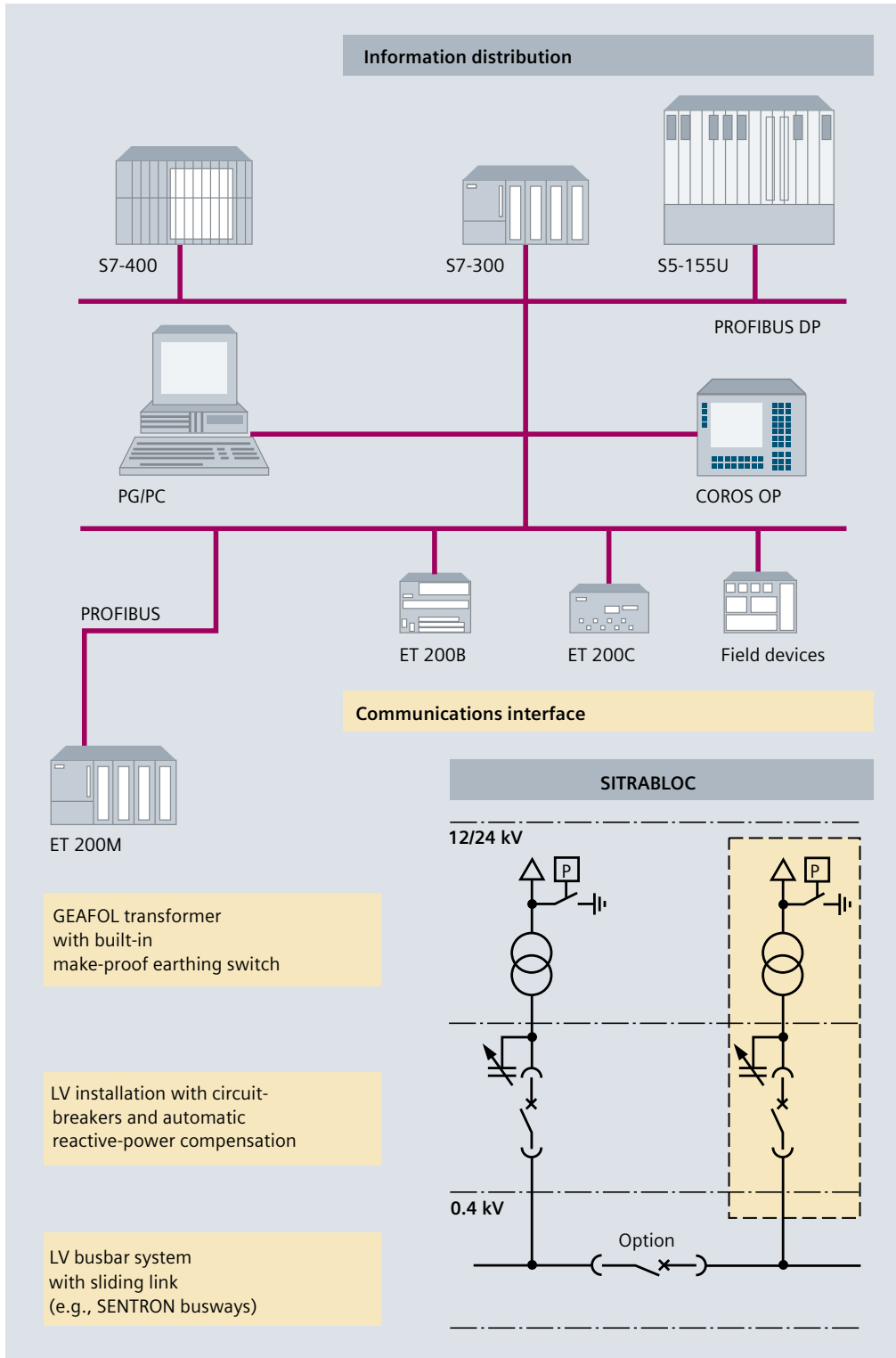


Fig. 3.2-44: SIMATIC ET 200/PROFIBUS interface for control monitoring system

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## 3.3 Low-Voltage Power Distribution Systems

### 3.3.1 Requirements for Electrical Power Systems in Buildings

The efficiency of electrical power supply rises and falls with qualified planning. Especially in the first stage of planning, the finding of conceptual solutions, the planner can use his creativity for an input of new, innovative solutions and technologies. They serve as a basis for the overall solution which has been economically and technically optimized in terms of the supply task and related requirements.

The following stages of calculating and dimensioning circuits and equipment are routine tasks which involve a great effort. They can be worked out efficiently using modern dimensioning tools like SIMARIS® design, so that there is more freedom left for the creative planning stage of finding conceptual solutions (fig. 3.3-1).

When the focus is limited to power supply for infrastructure projects, useful possibilities can be narrowed down. The following aspects should be taken into consideration when designing electric power distribution systems:

- Simplification of operational management by transparent, simple power system structures
- Low costs for power losses, e.g. by medium-voltage power transmission to the load centers
- High reliability of supply and operational safety of the installations even in the event of individual equipment failures (redundant supply, selectivity of the power system protection, and high availability)
- Easy adaptation to changing load and operational conditions
- Low operating costs thanks to maintenance-friendly equipment
- Sufficient transmission capacity of equipment during normal operation and also in the event of a fault, taking future expansions into account
- Good quality of the power supply, i.e. few voltage changes due to load fluctuations with sufficient voltage symmetry and few harmonic voltage distortions
- Compliance with applicable standards and project-related stipulations for special installations.

#### Standards

To minimize technical risks and / or to protect persons involved in handling electrotechnical components, essential planning rules have been compiled in standards. Standards represent the state of the art; they are the basis for evaluations and court decisions.

Technical standards are desired conditions stipulated by professional associations which are, however, made binding by legal standards such as safety at work regulations. Furthermore, the compliance with technical standards is crucial for any approval of operator granted by authorities or insurance coverage. While decades ago, standards were mainly drafted at a national level

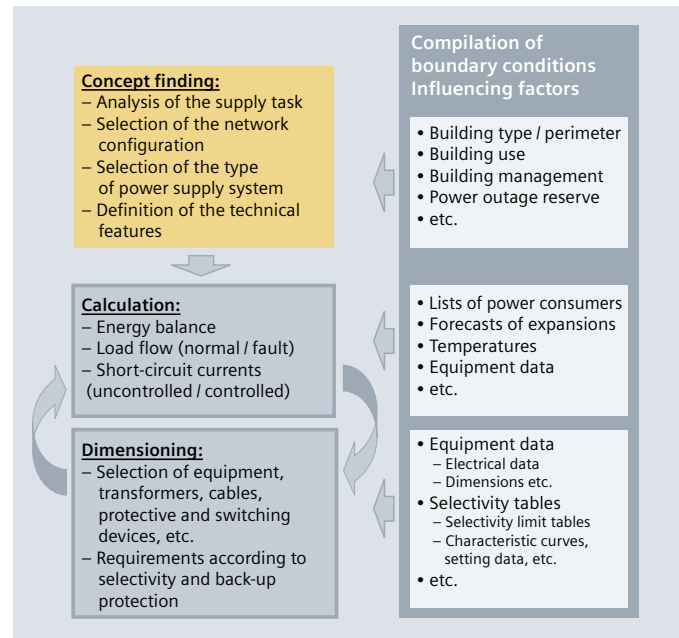


Fig. 3.3-1: Power system planning tasks

Regional	America PAS	Europe CENELEC	Australia	Asia	Africa
National	USA: ANSI CA: SCC BR: COBEI	D: DIN VDE I: CEI F: UTE GB: BS	AUS: SA NZ: SNZ	CN: SAC IND: BIS J: JISC	SA: SABS
ANSI	American National Standards Institute				
BIS	Bureau of Indian Standards				
BS	British Standards				
CENELEC	European Committee for Electrotechnical Standardization (Comité Européen de Normalisation Electrotechnique)				
CEI	Comitato Elettrotecnico Italiano Electrotechnical Committee Italy				
COBEI	Comitê Brasileiro de Eletricidade, Eletrônica, Iluminação e Telecomunicações				
DIN VDE	Deutsche Industrie Norm, Verband deutscher Elektrotechniker (German Industry Standard, Association of German Electrical Engineers)				
JISC	Japanese Industrial Standards Committee				
PAS	Pacific Area Standards				
SA	Standards Australia				
SABS	South African Bureau of Standards				
SAC	Standardisation Administration of China				
SCC	Standards Council of Canada				
SNZ	Standards New Zealand				
UTE	Union Technique de l'Electricité et de la Communication Technical Association for Electrical Engineering & Communication				

Table 3.3-1: Representation of national and regional standards in electrical engineering

and debated in regional committees, it has currently been agreed that initiatives shall be submitted centrally (on the IEC level) and then be adopted as regional or national standards. Only if the IEC is not interested in dealing with the matter, or if there are time constraints, a draft standard shall be prepared at the regional level.

The interrelation of the different standardization levels is illustrated in table 3.3-1. A complete list of the IEC members and further links can be obtained at [www.iec.ch](http://www.iec.ch) → Members & Experts → List of Members (NC); [www.iec.ch/dyn/www/f?p=103:5:0](http://www.iec.ch/dyn/www/f?p=103:5:0)

### System configurations

Table 3.3-2 and table 3.3-3 illustrate the technical aspects and influencing factors that should be taken into account when electrical power distribution systems are planned and network components are dimensioned.

- Simple radial system (spur line topology)  
All consumers are centrally supplied from one power source. Each connecting line has an unambiguous direction of energy flow.
- Radial system with changeover connection as power reserve – partial load:  
All consumers are centrally supplied from two to n power sources. They are rated as such that each of them is capable of supplying all consumers directly connected to the main power distribution system (stand-alone operation with open couplings). If one power source fails, the remaining sources of supply can also supply some consumers connected to the other power source. In this case, any other consumer must be disconnected (load shedding).
- Radial system with changeover connection as power reserve – full load:  
All consumers are centrally supplied from two to n power sources (stand-alone operation with open couplings). They are rated as such that, if one power source fails, the remaining power sources are capable of additionally supplying all those consumers normally supplied by this power source. No consumer must be disconnected. This means rating the power sources according to the (n–1) principle. With three parallel power sources or more, other supply principles, e.g. the (n–2) principle would also be possible. In this case, these power sources will be rated so that two out of three transformers can fail without the continuous supply of all consumers connected being affected.

- Radial system in an interconnected network  
Individual radial systems, in which the connected consumers are centrally supplied by one power source, are additionally coupled electrically with other radial systems by means of coupling connections. All couplings are normally closed.

Depending on the rating of the power sources in relation to the total load connected, the application of the (n–1) principle, (n–2) principle, etc. can ensure continuous and faultless power supply of all consumers by means of additional connecting lines.

The direction of energy flow through the coupling connections may vary depending on the line of supply, which must be taken into account for subsequent rating of switching/protective devices, and above all for making protection settings.

- Radial system with power distribution via busbars  
In this special case of radial systems that can be operated in an interconnected network, busbar trunking systems are used instead of cables.

In the coupling circuits, these busbar trunking systems are either used for power transmission (from radial system A to radial system B, etc.) or power distribution to the respective consumers.

Quality criterion	LV-side system configurations																									
	Simple radial system					Radial system with changeover connection as power reserve					Radial system in an interconnected network					Radial system with power distribution via busbars										
						Partial load															Full load					
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
Low cost of investment	1					1	2				1		3			1				4		1				5
Low power losses					5			3						4					3			2				
High reliability of supply					5				4				3			1					3					
Great voltage stability					5				4					4		1					1					
Easy operation	1					1					1							2				2				
Easy and clear system protection	1					1					1								3			2				
High adaptability					5				4					4					3			1				
Low fire load			3						4					4					4			1				
Rating: very good (1) to poor (5) fulfillment of a quality criterion																										

Rating: very good (1) to poor (5) fulfillment of a quality criterion

Table 3.3-2: Exemplary quality rating dependent on the power system configuration

# Switchgear and Substations

## 3.3 Low-Voltage Power Distribution Systems

### Power supply systems according to the type of connection to earth

*TN-C, TN-C/S, TN-S, IT and TT systems*

The implementation of IT systems may be required by national or international standards.

- For parts of installations which have to meet particularly high requirements regarding operational and human safety (e.g. in medical rooms, such as the OT, intensive care or post-anaesthesia care unit)
- For installations erected and operated outdoors (e.g. in mining, at cranes, garbage transfer stations, and in the chemical industry).

- Depending on the power system and nominal system voltage there may be different requirements regarding the disconnection times to be met (protection of persons against indirect contact with live parts by means of automatic disconnection).
- Power systems in which electromagnetic interference plays an important part should preferably be configured as TN-S systems immediately downstream of the point of supply. Later, it will mean a comparatively high expense to turn existing TN-C or TN-C/S systems into an EMC-compatible system.

The state of the art for TN systems is an EMC-compatible design as TN-S system.

Characteristics	TN-C			TN-C/S			TN-S			IT system			TT system		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Low cost of investment	1				2			2				2	1		
Little expense for system extensions	1				2		1				2				2
Any switchgear/protective technology can be used	1				2		1			1					2
Earth-fault detection can be implemented			1		2		1			1			1		
Fault currents and impedance conditions in the system can be calculated	1			1			1			1					2
Stability of the earthing system	1			1			1			1					2
High degree of operational safety		1			2		1			1					2
High degree of protection	1			1			1			1				2	
High degree of shock hazard protection		1			2			2		1					2
High degree of fire safety		1			2			2		1					2
Automatic disconnection for protection purposes can be implemented	1			1			1			1				2	
EMC-friendly			1		2		1			1				2	
Equipment functions maintained in case of 1 <sup>st</sup> earth or enclosure fault		1			2			2		1					2
Fault localization during system operation		1			2				1	1					2
Reduction of system downtimes by controlled disconnection	1			1					1	1					2

1 = true 2 = conditionally true 3 = not true

Table 3.3-3: Exemplary quality rating dependent on the power supply system according to its type of connection to earth

### 3.3.2 Dimensioning of Power Distribution Systems

When the basic supply concept for the electricity supply system has been established, it is necessary to dimension the electrical power system. Dimensioning means the sizing and/or rating of all equipment and components to be used in the power system.

The dimensioning target is to obtain a technically permissible combination of switching/protective devices and connecting lines for each circuit in the power system.

#### Basic rules

In principle, circuit dimensioning should be performed in compliance with the technical rules standards listed in fig. 3.3-2.

#### Cross-circuit dimensioning

When selected network components and systems are matched, an economically efficient overall system can be designed. This cross-circuit matching of network components may bear any degree of complexity, because subsequent modifications to certain components, e.g., a switching/protective device, may have effects on the neighboring higher-level or all lower-level network sections (high testing expense, high planning risk).

#### Dimensioning principles

For each circuit, the dimensioning process comprises the selection of one or more switching/protective devices to be used at the beginning or end of a connecting line, and the selection of the connecting line itself (cable/line or busbar connection) after considering the technical features of the corresponding switching/protective devices. For supply circuits in particular, dimensioning also includes rating the power sources.

The objectives of dimensioning may vary depending on the circuit type. The dimensioning target of overload and short-circuit protection can be attained in correlation to the mounting location of the protective equipment. Devices applied at the end of a connecting line can ensure overload protection for this line at best, but not short-circuit protection.

#### Circuit types

The basic dimensioning rules and standards listed in fig. 3.3-2 principally apply to all circuit types. In addition, there are specific requirements for these circuit types (fig. 3.3-3) that are explained in detail below.

#### Supply circuits

Particularly stringent requirements apply to the dimensioning of supply circuits. This starts with the rating of the power sources.

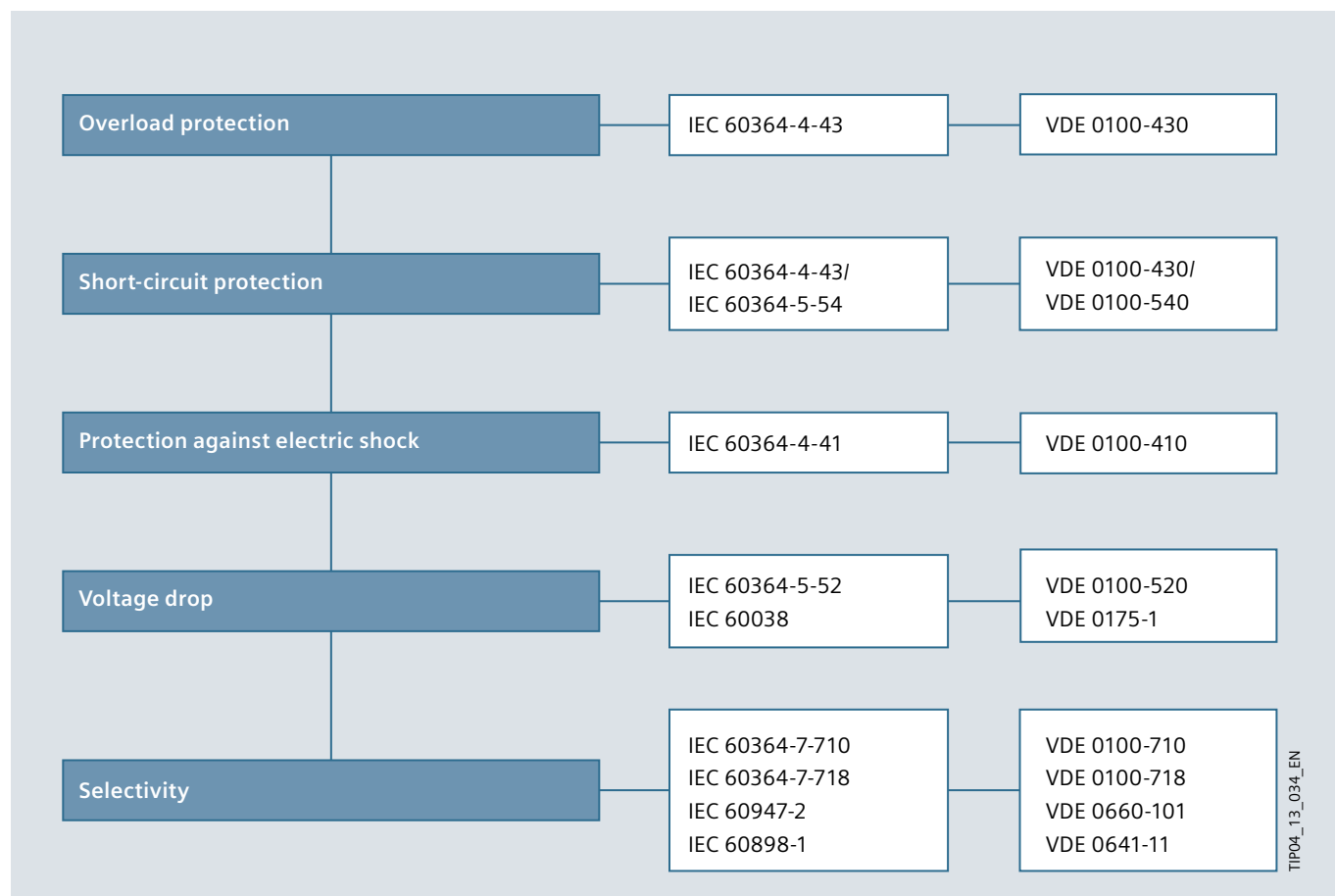


Fig. 3.3-2: Relevant standards for circuit dimensioning

Power sources are rated according to the maximum load current to be expected for the power system, the desired amount of reserve power, and the degree of supply reliability required in case of a fault (overload / short circuit).

Load conditions in the entire power system are established by taking the energy balance (in an "energy report"). Reserve power and operational safety in the vicinity of the supply system are usually established by building up appropriate redundancies, for example, by doing the following:

- Providing additional power sources (transformer, generator, UPS).
- Rating the power sources according to the failure principle; n- or (n-1) principle: Applying the (n-1) principle means that two out of three supply units are principally capable of continually supplying the total load for the power system without any trouble if the smallest power source fails.
- Rating those power sources that can temporarily be operated under overload (e.g., using vented transformers).

Independently of the load currents established, dimensioning of any further component in a supply circuit is oriented to the ratings of the power sources, the system operating modes configured and all the related switching states in the vicinity of the supply system.

As a rule, switching/protective devices must be selected in such a way that the planned power maximum can be transferred. In addition, the different minimum/maximum short-circuit current conditions in the vicinity of the supply system, which are dependent on the switching status, must be determined.

When connecting lines are rated (cable or busbar), appropriate reduction factors must be taken into account; these factors depend on the number of systems laid in parallel and the installation type.

When devices are rated, special attention should be paid to their rated short-circuit breaking capacity. In addition, a high-quality tripping unit with variable settings is preferred, because this component is an important foundation for attaining the best possible selectivity toward all upstream and downstream devices.

### Distribution circuit

Dimensioning of cable routes and devices follows the maximum load currents to be expected at this distribution level.

### As a rule

$$I_{B \max} = \sum \text{installed capacity} \times \text{simultaneity factor}$$

Switching/protective device and connecting line are to be matched with regard to overload and short-circuit protection.

In order to ensure overload protection, the standardized conventional (non-)tripping currents referring to the devices in application have to be observed. A verification based merely on the rated device current or the setting value  $I_r$  would be insufficient.

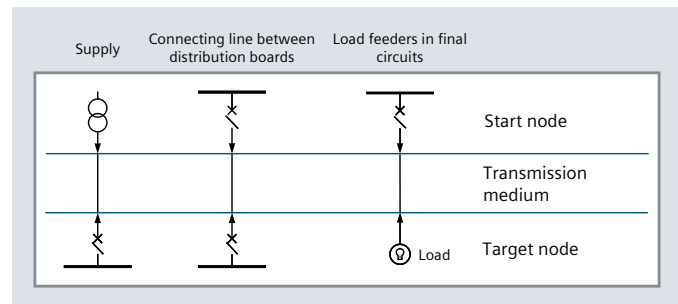


Fig. 3.3-3: Schematic representation of the different circuit types

### Basic rules for ensuring overload protection:

#### Rated current rule

- Non-adjustable protective equipment

$$I_B \leq I_n \leq I_z$$

The rated current  $I_n$  of the selected device must be between the calculated maximum load current  $I_B$  and the maximum permissible load current  $I_z$  of the selected transmission medium (cable or busbar).

- Adjustable protective equipment

$$I_B \leq I_r \leq I_z$$

The rated current  $I_r$  of the overload release must be between the calculated maximum load current  $I_B$  and the maximum permissible load current  $I_z$  of the selected transmission medium (cable or busbar).

#### Tripping current rule

$$I_2 \leq 1.45 \times I_z$$

The maximum permissible load current  $I_z$  of the selected transmission medium (cable or busbar) must be above the conventional tripping current  $I_2/1.45$  of the selected device.

The test value  $I_2$  is standardized and varies according to the type and characteristics of the protective equipment applied.

### Basic rules for ensuring short-circuit protection:

#### Short-circuit energy

$$K^2 S^2 \geq I^2 t$$

(K = Material coefficient; S = Cross-section)

The amount of energy that is set free when a short circuit occurs – and up to the moment it is cleared automatically – must be less than the energy that the transmission medium can carry as a maximum, or there will be irreparable damage. As a standard, this basic rule applies in the time range up to max. 5 s.

Below 100 ms of short-circuit breaking time, the let-through energy of the switching/protective device (according to the equipment manufacturer's specification) must be taken into account.



When devices with a tripping unit are used, observance of this rule across the entire characteristic device curve must be verified.

A mere verification in the range of the maximum short-circuit current applied ( $I_{k\max}$ ) is not always sufficient, in particular when time-delayed releases are used.

#### Short-circuit time

$$t_a(I_{k\min}) \leq 5 \text{ s}$$

The resulting current-breaking time of the selected protective equipment must ensure that the calculated minimum short-circuit current  $I_{k\min}$  at the end of the transmission line or protected line is automatically cleared within 5 s at the most.

Overload and short-circuit protection need not necessarily be provided by one and the same device. If required, these two protection targets may be realized by a device combination. The use of separate switching/protective devices could also be considered, i.e., at the start and end of a cable route. As a rule, devices applied at the end of a cable route can ensure overload protection for that line only.

#### Final circuits

The method for coordinating overload and short-circuit protection is practically identical for distribution and final circuits. Besides overload and short-circuit protection, the protection of human life is also important for all circuits.

#### Protection against electric shock

$$t_a(I_{k1\min}) \leq t_{a\text{perm}}$$

If a 1-phase fault to earth ( $I_{k1\min}$ ) occurs, the resulting current breaking time  $t_a$  for the selected protective equipment must be shorter than the maximum permissible breaking time  $t_{a\text{perm}}$  that is required for this circuit according to IEC 60364-4-41 (VDE 0100-410) to ensure the protection of persons.

Because the required maximum current breaking time varies according to the rated system voltage and the type of load connected (stationary and non-stationary loads), protection requirements regarding minimum breaking times  $t_{a\text{perm}}$  may be transferred from one load circuit to other circuits. Alternatively, this protection target may also be achieved by observing a maximum touch voltage.

Because final circuits are often characterized by long supply lines, their dimensioning is often affected by the maximum permissible voltage drop.

As far as the choice of switching/protective devices is concerned, it is important to bear in mind that long connecting lines are characterized by high impedances, and thus strong attenuation of the calculated short-circuit currents.

Depending on the system operating mode (coupling open, coupling closed) and the medium of supply (transformer or generator), the protective equipment and its settings must be configured for the worst-case scenario for short-circuit currents.

In contrast to supply or distribution circuits, where the choice of a high-quality tripping unit is considered very important, there are no special requirements on the protective equipment of final circuits regarding the degree of selectivity to be achieved. The use of a tripping unit with LI characteristics is normally sufficient.

#### Summary

Basically, the dimensioning process itself is easy to understand and can be performed using simple means.

Its complexity lies in the procurement of the technical data on the products and systems required. This data can be found in various technical standards and regulations as well as in numerous product catalogs.

An important aspect in this context is the cross-circuit manipulation of dimensioned components owing to their technical data. One such aspect is the above mentioned inheritance of minimum current breaking times of the non-stationary load circuit to other stationary load or distribution circuits.

Another aspect is the mutual impact of dimensioning and network calculation (short circuit), e.g., for the use of short-circuit current-limiting devices.

In addition, the complexity of the matter increases, when different national standards or installation practices are to be taken into account for dimensioning.

For reasons of risk minimization and time efficiency, a number of engineering companies generally use advanced calculation software, such as SIMARIS design, to perform dimensioning and verification processes in electrical power systems.

### 3.3.3 Low-Voltage Switchboards

When developing a power distribution concept including dimensioning of the systems and devices, its requirements and feasibility have to be matched by the end user and the manufacturer. When selecting a low-voltage main distribution board (LVMD), the prerequisite for its efficient sizing is knowledge of its use, availability, and future options for extension. The demands on power distribution are extremely diverse. They start with buildings that do not place such high demands on the power supply, such as office buildings, and continue through to the high demands, for example, made by data centers, in which smooth operation is of prime importance.

Because no major switching functions in the LVMD have to be considered in the planning of power distribution systems in commercial buildings and no further extensions are to be expected, a performance-optimized technology with high component density can be used. In these cases, mainly fuse-

protected equipment in fixed-mounted design is used. When planning a power distribution system for a production plant, however, system availability, extendibility, control and visualization are important functions to keep plant downtimes as short as possible. The use of circuit-breaker-protected and fuse-protected withdrawable design is an important principle. Selectivity is also of great importance for reliable power supply. Between these two extremes there is a great design variety that is to be optimally matched to customer requirements. The prevention of personal injury and damage to equipment must, however, be the first priority in all cases. When selecting an appropriate switchboard, it must be ensured that it is a design verified assembly (in compliance with IEC 61439-2, resp. EN 61439-2, VDE 0660-600-2) with extended testing of behavior in the event of an accidental arc (IEC/TR 61641, VDE 0660-500 Addendum 2), and that the selection is always made in light of the regulations governing the entire supply system (full selectivity, partial selectivity).



Fig. 3.3-4: SIVACON S8 switchboard

### Overview

The SIVACON S8 low-voltage switchboard (fig. 3.3-4) is a variable, multi-purpose and design verified low-voltage switchgear assembly that can be used for the infrastructure supply not only in administrative and institutional buildings, but also in industry and commerce. SIVACON S8 consists of standardized, modular components that can be flexibly combined to form an economical, overall solution, depending on the specific requirements. Siemens will perform the following:

- The customer-specific configuration
- The mechanical and electrical installation
- The testing, for which design verified function modules are used.

The authorized contracting party will use the specified documentation. SIVACON S8 can be used as a design verified power distribution board system up to 7,000 A.

### Standards and regulations

SIVACON S8 is a design verified low-voltage switchgear assembly in compliance with IEC 61439-2 (VDE 0660-600-2). SIVACON S8 is resistant to accidental arcs, in compliance with IEC/TR 61641 (VDE 0660-500 Addendum 2). SIVACON S8 is available in several mounting designs (fig. 3.3-5).

### Circuit-breaker design

The panels for installation of 3WL and 3V... circuit-breakers are used for the supply of the switchboard and for outgoing feeders and bus ties (bus sectionalizer and bus coupler). The rule that only one circuit-breaker is used for each panel applies to the entire circuit-breaker design (fig. 3.3-6).

The device mounting space is intended for the following functions:

- Incoming/outgoing feeders with 3WL air circuit-breakers in fixed-mounted and withdrawable unit designs up to 6,300 A
- Bus sectionalizer and bus coupler with 3WL air circuit-breakers in fixed-mounted and withdrawable designs up to 6,300 A
- Incoming/outgoing feeders with 3V... molded-case circuit-breakers in fixed-mounted design up to 1,600 A or 3VA molded-case circuit-breakers up to 630 VA

### Universal installation design

The panels for cable feeders in fixed-mounted and plug-in designs up to 630 A are intended for the installation of the following switching devices (fig. 3.3-7):

- SIRIUS 3RV or 3VA/3VL circuit-breaker
- 3K switch-disconnector
- 3NP fuse switch-disconnector
- 3NJ6 fuse switch-disconnector in plug-in design.

The switching devices are mounted on mounting plates and connected to the vertical current distribution bars on the supply side. Plug-in 3NJ6 in-line switch-disconnectors can be installed using an adapter. The front is covered by panel doors or compartment doors. The withdrawable unit design offers safe and simple handling. So modifications can be carried out quickly, ensuring a high level of system availability. No connection work is required inside the withdrawable unit compartments.

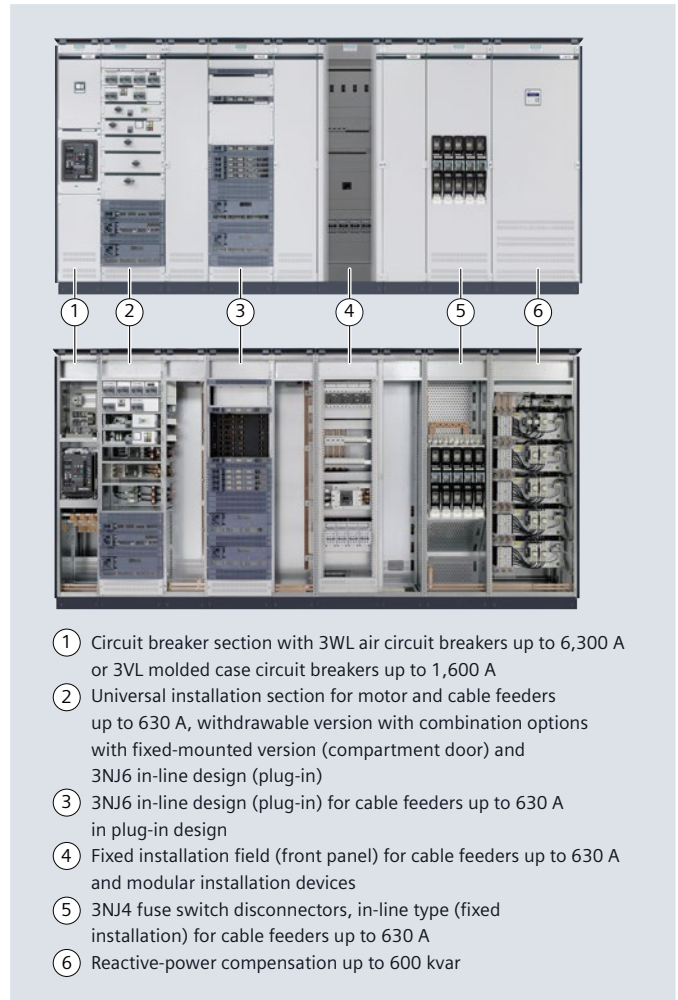


Fig. 3.3-5: The following mounting designs are available

### Plug-in 3NJ6 in-line fuse switch-disconnector design

The panels for cable feeders in the plug-in design up to 630 A are intended for the installation of in-line switch-disconnectors. The plug-in contact on the supply side is a cost-effective alternative to the withdrawable design. The modular design of the plug-ins enables an easy and quick retrofit or replacement under operating conditions. The device mounting space is intended for plug-in, in-line switch-disconnectors with a distance between pole centers of 185 mm. The vertical plug-on bus system is arranged at the back of the panel and is covered by an optional touch protection with pick-off openings in the IP20 degree of protection. This enables the in-line switch-disconnectors to be replaced without shutting down the switchboard (fig. 3.3-8).

### Fixed-mounted design with front covers

The panels for cable feeders in fixed-mounted design up to 630 A are intended for the installation of the following switching devices (fig. 3.3-9):

- SIRIUS 3RV or 3VL/3VA circuit-breaker
- 3K switch-disconnector
- 3NP fuse switch-disconnector
- Modular installation devices (assembly kit available).

# Switchgear and Substations

## 3.3 Low-Voltage Power Distribution Systems

The switching devices are mounted on infinitely adjustable device holders and connected to the vertical current distribution bars on the supply side. The front of the panel has either covers or additional doors (with or without a window).

### *Fixed-mounted 3NJ4 in-line fuse switch-disconnector design*

The panels for cable feeders in fixed-mounted design up to 630 A are intended for the installation of 3NJ4 in-line fuse switch-disconnectors. With their compact design and modular structure, in-line fuse switch-disconnectors offer optimal installation conditions with regard to the achievable packing density. The busbar system is arranged horizontally at the back of the panel. This busbar system is connected to the main busbar system via cross-members. The in-line fuse switch-disconnectors are screwed directly onto the busbar system (fig. 3.3-10).

### **Low-voltage main distribution**

When selecting a low-voltage main distribution system, the prerequisite for its efficient sizing is knowing about its use, availability, and future options for extension. The requirements for power distribution are extremely diverse.

Normally, frequent switching operations need not be considered in the planning of power distribution for commercial, institutional and industrial building projects, and extensions are generally not to be expected. For these reasons, a performance-optimized technology with high component density can be used. In these cases, Siemens mainly uses circuit-breaker-protected equipment in fixed-mounted design. When planning a power distribution system for a production plant, however, system availability, extendibility, control, and the visualization of status information and control functions are important issues related to keeping plant downtimes as short as possible. The use of circuit-breaker-protected technology in withdrawable design is important. Selectivity is also of great importance for reliable power supply. Between these two extremes there is a great design variety that should be optimally matched to customer requirements. The prevention of personal injury and damage to equipment must, however, be the first priority in any case. When selecting an appropriate switchboard, it must be ensured that it is a design verified switchgear assembly (in compliance with IEC 61439-2, VDE 0660-600-2), with extended testing of behavior in the event of an internal arc fault (IEC/TR 61641, VDE 0660-500 Addendum 2).

Low-voltage main distribution systems should be chosen among those featuring a total supply power up to 3 MVA. Up to this rating, the equipment and distribution systems are relatively inexpensive due to the maximum short-circuit currents to be encountered.

For rated currents up to 3,200 A, power distribution via busbars is usually sufficient if the arrangement of the incoming/outgoing feeder panels and coupler panels has been selected in a performance-related way. Ambient air temperatures, load on individual feeders, and the maximum power loss per panel have a decisive impact on the devices to be integrated and the number of panels required, as well as their component density (number of devices per panel).



Fig. 3.3-6: Circuit-breaker design



Fig. 3.3-7: Universal installation design



Fig. 3.3-8: Plug-in 3NJ6 in-line switch-disconnector design



Fig. 3.3-9: Fixed-mounted design with front covers



Fig. 3.3-10: Fixed-mounted 3NJ4 in-line switch-disconnector design

### 3.3.4 Planning Notes for Low-Voltage Switchboards

#### Installation – clearances and corridor widths

The minimum clearances between switchboard and obstacles specified by the manufacturer must be taken into account when installing low-voltage switchboards (fig. 3.3-11). The minimum dimensions for operating and servicing corridors according to IEC 60364-7-729 (VDE 0100-729) must be taken into account when planning the space requirements (table 3.3-4, fig. 3.3-12, fig. 3.3-13).

**Caution!** If a lift truck is used to insert circuit-breakers or withdrawable units, the minimum corridor widths must be adapted to the lift truck!

#### Transportation units

Depending on the access routes available in the building, one or more panels can be combined into transport units (TU). The max. length of a TU should not exceed 2,400 mm.

Space requirements				
Height:	2,000 mm and 2,200 mm (optionally with 100 mm or 200 mm base)			
Width:	For data required for the addition of panels please refer to the panel descriptions			
Depth:	Busbar position	Rated current of the main busbar	Type of installation	Cable/busbars entry
600 mm	Rear	4,000 A	Single front	Top & bottom
800 mm	Rear	7,010 A	Single front	Top & bottom
1,000 mm	Rear	4,000 A	Double front	Top & bottom
1,200 mm	Rear	7,010 A	Double front	Top & bottom
500 mm	Top	3,270 A	Single front	Bottom
800 mm	Top	3,270 A	Single front	Top & bottom
800 mm	Top	6,300 A	Single front	Bottom
1,200 mm	Top	6,300 A	Single front	Top & bottom

Table 3.3-4: SIVACON S8 switchboard dimensions

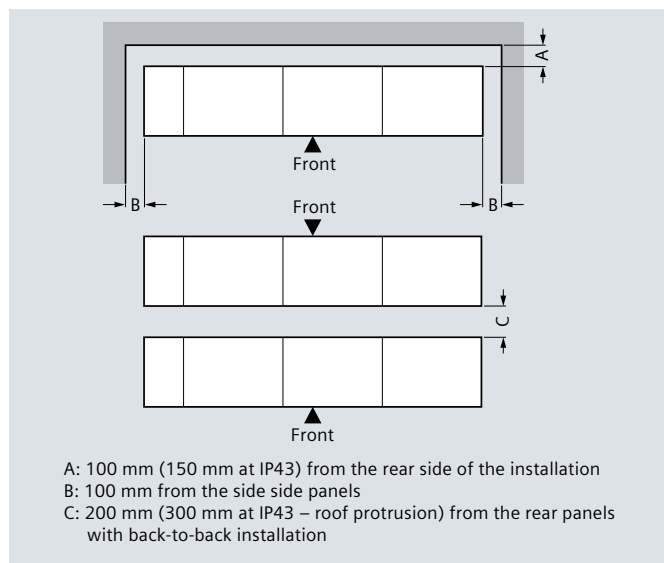


Fig. 3.3-11: Clearances to obstacles

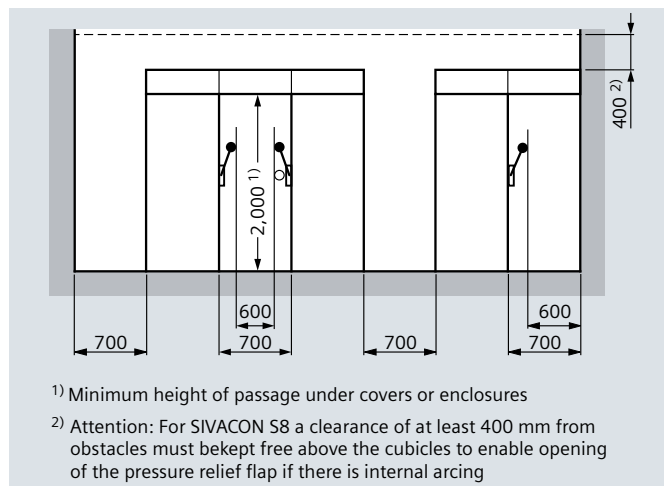


Fig. 3.3-12: Reduced corridor widths within the area of open doors

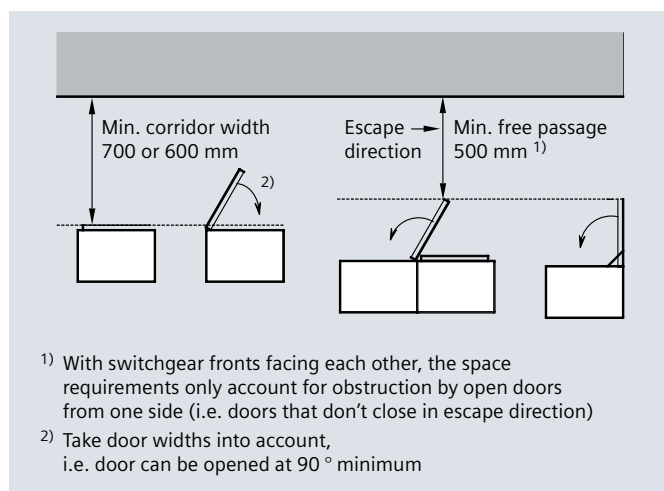


Fig. 3.3-13: Minimum corridor width according to IEC 60364-7-729 (VDE 0100-729)



# Switchgear and Substations

## 3.3 Low-Voltage Power Distribution Systems

### Double-front installations

In the double-front installation, the panels are positioned in a row next to and behind one another. The main advantage of a double-front installation is the extremely economic design through the supply of the branch circuits on both operating panels from one main busbar system.

The "double-front unit" system structure is required for the assignment of certain modules.

A double-front unit (fig. 3.3-14) consists of at least 2 and a maximum of 4 panels. The width of the double-front unit is determined by the widest panel (1) within the double-front unit. This panel can be placed on the front or rear side of the double-front unit. Up to three panels (2), (3), (4) can be placed on the opposite side. The sum of the panel widths (2) to (4) must be equal to the width of the widest panel (1). The panel combination within the double-front unit is possible for all technical installations with the following exceptions.

#### Exceptions

The following panels determine the width of the double-front unit and may only be combined with an empty panel:

- Bus sectionalizer unit
- 5,000 A incoming/outgoing feeder
- 6,300 A incoming/outgoing feeder.

### Weights

The panel weights as listed in table 3.3-5 should be used for the transportation and dimensioning of building structures such as cable basements and false floors.

### Environmental conditions for switchboards

The climate and other external conditions (natural foreign substances, chemically active pollutants, small animals) may affect the switchboards to a varying extent. The effect depends on the heating/air-conditioning systems of the switchboard room. If higher concentrations are present, pollutant-reducing measures are required, for example:

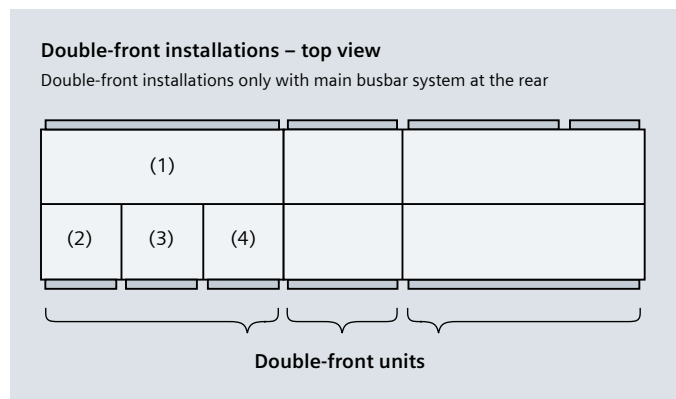


Fig. 3.3-14: Panel arrangement of double-front installations

- Air intake for operating room from a less contaminated point
- Slightly pressurizing the operating room (e.g. by blowing uncontaminated air into the switchboard)
- Switchboard room air conditioning (temperature reduction, relative humidity < 60 %, if necessary, use air filters)
- Reduction of temperature rise (oversizing of switchboard or components such as busbars and distribution bars).

### Power losses

The power losses listed in table 3.3-6 are approximate values for a panel with the main circuit of functional units to determine the power loss to be discharged from the switchboard room.

	Rated current [A] Size		Minimum panel width [mm]	Approx. weight [kg]
Circuit-breaker design with 3WL (withdrawable unit)	630–2,000	Size I	400	340
	2,000–3,200	Size II	600	510
	4,000	Size III	800	770
	4,000–6,300	Size III	1,000	915
Universal mounting design panel (incl. withdrawable units, fixed-mounted with front doors)			1,000	400
3NJ4 in-line-type switch-disconnector panel (fixed-mounted)			600	360
3NJ6 in-line-type switch-disconnector design panel (plugged)			1,000	415
Reactive power compensation panel			800	860

Table 3.3-5: Average weights of the panels including busbar (without cable)

	Circuit-breaker type	Approx. $P_v$ [W] for % of the rated current of the switch	
		100 %	80 %
Circuit-breaker design with 3WL (withdrawable unit)	3WL1106 630 A Size I	215	140
	3WL1108 800 A Size I	345	215
	3WL1110 1,000 A Size I	540	345
	3WL1112 1,250 A Size I	730	460
	3WL1116 1,600 A Size I	1,000	640
	3WL1220 2,000 A Size II	1,140	740
	3WL1225 2,500 A Size II	1,890	1,210
	3WL1232 3,200 A Size II	3,680	2,500
	3WL1340 4,000 A Size III	4,260	2,720
	3WL1350 5,000 A Size III	5,670	3,630
	3WL1363 6,300 A Size III	8,150	5,220
Universal mounting design panel (incl. withdrawable units, fixed-mounted with front doors)			600 W
3NJ4 in-line-type switch-disconnector panel (fixed-mounted)			600 W
3NJ6 in-line-type switch-disconnector design panel (plugged)			1,500 W
Fixed-mounted type panel with front covers			600 W
Reactive power compensation panel		non-choked choked	1.4 W / kvar 6.0 W / kvar

Table 3.3-6: Power loss generated per panel (average values)

### Arc resistance

Arcing faults can be caused by incorrect dimensioning and reductions in insulation due to contamination etc., but they can also be a result of handling errors. The effects, resulting from high pressure and extremely high temperatures, can have fatal consequences for the operator, the system, and even the building. SIVACON S8 offers evidence of personal safety through testing under arcing fault conditions with a special test in accordance with IEC/TR 61641 (VDE 0660-500 Addendum 2).

Active protection measures, such as the high-quality insulation of live parts (e.g. busbars), standardized and simple operation, prevent arcing faults and the associated personal injuries. Passive protections increase personal and system safety many times over. These include: hinge and locking systems with arc resistance, the safe operation of withdrawable units or circuit-breakers behind a closed door and patented swing check valves behind ventilation openings on the front, arcing fault barriers or arcing fault detection system combined with the rapid disconnection of arcing faults.

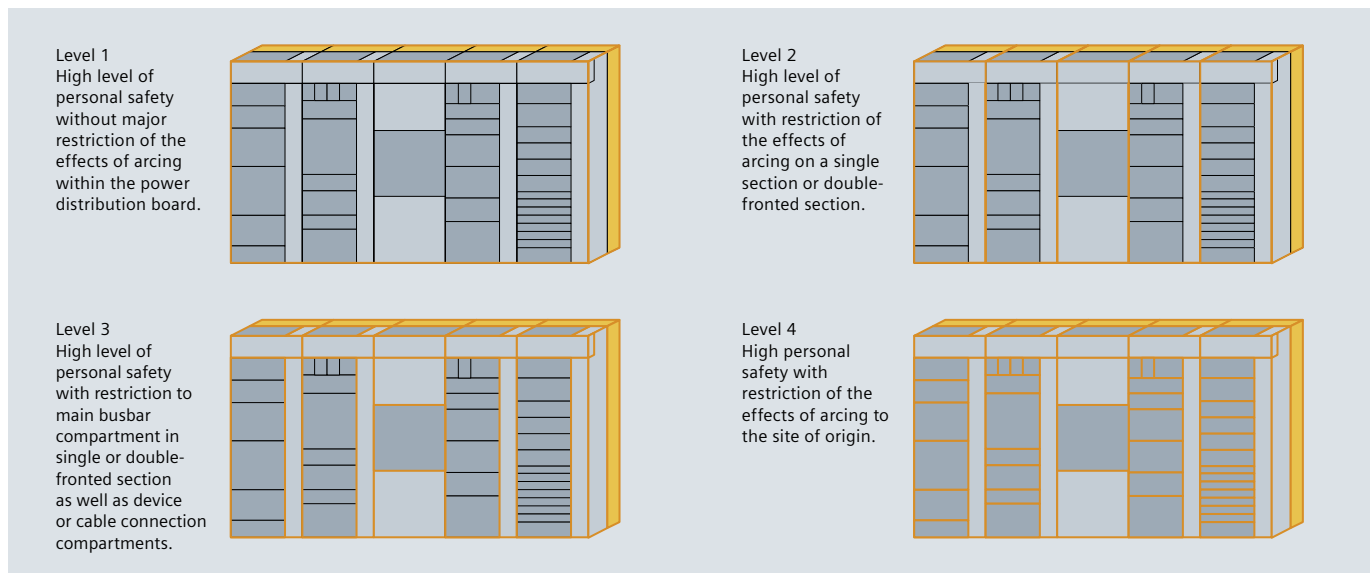


Fig. 3.3-15: The arcing fault levels describe the classification in accordance with the characteristics under arcing fault conditions and the restriction of the effects of the arcing fault to the system or system section

### 3.3.5 Low-Voltage Switchboard – Panel Types and Example

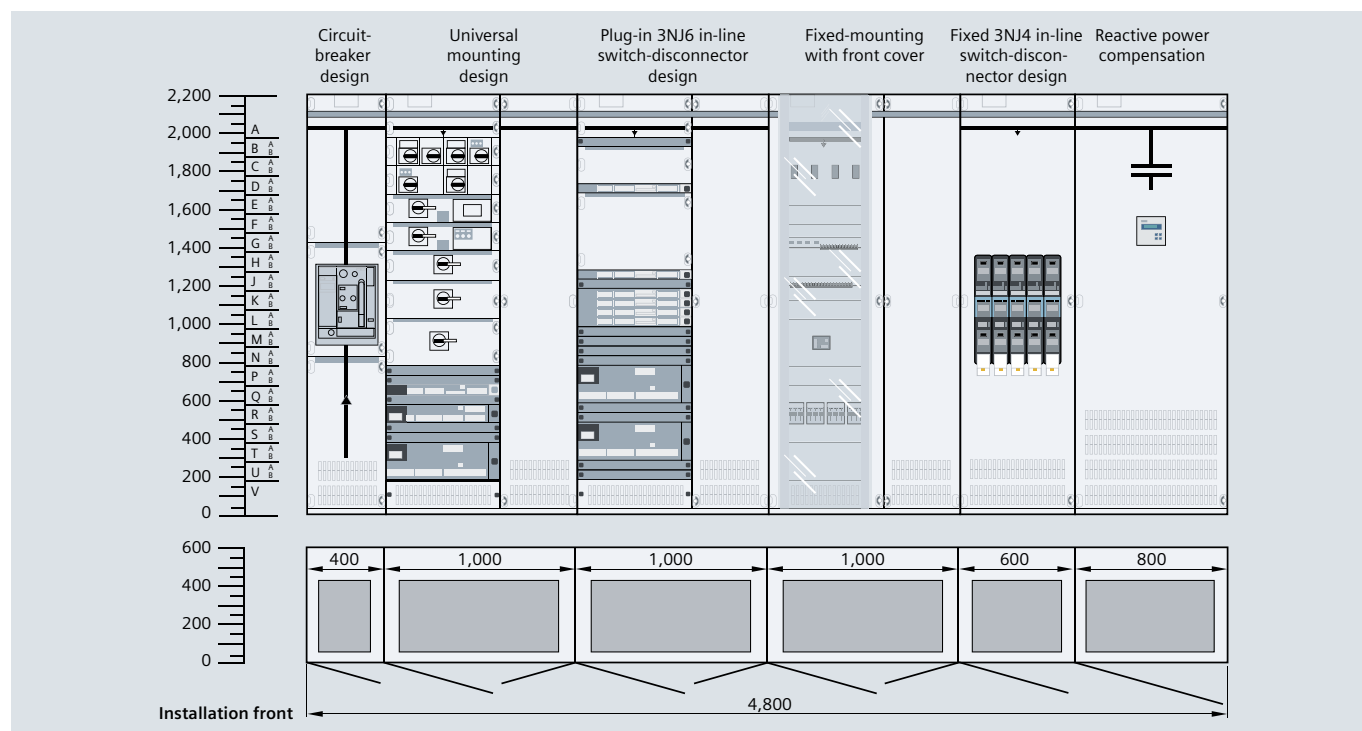


Fig. 3.3-16: SIVACON S8, busbar position at rear 2,200 × 4,800 × 600 (H × W × D in mm)

Panel type	Circuit-breaker design	Universal mounting design	3NJ6 in-line switch-disconnector design	Fixed-mounted design	3NJ4 in-line switch-disconnector design	Reactive power compensation
Mounting design	Withdrawable unit Fixed-mounted	Withdrawable unit Fixed-mounted Plug-in	Plug-in	Fixed-mounted with front covers	Fixed-mounted	Fixed-mounted
Function	Incoming feeder Outgoing feeder Coupling	Cable feeders Motor feeders	Cable feeders	Cable feeders	Cable feeders	Central compensation of the reactive power
Current $I_n$	Up to 6,300 A	Up to 630 A / Up to 250 kW	Up to 630 A	Up to 630 A	Up to 630 A	Up to 600 kvar
Connection	Front or rear side	Front or rear side	Front side	Front side	Front side	Front side
Panel width [mm]	400/600/800/ 1,000/1,400	600/1,000/1,200	1,000/1,200	1,000/1,200	600/800/1,000	800
Internal compartmentalization	1, 2b, 3a, 4b 4 Type 7 (BS)	3b, 4a, 4b, 4 Type 7 (BS)	3b, 4b	1, 2b, 3b, 4a, 4b	1, 2b	1, 2b
Protection degree of panel type against interior	Up to IP 54	Up to IP 54 (up to IP 41 with 3NJ6 plug-in design)	Up to IP 41	Up to IP 54	Up to IP 54	Up to IP 43
Protection degree of assembly against interior	If section ventilated: IP 30 / IP 31 / IP 40 / IP 41 / IP 43 if section non-ventilated: IP 54					
Busbars	Rear/top	Rear/top	Rear/top	Rear/top	Rear	Rear/ top/without

Table 3.3-7: Various mounting designs according to panel types

#### For further information:

[www.siemens.com/sivacon](http://www.siemens.com/sivacon)

Brochure: The low-voltage power distribution board that sets new standards – SIVACON S8, Order no. E10003-E38-2B-D0020-7600

### 3.3.6 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 earth 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 switchboard 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 (VDE 0100-710 and -718) and the MLAR (Sample Directive on Fireproofing Requirements for Line Systems) in Germany.

##### *Standards to be observed for dimensioning*

- IEC 60364-1 (VDE 0100-100) Low-voltage electrical installations, part 1: Fundamental principles, assessment of general characteristics, definitions
- IEC 60364-4-41 (VDE 0100-410) Protection against electric shock
- IEC 60364-4-43 (VDE 0100-430) Protection against overcurrent
- IEC 60364-5-51 (VDE 0100-510) Selection and erection of electrical equipment; common rules
- IEC 60364-5-52 (VDE 0100-520) Wiring systems
- VDE 0298-4 Recommended values for the current carrying capacity of sheathed and non-sheathed cables
- 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.

### 3.3.7 Busbar Trunking Systems

#### General

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 a 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 creation of an energy concept are:

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

The result will never be a single solution. Several options must be assessed in terms of their technical and economic impacts. The following requirements are the main points of interest:

- Easy and transparent planning
- Long service life
- High availability
- Low fire load
- Integration in energy management systems
- Future-proof investment
- Flexible adaptation to changes in the building.

Most applications suggest the use of suitable busbar trunking systems (BTS) to meet these requirements. For this reason, engineering companies increasingly prefer busbar trunking to cable installation for power transmission and distribution. Siemens offers BTS (fig. 3.3-17) ranging from 40 A to 6,300 A:

- The BD01 system from 40 to 160 A for the supply of light fixtures as well as workshops with tap-offs up to 63 A
- The BD2 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 at production sites with a high energy demand as well as on ships or in wind turbines
- The LI system in sandwich design from 800 to 6,300 A is a design verified solution according to IEC 61439-1/-6 (VDE 0660-600-1/-6), mainly used for power transmission irrespective to the mounting position in buildings, data centers or industrial applications with the requirements of degree of protection IP55, low fire load and special conductor configurations such as double N or insulated PE
- The encapsulated LR system from 400 to 6,150 A for power transmission under extreme environmental conditions (IP68).

#### Planning notes

Considering the complexity of modern building projects, transparency and flexibility of power distribution are indispensable requirements. In industry, the focus is on continuous supply of energy as an essential prerequisite for multi-shift production. Busbar trunking systems meet all these requirements on efficient power distribution by being easily planned, quickly installed, and providing a high degree of flexibility and safety. The advantages of busbar trunking systems are:

- Straightforward network configuration
- Low space requirements
- Easy retrofitting in case of changes of locations and consumer loads
- High short-circuit rating and low fire load
- Increased planning security.

#### Power transmission

Electrical energy from the transformer to the low-voltage switchboard is transmitted by suitable components in the busbar trunking system. These components are installed between transformer and main distribution board, then branching to subdistribution systems.

Trunking units without tap-off points are used for power transmission. These are available in standard lengths. Besides the standard lengths, the customer can also choose a specific length from various length ranges to suit individual constructive requirements.

#### Power distribution

Power distribution is the main area of application for busbar trunking systems. This means that electricity cannot just be tapped from a permanently fixed point as with a cable installation. Tap-off points can be varied and changed as desired within the entire power distribution system.

In order to tap electricity, you just have to plug a tap-off unit on the busbar at the tap-off point. This way a variable distribution system is created for linear and/or area-wide, distributed power supply. Tap-off points are provided on either or just one side on the straight trunking units.

For each busbar trunking system, a wide range of tap-off units is available for the connection of equipment and electricity supply.



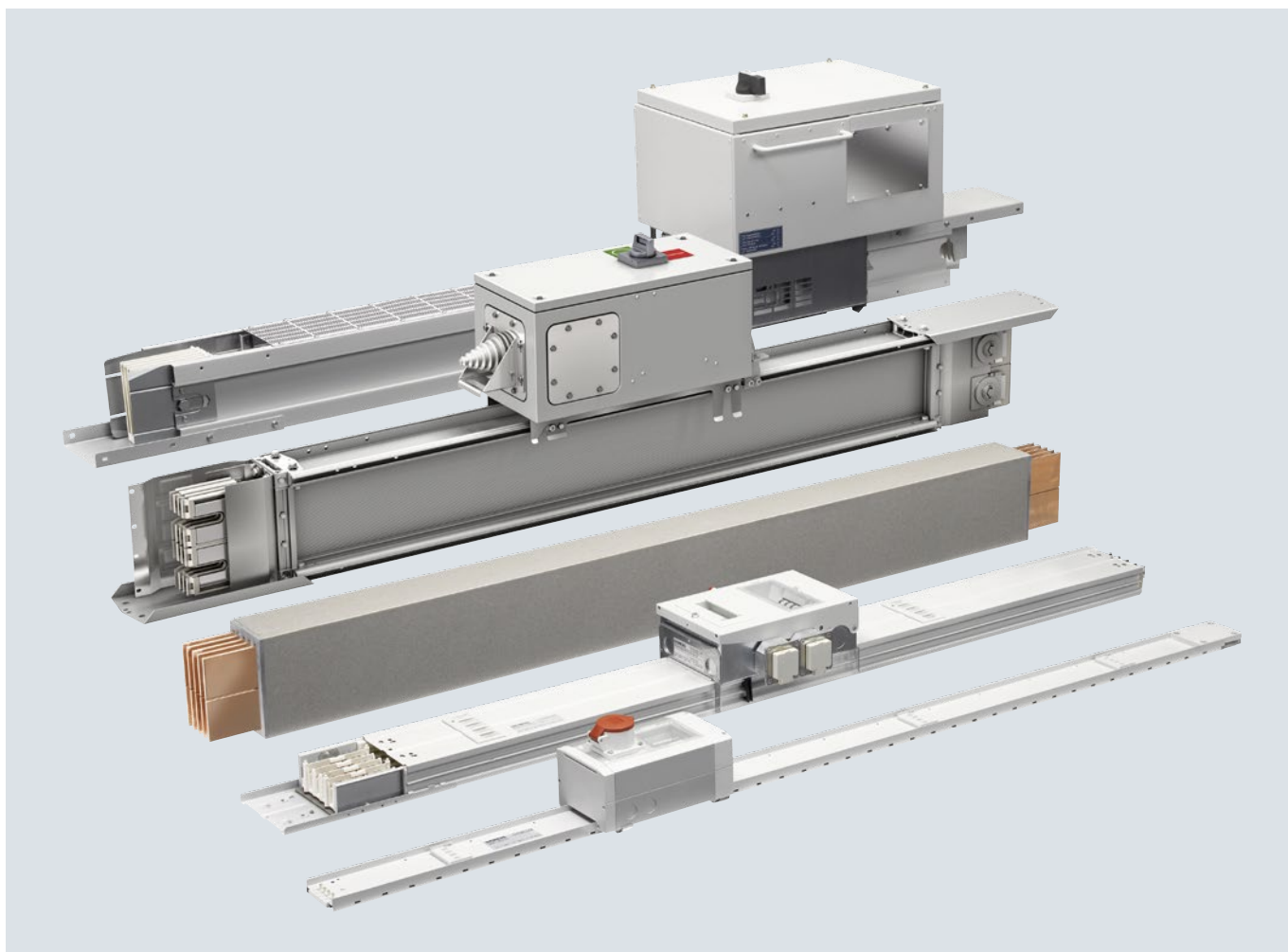


Fig. 3.3-17: Busbar trunking systems

### Configuration

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 rating 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, busbar position (vertical, horizontal edgewise or flat), 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 design verified solution (according to IEC 61439-6 / VDE 0660-600-6) 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 tap-off 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 (EI90 and EI120 according to EN 1366-3) of the fire barriers
- 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).

# Switchgear and Substations

## 3.3 Low-Voltage Power Distribution Systems

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 for 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).

A comparison between busbar and cable solution is summarized in table 3.3-8 and fig. 3.3-18.

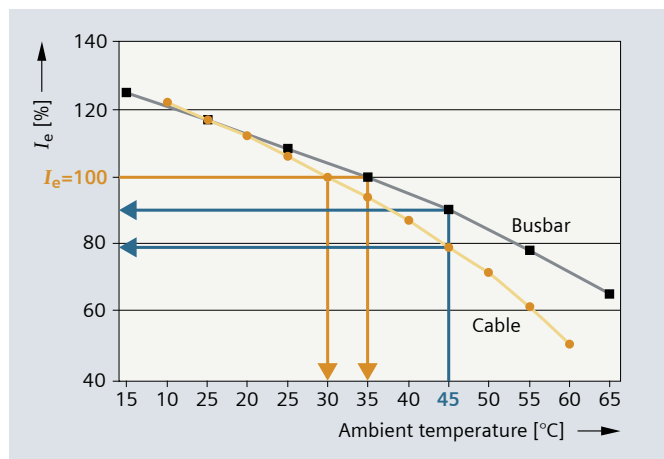


Fig. 3.3-18: Comparison of temperature response and derating

Characteristic	Cable	Busbar
Planning, calculation	High determination and calculation expense; the consumer locations must be fixed	Flexible consumer locations; only the total load is required for the planning
Expansions, changes	High expense, interruptions to operation, calculation, risk of damage to the insulation	Low expense as the tap-off units are hot pluggable
Space requirements	More space required because of bending radii and the spacing required between parallel cables	Compact directional changes and fittings
Temperature responses and derating	Limits depend on the laying method and cable accumulation. The derating factor must be determined / calculated	Design verified switchgear assembly; limits from catalog
Halogen-free	PVC cables are not halogen-free; halogen-free cable is very expensive	Principally halogen-free
Fire load	Fire load with PVC cable is up to 10 times greater, with PE cable up to 30 times greater than with busbars	Very low, see catalog
Design verified switchgear assembly	The operational safety depends on the design	Tested system, non-interchangeable assembly

Table 3.3-8: Cable/busbar comparison

### 3.3.8 Benefits and Data of the BTS Families

#### BD01 system 40 A –160 A

The BD01 system is the BTS for power distribution in trade and commerce:

- High degree of protection up to IP55
- Flexible power supply
- Easy and fast planning
- Time-saving installation
- Reliable mechanical and electrical cables and connections
- High stability, low weight
- Small number of basic modules
- Modular system reduces stock-keeping
- Variable changes of direction
- Multi-purpose tap-off units
- Forced opening and closing of the tap-off point

It is designed for applications from 40 to 160 A. Five current ratings 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 tap-off points: 0.5 m and 1 m
- Rated operating voltage: 400 V AC

#### 2. Junction unit

- 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 modular widths
- With or without assembly kit

#### 5. Ancillary equipment unit

- For 4 or 8 modular widths
- 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 (fire safety for 90 minutes according to European standards)

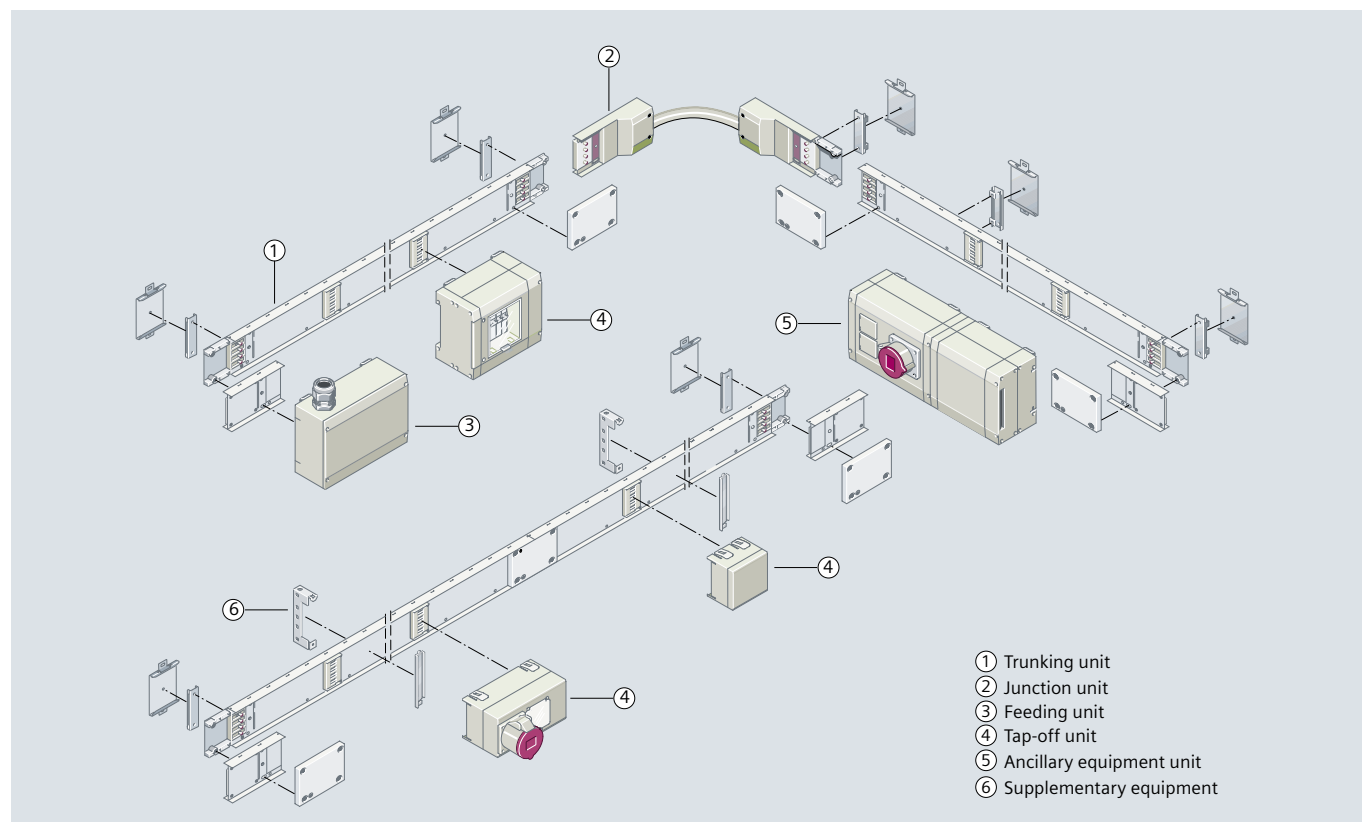


Fig. 3.3-19: System components for BD01 system

# Switchgear and Substations

## 3.3 Low-Voltage Power Distribution Systems

### BD2 system 160 A –1,250 A

The BD2 system is used for power distribution in the aggressive industrial environment:

- High degree of protection up to IP55
- Easy and fast planning
- Time-saving and economic installation
- Safe and reliable operation
- Flexible, modular system providing simple solutions for every application
- Advance power distribution planning without precise knowledge of device locations
- Ready to use in no time thanks to fast and easy installation

- Innovative design: expansion units to compensate for expansion are eliminated
- Tap-off units and tap-off points can be coded at the factory
- Uniformly sealable.

The choice of aluminum or copper as busbar material allows 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 system is used as rising power supply system 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 × 167 mm), 630 A, 800 A, 1,000 A, 1,250 A (126 mm × 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 classes (90 and 120 minutes) according to European standards

#### 2. Junction unit

- Edgewise or flat position
- With or without fire protection
- Elbow 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-type terminal
- Cable entry from 1, 2 or 3 sides
- Distribution board feeding

#### 4. Tap-off unit

- 25 A to 530 A
- With fuse, miniature circuit-breaker (MCB) or fused outlet installed

#### 5. Ancillary equipment unit

- For 8 modular widths
- With or without assembly unit

#### 6. Possible supplementary equipment

- End flange
- For fixing:
  - Universal fixing clamp for edgewise or flat position
  - Fixing elements for vertical phases, for fixing to walls or ceilings
- Terminal block

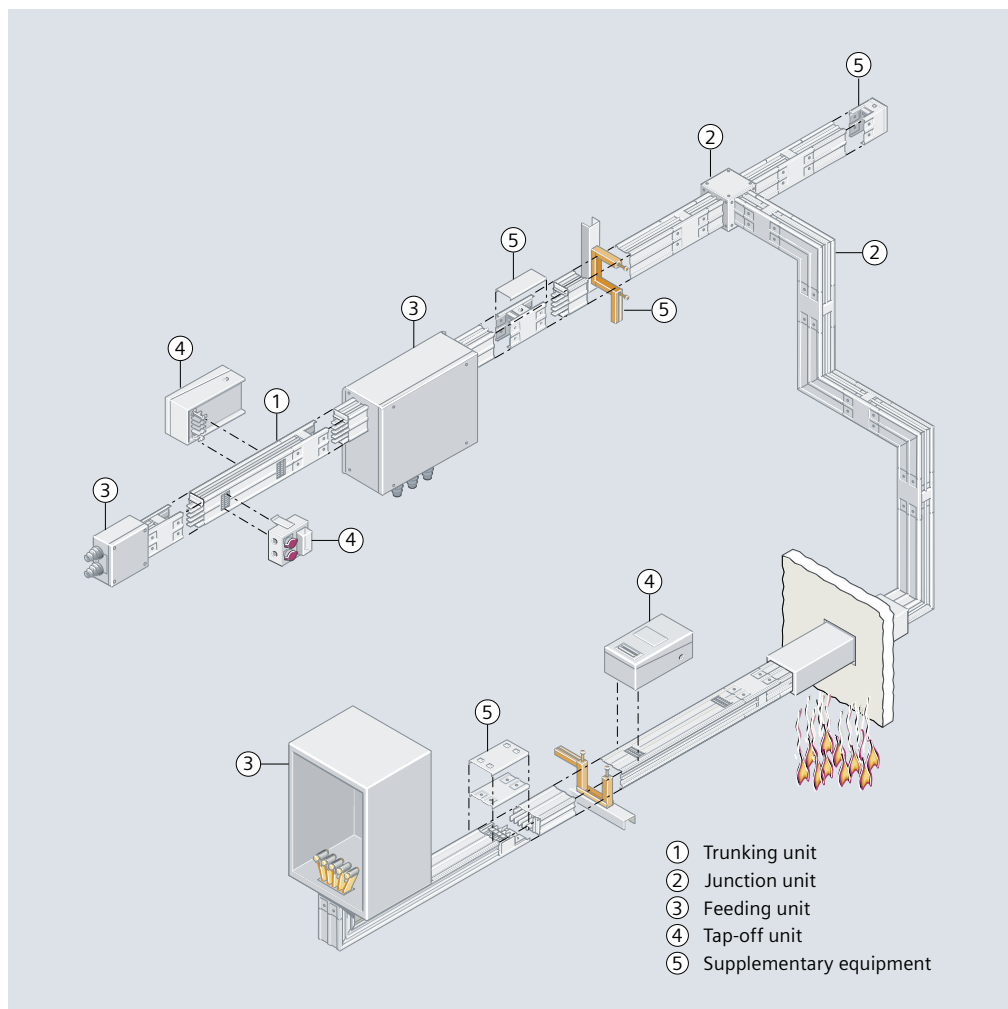


Fig. 3.3-20: System components for BD2 system

### LD system

#### 1,100 A – 5,000 A

The LD system fits for power distribution in industrial environments:

- High degree of protection up to IP54
- Easy and fast installation
- Safe and reliable operation
- Space-saving, compact design, up to 5,000 A in one housing
- Tap-off units up to 1,250 A
- Design verified connection to distribution board and transformers

The LDA/LDC system is used both for power transmission and power distribution. A special feature of the system is a high short-circuit rating, 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
- LD...1 to LD...3 (180 mm × 180 mm)
- LD...4 to LD...8 (240 mm × 180 mm)

- Degree of protection: IP34 and IP54
- Standard lengths: 1.6 m, 2.4 m and 3.2 m
- Lengths available: from 0.5 m to 3.19 m
- Tap-off points:
  - Without
  - With user-configurable tap-off points
- Fire barriers (fire resistance for 120 minutes according to European standards)

#### 2. Junction unit

- With or without fire barrier
- Elbow 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 units 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

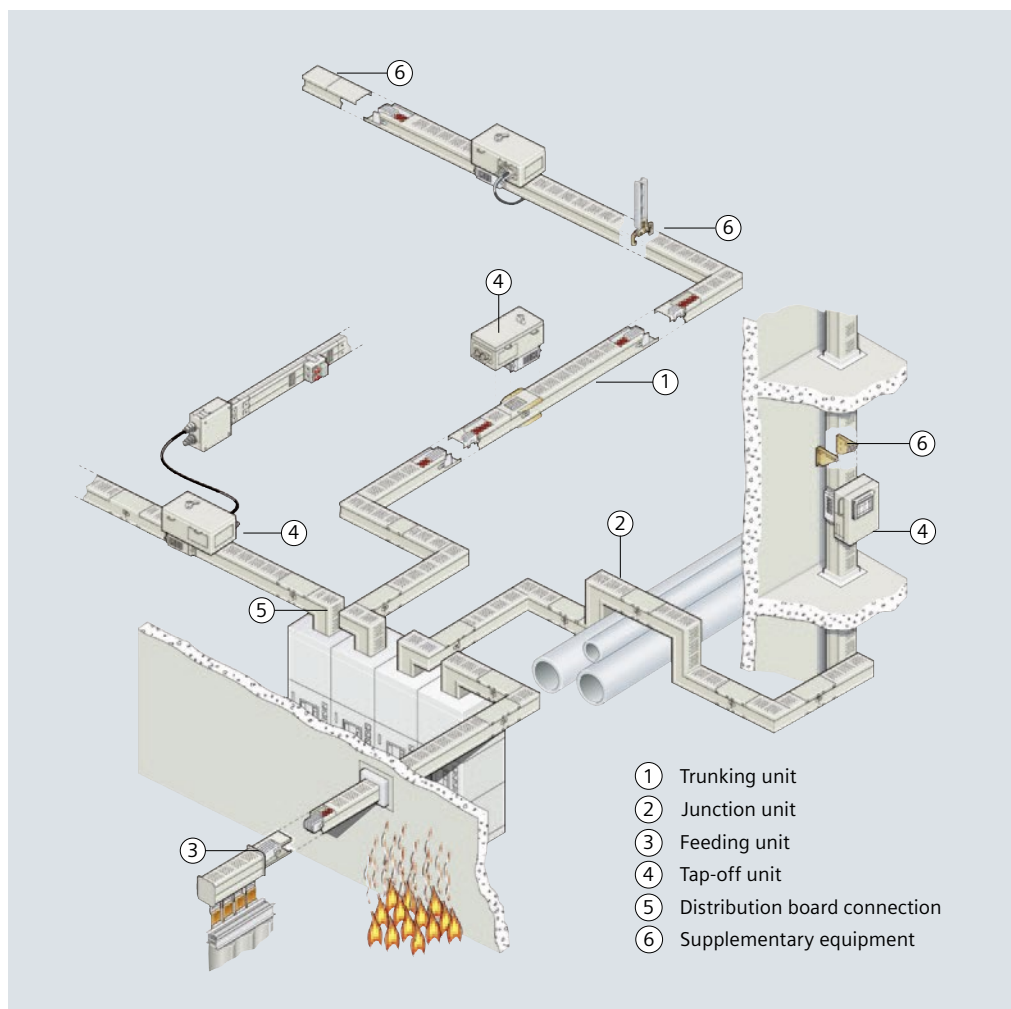


Fig. 3.3-21: System components for LDA/LDC system



### LI system from 800 A – 6,300 A

The LI system is used for power transmission and distribution in buildings, data centers, and industrial applications:

- High degree of protection of IP55 as a standard
- Hook and bolt connection with shear-off nut for optimized connection of the busbar trunkings
- Side-by-side double body system for compact construction
- Low fire load
- Safe and reliable operation with high short-circuit ratings
- Flexibility of tap-off units (up to 1,250 A<sup>2)</sup>); for example with communication capable measuring devices
- Design verified BTS system with design verified connections to SIVACON S8

#### switchboards

- Standard interfaces to cast-resin LR system of Siemens for outdoor use
- Integration of measuring devices in a rotatable box added to tap-off units possible

Special features of the LIA/LIC system include high flexibility and position insensitivity, and it is particularly suitable for power distribution in high-rise buildings and data centers. The high degree of protection IP55, which is standard for this system, and tap-off units up to 1,250 A<sup>2)</sup> also guarantee a safe supply if there is a high energy demand. It can be used in industry as well as for other relevant infrastructure projects such as hospitals, railroad stations, airports, sports venues, etc.

#### 1. Trunking unit

- Single and double bodies with 3 to 6 bars in one housing, resp. 6 to 12 bars in two housings
- Conductor configurations for all grid types, with 100% or double N, 50% or 100% PE as well as a Clean Earth solution (insulated PE conductor for a clean PE, CPE)
- Busbar material: copper or aluminum
- Insulation material: Mylar
- Rated current: 800 up to 6,300 A
- For sizes, see table 3.3-9
- Degree of protection: IP55
- Selectable lengths: available from 0.5 m to 3 m on a 1 cm scale
- Layout: horizontal and vertical without derating

- 3 tap-off points at 3 m length:
  - On one side
  - On both sides
- Fire protection: Fire barriers according to class EI90 and EI120<sup>1)</sup> (categories of EN 13501-2) according to EN 1366-3 are available

#### 2. Junction unit

- With or without fire barrier
- Various elbow, knee and offset units are available, with either standard or customized dimensions and angles

#### 3. Modular tap-off units

- Degree of protection IP55
- With fuse switch-disconnector from 125 A to 630 A
- With circuit-breaker from 50 A to 1,250 A<sup>2)</sup>
- With measuring device in an additional rotatable box

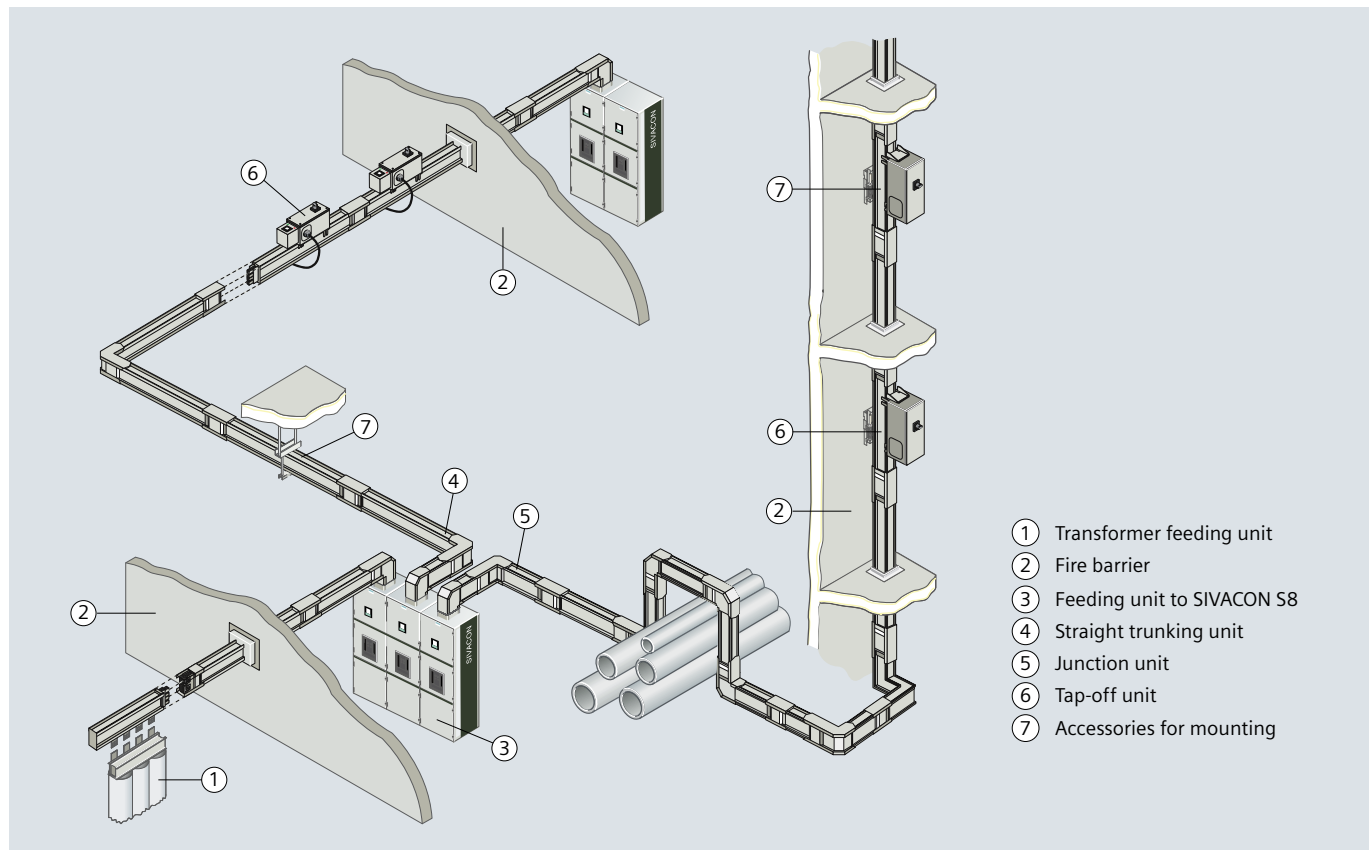


Fig. 3.3-22: System components for LIA/LIC system

- Pluggable while energized up to 1,250 A
- Leading PEN or PE conductor
- 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 units for connection to distribution board

- Design verified connection to the SIVACON S8 system from the top/bottom
- Flanged end

1) EI120 in preparation

2) Tap-off units from 800 A up to 1,250 A in preparation

Single body (width 155 mm)					
Al			Cu		
$I_e$ [A]	System	Height [mm]	$I_e$ [A]	System	Height [mm]
800	LIA0800	111	1,000	LIC1000	111
1,000	LIA1000	132	1,250	LIC1250	117
1,250	LIA1250	146	1,600	LIC1600	146
1,600	LIA1600	182	2,000	LIC2000	174
2,000	LIA2000	230	2,500	LIC2500	213
2,500	LIA2500	297	3,200	LIC3200	280
Double body (width 410 mm)					
Al			Cu		
$I_e$ [A]	System	Height [mm]	$I_e$ [A]	System	Height [mm]
3,200	LIA3200	182	4,000	LIC4000	174
4,000	LIA4000	230	5,000	LIC5000	213
5,000	LIA5000	297	6,300	LIC6300	280

Table 3.3-9: Sizes for LIA/LIC system

# Switchgear and Substations

## 3.3 Low-Voltage Power Distribution Systems

### LR system from 400 A – 6,150 A

The LRA/LRC system is used for power transmission under extreme ambient conditions (IP68):

- Reliable and safe operation
- Fast and easy installation
- Cast-resin system up to 6,150 A
- Safe connection to distribution boards and transformers
- High degree of protection IP68 for outdoor applications

A special feature of the system is high resistance to external influences of chemical and corrosive substances, and it is particularly suitable for use outdoors and in environments with high air humidity. The high degree of protection IP68 is guaranteed with the encapsulated epoxy cast-resin housing 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 aluminum
- Degree of protection: IP68
- User-configurable lengths: from 0.30 m to 3.00 m
- For sizes see table 3.3-10
- Layout: horizontal and vertical without derating
- Fire barriers (fire resistance for 120 minutes according to European standards)

#### 2. Junction unit

- With or without fire barrier
- Elbow unit with or without offset
- Z-unit
- T-unit

#### 3. Feeding unit and distributor units

- Universal terminals for transformers, external distribution boards and cable connection

#### 4. Possible supplementary equipment

- End flange
- Terminal block
- Tap-off point every 1 m, on one side; tap-off unit on request
- Adapters to the LI and LD systems

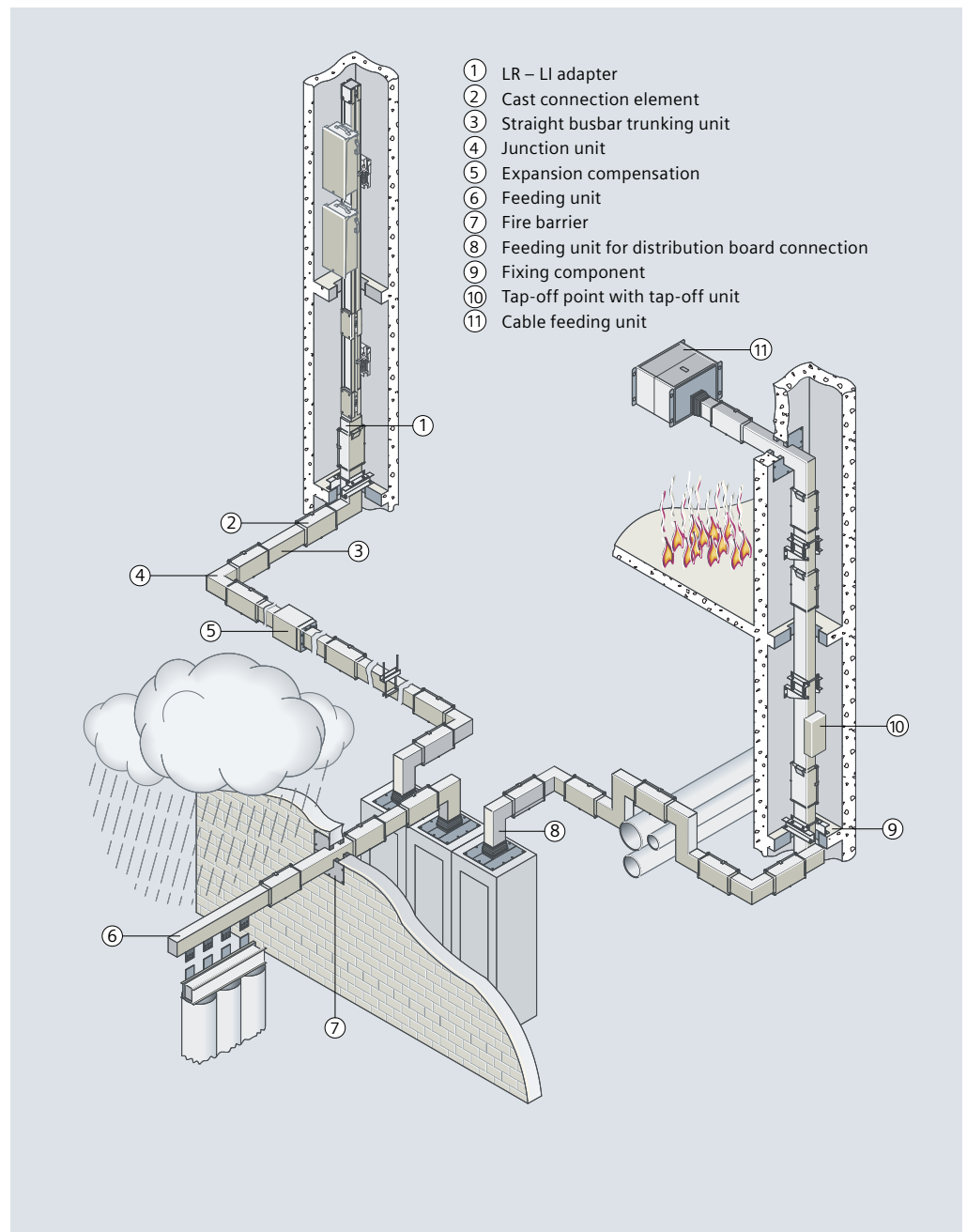


Fig. 3.3-23: System components for LRA/LRC system

Al system				
$I_e$ [A]	System	Width [mm]		Height [mm]
		4-conductor system	5-conductor system	
400	LRA01	90	90	90
630	LRA02	90	90	90
800	LRA03	90	90	90
1,000	LRA04	100	120	110
1,200	LRA05	100	120	130
1,400	LRA06	100	120	150
1,600	LRA07	100	120	190
2,000	LRA08	100	120	230
2,500	LRA09	100	120	270
3,200	LRA27	100	120	380
4,000	LRA28	100	120	460
4,600	LRA29	100	120	540
Cu system				
$I_e$ [A]	System	Width [mm]		Height [mm]
		4-conductor system	5-conductor system	
630	LRC01	90	90	90
800	LRC02	90	90	90
1,000	LRC03	90	90	90
1,350	LRC04	100	120	110
1,600	LRC05	100	120	130
1,700	LRC06	100	120	150
2,000	LRC07	100	120	190
2,500	LRC08	100	120	230
3,200	LRC09	100	120	270
4,000	LRC27	100	120	380
5,000	LRC28	100	120	460
6,150	LRC29	100	120	540

Table 3.3-10: Sizes for LRA/LRC system

### Communication-capable BTS

Communication-capable functional extensions to be combined with known tap-off units:

- For use with the systems BD01, BD2, LD and LI
- Applications:
  - Large-scale lighting control
  - Remote switching and signaling in industrial environments
  - Consumption metering of distributed load feeders
- Interfacing to KNX / EIB, AS-Interface, PROFINET, PROFIBUS and Modbus systems
- Easy contacting of the bus line with insulation displacement method
- Easy and fast planning
- Flexible for extension and modification
- Modular system
- Retrofitting to existing installations possible.

### For further information:

[www.siemens.com/busbar](http://www.siemens.com/busbar)

#### Planning manual

Busbar trunking system SIVACON 8PS – Planning with SIVACON 8PS

- German: Order no. ASE 01541017-02
- English: Order no. ASE01541101-02

#### Brochures

For safe power flows - SIVACON 8PS busbar trunking systems

- German: Order no. IC1000-G320-A158-V1
- English: Order no. IC1000-G320-A158-V1-7600

An integrated solution for safe and efficient power supply - LI busbar trunking system

- German: Order no. IC1000-G320-A194-V1
- English: Order no. IC1000-G320-A194-V1-7600

#### Configurators

The following configurators are available via the Industry Mall ([www.siemens.com/industrymall](http://www.siemens.com/industrymall)):

- SIVACON 8PS system BD01, 40 ... 160 A
- SIVACON 8PS system BD2, 160 ... 1,250 A