6 Methods and aids for planning installations

6.1 Planning of switchgear installations

6.1.1 Concept, boundary conditions, pc calculation aid

The process of planning switchgear installations for all voltage levels consists of establishing the boundary conditions, defining the plant concept and deciding the planning principles to be applied.

The planning phase is a time of close cooperation between the customer, the consulting engineer and the contractor.

The boundary conditions are governed by environmental circumstances (plant location, local climatic factors, influence of environment), the overall power system (voltage level, short-circuit rating and arrangement of neutral point), the frequency of operation, the required availability, safety requirements and also specific operating conditions.

Table 6-1 gives an indication of the boundary conditions which influence the design concept and the measures to be considered for the different parts of a switchgear installation.

In view of the equipment and plant costs, the necessity of each measure must also be examined from an economic standpoint.

Taking the busbar concept as an example (Table 6-3), the alternatives are evaluated technically and economically. The example is valid for h.v. installations, and to some extent m.v. installations as well.

PC calculation aid

Numerous computer programs are available for use in planning switchgear installations, particularly for design calculation. Sections 6.1.5 to 6.1.7 deal with computer-aided methods for:

– short-circuit current
– cable cross section
– cable routing.

Table 6-2 summarizes the computer programs used in planning switchgear installations, together with their fields of application and contents.

Table 6-1

Choice of plant concept and measures taken in relation to given boundary conditions

Boundary conditions	Concept and measures
Environment, climate, location:	Outdoor/indoor Conventional/GIS/hybrid Equipment utilization Construction Protection class of enclosures Creepage, arcing distances Corrosion protection Earthquake immunity
Network data,network form:	Short-circuit loadings Protection concept Lightning protection Neutral point arrangement Insulation coordination
Availability and redundancy of power supply:	Busbar concept Multiple infeed Branch configuration Standby facilities Uninterruptible supplies Fixed/drawout apparatus Choice of equipment Network layout
Power balance:	Scope for expansion Equipment utilization Instrument transformer design
Ease of operation:	Automatic/conventional control Remote/local control Construction/configuration
Safety requirements:	Network layout Arcing fault immunity Lightning protection Earthing Fire protection Touch protection Explosion protection

Table 6-2

Computer programs for project planning and calculations for switchgear installations (CAD programs, see Section 6.3.3)

Program Name	Application area	Testing, determination, dimensioning
EMTP	Calculation of transient processes in any meshed multiphase electrical systems	– Internal and external overvoltages – Interference voltage affecting telecom cables – Transient voltage elevation in earthing systems on lightning strike – Operational response of battery power systems
PPCP	Calculation of potential-course in earthing systems	– Determination of the propagation resistance – Determination of step and touch voltages
STÖRLI	Calculation of the pressure characteristic in switchgear rooms on arcing	– Checking the pressure resistance of medium-voltage switchgear rooms – Dimensioning pressure relief equipment
KURWIN	Dynamic resistance	– Static resistance and thermal and dynamic short-circuit current capability of switchgear installations with conductor cables and tubular conductors as per DIN EN 60865-1 (VDE 0103)
ROBI	Static resistance	– Deflection line and torque curve of waves and tubular conductors
CALPOS®	Programming system for network calculation with the following modules:	
	Phase fault current calculation; calculation of symmetrical and non-symmetrical fault currents as per – DIN VDE 0102/IEC60909 – Superposting method	– Switchgear installations (busbars, connections) – Equipment (switches, transformers) – Protection devices
	Load flow calculation	– Switchgear installations – Equipment and power – Minimum loss system operation methods – Critical system states – Directed switchovers after equipment failure – Voltage drop on motor startup

(continued)

Table 6-2 (continued)

Computer programs for project planning and calculations for switchgear installations (CAD programs, see Section 6.3.3)

Program Name	Application area	Testing, determination, dimensioning
CALPOS®	Selectivity analysis (over-current protection)	– Checking protection coordination in MS and NS networks
	Distance protection	– Protection coordination of cable units – Creation of selective tripping schedules
	Harmonic analysis	– Harmonic currents and voltages in networks with converters – System perturbation by harmonics – Compensation equipment – Propagation of audiofrequency ripple control signals
	Dimensioning of earthing systems (VDE 0141, IEEE 80)	– Cross sections for earthing material – Hazardous voltages
	Dimensioning low-voltage cables	– Specification of cable type – Maximum length – Selection of protective devices
	Motor startup	– Dynamic simulation in the time range
	Dynamic network simulation	– Investigation of system response to dynamic processes
CALPOS® –	Ramses	– Determination of reliability quantities in networks
CALPOS® –	Main	– Determining an optimum maintenance strategy for installation equipment

6.1.2 Planning of high-voltage installations

The following criteria must be considered when planning high-voltage switchgear installations:

Voltage levels

High-voltage installations are primarily for power transmission, but they are also used for distribution and for coupling power supplies in three-phase and HVDC systems. Factors determining their use include network configuration, voltage, power, distance, environmental considerations and type of consumer:

Distribution and urban networks	> 52 – 245 kV
Industrial centres	> 52 – 245 kV
Power plants and transformer stations	> 52 – 800 kV
Transmission and grid networks	245 – 800 kV
HVDC transmission and system interties	> 300 kV
Railway substations	123 – 245 kV

Plant concept, configuration

The circuitry of an installation is specified in the single-phase block diagram as the basis for all further planning stages. Table 6-3 shows the advantages and disadvantages of some major station concepts. For more details and circuit configurations, see Section 11.1.2.

The availability of a switching station is determined mainly by:

– circuit configuration, i. e. the number of possibilities of linking the network nodes via circuit-breakers and isolators, in other words the amount of current path redundancy,

– reliability/failure rate of the principal components such as circuit-breakers, isolators and busbars,

– maintenance intervals and repair times for the principal components.

Table 6-3

Comparison of important busbar concepts for high-voltage installations

Concept configuration	Advantages	Disadvantages
Single busbar	– least cost	– BB fault causes complete station outage – maintenance difficult – no station extensions without disconnecting the installation – for use only where loads can be disconnected or supplied from elsewhere
Single busbar with bypass	– low cost – each breaker accessible for maintenance without disconnecting	– extra breaker for bypass tie – BB fault or any breaker fault causes complete station outage
Double busbar with one circuit-breaker per branch	– high changeover flexibility with two busbars of equal merit – each busbar can be isolated for maintenance – each branch can be connected to each bus with tie breaker and BB isolator without interruption	– extra breaker for coupling – BB protection disconnects all branches connected with the faulty bus – fault at branch breaker disconnects all branches on the affected busbar – fault at tie breaker causes complete station outage
2-breaker system	– each branch has two circuit-breakers – connection possible to either busbar – each breaker can be serviced without disconnecting the branch – high availability	– most expensive method – breaker defect causes half the branches to drop out if they are not connected to both bus bars – branch circuits to be considered in protection system; applies also to other multiple-breaker concepts

(continued)

Table 6-3 (continued)

Comparison of important busbar concepts for high-voltage installations

Concept configuration	Advantages	Disadvantages
Ring bus	– low cost – each breaker can be maintained without disconnecting load – only one breaker needed per branch – no main busbar required – each branch connected to network by two breakers – all changeover switching done with circuit-breakers	– breaker maintenance and any faults interrupt the ring – potential draw-off necessary in all branches – little scope for changeover switching
1½-breaker system	– great operational flexibility – high availability – breaker fault on the busbar side disconnects only one branch – each bus can be isolated at any time – all switching operations executed with circuit-breakers – changeover switching is easy, without using isolators – BB fault does not lead to branch disconnections	– three circuit-breakers required for two branches – greater outlay for protection and auto-reclosure, as the middle breaker must respond independently in the direction of both feeders

Dimensioning

On the basis of the selected voltage level and station concept, the distribution of power and current is checked and the currents occurring in the various parts of the station under normal and short-circuit conditions are determined. The basis for dimensioning the station and its components is defined in respect of

– insulation coordination
– clearances, safety measures
– protection scheme
– thermal and mechanical stresses

For these, see Sections 3, 4, and 5.

Basic designs and constructions

The basic designs available for switching stations and equipment together with different forms of construction offer a wide range of possibilities, see Table 6-4. The choice depends on environmental conditions and also constructional, operational and economic considerations.

For further details, see Sections 10 and 11.

Table 6-4

The principal types of design for high-voltage switchgear installations and their location

Basic design	Insulating medium	Used mainly for voltage level (kV)	Location Outdoor	Location Indoor
Conventional	Air	>52 – 123	×	×
Conventional	Air	123 – 800	×	
GIS	SF_6	>52 – 800	× [1]	×
Hybrid[2]	Air/SF_6	245 – 500	×	

[1] GIS used outdoors in special cases

[2] Hybrid principle offers economical solutions for station conversion, expansion or upgrading, see Section 11.4.2.2.

There are various layouts for optimizing the operation and space use of conventional outdoor switchgear installations (switchyards), with different arrangement schemes of busbars and disconnectors, see Section 11.3.3

6.1.3 Project planning of medium-voltage installations

Medium-voltage networks carry electrical energy to the vicinity of consumers. In public networks (electrical utility networks), they carry the power to local and private substations. In industrial and power station auxillary systems, larger motorized consumers are directly connected as well as the low-voltage consumers.

Most common voltage levels for medium-voltage networks (in Germany):

Electrical utility networks:	10 kV, 20 kV, (30 kV),
Industrial and power station service networks:	6 kV, 10 kV.

Industrial and power station service installations are primarily supplied by radial systems. Important installations are redundantly designed to meet the requirements regarding availability.

Characteristics of industrial and power station auxillary networks:

- high load density
- high proportion of motorized consumers
- occurrence of high short-circuit power.

Planning medium voltage distribution networks

Distribution networks have, in general, developed historically and as a result are frequently characterized by a high degree of meshing. The task of system planning is to design these networks to be simple and easy to comprehend.
In planning electrical networks, a distinction is made between operational structural planning and basic strategic planning. Basic planning covers the following points:

– Supply principles,
– Network concepts,
– Standard equipment,
– Standard installations.

The following forms of network are used with the corresponding switchgear installation configurations (DSS, ESS):

Ring network | Network with opposite station | Network with load-centre substation

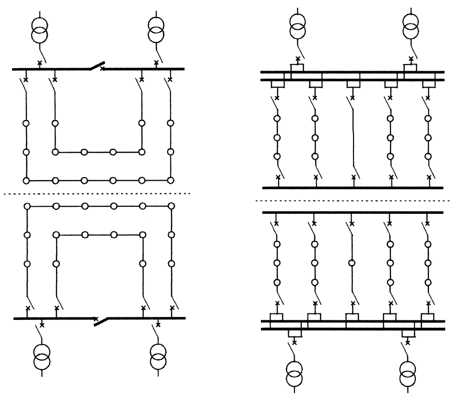


Fig. 6-1:

Networks in which the individual transformer substations on the medium-voltage side are not interconnected

Corresponding transformer substations

Corresponding transformer substations with opposite station

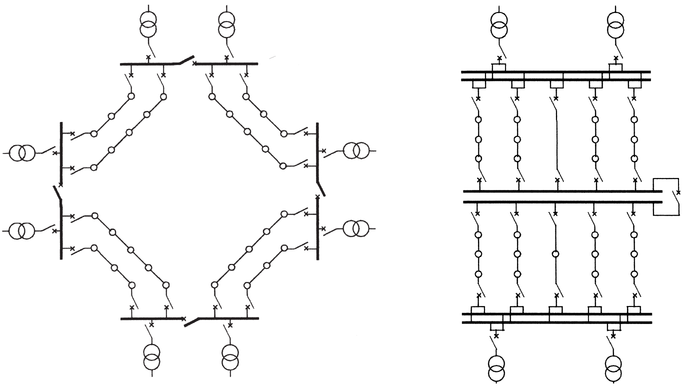


Fig. 6-2:

Networks in which the individual transformer substations on the medium-voltage side are interconnected

A simple protection concept can be implemented in radial networks. Troubleshooting in the event of a fault is much easier, particularly with single-phase faults.

An important aspect of system planning is the neutral treatment. Public distribution systems today are still mostly operated with earth fault compensation, with no tripping in the event of an earth fault. The low-resistance neutral earthing is available for selective breaking of single-phase faults. However, a new trend is to operate the networks with compensation and also to install short-time low-resistance neutral earthing (Kurzzeitige NiederOhmige SternPunktErdung, KNOSPE). The advantage of KNOSPE is its selective interception of earth faults without interruptions of power supply. The networks must be operated primarily as radial systems. Short-circuit indicators must be installed in the substations to allow selective fault location.

Planning medium-voltage switchgear

The standard structure of medium-voltage switchgear today is the factory-assembled type-tested switchgear installation conforming to DIN EN 60298 (VDE 0670 Part 6). The most common structural types are described in Section 8.2.

The most important distinguishing characteristics of the currently available structural types and the associated decision-making criteria are:

Distinguishing characteristics		Technical decision-making criteria
Low costs	Higher costs	—
Single busbars	Double busbars	Network concept
Air-insulated	Gas-insulated	Dimensions of the installation environmental conditions (contamination, moisture, service requirements, cleaning)
Cubile	Metal-clad	Personnel safety during wiring work Restriction of damage in the event of internal arcing (if compartmentalization is designed for this)
Switch disconnector installation type	Circuit-breaker installation type	Rating data – Short-circuit currents – Operating currents – Switching frequency Protection concept

6.1.4 Planning of low-voltage installations

Low-voltage installations are usually near the consumer and generally accessible, so they can be particularly dangerous if not installed properly.

The choice of network configuration and related safety measures is of crucial importance. The availability of electricity is equally dependent on these considerations.

Table 6-5 compares the advantages and disadvantages of commonly used network configurations, see also Section 5.1.

Another important step in the planning of low-voltage switchgear installations consists of drawing up a power balance for each distribution point. Here, one needs to consider the following:

– nominal power requirement of consumers,
– short-time power requirement (e.g. motor startup),
– load variations.

The IEC recommendations and DIN VDE standards give no guidance on these factors and point out the individual aspects of each installation.

For power plants and industrial installations, the circumstances must be investigated separately in each case.

The following Tables 6-5 and 6-6 are intended as a planner's guide. The planners can use the information in Table 6-6 for reference.The total power is derived from the sum of the installed individual power consumers multiplied by the requirement factor with the formula:

$$P_{max} = \Sigma Pi \cdot g$$

P_{max} = power requirement
Pi = installed individual power producer
g = requirement factor

Table 6-5

Summary of network configurations and protection measures for low-voltage installations

System[1)]	Advantages	Disadvantages	Main application
TN system	Fast disconnection of fault or short circuit. Least danger for people and property.	High cost of wiring and cable due to protective conductors. Any fault interrupts operations.	Power plants, public power supply and networks.
TT system	Less wiring and cable required. Zones with different touch voltages permitted. Can be combined with TN networks.	Complex operational earthing ($\leq 2\ \Omega$). Equipotential bonding necessary for each building.	Livestock farming.
IT system	Less expensive in respect of wiring and cables. Higher availability: 1st fault is only signalled, 2nd fault is disconnected.	Equipment must be insulated throughout for the voltage between the outside conductors. Equipotential bonding necessary.	Hospitals Industry.
Total insulation	Maximum safety. Can be combined with other networks.	Equipment doubly insulated, economical only for small consumers. With heat-generating loads, insulation constitutes fire hazard.	Residential, small-scale switchboards and equipment
Safety extra-low voltage Functional extra-low voltage	No dangerous touch voltages.	Limited power with cost-effective equipment use. Special requirements for circuitry.	Small apparatus.

[1)] For definitions and block diagram of the systems, see Section 5.1.2

Table 6-6

Demand factor g for main infeed of different electrical installations

Type of installation or building	Demand factor *g* for main infeed	Remarks
Residential buildings		
Houses	0.4	Apply *g* to average use per dwelling.
Blocks of flats		Total demand = heating + a.c. + general.
– general demand (excl. elec. heating)	0.6 typical	
– electric heating and air-conditioning	0.8 to 1.0	
Public buildings		
Hotels, etc	0.6 to 0.8	Power demand strongly influenced by climate, e.g.
Small offices	0.5 to 0.7	– in tropics high demand for air-conditioning
Large offices (banks, insurance companies, public administration)	0.7 to 0.8	– in arctic high heating demand
Shops	0.5 to 0.7	
Department stores	0.7 to 0.9	
Schools, etc.	0.6 to 0.7	
Hospitals	0.5 to 0.75	
Places of assembly (stadiums, theatres, restaurants, churches)	0.6 to 0.8	
Railway stations, airports, etc.	no general figure	Power demand strongly influenced by facilities
Mechanical engineering		
Metalworking	0.25	Elec. drives often generously sized.
Car manufacture	0.25	
Pulp and paper mills	0.5 to 0.7	*g* depends very much on standby drives.
Textile industry		
Spinning mills	0.75	
Weaving mills, finishing	0.6 to 0.7	
Miscellaneous Industries		
Timber industry	0.6 to 0.7	
Rubber industry	0.6 to 0.7	
Leather industry	0.6 to 0.7	
Chemical Industry } **Petroleum Industry** }	0.5 to 0.7	Infeed must be generously sized owing to sensitivity of chemical production processes to power failures.
Cement works	0.8 to 0.9	Output about 3500 t/day with 500 motors. (Large mills with h.v. motor drives.)
Food Industry	0.7 to 0.9	
Silos	0.8 to 0.9	
Mining		
Hard coal		
Underground working	1	
Processing	0.8 to 1	
Brown coal		
General	0.7	
Underground working	0.8	

(continued)

Table 6-6 (continued)

Demand factor g for main infeed of different electrical installations

Type of installation or building	Demand factor *g* for main infeed	Remarks
Iron and steel industry		
(blast furnaces, convertors)		
Blowers	0.8 to 0.9	
Auxiliary drives	0.5	
Rolling mills		
General	0.5 to 0.8[1)]	[1)] *g* depends on number of standby drives.
Water supply, Ventilation	0.8 to 0.9[1)]	
Aux. drives for		
– mill train with cooling table	0.5 to 0.7[1)]	
– mill train with looper	0.6 to 0.8[1)]	
– mill train with cooling table and looper	0.3 to 0.5[1)]	
Finishing mills	0.2 to 0.6[1)]	
Floating docks		
Pumps during lifting	0.9	Pumping and repair work do not occur simultaneously.
Repair work without pumps	0.5	
Lighting for road tunnels	1	
Traffic systems	1	Escalators, tunnel ventilation, traffic lights
Power generation		
Power plants in general		
– low-voltage station services	no general figure	
– emergency supplies	1	
Nuclear power plants		
– special needs, e.g. pipe heating, sodium circuit	1	
Cranes	0.7 per crane	Cranes operate on short-time: power requirements depend on operation mode (ports, rolling mills, ship-yards) .
Lifts	0.5 varying widely with time of day	Design voltage drop for simultaneous startup of several lifts

The *type of construction* depends on the station's importance and use (required availability), local environmental conditions and electromechanical stresses.

Construction	Main application
Type-tested draw-out switchgear	Main switching stations Emergency power distribution Motor control centres
Type-tested fixed-mounted switchgear	Substations a.c./d.c. services for h.v. stations Load centres
Cubicles or racks	Light/power switchboards Load centres
Box design	Local distribution, Miniature switchboards

The short-circuit currents must be calculated in terms of project planning activity, the equipment selected in accordance with thermal stresses and the power cable ratings defined. See also Sections 3.2, 7.1 and 13.2. Particularly *important is the selectivity* of the overload and short-circuit protection.

Selective protection means that a fault due to overloading or a short circuit is interrupted by the nearest located switchgear apparatus. Only then can the intact part of the system continue to operate. This is done by suitably grading the current/time characteristics of the protection devices, see also Sections 7.1.4,14.3 and 15.4. The choice of relays can be difficult if account has to be taken of operating conditions with powerful mains infeeds and comparatively weak standby power sources. In some cases changeover secondary protective devices have to be provided.

6.1.5 Calculation of short-circuit currents, computer-aided

A knowledge of the expected short-circuit currents in an installation is essential to the correct selection of the switching stations and the line-side connected networks. The methods of calculation are described in chapter 3.

The upper limit value of these fault currents determines:
- power ratings of the circuit-breaker,
- mechanical design of the installation,
- thermal design of the equipment,
- electrical design and configuration of earthing systems,
- maximum permissible interference in telecommunications systems.

The lower limit value of these fault currents determines:
- protective relays and their settings.

The calculation of short-circuit currents therefore helps to solve the following problems:
- dimensioning of equipment on the basis of (dynamic) stresses on closing and opening and also the thermal stress,
- designing the network protection system,
- questions of compensation and earthing,
- interference problems (e.g. in relation to telecommunications lines).

The CALPOS computer program enables simple but comprehensive calculation of short-circuit currents. It takes account of:
– different switching conditions of the installation,
– emergency operation,
– cold and hot states of the cable network,
– contribution of motors to short-circuit currents.

The program output provides the short-circuit currents at the fault location and in the branches

a) for the transient phase after occurrence of the fault:
– initial symmetrical short-circuit current I''_k,
– peak short-circuit current i_p,
– symmetrical short-circuit breaking current I_a.

b) for the steady-state phase after occurrence of the fault:
– sustained short-circuit current I_k,
– short-circuit powers S''_k,
– voltages at the nodes.

The results can be printed out both as phase values (L1, L2, L3) and as component values (1, 0, 2).

The comprehensive graphic functions offered by Calpos enable phase fault results to be displayed and plotted on the monitor as well as the network topology, see Fig. 6-3. The user creates and edits the graphic network display interactively with the mouse or the digitizing tablet. The calculation as done by the program closely follows the method described in Section 3.3 according to DIN VDE 0102/IEC 60909.

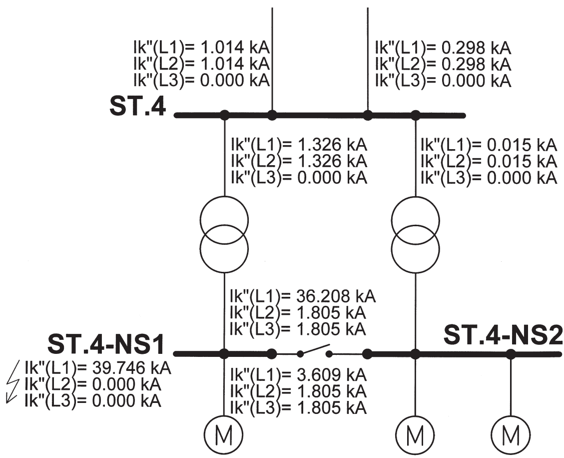


Fig. 6-3

Example of graphic output (plot) of a computer-supported short-circuit current calculation (partial section) done with the CALPOS program.

6.1.6 Calculation of cable cross-sections, computer-aided

Before the cross-sections of cables between the switchgear and their connected loads are finalized, they must be calculated in relation to the operating conditions and cable length.

Factors influencing the cross-section in this calculation are:

- permitted loadings under normal conditions, taking into account ambient temperatures and methods of laying,
- thermal short-circuit strength,
- permitted voltage drop along the cable run under normal conditions, and also during the starting phase when feeding motors,
- response of protective devices in the event of overloads and the smallest possible short-circuit current to interrupt dangerous touch voltages.

The ABB-developed LEIOP computer program and the matching Calpos module makes it possible to carry out this comprehensive calculation for every current circuit. By entering the circuit data, such as operating current, max. and min. short-circuit current, tripping currents/times of the protective devices and maximum permitted voltage drops, the program selects the appropriate minimum cross-section for the considered cable length. With the aid of program parameters, the range of cable types to be used can be limited, and a choice provided of the number of parallel cables for a given cable cross section. The method of calculation is in accordance with DIN VDE 0100, VDE 0276 and the respective cable manufacturer's data.

6.1.7 Planning of cable routing, computer-aided

The routing of cables in complex industrial installations, power plants and switching stations requires a great deal of work on the part of the planner. It involves arranging the cables to give the shortest path between their starting point and destination, while at the same time ensuring that certain combinations do not adversely influence each other.

The ABB program LEIOP offers very effective support here. It can provide data on the following:

- Cable lists
- Cable quantities incl. fittings (number of terminal ends, individual cable lengths)
- Cable markings
- Information on cable installation
- Information on tailoring cables for racks, trenches and conduit

6.2 Reference designations and preparation of documents

Two important series of standards in the last few years have guided the rules for the reference designation of equipment and the preparation of circuit documents. The symbols for individual equipments are specified in the series DIN 40900, and the series DIN 40719 regulates reference designation and representation.

The two series of standards have been or are being superseded due to international standardization in the IEC. DIN 40900 has been replaced by the series DIN EN 60617. The changes are minor, because DIN 40900 was already based on an earlier version of the international standard IEC 60617. The new revision corrects errors and includes essential supplementary symbols. The most important parts of DIN 40719 were superseded by DIN EN 61082 in 1996/97. Part 2 of DIN 40719, which covers the identification of electrical equipment, and Part 6, covering the area of function charts, are still applicable for Germany. The structure of reference designation systematics has been fundamentally revised on an international level. With the publication of DIN EN 61346-1, the first part – the basic rules – has already appeared. Part 2 with the important tables of code letters is currently in preparation. DIN 40719 Part 2 will remain in force until the German version is published. In the following section, the current designation systematics practice is reproduced virtually unchanged from the 9th edition, because this system is still used for extensions and for running projects. Section 6.2.4 gives an overview of future developments in reference designation systematics, in accordance with the new international standard IEC 61346.

6.2.1 Item designation of electrical equipment as per DIN 40719 Part 2

Four designation blocks are available to identify every single device (equipment) in the plant and in the circuit diagrams. They are distinguished by prefix signs.

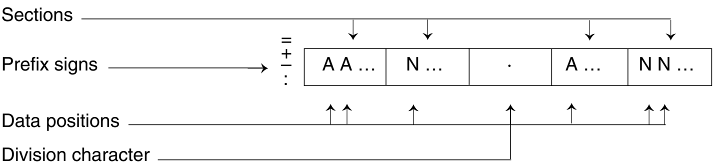
Prefix signs	Designation block
=	Higher level designation
+	Location of item
–	Type, number, function of the item
:	Terminal designation

Each designation block consists of a sequence of alphanumeric characters. It is divided into sections and each section into data positions. These signify:
A – an alphabetic data position (letter),
N – a numerical data position (digit).

Defined for each designation block are:

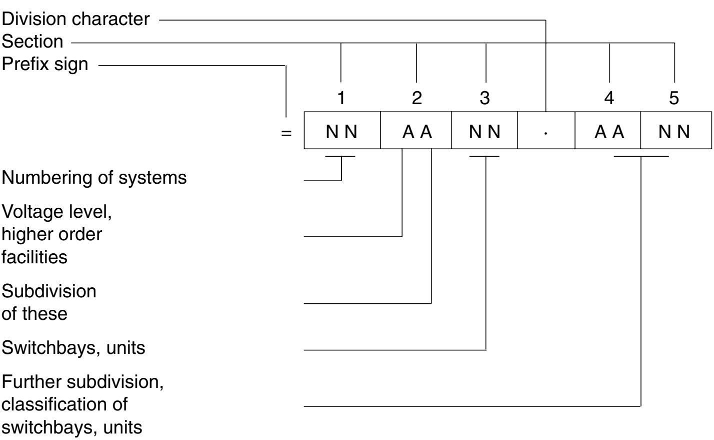
– the prefix signs,
– the maximum number of sections,
– the maximum number of data positions per section,
– the meaning of specific data positions in individual sections,
– whether and where an designation block is to be subdivided by the division character of a full stop (.) in order to split up its contents and make it easier to read.

The general structure of the four designation blocks is therefore as follows:



Designation block 'higher level'

The designation block for 'higher level' consists of five sections and is split between sections 3 and 4 by the division character (.). It begins on the left with the largest system component, and ends on the right with the smallest.

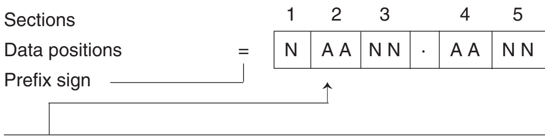


6

The meanings of the alphabetical data positions in section 2 are defined in the standard and can be seen in Tables 6-7 and 6-8.

Table 6-7

Letters for identifying voltage level in the designation block ‘higher level assignment’, 2nd section, 1st alphabetical data position (as Table C7 of DIN 40 719 Part 2).

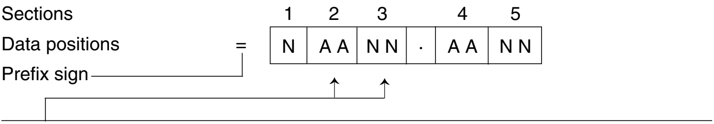


Identifying letter	System	
A	–	
B	> 420 kV	
C	380 kV to 420 kV	
D	220 kV to < 380 kV	
E	110 kV to < 220 kV	
F	60 kV to < 110 kV	
G	45 kV to < 60 kV	
H	30 kV to < 45 kV	
J	20 kV to < 30 kV	
K	10 kV to < 20 kV	
L	6 kV to < 10 kV	
M	1 kV to < 6 kV	
N	< 1 kV	
P	–	
Q	Facilities for measuring and metering	Facilities and systems not specifically referring to a branch or voltage (Q to Y)
R	Facilities for protection	
S	–	
T	Facilities for transformers	
U	Facilities for control, signalling and auxiliary equipment	
V	–	
W	Facilities for control rooms	
X	Central facilities, e g process computers, alarm systems	
Y	Facilities for telecommunications	
Z	–	

Note: The letters A to N for voltage level are the same as in Table 6-9, but there they are used for a different identification purpose.

Table 6-8

Letters for identifying voltage levels < 1 kV in designation block ‘higher level assignments’, 2nd section, 2nd alphabetical data position when the letter N is defined for the first alphabetical data position in *Table 6-7* (as Table C9 of DIN 40719 Part 2)



Identifying letter	Meaning
N	Systems < 1 kV
NA	AC 500 to 1000 V
NB	AC 500 to 1000 V
NC	AC 500 to 1000 V
ND	–
NE	AC 400/230 V
NF	AC 400/230 V
NG	AC 400/230 V
NH	AC 400/230 V
NJ	–
NK	DC 220/110 V
NL	DC 220/110 V
NM	DC 220/110 V
NN	DC 220/110 V
NP	–
NQ	DC 60/48 V
NR	DC 60/48 V
NS	DC 60/48 V
NT	–
NU	DC 24/12 V
NV	DC 24/12 V
NW	DC 24/12 V
NX	–
NY	–
NZ	–

Designation block ‘location’

The ‘location’ designation block is qualified by a plus sign (+) and indicates where an item of equipment is situated, e.g. topographical site: building, room, cubicle, rack and position.
The designation block is divided into six sections:

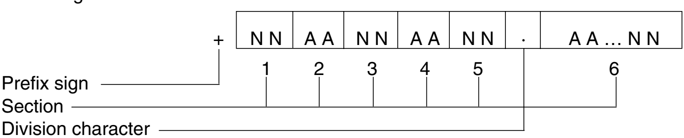


Table 6-9

Letters for identifying locations in designation block ‘location’, 4th section, 1st alphabetical data position (as Table C10 of DIN 40719 Part 2)

		1	2	3	4	5		6
Sections		1	2	3	4	5		6
Data positions	+	N N	A A	N N	A A	N N	·	A A … N N
Prefix sign	+							

Identifying letter	Meaning
A	–
B	> 420 kV
C	380 to 420 kV
D	220 to < 380 kV
E	110 to < 220 kV
F	60 to < 110 kV
G	45 to < 60 kV
H	30 to < 45 kV
J	20 to < 30 kV
K	10 to < 20 kV
L	6 to < 10 kV
M	1 to < 6 kV
N	< 1 kV bays
P	Desks
Q	Boards and cubicles for measuring and metering
R	Boards and cubicles for protective devices
S	Boards and cubicles decentralized
T	Boards and cubicles for transformers
U	Boards and cubicles for control, signalling and auxiliary systems
V	Marshalling cubicles
W	Control room board
X	Boards and cubicles for central facilities, e. g. alarm systems and process computers
Y	Boards and cubicles for telecommunications
Z	–

Application: The letters A to N for voltage level are the same as in Table 6-7, but there they are used for a different identificatiaon purpose.

The designation block begins on the left with the unit of largest volume or construction, and ends on the right with the smallest.
The designation block can be subdivided by the division charakter (·) between sections 5 and 6.
To the left of the division character is information on the location (building, room, row, etc.) and the nature of the structural unit (bay, cubicle, rack).
To the right of the division character in section 6 is information on the position (row, column, etc.) of an item of equipment within the structural unit. Section 6 may have up to eight data positions (letters and numbers in any sequence).
The meanings of the alphabetical data positions in section 4 are shown in Tables 6-9

Table 6-10

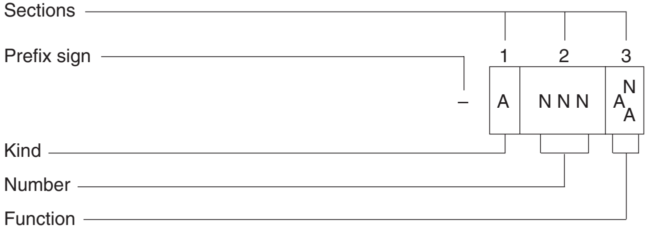
Letters for identifying application in designation block 'location', 4th section, 2nd alphabetical data position (as *Table C11* of DIN 40719, Part 2)

Sections		1	2	3	4	5		6
Data positions	+	N N	A A	N N	A A	N N	·	A A … N N
Prefix sign								

Identifying letter	Meaning
A	Circuit-breaker accessories
B	Multiply, re-position, decouple
C	Instrument transformer accessories
D	Compressed air, hydraulics
E	–
F	–
G	–
H	–
J	Automatic, closed-loop control
K	–
L	Simulating network, voltage selection
M	Measurement
N	System services
P	Recorder
Q	Metering
R	Protection
S	Synchronizing
T	Transformers
U	Auxiliaries
V	Main, secondary busbars etc.
W	Display, operation, supervision
X	Alarm system
Y	–
Z	–

Designation block 'identification of item'

The designation block for 'identification of item' is qualified by a hyphen (–) and consists of three sections.
Specified for the data positions in this designation block are the following symbols (letters and numbers) in the order given.



Section 1 identifies the kind of item as in Table 6-11.

Section 2 states the number of the equipment. Each item of equipment must be identified by a number of one to three digits.

Items of different kinds that belong together should be given the same number.

DIN 40719 Part 2 gives rules for the numbering of items in high-voltage switchgear installations, a distinction being made between numbers for

– switchgear in the main circuits (Table 6-12a)
– auxiliary devices which can be assigned to the switchgear in the main circuits (Table 6-12b)
– current and voltage transformers in the main circuits (Table 6-13)
– equipment which is specific to a branch but cannot be assigned to the main switchgear (Table 6-14).

If necessary, the function of an item of equipment can be identified in section 3. The following letters are specified for the alphabetical data position:
A – OFF function
E – ON function
L – conductor identification

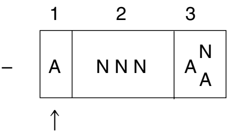
The other letters can be chosen arbitrarily.

The second data position for further subdivision/numbering can be occupied by an additional, arbitrarily chosen letter or number.

In the case of conductor identification, a distinction is made between a neutral identity LA, LB, LC and an identity assignable to the conductors L1, L2, L3. If neutral conductor identification is used, its assignment to L1, L2 and L3 must be stated in the circuit documentation.

Table 6- 11

Letters for identifying the kind of item *(as Table 1* of DIN 40719 Part 2)



Letter code	Kind of item
A	Assemblies, subassemblies
B	Conversion from non-electrical to electrical quantities and vice versa
C	Capacitors
D	Binary elements, delay devices, storage devices
E	Miscellaneous
F	Protection devices
G	Generators, power supply systems
H	Signalling systems
J	–
K	Relays, contactors
L	Inductors, reactors
M	Motors
N	Analogue elements as amplifiers, controllers
P	Measuring instruments, testing devices
Q	Switching devices for power circuits
R	Resistors
S	Switching devices for control circuits, selectors
T	Transformers
U	Modulators, converters from one electrical quantity to another
V	Tubes, semiconductors
W	Transmission paths, cables, busbars, hollow conductors, antennas
X	Terminals, plugs, sockets
Y	Electrically operated mechanical devices
Z	Terminations, bifurcations, filters, equalizers, limiters, balancing devices, bifurcation terminations

Table 6-12

Designation block ‘identification of item’

Table 6-12a (taken from *Table* C3 of DIN 40719 Part 2). Number for the designation of switchgear in the main current circuit in the title block “Type, number, function”, 2nd section, 1st and 2nd numeric data position.

	1	2	3
–	A	N N N	A N N

If in the 1st section, the letter “Q” as in *Table 6-11* is used for switchgear in the main circuit.

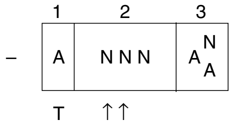
Table 6-12b (taken from *Table C4* of DIN 40 719 Part 2). Number for the designation of auxiliary devices that can be associated with the switchgear as in Table 6-12a in the title block “Type, number, function”, 2nd section, 1st and 2nd numeric data position.

	1	2	3
–	A	N N N	A N A

Kind of item	Designation	Control-discrepancy switch	Control button open	Control button closed
Circuit-breakers				
General	Q 0	S 0	S 0A	S 0E
1st circuit-breaker	Q01	S01	S01A	S01E
2nd circuit-breaker	Q02	S02	S02A	S02E
Bus system I				
Bus disconnector	Q 1	S 1	S 1A	S 1E
Bus-coupler disconnector, 2nd disconnector	Q10	S10	S10A	S10E
Bus sectionalizer	Q11…14	S11…14	S11…14	S11E…14E
Bus-earthing switch	Q15…19	S15…19	S15A…19A	S15E…19E
Maintenance earthing sw.				
General	Q 5	S 5	S 5A	S 5E
1st maint. earthing sw.	Q51	S51	S51A	S51E
2nd maint. earthing sw.	Q52	S52	S52A	S52E
Freely available neutral earthing switch, test disconnector	Q 6	S 6	S 6A	S 6E
Bypass bus				
Disconnector	Q 7	S 7	S 7A	S 7E
2nd disconnector	Q70	S70	S70A	S70E
Sectionalizer	Q71…74	S71…74	S71A…74A	S71E…74E
Earthing switch	Q75…79	S75…79	S75A…79A	S75E…79E
Earthing switches				
General	Q 8	S 8	S 8A	S 8E
1st earthing switch	Q81	S81	S81A	S81E
2nd earthing switch	Q82	S82	S82A	S82E
Feeder disconnector				
General	Q 9	S 9	S 9A	S 9E
1st feeder disconnector	Q91	S91	S91A	S91E
2nd feeder disconnector	Q92	S92	S92A	S92E

Table 6-13

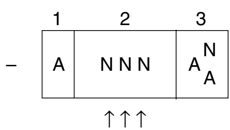
Number for identifying the application in designation block ‘identification’, 2nd section, 1st and 2nd numerical data position (as Table C5 of DIN 40 719 Part 2) if the letter “T” as in Table 5 is used in the section for instrument transformers in the main circuits.



Instrument transformers Kind of item	Designation	Kind of item	Designation
Current transformers		Voltage transformers	
Feeder transformers	T 1 to 4	Feeder transformers	T 5 to 9
Transformer bus I	T11 to 14	Transformer bus I	T15 to 19
Transformer bus II	T21 to 24	Transformer bus II	T25 to 29
Transformer bus III	T31 to 34	Transformer bus III	T35 to 39
Transformer bus IV	T41 to 44	Transformer bus IV	T45 to 49
Cable-type transformers			
General	T90		
1st transformer	T91		
2nd transformer	T92		

Table 6-14

Number for identifying purpose of non-assignable feeder-related auxiliaries in designation block ‘identification’, 2nd section, 1st, 2nd and 3rd numerical data position (as Table C6 of DIN 40719 Part 2)



Identifying letter as *Table 6-11,* three-digit number

Recommended categories for the three-digit number:
100 to 199 Station services 200 to 299 Control 300 to 399 Protection 400 to 499 Measurement from 500 arbitrary use
The number of auxiliaries in higher-order facilities and within branch-related combinations can be chosen at will.

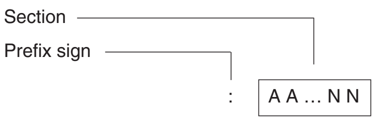
Composite items

To identify an item of equipment forming part of higher level equipment (composite item), the identifying designation blocks are arranged in sequence with the higher level equipment at the left. In the case of composite items, each item is given its own identity and the prefix sign of a hyphen (–) is repeated for each item, e.g. –QO-Y1 for a circuit-breaker –QO containing a tripping coil –Y1.

The numbers for equipment forming part of higher level equipment can be chosen arbitrarily, e.g. equipment in disconnector operating mechanisms, circuit-breakers, combinations, truck-mounted assemblies.

Designation block 'terminal'

The 'terminal' designation block has the prefix sign of a colon (:) and consists of one section.



The designation block contains the terminal identifications as stated on the equipment.

6.2.2 Preparation of documents

As per DIN EN 61082, “document” is defined as “information on a data medium”; “documentation” as:

– collection of documents related to a given subject, and
– processing of documents.

The “standard” classification for documents in electrical engineering as per DIN 40719 distinguishes between a) purpose and b) type of representation. The most important parts of DIN 40719 were superseded by DIN EN 61082 in 1996. This standard is a direct translation of the international standard IEC 61082 “Preparation of documents used in electrotechnology”. Document classification is also covered here – including new terms in some cases. The following definitions of the new standard can be assigned to the term “purpose” in the old standard without problems:

– Function oriented documents
– Location documents
– Connection documents
– Item lists
– Installation-specific documents
– Other documents
– Commissioning-specific documents
– Operation-specific documents
– Maintenance-specific documents
– Reliability and maintainability-specific documents

Regarding the “type of representation”, the new standard distinguishes the following types:

– Attached representation
– Semi-attached representation
– Detached representation
– Repeated representation
– Grouped representation
– Dispersed representation
– Multi-line representation
– Single-line representation

A distinction is also made between a “functional oriented layout” and a “topographical oriented layout” in the types of representations for circuit diagrams.

An important change from the former practice as per DIN 40719 is the strict separation of title block data and information on the reference designation (formerly equipment identification). Common designation blocks for represented equipment may no longer be given in the title block. Only data relevant to the document itself is given here now. Higher-order parts of the reference designation must be given at the specified positions in the drawing field (e.g. top left of the circuit diagram).

The following definitions from DIN 61082 / IEC 61082 and descriptions are given for some documents – important for substation engineering.

Overview diagram
An overview diagram is a relatively simple diagram often using single-line representation, showing the main interrelations or connections among the items within a system, subsystem, installation, part, equipment or software (Fig. 6-4).
The overview diagram of a switchgear should include, as the minimum information, the reference designation of the station components and of the equipment represented and also the most important technical data. The designation and cross-references to documents of a lower level should also be included.

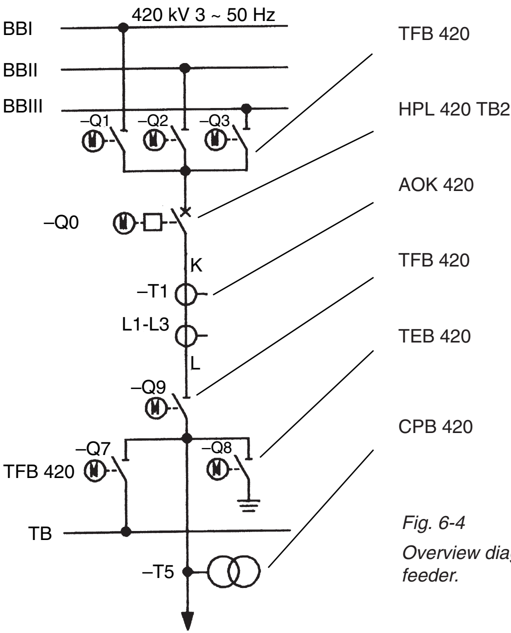


Fig. 6-4
Overview diagram of a 420 kV feeder.

Function chart
A function chart is a diagram that describes the functions and behaviour of a control or regulation system using steps and transitions.

Circuit diagram
The circuit diagram is the diagram that shows the circuits of a functional or structural unit or an installation as they are implemented. The parts and connections are represented by graphical symbols. Their configuration must show the function. The size, shape and location of the equipment does not need to be considered (Fig. 6-5).

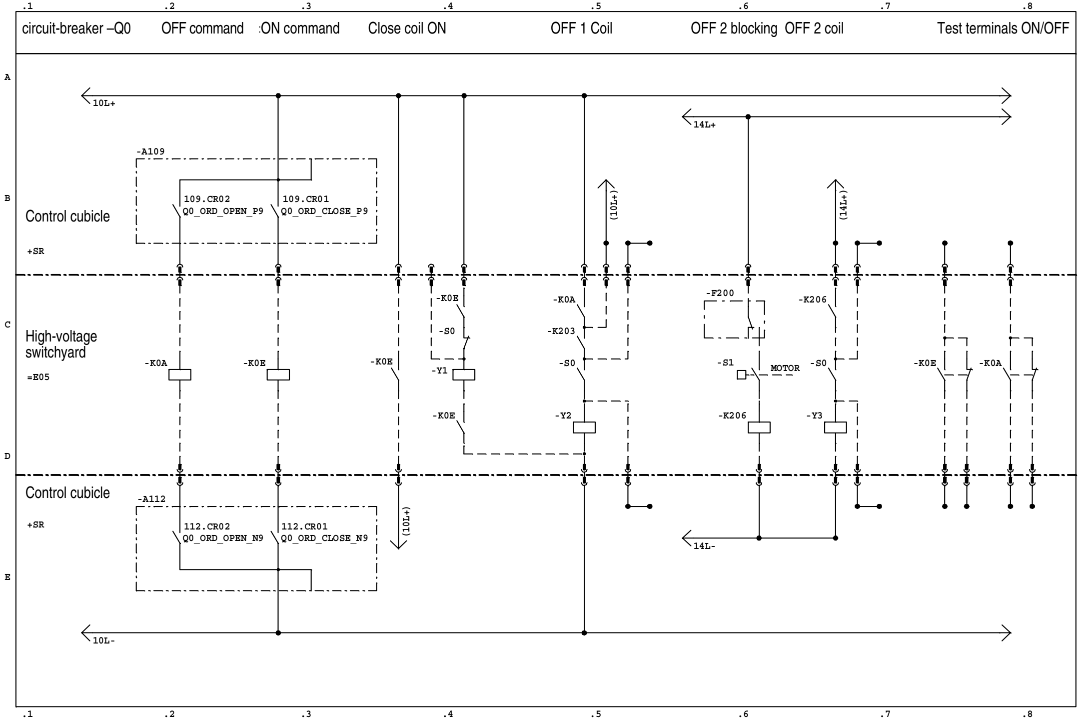


Fig. 6-5
Circuit diagram

The circuit diagram for a feeder or a functional unit is generally subdivided into function groups, such as control, position indication, interlocking, alarm, synchronization, protection, measuring etc. Above the current path, a short description of the represented subfunction using keywords is useful. The most important part of the circuit diagram is the information on following circuits or signals and notes on further representations.

Terminal function diagram
A circuit diagram for a functional unit, which shows the terminals for the interface connection and describes the internal functions. The internal functions may be shown or described in simplified form.

Arrangement drawing
A drawing showing the location and/or the physical implementation of a group of associated or assembled parts.

Terminal connection diagram
A diagram that shows the terminals of a construtional unit and the internal and/
or external connections.

6.2.3 Classification and designation of documents

The international standard IEC 61355 has the title "Classification and designation of documents for plants, systems and equipment". The goal of this standard is described as follows in its introduction:

> *One aim of this standard is to establish a method for better communication and understanding between parties involved in document interchange. In order to get a basis for a system, it is necessary to disregard, more or less, what a document is called today. Different names are in use for the same document kind or the names may have different meanings for different parties. The purpose and object of interest are sometimes also part of document titles, which hampers general understanding. Therefore the basis for a common understanding should be a classification scheme which is based only on the content of information.*
>
> *Another aim of this standard is to set up rules for relating documents to the objects they describe. For this purpose a document designation system is provided, linking the document kind designation to the object designation used within the plant, system or equipment. Following the rules and recommendations given, the documentation reflects the structure of the "real installation". By that also guidance is given for order and filing as well as for structured searching for information, for example in document retrieval systems.*

The principle of classification also covers the needs of computer-based documentation in general. An increasing amount of information will be stored and interchanged in a standardized data base format. The information to be delivered may be specified in such a way that each document kind required and agreed tby parties can be derived from that data base by the receiver's computer system.

This standard specifies a generally valid "Document kind Classification Code (DCC)" for the first time and explains it in a detailed table with examples – see the fields with grey background in the following table.
Documents are identified in accordance with the following scheme:

= + –	A .... N	&	A1	A2	A3	N	N	N	/	A	....	N

Object designation
Prefix sign
Identifying letters and numbers
Prefix sign
Counting numbers of sheets

The letter symbol "A1" stands for the Technical Area, e.g. "E" for electrotechnology; the letter symbol "A2" stands for the "Main Document Kind Class", e.g. "F" for function-describing documents; the letter symbol "A3" stands for the "Document Type Subclass", e.g. "S" for circuit diagram.
Object designation follows the rules of IEC 61346, and currently still DIN 40719-2. The page number after the prefix sign "/" has a maximum of six data spaces and can be formed by the customary procedure (e.g. "D" for power supply AC, or "N" for protection).
Table 6-15 shows examples of document kind classes from switchgear installation technology.

Table 6-15
Examples for documents in switchgear installations

Letter symbol 2nd & 3rd A position as per IEC 61355	Document kind; examples from switchgear installation technology
	Documentation describing documents
AA	Administrative documents: cover sheets, documentation structure, designation system
AB	Tables: lists of documents, lists of contents
	Management documents
B.	Document list, schedule, delivery list, training documentation, letters, memos
	General technical documents
DA	Dimension drawings, circuit diagrams for equipment
DC	Operating and maintenance instructions
	Technical requirements and dimensioning documents
E.	Environmental conditions, studies, calculations
	Function-describing documents
FA	Overview diagrams, network maps
FB	Flowcharts, block diagrams
FE	Function descriptions
FF	Function diagrams
FP	Signal descriptions, signal lists
FS	Circuit diagrams
FT	Software-specific documents
	Location documents
LD	Site plan, cable routing drawings, earthing plans, layouts, dispositions, sections
LH	Building plans
LU	Assembly drawings, arrangement drawings, equipment layout ˇˇ diagrams
	Connection-describing documents
MA	Terminal diagrams, connection diagrams, interconnection diagram
MB	Cable tables, cable lists
	Documents listing material
PA	Material lists (conduits, stranded wires, terminals, bolts ...)
PB	Parts lists, spare parts lists, lable lists
	Quality managment documents
QA	Test reports, test certifications, audit reports

6.2.4 Structural principles and reference designation as per IEC 61346

As noted in the introduction to Section 6.2, this section gives an outlook on the expected structural principles and reference designations in installations for energy distribution. The significance of this change from the former practice justifies this early explanation.

Formerly designation in installations was done with designation blocks and tables with a fixed arrangement for particular, specified data positions within the designation blocks. However, in future, the hierarchical structure will be in the foreground and at the centre. Hierarchical structures are characterized in that they build on "component relationships". The elements in a lower-order level in such a structure are always a complete component of the next higher level. The structure formed in this way can be depicted as a tree structure with nodes and branches (Fig. 6-6).

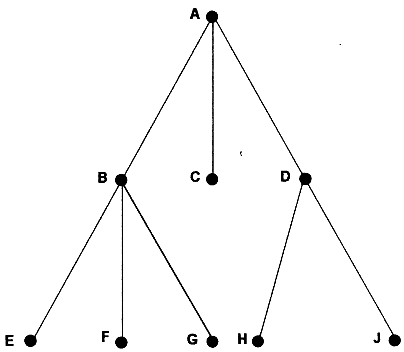


Fig. 6-6
Example of tree structure
B, C and D are components of A
E, F and G are components of B

The letters are for explanation only; they have nothing to do with any coding.

In its practical application for a switchgear installation, a structure will be implemented in accordance with the purpose under the following familiar classes: "association with voltage level" and "function". Every object considered in a hierarchical structure, in fact the entire structure, the entire system itself can be considered from various points of view, referred to as "aspects", e. g.:

- – what it does;
- – how it is constructed;
- – where it is located.

With reference to these three types of aspect, the new designation system distinguishes system structures under the following three views:

- – function-oriented structure;
- – product-oriented structure;
- – location-oriented structure.

Reference designations derived from this are identified with the allocated prefix signs "=", "–" and "+". Note the following: the functional identification "=" is used only for identifying pure functions, such as "= F" for "protection"; implementation with any product is not considered at this stage! An example of an application would be a neutral description independant of manufacturer as a request in a specification. In actual use this function might be implemented with, for example, the protection device "- F 312". Consultations have shown that it makes sense for equipment in installations of energy distribution to be designated under a product-based structure. Designation in the location-oriented structure "+" remains open for straight topographical information, such as waypoints, floors, room numbers, etc. The difference from the previous equipment designation is primarily that there is no combination of the designation blocks "=", "–" and "+".

An actuating element in a 380 kV control cubicle would for example be uniquely described with the reference identification **"– C3 – S1 – K1"** in the product-oriented structure.

6.3 CAD/CAE methods applied to switchgear engineering

The first CAD systems came on the market early in 1970. They were suitable for 2-dimensional design work, e.g. drafting circuit diagrams, circuit board layouts and simple design drawings. Now there is a wide variety of CAD workstations available, from low- to high-performance and all kinds of applications. Since 1970, CAD stations and methods have evolved into a powerful tool. This development process can be expected even to accelerate in coming years. The following section aims to explain the most important terms that have grown out of this new technology, and to give a general picture of the hardware and software systems employed. Attention is focused on the CAD methods used by ABB for switchgear engineering, together with examples.

6.3.1 Terminology, standards

Table 6-16 gives an outline of the principal CAD terms and their related fields of application.

Table 6-16

CAD terms, summary and applications

CIM	Computer-Integrated Manufacturing		
	CAE	Computer-Aided Engineering	
			Typical applications
		CAD Computer-Aided Design Computer-Aided Drafting	Design development; Preparation of drawings and calculation
		CAP Computer-Aided Planning	Production planning e.g. pricing and deployment
		CAM Computer-Aided Manufacturing	Production control e.g. parts lists, documentation for NC machines
	CAT	Computer-Aided Testing	Control of automatic testing; test reports

Depending on the degree of standardization, the solutions stored in the computer and the ability to help the designer find the right solution, CAD = Computer-Aided Drafting becomes a complete design system. By further processing of CAD data for manufacturing documents, production planning and testing, you can create a CAM or CIM system. Fig. 6-7 gives a general overview of the CAD areas in relation of the engineering and manufacturing, showing the possibilities for standardization in the preparation of circuit diagrams.

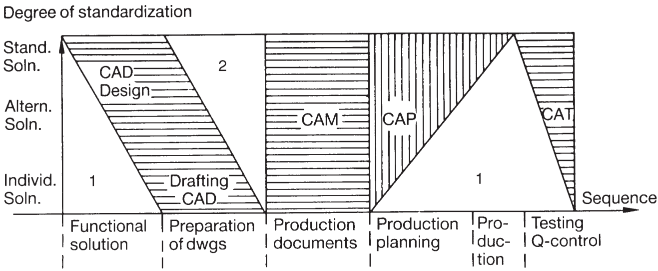


Fig. 6-7

Possibilities of standardization using CAD for producing circuit diagrams
hatching = CAD / CAE solutions
1 Preparatlon by hand, 2 Manual preparation is replaced by advancing use of CAE

Table 6-17

Overview of the most important CAD standards

Standard	Status	Working title
DIN V 40719 -1000	04/93	Rules for computer-supported creation of circuit diagrams
DIN EN 61355	11/97	Classification and identification of documents for installations, systems and equipment
DIN EN 61082-1 bis-4	*)	Documents of electrical engineering
DIN EN 61360-1, -2 und -4	*)	Standard data element types with associated classification scheme for electrical components
DIN EN 81714 -2	09/99	Generating graphic symbols for application in the documentation of products
DIN EN 60617-2 bis -13	*)	Graphic symbols for circuit diagrams

*) See Table 6-24

(continued)

Table 6-17 (continued)

Overview of the most important CAD standards

Standard	Status	Working title
DKE standard symbol file	04/96	Standard symbol file for graphic symbols according to DIN EN 60617 standards series based on DIN V 40900-100 and DIN V 40950
CAD-Lib		Standard library with standard mechanical parts
VDA-PS		FORTRAN interface for graphic design
IGES		Initial graphics exchange standard, interface for exchange of CAD data, emphasis in geometry
EDIF		Electronic data interface format for electrical engineering, emphasis on digital and analogue elements
DIN V 40950	08/92	Process-neutral interface for circuit-diagram data (VNS) Format for exchange of documentation of electrotechnical installations 2nd edition
ISO/IEC 10303		STEP Standard for the exchange of product-model data

In the last few years, the necessity of standards in the CAD area has been recognized at both national and international level. Table 6-17 contains an overview of the most important standards and drafts in the CAD area.

All interfaces are worked out at international level by the ISO (International Organization for Standardization) in TC 184 "STEP", with application models for the various applications being processed in special working groups.

6.3.2 Outline of hardware and software for CAD systems

A CAD station consists of a computer with its immediate peripherals such as disk and cassettes, the dialogue peripherals and the CAD output devices. Tables 6-18 to 6-21 show selection criteria and the capabilities of components for CAD systems. The CAD workstation today is a single working place with central data storage at a server in the network.

Table 6-18

CAD computer system with directly connected peripherals (without plotter);

Main processor of the CAD computer	Application	Peripheral
Personal computer with graphics processors	2D/3D	Magnetic disk Floppy disk CD drive
Workstation with graphics processors	2D/ 3D	Magnetic disk Cassette drive

Table 6-19 Input/output devices of CAD systems

	Input device	Output device	Graphics	Alpha-numeric
Digitizer	×		×	
Plotter		×	×	
Laser printer		×	×	×
Passive graphics terminal		×	×	
Interactive alphanumer. terminal	×	×		×
Interactive graphics workstation	×	×	×	×

Table 6- 20

Alternative hardware components of an interactive graphics CAD terminal

Graphics display unit	Coordinate positioning and input	Command input, alphanumeric
– refresh rate > 75 Hz mono/colour 15” to 19” diagonal 1024 x 768 pixels	– electronic stylus with menu tablet – mouse	– A/N keyboard – predefined fields on menu – allocation of function keys – command menu display on screen, selection mouse (windows method)

Table 6-21

The important graphics output devices

Plotter principle	Format size	Output, quality	Plot production time
Electrostatic plotter, drawing resolved into dots	Height A4 to A0 Length up to 10 m	Multicolour, quality very good	1 to 2 minutes
Ink-jet plotter, Ink spray nozzle	A4 to A0	Multicolour, filled-in areas, quality average	Up to 1 hr, depending on information volume
Microfilm plotter	Up to A0	Film, quality very good	Measured in seconds, up to 1 minute to A1/A0
Laser printer/plotter	A4 to A0	Multicolour, quality very good	Seconds to minutes

The performance of CAD systems depends not solely on the hardware, but to a very large degree on the software. While the hardware generally determines the response time and processing speed, the software influences the methodology and how the applications function.

The bottom rung in the software hierarchy is the operating system level, which is usually provided by the hardware supplier. The CAD software constitutes the user software and is the second level in the software hierarchy. This user software is usually divided into a general CAD-oriented part and a problem-oriented part which takes into account the particular criteria and boundary conditions of the engineering task in hand. A CAD system for switchgear engineering thus includes problem-oriented user software for tasks such as

– station layout and planning,
– planning of buildings,
– preparation of circuit diagrams,
– cable systems,
– mechanical design

The computer is able to generate either 2D or 3D models.

Here,
2D means representation in one plane.

3D means true working in three dimensions, showing views from different angles and perspectives. A distinction is made between edge or wire models, surface and volume models.

The objectives of introducing CAD methods are as follows:

– Improved quality of engineering solutions and drawing documentation,
– Time savings on individual steps and entire project,
– Flexible handling of modifications,
– Technically safe, common standard variants and repeating solutions,
– Comprehensive use of EDP by linking CAD, CAM, CAP and CAT.

In any overall assessment of new CAD methods or systems, these advantages must be set against the preparatory work and requirements in each individual case:

– Analysis of present situation and structuring of tasks,
– Investment for hardware and software,
– Establishment of symbol and drawing library and databases,
– Training of engineering staff,
– Initial acceptance.

6.3.3 Overview of CAD applications in ABB switchgear engineering

ABB switchgear engineering has been using CAD methods for many years and on an ever increasing scale for planning tender and order processing. The CAD systems are subject to a continuous process of development to meet the continuing progress in the area of switchgears and the increasing use of digital station control systems.

Integration of the various CAD systems into an object-oriented environment is an essential requirement for optimizing the entire planning process. This extends from processing tenders to processing orders for commissioning and further to service. So also the documentation of the installation and archiving is included.

The CAD systems in use are based on CAD operating software, which can now generally run on different hardware platforms with different operating systems. In addition, problem-oriented application programs, mostly ABB-internal, have been developed to run with them. They are designed to meet the requirements of users and customers. The quality assurance of the process is shown in Fig. 6-8.

A number of CAD systems with varying internal system logic are available on the German market in the area of electrical engineering. A decisive point in selecting a CAD system, in addition to the straight hardware and software costs, is the expense of the training required and of establishing internal company databases for symbols and components. Other important criteria are the functionality of the CAD system, the options for connecting to the internal company processes and the supported interfaces.

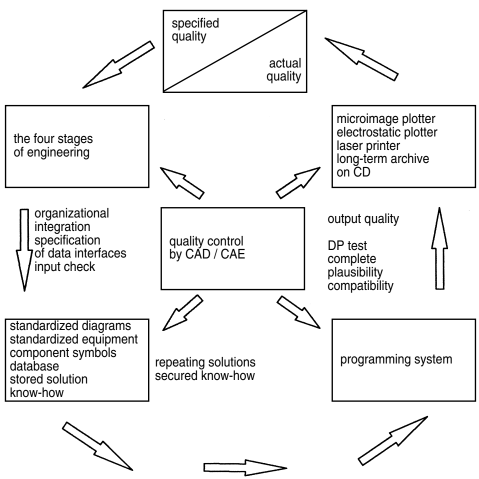


Fig. 6-8

Quality features of the CAD/CAE process. Quality loop with the engineering organization control functions, repeating solution, data processing testing and output technology.

The time sequence in switchgear engineering and the requirement for high-quality documentation (Fig. 6-9) demands the application of highly developed CAE techniques.

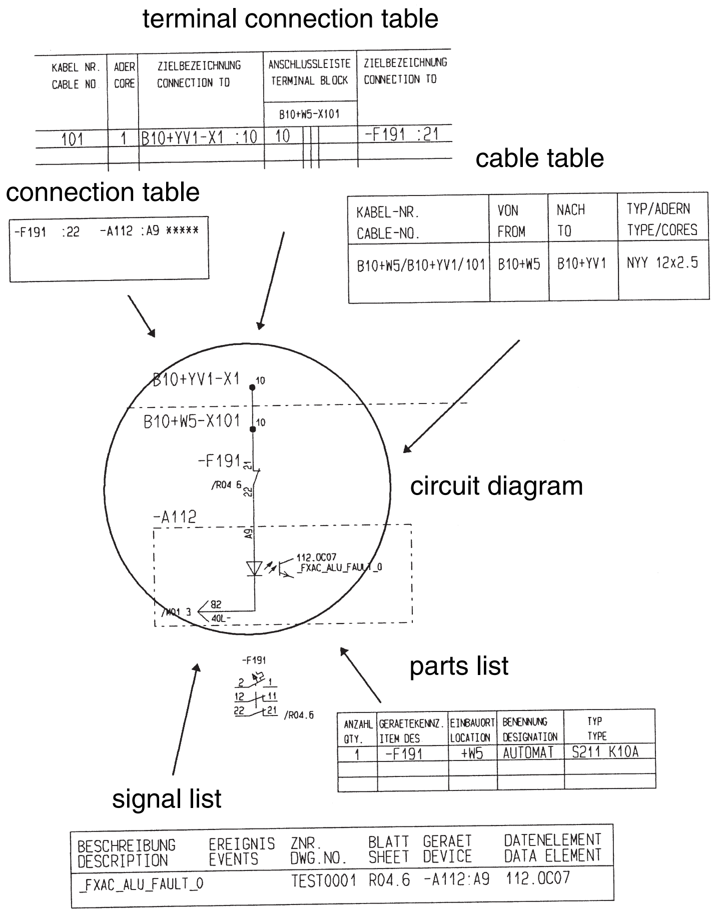


Fig. 6-9

Documentation automatically generated by CAD/CAE with cross references between circuit diagram, terminal connection table, cable table, connection table, parts list and signal list.

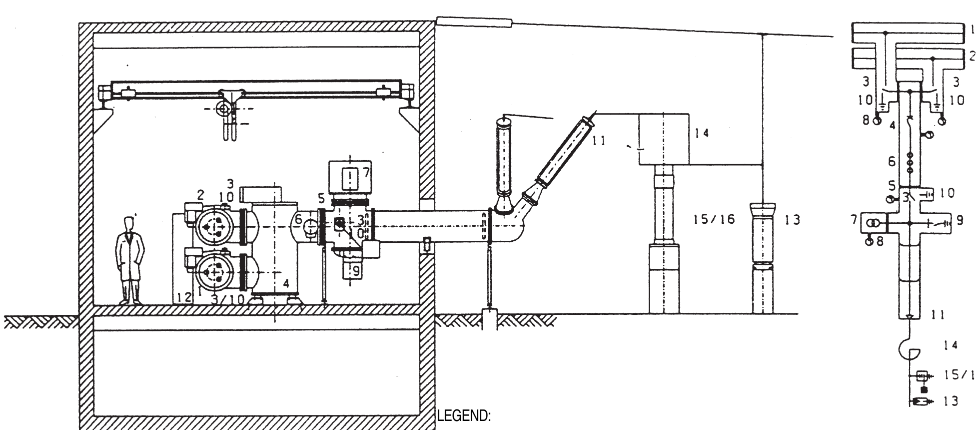
Interfaces for high-end data exchange are becoming increasingly important for CAD/CAE technologies. More and more customers today are demanding their documentation on electronic media. Particularly in Germany, the CAD system with which the documentation must be generated is frequently specified. For switchgear engineering, this is a significant restriction and above all, extremely cost-intensive. Today in particular, no company can afford to run several CAD systems internally in parallel for one application. The cost of hardware, software, administration and employment of trained staff for several systems is simply too high.

However, even within ABB, data must be forwarded to subcontractors and processed. This leaves only the subject of interfaces (and those high-end) as the only alternative for an efficient data exchange.

The standard IGES and DXF interfaces are suitable only for simple graphic data exchange. Higher-end interfaces such as VNS (process-neutral interface for circuit diagram data as per DIN V 40950 2nd edition) offer options for exchanging graphic and logical information between electrical CAD systems at a significantly higher level. A data exchange process that covers nearly everything has been developed with STEP (**ST**andard for the **E**xchange of **P**roduct model data as per ISO/IEC 10303). However, this also requires a general rethink among the software suppliers, because data exchange using STEP also requires STEP-conforming tools with object-oriented databases as a starting point. The first CAD suppliers have already started on this path. The interface properties defined as the application model for the various applications have already been published for mechanical engineering (AP 214) as a standard, and are in the process of being internationally approved for electrical engineering (AP 212).

Suitable CAD/CAE tools are also available for CAD and computer-supported processing of the primary engineering. Here the entire spectrum is being processed with the encapsulated medium-voltage substations of the voltage level from 6 kV to the 3-phase encapsulated GIS switchgears of the ELK-0 range to 170 kV up to outdoor switchgears to the 500 kV and even 800 kV maximum voltage levels. Various tools are also used here for the correspondingly varied requirements and developed structures at the various engineering locations. However, even these tools are embedded in the entire engineering process. It begins at tender preparation with automatic printout of tender documents; it includes the generation of the CAD drawings and contains check mechanisms; automatic generation of derived documents, drawings as well as material and order lists are also included. Finally, the process is complete after submission of the final documentation to the customer with long-term archiving.

Figs. 6-10 and 6-11 show disposition drawings prepared with CAD/CAE .



LEGEND:

1 = BUSBAR I
2 = BUSBAR II
3 = DISCONNECTOR
4 = CIRCUIT-BREAKER
5 = BARRIER INSULATOR
6 = CURRENT TRANSFORMER
7 = VOLTAGE TRANSFORMER
8 = DENSITY MONITOR
9 = HIGH-SPEED EARTHING SWITCH
10 = EARTHING SWITCH
11 = OUTDOOR BUSHING
12 = LOCAL CONTROL CUBICLE
13 = SURGE ARRESTER
14 = REACTOR
15 = PLC LINK
16 = COUPLING CAPACITOR

Fig. 6-10

Sectional elevation and gas diagram of a 145 kV GIS branch with cable basement and outdoor connection

Fig. 6-11 shows the plan view of a 123 kV switchyard created by using the CAD system, with double busbars and in-line layout.

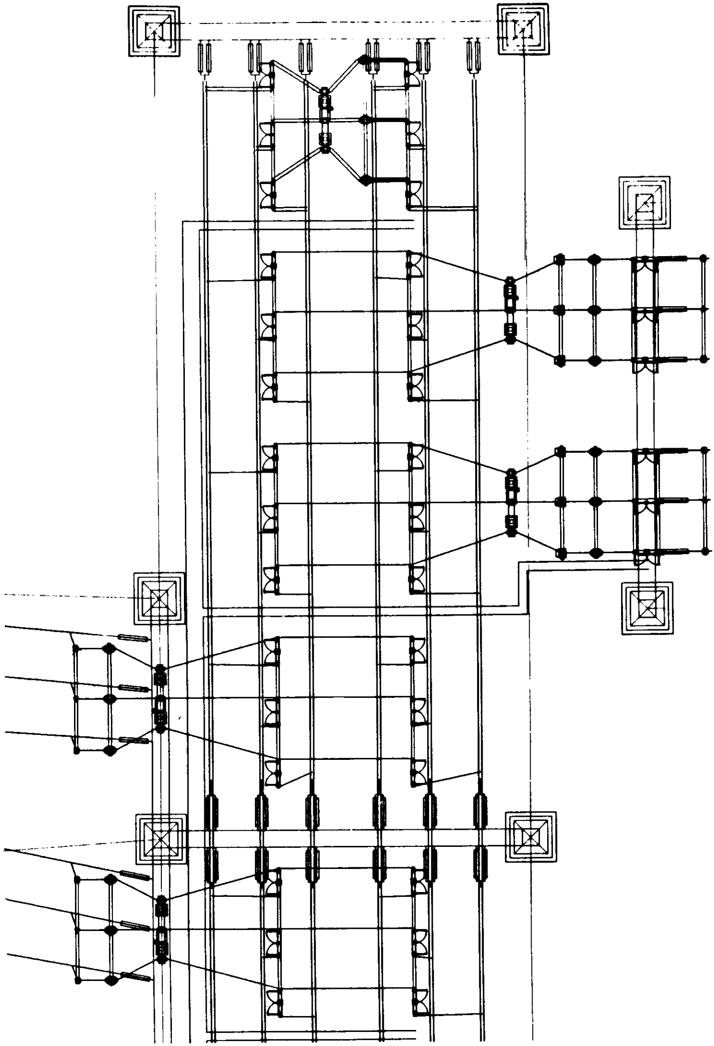


Fig. 6-11

123 kV outdoor switching station with double busbars, in-line layout

6

6.4 Drawings

In technical drawings the information required for constructing and operating an installation or a station component is given in a font that is “readable” for engineers and technicians. The drawings, or these days preferably referred to as documents, are therefore subject to specific, generally accepted rules and implementation guidelines, which are based on national and international standards. The specifications cover such items as:

– Paper formats, paper types
– Representation, symbols, characters
– Lettering, font sizes
– General design, header, metadata
– Document types, -identification and -order
– Creation of documents, processing
– Minimum content of documents

6.4.1 Drawing formats

Table 6-22

A-series formats as per DIN 6771-6, and ISO 5457

Format symbol	Size		Number of fields	
	cut	uncut	short side	long side
A0	841 x 1189	880 x 1230	16	24
A1	594 x 841	625 x 880	12	16
A2	420 x 594	450 x 625	8	12
A3	297 x 420	330 x 450	6	8
A4	210 x 297	240 x 330	4	6

Table 6-23

Continuous formats as per DIN 6771-6

Format symbol	Size		Number of fields	
	cut	uncut	short side	long side
A2.0	420 x 1189	450 x 1230	8	24
A2.1	420 x 841	420 x 880	8	16
A3.0	297 x 1189	330 x 1230	6	24
A3.1	297 x 841	330 x 880	6	16
A3.2	297 x 594	330 x 625	6	12

Continuous formats should be avoided as far as possible.
For formats >A0, see DIN 476.

6.4.2 Standards for representation

The rules for representation in electrical engineering documents are specified in DIN standards. There have been some modifications in connection with the incorporation of international standards since the last edition of the ABB manual; see also Section 6.2. Table 6-24 gives an overview of the most important DIN standards covering the preparation of electrical engineering documents.

Table 6-24
Overview of important DIN standards for the preparation of drawings

Standard or Part	Edition	Title
DIN 6-1, 6-2	12.86	Representation, views, sections
DIN 15-2, 15-3	12.86	Basics, lines
DIN 6771-1	12.70	Title blocks for drawings, plans and lists
DIN 6771-5	10.77	Standard forms for technical documentation; circuit diagram in A3 format
DIN 6776-1	04.76	Lettering, graphic characters
DIN 40719-2	06.78	Circuit documentation; reference designation of electrical equipment
DIN 40719-2 Sup. 1	06.87	Circuit documentation; reference designation of electrical equipment, alphabetically arranged examples
DIN 40719-6	02.92	Circuit documentation; rules for functional diagrams; IEC 848 modified
DIN EN 61082-1	05.95	Documents in electrical engineering – Part 1: General requirements
DIN EN 61082-1/A1	05.96	Documents in electrical engineering – Part 1: General rules, amendment 1
DIN EN 61082-1/A2	07.97	Documents in electrical engineering – Part 1: General rules, amendment 2
DIN EN 61082-2	05.95	Documents in electrical engineering – Part 2: Function-oriented diagrams
DIN EN 61082-3	05.95	Documents in electrical engineering – Part 3: Connection diagrams, tables and lists
DIN EN 61082-4	10.96	Documents in electrical engineering – Part 4: Location and installation documents
DIN EN 61346-1	01.97	Structuring principles and reference designations – Part 1: General requirements
DIN EN 61175	05.95	Designations for signals and connections
DIN EN 61355	11.97	Classification and designation of documents for plants, systems and equipment

(continued)

Table 6-24 (continued)
Overview of important DIN standards for the preparation of drawings

Standard or Part	Edition	Title
DIN EN 60617-2	8/97	Graphical symbols for diagrams; Part 2: Symbol elements and other symbols having general application
DIN EN 60617-3	08/97	Graphical symbols for diagrams; Part 3: Conductors and connecting devices
DIN EN 60617-4	08/97	Graphical symbols for diagrams; Part 4: Basic passive components
DIN EN 60617-5	08/97	Graphical symbols for diagrams; Part 5: Semiconductors and electron tubes
DIN EN 60617-6	08/97	Graphical symbols for diagrams; Part 6: Production and conversion electrical energy
DIN EN 60617-7	08/97	Graphical symbols for diagrams; Part 7: Switchgear, controlgear and protection devices
DIN EN 60617-8	08/97	Graphical symbols for diagrams; Part 8: Measuring instruments, lamps and signalling devices
DIN EN 60617-9	08/97	Graphical symbols for diagrams; Part 9: Telecommunications: switching and peripheral equipment
DIN EN 60617-10	08/97	Graphical symbols for diagrams; Part 10: Telecommunications: transmission
DIN EN 60617-11	08/97	Graphical symbols for diagrams; Part 11: Architectural and topographical installation plans and diagrams
DIN EN 60617-12	04/99	Graphical symbols for documentation; Part 12: Binary logic elements
DIN EN 60617-13	01/94	Graphical symbols for documentation; Part 13: Analogue elements
DIN EN 61360-1	01/96	Standard data element types with associated classification scheme for electric components – Part 1: Definitions - principles and methods
DIN EN 61360-2	11/98	Standard data element types with associated classification scheme for electric components – Part 2: EXPRESS data model
DIN EN 61360-4	06/98	Standard data element types with associated classification scheme for electric components – Part 4: IEC Reference collection of standardized data elements type, component classes and terms.

On a national german level the recommendations of the IG EVU, i.e. the “Energy Distribution Group”, have been developed into generally accepted rules with normative character for documentation of plants, process sequences and equipment.

6.4.3 Lettering in drawings, line thicknesses

Letter type B as per DIN 6776. Preferred font sizes: 2.5, 3.5, 5 and 7 mm (2 mm for CAD processing).

The font sizes, letter and line thicknesses must be selected so that the alphanumeric characters and lines are still easily readable at reduced reproduction sizes; this meets the requirements for microfilming drawings.

Table 6-25

Recommended line thickness (stroke widths in mm)

Line types		Recommended application of line thicknesses (mm)			
		A 4 / A 3	A 2 / A 1	A 0	
Thick	A G	0.5	0.7	1	1.4
Medium	D	0.25	0.35	0.5	0.7
Thin	B C E		0.25	0.35	0.5
Thick/Thin	F	0.25 / 0.5	0.25 / 0.7	0.35 / 1	0.5 / 1.4

Table 6-26

Recommended font sizes for drawings (mm)

Sheet size	Drawing title	Drawing number	Text, remarks	Item no.
A4 A3 A2	3.5-5	5 – 7	2.5 – 3.5	5 – 7
A1 A0	5 – 7	7	3.5 – 5	7

The above table values must be considered generally applicable typical values. The font sizes depend on the format. Once selected, the font size shall be retained for dimensions, positions, remarks, etc. within one drawing. A 2 mm font size is preferred for CAD-generated circuit documents.

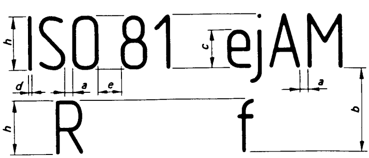


Table 6-27

Font style B (d = h / 10) to DIN 6776

Type		Ratio	Dimension in mm						
Letter height Upper case (capital) Lower case (small) (without ascenders/decenders)	 *h* *c*	 (10/10) *h* (7/10) *h*	 2.5 –	 3.5 2.5	 5 3.5	 7 5	 10 7	 14 10	 20 14
Minimum foot spacing Minimum line spacing Minimum word spacing	*a* *b* *e*	(2/10) *h* (14/10) *h* (6/10) *h*	0.5 3.5 1.5	0.7 5 2.1	1 7 3	1.4 10 4.2	2 14 6	2.8 20 8.4	4 28 12
Stroke width	*d*	(1/10) *h*	0.25	0.35	0.5	0.7	1	1.4	2

6.4.4 Text panel, identification of drawing

A drawing is a document which aids in setting up or operating an installation or a station component. It must therefore include identifications and data showing its content, status and origins.

- Origin, originator, release
- Date of production, if necessary with indication of source in view of patent claims
- Drawing number
- Subject of drawing (title block)
- Modification status
- Filing instructions, if appropriate
- Scale (for layouts, designs)
- Classification

From these indications and by filling out the text panel, it is confirmed that the relevant standards and quality specifications have been observed.

The identifier drawing number at ABB consists of a minimum of three alpha and seven numeric characters, whose position provides varying information.

Key to drawing number:

Sequence of symbols	N	A	A	A	N	N	N	N	N	N
Example:	1	H	D	E	3	3	1	2	3	4

Business Area Code to CS 9 ADA 11 — 1 H

Country code (Germany) — D

Organization unit: dept. etc. — E

Organization unit: group etc. — 3

Paper size: A3 — 3

Identification number: 0 … 9999 — 1234

If a drawing consists of several pages, e.g. circuit documentation manual, additional information is required, see Section 6.2.

6.4.5 Drawings for switchgear installations

The drawings are classified in the following groups, according to their function:

– Civil engineering drawings, architectural diagrams
– Layout drawings
– Design drawings, arrangement drawings, parts lists
– Circuit documentation
– Tables of contents, lists of drawings

Standard paper sizes are available for the different kinds of drawings, depending on their purpose. DIN format A3 with title block conforming to DIN 6771 Part 5 is preferred for circuit documentation and also for related switchboard arrangement drawings, tables etc.

Layout and design drawings have to be drawn to scale. Format and title block are selected in accordance with DIN 6771-1. Preferred scales are specified for the different kinds of installation and voltage levels (Table 6-28).

Table 6-28

Preferred scales

Design Layout	Scale
Outdoor installations	
Up to 525 kV	1 : 500; 1 : 200
Up to 245 kV	1 : 200; 1 : 100
Up to 145 kV	1 : 100; 1 : 50
GIS installations	1 : 50; 1 : 25 (not standardized)
Generator busducts	1 : 50; 1 : 20
Medium-voltage installations	1 : 20
Cubicles, inside arrangement	1 : 10
Other, details	1 : 5; 1 : 2.5; 1 :1
Enlargements	2 : 1; 5 : 1; 10 :1

6.4.6 Drawing production, drafting aids

The following methods are used for economical preparation of documents:

– CAD (Computer-Aided Design and Drafting) with drawings output by plotter, see Section 6.3

– CAE (Computer-Aided Engineering) with documents generated by computer programs and output by plotters, see Section 6.3.3, e.g. terminal diagrams, wiring lists, cable tables, etc.

– Drawing reproduction with photomachines

– Computer-aided microfilming (COM system)