

Code of practice for

Design of high-voltage open-terminal stations —

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Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Power Electrical Engineering Standards Policy Committee (PEL/-) to Technical Committee PEL/92, upon which the following bodies were represented:

- ASTA Certification Services
- Association of Manufacturers Allied to the Electrical and Electronic Industry (BEAMA Ltd.)
- British Railways Board
- Copper Development Association
- Department of the Environment (Property Services Agency)
- ERA Technology Ltd.
- Electricity Supply Industry in England and Wales
- GAMBICA (BEAMA Ltd.)
- Health and Safety Executive
- Transmission and Distribution Association (BEAMA Ltd.)

The following bodies were also represented in the drafting of the standard, through subcommittees and panels:

- Association of Consulting Engineers
- Association of Supervisory and Executive Engineers
- Electrical Installation Equipment Manufacturers' Association (BEAMA Ltd.)
- Engineering Equipment and Materials Users' Association

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Foreword

This British Standard has been prepared under the direction of the Power Electrical Engineering Standards Policy Committee. It supersedes BS 162:1961, which is withdrawn.

This code of practice represents a standard of good practice and takes the form of recommendations.

Attention is drawn to the following Regulations:

- a) The Health and Safety at Work etc. Act 1974;
- b) The Factories Act 1961;
- c) The Electricity at Work Regulations 1989;
- d) The Electricity Supply Regulations 1988.

In a limited number of locations the Mines and Quarries Act 1954 may apply. It is essential that all persons responsible for electrical work or operation make themselves acquainted with the appropriate standing regulations and statutory regulations.

It has been assumed in the drafting of this British Standard that the execution of its provisions will be entrusted to appropriately qualified and experienced people for whose guidance it has been prepared.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 54, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

Section 1. General

1.1 Scope

1.1.1 General

This British Standard gives recommendations for the design of high-voltage open-terminal stations. This standard does not cover equipment included in installations for which separate standards exist. Such equipment should comply with the relevant separate standards. Some relevant British Standards are listed in Table 1.

1.1.2 International practice

Both UK and international practice concerning clearances are included in section 5. International practice is included to allow this standard to be applied to installations designed in the UK for construction overseas. See also note 1 to 1.3.

NOTE The titles of the publications referred to in this standard are listed on the inside back cover. (See also Table 1.)

1.2 Definitions

For the purposes of this British Standard the definitions given in BS 4727-2: Group 06 apply together with the following.

1.2.1

switchgear

a general term covering switching devices and their combination with associated control, measuring, protective and regulating equipment and also assemblies of such devices and equipment with associated interconnections, accessories, enclosures and supporting structures, intended in principle for use in connection with generation, transmission, distribution, and conversion of electric power

1.2.2

open-type switchgear

switchgear in which the live parts are not provided with protective covers

1.2.3

outdoor open-type switchgear

open-type switchgear suitable for installation in the open air, i.e. capable of withstanding wind, rain, snow, dirt deposits, condensation, ice and hoar-frost

1.2.4

indoor open-type switchgear

open-type switchgear designed solely for installation within a building or other housing, where the open-type switchgear is protected against wind, rain, snow, abnormal dirt deposits, abnormal condensation, ice and hoar-frost

1.2.5

busbar

a conductor forming a common electrical connection between a number of circuits

1.2.6

busbar connection

a conductor forming the electrical connection between a busbar and an individual piece of apparatus

1.2.7

connection

a conductor other than a busbar or busbar connection which carries current to or from an individual piece of apparatus

1.2.8

clearance

the distance between two conductive parts measured by a taut string

1.2.9

clearance to earth

the clearance between any conductive parts and any parts which are earthed or intended to be earthed

1.2.10

clearance between poles

the clearance between any conductive parts of adjacent poles

1.2.11

clearance between connections of the same pole

the total clearance between parts of the same pole separable electrically from each other by a mechanical switching device in the open position or by any other means

1.2.12

short-circuit

the connection of two or more points of different poles or parts of a circuit through a negligible impedance

1.2.13

short-circuit current

an overcurrent resulting from a short-circuit due to a fault or an incorrect connection in an electric circuit

1.2.14

short-time withstand current (of a circuit)

the current that a circuit or a switching device in the closed position can carry during a specified short time under prescribed conditions of use and behaviour

1.2.15**highest voltage for equipment (U_m)**

the highest r.m.s. phase-to-phase voltage for which the equipment is designed in respect of its insulation as well as other characteristics which relate to this voltage in the relevant equipment standards. This voltage is the maximum r.m.s. value of the highest voltage of the system for which the equipment may be used

NOTE In systems with highest voltage for equipment equal to or greater than 123 kV, this voltage U_m in general does not materially differ from the highest value of the system operating voltage. Below 123 kV, the voltage U_m may be higher than the highest system voltage, since each standard value of the voltage U_m applies to different systems the nominal voltage of which may differ by as much as 20 % (for instance, $U_m = 24$ kV covers both 20 kV and 22 kV), and having therefore different values of the highest system voltage.

Table 1 — Relevant standards and documents

Item	Reference
Air compressor: code of practice	BS 6244
Air conditioning of building: code of practice	BS 5720
Air receivers: fusion welded steel	BS 5169
Batteries	BS 397 and BS 6290
Batteries: maintenance code of practice	BS 6133
Batteries: sulphuric acid	BS 3031
Busbars	BS 159
Bushings	BS 223
Cable boxes for transformer	BS 2562
Cable covers	BS 2484
Cables: compression joints	BS 4579
Cables: polyethylene, polypropylene and rubber	BS 6469 and BS 6899
Cables: mineral insulated	BS 6207
Cables: telecommunications	BS 3573
Cables: telecommunications (internal)	BS 4808
Cables: thermosetting insulator armoured	BS 5467
Cables: 1 000 V, paper insulated aluminium covered	BS 5593
Cables: up to 33 kV paper insulated lead covered	BS 6480
Cables: power and lighting, PVC	BS 6004
Cables: power and lighting, rubber	BS 6007
Cables: up to 1 000 V, PVC for switchgear and controlgear	BS 6231
Cable glands and sealing boxes for use in mines	BS 542
Cable sockets	BS 91
Capacitors: power	BS 1650
Cathodic protection	CP 1021
Conduit: steel	BS 31
Circuit-breakers: high-voltage	BS 5311
Construction electrical supplies	CP 1017
Contactors	BS 775 and BS 5424
Cranes: safe use of	CP 3010
Current transformers	BS 3938
Disconnectors and earth switches	BS 5253
Earthing	CP 1013
Fire detection and alarm system	BS 5839
Fire extinguishing installations	BS 5306
Flameproof enclosures	BS 229
Fuses	BS 88, BS 2692 and BS 3036
Indicating lamp colours	BS 4099
Instruments	BS 89 and BS 90
Insulating oil maintenance	BS 5730
Insulation co-ordination guide: high-voltage	BS 5622
Insulation co-ordination: low-voltage	PD 6499
Insulation and fillings for overhead lines	BS 3288, BS 137, BS 5419 and BS 5253

Table 1 — Relevant standards and documents

Item	Reference
Insulators post: guide	BS 3297
Interference radio abatement: code of practice	BS 5602
Interference radio measurement	BS 5049
Intruder alarm signalling: code of practice	BS 5979
Oil: insulating	BS 148
Ladders: fixed	BS 4211
Lighting: emergency	BS 5266 and BS 764
Lightning: protection of structures, code of practice	BS 6651
Lightning arresters	BS 2914
Line traps	BS 4996
Maintenance of switchgear/controlgear	BS 6423, BS 6626 and BS 6867
Meters	BS 5685
Motors	BS 5000
Motor starters and controllers	BS 587
Power line carrier systems	IEC 481
Pressure vessel access openings	BS 470
Reactors	BS 4944
Rectifier equipment (semiconductor)	BS 4417
Relays	BS 5992 and BS 142
Rubber mats	BS 921
Safety of machinery	BS 5304
Safety isolating transformers	BS 3535
Sealing compound	BS 1858
Surge diverters	BS 2914
Switches above 1 kV	BS 5463
Switches air breaker up to 1 kV	BS 5419
Switchgear assemblies up to 1 kV	BS 5486
Switchgear metal clad above 1 kV	BS 5227
Switchgear protective enclosures	BS 5420
Symbols	BS 3939
Tap-changers: applications guide	BS 5611
Tap-changers: on-load	BS 4571
Telemetry and control signals	BS 5863
Telephones: private	BS 6701
Television cabling	BS 6513
Terminals: marking of	BS 5559
Terminology: switchgear and controlgear	BS 4727-2: Group 06
Testing of SF ₆ gas	BS 5270 and BS 5209
Transformer: current	BS 3938
Transformer: loading of	CP 1010
Transformer: oil gas analysis, guide	BS 5800
Transformer: power	BS 171
Transformer: power application, guide	BS 5953
Transformer: voltage	BS 3941
Valves, etc. for compressed air installations	BS 1123

1.2.16**rated voltage for equipment**

the r.m.s. phase-to-phase voltage by which the equipment is designated and to which certain operating characteristics of the equipment are related

1.2.17**basic insulation level (BIL)**

the voltage of the standard lightning impulse waveform that, under specified conditions, the insulation of a device is designed to withstand

1.2.18

switching impulse level (SIL)

the voltage of the standard switching impulse waveform that, under specified conditions, the insulation of a device is designed to withstand

1.3 Relevant acts and regulations

A list of some relevant acts and regulations is given in the foreword of this British Standard.

NOTE 1 The implementation of this standard in any country should take into account the safety legislation of that country covering such installations.

NOTE 2 The list of the publications referred to in this standard given on the inside back cover does not include all those given in Table 1.

Section 2. Switching arrangements

2.1 General

This section gives some guidance in the choice of switching arrangements. The continuity of service under fault and maintenance conditions for switching arrangements are categorized.

Figure 1 shows some commonly used switching arrangements. In a substation, flexibility can be achieved by the introduction of sectionalization of the busbars or by using different arrangements.

More than one of the examples shown in Figure 1 may be used on the same site but at different voltage levels.

2.2 Service continuity

When choosing a specific switching arrangement one of the prime considerations should be the effect of the loss of plant due to fault conditions or for maintenance.

In all the examples given, if line or transformer faults are considered continuity cannot be maintained on the affected circuits. Apart from these limitations a measure of service continuity can be maintained.

An assessment of the continuity that can be obtained from any example in Figure 1 has been categorized as follows and is shown in Table 2.

- a) *Category 1.* No outage necessary within the substation for either maintenance or fault.

NOTE Category 1 necessitates no system outage but does not necessarily provide a secure supply, i.e. continuity of supply, for single faults even if these are limited to busbar and circuit-breaker faults.

- b) *Category 2.* Short outage necessary to transfer the load to an alternative circuit for maintenance or fault.
- c) *Category 3.* Loss of circuit or section.
- d) *Category 4.* Loss of substation.

The above categories do not apply in situations where a fault occurs when maintenance is in progress on other equipment.

2.3 Choice of switching arrangements

Choice of switching arrangements may be influenced by:

- a) the level of skill and experience of operating staff;
- b) the future growth and development of the supply system;
- c) economy in the early stages of development;
- d) the ease of facilitating future extensions;
- e) duplication of circuits to give alternative supply routes;
- f) amount of power to be transmitted;

- g) strategic importance of the circuits;

- h) the service continuity of other significant parts of the network.

Considering the above influences on choice, the following gives suggestions regarding the application of the individual switching arrangements shown in Figure 1.

- 1) *Arrangements A, B and F.* Single busbar arrangements are more commonly used for local distribution systems.

Single busbar with transfer busbar and single busbar installations connected in a ring of stations offer limited systems security. These arrangements have no security against busbar faults, no switching flexibility, and involve fairly extensive outage for busbar and busbar disconnector maintenance.

Except in the case of single busbar with transfer busbar, circuits are lost during circuit-breaker maintenance unless some form of circuit-breaker by-passing facility is added.

- 2) *Arrangements C and D.* The duplicate busbar arrangement is recommended for large substations where security of supply is important. These are particularly suitable for highly interconnected power networks in which switching flexibility is important and multiple supply routes are available.

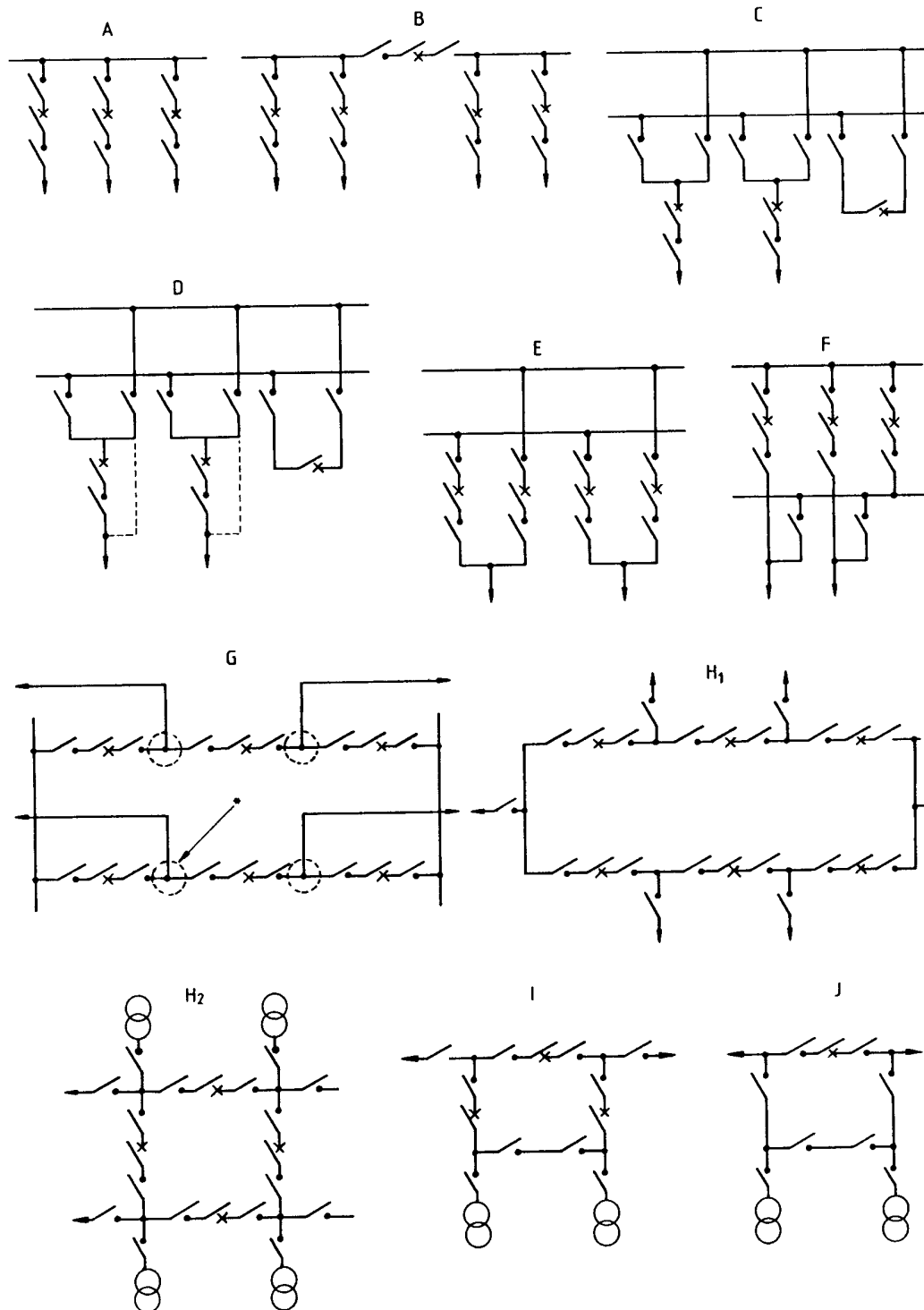
- 3) *Arrangements E and G.* The double circuit-breaker and 1½ circuit-breaker arrangements are particularly suitable for substations handling large amounts of power, such as those associated with generating stations.

It should be noted that to cover all contingencies of switching, the circuit-breakers and associated equipment in arrangement G should be capable of handling the combined load current of two circuits.

- 4) *Arrangements H₁ and H₂.* The mesh arrangements are particularly suited to applications where maximum security against busbar faults and minimum outage for maintenance are required.

It should be noted that equipment in the ring connections of the mesh should be capable of carrying the maximum load current that may occur due to any switching contingency.

- 5) *Arrangements I and J.* The single and three switch arrangements have limited application and are mainly suited to a ring system of supply feeding bulk supply points consisting of duplicate transformers or banks of transformers.



* See note 3 to table 2.

Key

× circuit breaker
O disconnector

Figure 1 — Commonly used switching arrangements

Table 2 — Analysis of service continuity

Type of arrangement (see Figure 1)	Service continuity category (see 2.2)	
	Circuit-breaker area	Busbar area
A Single busbar	3	4
B Single busbar with bus section circuit-breaker	3	3
C Double busbar	3	2 (see note 1)
D Double busbar with by-pass facilities	2 (see note 1)	2 (see note 1)
E Double busbar with double circuit-breaker	1 or 2	1 or 2
F Single busbar with transfer bar	2 (see note 1)	3
G Double busbar with 1½ circuit-breaker	1 or 2 (see note 2)	1 or 3 (see note 3)
H Mesh	1 or 2	3
I Three switch with by-pass	1 or 2	3
J One switch with by-pass	1 or 2	3
NOTE 1 To achieve these stated categories requires the inclusion of a bus coupler switch.		
NOTE 2 Category 1 applies for maintenance conditions. Category 2 applies for fault conditions.		
NOTE 3 Category 1 applies if maintenance is required on the busbars. Category 3 applies if a fault occurs or maintenance is required on circuit connections identified with an asterisk in Figure 1.		

Section 3. Busbar connection and structures

3.1 General

It has been the practice in the United Kingdom and some other countries to assess the working loads or forces acting on substation equipment and supporting structures, and then to add safety factors when calculating stresses in materials and equipment. In some countries such practices are required by regulations, e.g. in the design of overhead lines.

The recommended practice is to establish the maximum force that any piece of equipment would be expected to withstand in its lifetime, rather than apply estimated safety margins over assumed working loads. In order to establish the total mechanical forces acting on electrical equipment and supporting structures it is necessary that consideration be given to forces resulting from:

- short-circuit current;
- wind loading;
- deadweight;
- ice covering (where appropriate);
- conductor tension (where appropriate);
- seismic forces (where appropriate).

Where a site is subject to earthquake, all parts essential to the safe and satisfactory operation of the station should be designed and installed in such a way as to have an adequate degree of resistance to expected disturbances. The design should be based upon stated values and factors indicating earthquake patterns and intensity which should be furnished by the purchaser.

3.2 Design parameters

3.2.1 General

All equipment should be designed to meet the maximum values of the following:

- stated wind speed applied to the equipment, without ice covering, plus the appropriate short-circuit force;
- stated wind speed applied to the equipment with a stated radial thickness of ice (where appropriate) but not including short-circuit force.

NOTE Where severe wind and icing conditions are persistent for a significant proportion of the year, special design procedures are necessary.

3.2.2 Force due to short-circuit

3.2.2.1 Forces between parallel conductors

The internationally accepted formula for the force between two parallel conductors each carrying symmetrical current I is given by:

$$F = \frac{0.2KI^2}{d} \quad (1)$$

where

- F is the average force (in N/m);
- I is the symmetrical short-circuit r.m.s. fault current (in kA);
- d is the spacing between conductors (in m);
- K is the stress factor.

Assuming the supporting structures and conductors to be rigid they will have to withstand the force due to the peak current which is $\sqrt{2}F$. At the beginning of a short-circuit the current may be approaching full asymmetry and have an instantaneous peak value which is a function of the X/R ratio of the circuit:

$$F_{\max} = \frac{0.2KI^2}{d} \quad (2)$$

where

- X is the reactance;
- R is the resistance.

NOTE Maximum values of the asymmetrical peak current can usually be taken as 2.5 times the symmetrical r.m.s. current and this gives a K value of 2.5^2 for the maximum force.

Practical connection systems however have considerable mass and a natural frequency normally lower than the supply frequency and hence would not respond to the maximum value of the asymmetrical fault current and therefore lower values than the maximum value of K can be used in the calculations.

3.2.2.2 Forces between rigid conductors

Full scale tests on rigid busbar systems subjected to two-phase and three-phase faults have demonstrated that for practical design purposes a much lower value of K gives realistic results.

For two-phase faults a value of $K = 4$ and for three-phase faults a value of $K = 3$ should be used.

NOTE Forces due to single phase-to-earth faults are less than for the conditions described in this subclause.

3.2.2.3 Forces between flexible conductors

In the case of flexible conductor arrangements, forces can be determined from 3.2.2.1 but the overall flexibility of conductor/structure is increased and the factor K becomes a function of span length as follows:

- for a span of 15 m to 30 m, $K = 1.6$;
- for a span of 60 m, $K = 0.8$;
- values of K for a span of between 30 m and 60 m can be obtained by linear interpolation.

When multiple conductors are employed for a single phase, allowance should be made for the short time “snatch” force produced by the mutual attraction between parallel conductors. This force is a function of the conductor spacing and distance between spacers. Tests have shown that this force is not coincident with the maximum short-circuit forces between phases.

It has been found in practice that structures designed for normal working and dynamic load due to short-circuit forces between phases have been adequate to meet the impulse forces due to multiple conductors.

3.2.3 Force due to wind loading

It is essential that a maximum wind speed is stated by the user, and for calculation purposes this will be assumed to be acting normal to the axis of the conductor or item of equipment.

If the wind speed varies with height, this fact should be included in the information supplied. For UK practice, CP 3: Chapter V-2 gives further information. This document indicates that wind force is affected by height, type of ground and size of obstacles, e.g. buildings.

For a typical open-type station, the wind pressure P (in N/m^2) for a nominal height of 10.0 m is given by:

$$P = 0.613V^2 \quad (3)$$

where

V is the windspeed (in m/s).

The force F (in N) applied to the conductor or item of equipment is given by:

$$F = PA \quad (4)$$

where

A is the projected surface area (in m^2).

The force obtained from equation (4) is affected by the shape of the item concerned. CP 3: Chapter V-2 provides force coefficients (C_f) for this purpose, and equation (4) becomes:

$$F = PAC_f \quad (5)$$

For items of equipment normally found in open-type substations the value of C_f rarely exceeds 1.0 and for practical design purposes the following values can be applied:

- a) all cylindrical shapes including insulators, $C_f = 0.7$;
- b) rectangular shapes, $C_f = 1.0$.

When applying the above, allowance should be made for increase in dimensions due to ice where appropriate. Lattice structures should be treated as a special case in accordance with CP 3: Chapter V-2.

3.2.4 Force due to deadweight

When calculating the deadweight of conductor or other items, the mass of an even thickness of ice should be included where applicable.

The thickness of ice should be stated by the user and its mass per unit volume calculated at 912 kg/m^3 .

3.3 Factor of safety

Since the method described in 3.2 provides forces which are known maxima then the resultant stresses can be up to the maximum allowable, e.g.:

- a) porcelain: guaranteed cantilever breaking strength;
- b) drawn or extruded metals: guaranteed minimum proof stress;
- c) cast metals: manufacturer's recommendation and/or manufacturer's experience.

3.4 Insulators

3.4.1 Post-type insulators for use as busbar or connection supports

Normally of porcelain construction, the location of post-type insulators for use as busbar or connection supports is largely dictated by the form of layout adopted and the maximum permissible conductor span between adjacent supports.

In selecting the correct insulator for a particular application, it is necessary for the designer to determine the following.

- a) The mechanical strength required. This can be readily determined by the method described in 3.2.
- b) The electrical requirements. This data will determine the overall height of the insulator, the minimum height being dictated by the clearance requirements of 5.2.
- c) The minimum surface creepage. This will normally be specified to suit the pollution conditions prevailing on site.

3.4.2 Tension insulators

Tension insulators are normally of the cap and pin type and it is common practice to use overhead line insulators since these are established designs.

Appropriate insulators should be selected having regard to the mechanical strength and the number required in series for the electrical requirements. Units with different profiles are available and this enables selection to suit the specified creepage length.

3.5 Busbars and connections

The conductors used for busbars and connections will in general be of either rigid, tubular or flexible form, the choice largely being determined by the type of substation construction adopted.

The materials used should preferably be either copper or aluminium, to provide the highest current-carrying capacity for a given size.

Where flexible tensioned conductors are applied the size should be determined for both the mechanical strength and electrical requirements.

The size of tubular conductors can be determined in a similar manner and, particularly when applied to busbars, the maximum possible length or span should be utilized since this requires the minimum number of supporting insulators. These rigid forms of connection are prone to wind induced vibration and care should be taken to ensure that the maximum span determined from mechanical strength is adjusted as necessary to avoid this phenomenon.

As a guide, a tubular conductor rigidly fixed at one end and supported at the other is generally insensitive to vibration if the material frequency of oscillation is greater than 2.75 Hz.

3.6 Terminal fittings and clamps

Termination of busbars and connections on equipment terminals or supports is achieved by the use of correctly designed fittings or clamps appropriate to the application.

Clamps and fittings applied to tubular conductors should be of the split clamp or multiple half clamp bolted types and it is important that each length of conductor is equipped with a rigid clamp at one end and an expansion or sliding type at the other, to allow for equipment movement and thermal expansion.

When selecting clamps and terminal fittings the following should be taken into consideration:

- a) materials should be compatible with the conductor and with the associated equipment terminal;
- b) design should be such that the temperature rise at rated current is less than that of the conductor;
- c) design should be such that visible corona or radio interference voltages are limited to acceptable values.

The making of bolted aluminium joints should comply with the supplier's recommended procedures.

Since joint faces between clamps and conductors are subject to deterioration, steps should be taken to ensure their effective longevity by preparation of the surfaces immediately prior to making the joint.

Preparation is particularly important where high resistance oxides form quickly, as in the case of aluminium, and where electrolytic action takes place, as in the case of dissimilar metals.

All joints should be protected against the ingress of moisture, where this would cause corrosive action, by the application of appropriate greases or sealants immediately after the joint has been made and in accordance with manufacturer's recommendations or instructions.

Manufacturer's recommended procedures should be followed.

3.7 Supporting structures

Structures for busbar supports should provide the minimum insulation clearance given in Table 3 and Table 4, and be designed to withstand static and dynamic loads. The latter can be determined from the method described in 3.2 but they should also comply with appropriate national standards.

Section 4. Main switching equipment

4.1 General

The main equipment incorporated in any of the switching arrangements in section 2 should be laid out as uniformly as possible in each bay. Distances between the circuit-breakers, current transformers, etc. on each phase of each circuit should conform with the minimum separation distance recommended by the manufacturers of the equipment, to provide adequate access for maintenance, temporary structures and all necessary clearances. Special consideration of seismic effects should be taken into account in the method of mounting equipment in the substation when specified by the customer.

Structures should conform with the dimensions recommended by the equipment manufacturer and be designed to withstand static and dynamic loads.

4.2 Circuit-breakers

Each circuit-breaker should be capable of operating as a three-phase group although it may be required to operate on one phase only when single phase auto-reclosure is required.

Indication devices, blocking devices and alarms provided for the operating pressure range should be accommodated centrally, preferably at a convenient height for inspection and with the minimum need for opening cubicle doors.

All cabling and power supplies to the operating mechanisms should be arranged vertically and in a manner to facilitate the easy erection of maintenance platforms. The separation of the phases and the location of all associated disconnectors should be in accordance with the manufacturer's recommendations to ensure the operational and safety working clearances in Table 3 or Table 4 can be obtained.

4.3 Disconnectors

It is essential that the adoption of any type in the layout of the station takes account of the minimum earth and phase clearances with the disconnectors in the open position and the safety working clearances for maintenance purposes.

4.4 Current transformers

The preferred position of current transformers is on the circuit side of and adjacent to the circuit-breaker for arrangements A, B, C and E of Figure 1. With the circuit-breaker by-pass arrangement D and the transfer busbar arrangement F, the current transformers are sometimes located on the line side of the by-pass connection to eliminate the need to switch the current transformer secondaries. The 1½ circuit-breaker arrangement G, the mesh arrangements H₁ and H₂ and section and couplers as shown in B, C and D may have current transformers on each side of each circuit-breaker but for some protection schemes current transformers on any one side may be omitted.

Consideration should be given to allowing space for a second current transformer should this be necessary in the future development of the substation.

Also, on feeder circuits, a current transformer on the circuit side of the incoming circuit disconnector is preferred for use in distance protection schemes. The mesh arrangements H₁ and H₂ usually have current transformers each side of each circuit-breaker but even if one of these can be dispensed with for some protection schemes, it is preferable to allow space for the current transformer to be included as a development of the station.

4.5 Capacitive couplers and voltage transformers

Voltage transformers and capacitor couplers together with line traps associated with line protection schemes should be connected electrically to the line at all times and should be located on the line side of the circuit disconnecting switch.

Capacitor type voltage transformers at this location assist in reducing the severity of incoming lightning overvoltages.

For the 1½ circuit-breaker arrangement G an alternative location for this equipment is at the position of the down droppers to the inter-busbar connections. Care should be exercised to ensure adequate clearance between the line connection and connections inboard of the line trap, as the time delay of an incoming lightning overvoltage traversing the line trap coil can produce a voltage difference up to the full overvoltage. The need for this clearance could increase the spacing between the phase connections. In view of these added complications the preferred practice is to locate the capacitive couplers and line traps for all schemes adjacent to the incoming line termination structure.

4.6 Surge arresters

A surge arrester is a protective device designed for repeated operation to limit voltage surges on an electrical power system to acceptable values. The operation of a surge arrester, unlike a spark gap, does not cause an interruption in supply.

There are two types of surge arrester. The first type consists of non-linear silicon carbide resistors connected in series with spark gaps. The second type consists of highly non-linear zinc oxide resistors which normally do not require series spark gaps. Elimination of the series spark gap is possible because the zinc oxide resistors can be dimensioned so that they present a very high impedance at normal system voltage and a comparatively low impedance at significantly higher voltages.

As a basic guideline, a surge arrester would normally be located as close as possible to the item of equipment requiring protection. It is essential that both the line and earth connections to the arrester should be as straight and short as practicable.

To aid the attainment of a co-ordinated insulation scheme, guidelines for the insulation and location of surge arresters are given in BS 5622-1 and BS 5622-2 and BS 2914. Complex cases, consisting of interconnected cables and lines will warrant specialized study.

NOTE This standard does not relate to zinc oxide surge arresters for which guidelines are in preparation.

Section 5. Layout

5.1 General

The layout of open-terminal high-voltage electrical equipment in switching stations should be arranged to ensure the integrity of the air space between all the conductors and live parts of the equipment for both the normal and abnormal voltage conditions expected to occur. Clearances given in this section do not apply to insulation paths that have been impulse tested. Safety to persons should be maintained by the provision of adequate clearance to live parts for maintenance, vehicular and pedestrian access and if necessary to barriers or fences.

The need for extending stations with the minimum of disruption to normal working or operating practice should be accommodated in the design and layout of the equipment.

Control buildings should be located to minimize lengths of control and protection cabling, arrangements of access roadways and other facets. These are all important considerations in the design of the stations, but are not referred to in this section because they are influenced by a variety of constraints particular to each site.

The general recommendations for clearances, safety and access are provided in this section.

5.2 Clearances

5.2.1 Provision of clearances for safety purposes

Safety clearances are distances in air applied in the design and layout of open-type high-voltage substations, or any other arrangement involving high-voltage switchgear apparatus, to enable persons to carry out work without danger.

Compliance with the relevant legislation and practice of the country where the installation is built is necessary for safe working and environmental conditions.

The safety legislation covering such installations in the UK include The Health and Safety at Work etc. Act 1974 and the Factories Act 1961. In particular the specific requirements of the Electricity (Factories Act) Special Regulations 1908 and 1944 apply to both factory premises and electrical stations as defined in section 123 of the Factories Act 1961. The Electricity Supply Regulations 1988 apply to public supply installations. Other legislation may apply elsewhere, particularly for hazardous areas.

The occupier of the site is responsible for ensuring adequate safety clearances and should therefore be fully conversant with possible system overvoltages, including lightning and switching and how these and other electrical phenomena could cause danger to persons operating or maintaining dead apparatus. In the UK it is not sufficient for the occupier to give precise instructions to persons doing work; due allowance should be made for their reasonable movements and actions. The occupier should provide work people with instructions for safety in work on the electrical installation(s), e.g. safety rules.

For a typical example of safety rules, including model form of permit-to-work, etc. see Appendix D of BS 6626.

To determine appropriate clearances for the purpose of design it is necessary to consider all types of operational and maintenance work which might reasonably be required to be done, the positions where people may be required to have access and the nature of their movements and actions.

The general approach herein is to require the designer of the substation to decide at which positions persons should stand to do work and provide appropriate clearances from the standing positions. Each safety clearance includes a basic dimension of 2.4 m (8 ft) which is widely accepted both in the UK and elsewhere as the vertical distance from a person's feet to the tip of the fingers of an upwards stretched hand. This distance is the minimum to be provided to any part of an insulator which is supporting a live conductor to avoid electrical shock.

The horizontal distance representing the reach of a person on a working platform is taken to be 1.4 m. This distance is considered to be a safe representation of practice, but is not as widely accepted as the vertical reach.

The following recommendations are intended primarily for the purposes of design and layout of high-voltage stations and cover arrangements of apparatus which would enable safety rules in general use to be complied with. Where these safety rules are not to be applied special arrangements should be made.