LOW-VOLTAGE POWER SWITCHGEAR AND CONTROLGEAR ASSEMBLIES

A guide to the requirements of:

BS EN 61439-1:2011

BS EN 61439-2:2011

GAMBICA
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Foreword

Under current electrical and safety legislation it is a requirement that equipment purchased within Europe (EEA) should be both fit for purpose and safe. Subject to any overriding national legislation, this may be demonstrated through meeting the requirements of European harmonised standards. These are implemented in the UK as BS EN standards. Following an extensive period of development, a new standard for Low Voltage Switchgear and Controlgear Assemblies has been introduced by the International Electrotechnical Commission (IEC) and subsequently adopted into European (EN) and National (BS) Standards. In the UK, the new standard is described and embodied within the BS EN 61439 series, replacing the BS EN 60439 series. Either series can be used until 1 November 2014. From that date BS EN 60439-1 is withdrawn and BS EN 61439-1 and BS EN 61439-2 should be used. Since the publication of IEC 61439-2 other parts of the 61439 series have progressively been added until all parts of the 60439 series are now replaced.

In addition IEC 61439-1 and IEC 61439-2 have been amended, clarified and refined, and issued as Edition 2. Accordingly, this guide has been revised to reflect the changes in the standard.

Why a new standard?

The new standard has been developed to simplify and clarify the means by which the performance of applicable products and assemblies can be verified against the requirements of the standards. Some established definitions and practices have been radically revised and new methods of verification have been added. Whilst retaining critical safety-related technical performance requirements, the methods by which performance can be verified have variously been extended, simplified and made more accessible.

In addition, the structure of the standard series has been radically modified to create a General Rules document with associated product-specific Parts. This is intended to make the standards simpler and more readily understood by product design engineers, consultants and end user customers for whom a clear understanding of the performance requirements and capability of equipment is critical.

This guide has been compiled by members of the GAMBICA Controlgear Group Technical Committee to provide specifiers, designers and purchasers of Power Switchgear and Controlgear Assemblies (PSC-assemblies) with a clearer understanding of BS EN 61439-2 and to assist in the selection of fully compliant and safe products in accordance with this standard. This guide is intended to complement the standard, not to be a substitute for it.

The guide seeks to highlight the most relevant areas of the standard and to give the purchaser confidence in the safety and reliability of the equipment. In addition, it explains commonly used terminology and areas of customer choice to assist in the decision making process.

GAMBICA gratefully acknowledges the significant amount of time and effort put into the preparation of this guide by representatives of member companies.

The greatest care has been taken to ensure the accuracy of the information contained in this guide, but no liability can be accepted by GAMBICA, or its members, for errors of any kind.

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1. Power Switchgear and Controlgear Assemblies (PSC-assemblies)

BSEN61439-2 is Part 2 of the 61439 series of standards, as shown in Figure 1, and is the product-specific part covering the requirements for Power Switchgear and Controlgear Assemblies (PSC-assemblies).

BS EN 61439-1: General rules
BS EN 61439-2: Power switchgear and controlgear ASSEMBLIES
BS EN 61439-3: Distribution boards (superseded BS EN 60439-3)
BS EN 61439-4: ASSEMBLIES for construction sites (superseded IEC 60439-4)
BS EN 61439-5: ASSEMBLIES for power distribution (superseded IEC 60439-5)
BS EN 61439-6: Busbar trunking systems (superseded IEC 60439-2).
BS EN 61439-7: **Assemblies for specific installations at public sites such as marinas, camping sites, market squares and similar applications and for charging stations for Electrical Vehicles. (New Part being developed to cover assemblies with recently identified and particular needs)**

An IEC/TR 61439-0 Specifier's Guide has also been published.

Figure 1: The BS EN 61439 series of standards

The '*General rules*' document BS EN 61439-1(Part 1) is not a product standard in its own right and as such, no assembly can be declared as compliant to Part 1. The particular part (Parts 2-7) applicable to the assembly in question must be read in conjunction with Part 1 which defines and declares requirements common to more than one assembly type.

Therefore, for PSC-assemblies Part 2 has to be read in conjunction with Part 1. The other product-specific parts, which also have to be read in conjunction with Part 1, deal with the particular requirements for certain specialized forms of assemblies. In standards terminology, low-voltage control panels, motor control centres, distribution boards and the like are known collectively as 'Power Switchgear and Controlgear assemblies', or 'PSC-assemblies' for short. By 'low-voltage' is meant voltages up to 1000 V a.c. or 1500 V d.c.

The need to conform to standards

PSC-assemblies are typically subject to the Low Voltage Directive (LVD) and the EMC Directive. These directives apply in all Member States of the EEA (European Economic Area – comprising the EU Member States, Norway, Iceland and Liechtenstein).

Note: Although not members of the EU or EEA, both Switzerland and Turkey have introduced legislation that allows CE marked product that complies with these directives to be placed on their respective markets without further testing.

Significantly, the requirements of these directives can be presumed to be met by electrical equipment which satisfies the provisions of certain European harmonised standards.
In the case of PSC-assemblies, the relevant harmonised standard is BS EN 61439-2.

Therefore, quite apart from the assurance which conformity with the standard provides i.e. that a PSC-assembly will achieve acceptable levels of performance, safety, reliability, and electromagnetic compatibility, it is also the preferred and most straightforward means of demonstrating that the equipment meets the technical requirements of the relevant legislation.

1.1 So, what is a PSC-assembly?

The scope of BS EN 61439-2 covers those products which were previously covered by BS EN 60439-1. In addition it now includes other bespoke assemblies and small assemblies. Significant changes have been incorporated, not least that the concepts of type-tested assemblies (TTA) and partially type-tested assemblies (PTTA) have been removed entirely.

The rationale for the elimination of TTA and PTTA is clear:

A TTA (Type-Tested Assembly) was defined in BS EN 60439-1 as *'A low-voltage switchgear and controlgear assembly conforming to an established type or system without deviations likely to significantly influence the performance, from the typical ASSEMBLY verified to be in accordance with this standard.'*

To be able to declare an assembly as a TTA therefore, the equipment had to be virtually identical to the representative sample product verified. This is not an issue where, for example, batch production of large numbers of identical systems is to be managed but does not suit bespoke, turnkey assemblies so well.

Major problems arise with, for example, the definition of what constitutes a 'significant' influence on performance

The definition of a PTTA (Partially Type-Tested Assembly) was *'A low-voltage switchgear and controlgear assembly, containing both type-tested and non-type-tested arrangements provided the latter are derived (e.g. by calculation) from type-tested arrangements which have complied with the relevant tests.'*

This definition would cover the majority of bespoke assemblies, being generally designed and assembled to meet specific customer application requirements and comprising designs that are closely aligned with verified examples (such as incoming sections) and other special designs that may or may not have significant influence on the performance of the equipment overall and thus need back-up calculations to show that adequate provision has been made.

The lack of consistency by manufacturers in declaring an assembly a TTA or PTTA – or indeed declaring part of the assembly TTA and other parts PTTA –can lead to customer confusion and mistrust.

The previous practice of undertaking tests on representative samples of assemblies as part of the process of verifying equipment designs and material selections is largely carried through to the new BS EN 61439 series as one of the routes to verification. However, other methods are now available for some aspects of performance verification that do not require expensive and time consuming testing. Verification by comparison with a reference design and/or verification by assessment (calculation or design rules) may be used. The applicable alternatives are defined in the standard. When these alternatives to testing are used, the standard insists on minimum safety margins being applied to ensure these alternative methods of verification are at least equivalent to testing. Whichever method is used, the purchaser can be assured that the performance requirements laid down in the standard are met.

Such design verification should not be confused with "routine verifications" which are those carried out on actual production assemblies prior to dispatch/installation and which serve to check for manufacturing or material defects.

See Chapters 2, 3 and 4 for more details of the routes to product verification, tests to be performed, and the alternatives to test where appropriate.

1.2 Performance requirements

The standard specifies a comprehensive package of performance requirements. These come under 13 basic headings (see Figure 2) and all must be verified.

- Strength of materials and parts
- Degree of protection of enclosures
- Clearances
- Creepage distances
- Protection against electric shock and integrity of protective circuit
- Incorporation of switching devices and components
- Internal electrical circuits and connections
- Terminals for external conductors
- Dielectric properties
- Verification of temperature rise
- Short-circuit withstand strength
- Electromagnetic compatibility
- Mechanical operation

Summary

The principal standard for low-voltage power switchgear and controlgear assemblies is BS EN 61439-2, when read in conjunction with the General Rules document, BS EN 61439-1

Assemblies conforming to this standard are deemed to satisfy the relevant essential requirements of both the Low Voltage Directive and the EMC Directive and may bear the CE marking accordingly.

2. Design Verification

Introduction

BS EN 61439-2 details 13 characteristics that must be verified, as shown in Figure 3. Verification of all 13 characteristics is necessary to satisfy the requirements of the standard. It will readily be noted that in many cases there are alternative routes to verification although in certain key areas testing is the only method of verification permitted by the standard.

At first sight, all verifications may appear to be associated with constructional and key performance aspects of the assembly. Careful examination shows that most are also very much related to safety, as will be identified. Ironically, the most significant verifications are also the most difficult and expensive to carry out.

Design verification is ultimately the responsibility of the assembly manufacturer, defined as the 'organization taking responsibility for the completed assembly' (BS EN 61439-1, definition 3.10.2).

However, the task of verification can be simplified for the assembly manufacturer by the use of a proprietary system or enclosure. For example, an enclosure manufactured and verified to the relevant standard, BS EN 62208 by the enclosure manufacturer will allow the assembly manufacturer to use the enclosure manufacturer's verification results to satisfy some of the requirements of BS EN 61439-2. The assembly manufacturer has then to verify the assembly by completing the remaining verification requirements but avoids the need to repeat verifications undertaken by the enclosure manufacturer.

2.1 Strength of materials and parts

Constructional requirements: Subclause 8.1
Design verification: Subclause 10.2

The mechanical, electrical and thermal capability of materials and parts used in the construction of the assembly has to be verified. Where relevant, aspects such as resistance to corrosion, thermal stability of materials (such as insulators) under normal and abnormal heat, resistance to UV light exposure and the ability of the assembly to be lifted (e.g. for transportation) and to resist mechanical impact (as necessary) are all verified to performance levels as specified by the standard or as agreed between manufacturer and user.*

Except where the standard permits use of the material manufacturer's test results, e.g. resistance to UV radiation on enclosures constructed from insulating materials, all characteristics detailed in Subclause 8.1 can ONLY be verified by test, no alternative verification methods are permitted by Subclause 10.2.

* *'Subject to agreement between manufacturer and user'* is a recurring theme in the BS EN 61439-2 standard. There are 58 separate aspects of installation environment or performance defined in Table BB.1 of the standard that may affect the design of the assembly and that must be clarified prior to manufacture to ensure performance in the installation environment and to the level anticipated.

No.	Characteristic to be verified	Clauses or subclauses	Verification options available		
			Testing	Comparison with a reference design	Assessment
1	Strength of material and parts:	10.2			
	Resistance to corrosion	10.2.2	YES	NO	NO
	Properties of insulating materials:	10.2.3			
	Thermal stability	10.2.3.1	YES	NO	NO
	Resistance to abnormal heat and fire due to internal electric effects	10.2.3.2	YES	NO	YES
	Resistance to ultra-violet (UV) radiation	10.2.4	YES	NO	YES
	Lifting	10.2.5	YES	NO	NO
	Mechanical impact	10.2.6	YES	NO	NO
	Marking	10.2.7	YES	NO	NO
2	Degree of protection of enclosures	10.3	YES	NO	YES
3	Clearances	10.4	YES	NO	NO
4	Creepage distances	10.4	YES	NO	NO
5	Protection against electric shock and integrity of protective circuits:	10.5			
	Effective continuity between the exposed conductive parts of the ASSEMBLY and the protective circuit	10.5.2	YES	NO	NO
	Short-circuit withstand strength of the protective circuit	10.5.3	YES	YES	NO
6	Incorporation of switching devices and components	10.6	NO	NO	YES
7	Internal electrical circuits and connections	10.7	NO	NO	YES
8	Terminals for external conductors	10.8	NO	NO	YES
9	Dielectric properties:	10.9			
	Power-frequency withstand voltage	10.9.2	YES	NO	NO
	Impulse withstand voltage	10.9.3	YES	NO	YES
10	Temperature-rise limits	10.10	YES	YES	YES
11	Short-circuit withstand strength	10.11	YES	YES	NO
12	Electromagnetic compatibility (EMC)	10.12	YES	NO	YES
13	Mechanical operation	10.13	YES	NO	NO

Figure 3: Characteristics to be verified (derived from BS EN 61439-1 Table D.1)

2.2 Degree of protection provided by an assembly enclosure

Constructional requirements: Subclause 8.2
Design verification: Subclause 10.3

The IP Code defines the extent to which the assembly is protected against harmful effects caused by dust or water entering the assembly and the extent to which persons are protected against contact with hazardous parts within the assembly. When the assembly is in its normal service condition, personnel outside the equipment should not be able to touch any hazardous live parts. If the degree of protection of part of the assembly, for example the operating face, differs from that of the remainder, then the manufacturer must indicate the degree of protection of the various parts.

The IP code is also used to specify the level of separation assigned to parts of the assembly (see Chapter 6). This includes protection of persons against contact with hazardous live parts in adjacent compartments, and protection of the assembly against the passage of objects from one compartment to another.

Verification is carried out in accordance with BS EN 60529. For a PSC-assembly no IP code can be given unless the appropriate verification has been made or tested prefabricated enclosures are used.

Although the design and construction requirements for protection against electric shock are treated as a separate issue in the standard, verification of protection against electric shock by direct contact is embedded within the section dealing with degrees of protection.

As an alternative to testing for degree of protection design assessment (design rule) may be applied to verify compliance with Subclause 10.3. This allows for the use of an empty enclosure manufactured to BS EN 62208 where no external modifications that will degrade the degree of protection have been made.

2.3 Clearances and creepage distances

Constructional requirements: Subclause 8.3
Design verification: Subclause 10.4
Routine Verification: Subclause 11.3

When considering this particular verification, the requirements of the standard are fairly brief:

'It shall be verified that clearances and creepage distances comply with the requirements of 8.3.'

'The clearances and creepage distances shall be measured in accordance with Annex F.'

Two tables (Tables 1 & 2 in the standard) are referenced which define the minimum clearances in air and minimum creepage distances for various voltage levels. The latter is further complicated by the need to consider pollution degree and the CTI (comparative tracking index) of insulation materials used.

If the user does not indicate otherwise, the manufacturer will assume pollution degree 3 (i.e. conductive pollution occurs or dry, non-conductive pollution occurs which becomes conductive due to condensation). Similarly, creepage distances are a function of pollution degree and the 'tracking index' of insulation material (material group) being used. Creepage and clearance distances of 8 mm or less for main busbars and connections may well be acceptable in many applications.

Clearances and creepage distances are also required to be verified as part of the manufacturer's routine verification process. Clause 11.3 defines three alternatives to undertake verification of clearances, depending on the magnitude of the 'as built' clearances relative to the same reference table as referred to by Clause 8.3 (Table 1). The verification according to the standard can thus be via an impulse test when distances are less than specified, by physical measurement or by visual inspection when distances are obviously greater than the specified minimum.

2.4 Protection against electric shock

Constructional requirements: Subclause 8.4
Design Verification: Subclause 10.5

There are two aspects to protection against electric shock.

2.4.1 Basic protection

Essentially this is the prevention of accidental contact with hazardous live parts. Usually it is achieved by means of enclosures, barrier and/or the insulated covering on conductors. See 2.2 above. The opening of a door, removal of a cover or barrier must require the use of a key or tool, unless, interlocks are provided to ensure any hazardous live parts are de-energised prior to them being exposed. With the exception of horizontal top surfaces on accessible enclosures, which must provide protection in accordance with at least IP XXD, the minimum degree of protection provided against contact with hazardous live parts must be IP XXB.

2.4.2 Fault protection

In order to ensure the earth fault currents are suitably managed, adequate protective circuits within an assembly are vital.

The standard defines two conditions which must be taken account of in the design of the assembly:

i) protection against the consequences of faults within the assembly, and

ii) protection against the consequences of faults in external circuits supplied through the assembly.

The principal objective is to protect personnel should non-current carrying parts accidentally become live whether as a result of internal or external faults.

Generally, the basis of the protective circuit is the metal structure of the assembly. It is usual, but not essential to ensure compliance with the standard, for multi-section units to have a supplementary protective conductor (earth bar) running the full length of the assembly. To this are connected supplementary earth bonds from instruments, cable glands, etc., where appropriate.

2.4.2.1 Internal faults

Verification of the effectiveness of the protective circuit is achieved by examination and by tests.

Examination

An examination of the PSC-assembly is carried out to confirm that the constructional requirements to ensure an effective protective circuit have been met, i.e.:

i) All exposed conductive parts greater than 50 mm by 50 mm and which can be touched are connected to the protective circuit.

ii) Manual operating handles, etc., are effectively connected to the protective circuit or adequately insulated.

iii) The removal of a part from a PSC-assembly does not interrupt the protective circuit for other parts of the assembly.

iv) Doors and covers are effectively bonded.

v) Protective conductors are sized in accordance with the standard.

Tests

Subclause 10.5.2 of the standard requires that it must be verified by a specified test method that the resistance between the incoming protective conductor and exposed conductive parts does not exceed 0,1 ohms.

2.4.2.2 External faults

Requirements for verification of the short-circuit withstand capability of the protective circuit are covered by Subclause 10.5.3 of the standard. This verifies that the PSC-assembly enclosure and its protective circuit (earthing system) are capable of withstanding the thermal and electrodynamic stresses resulting from a short-circuit downstream of the assembly, based on the prospective short-circuit current at the incoming terminals of the assembly. Unless otherwise specified the maximum prospective short-circuit current will be assumed to be 60% of the three-phase value and at phase-to-neutral voltage. The verification can be via test or comparison with a reference design previously verified by test.

The various component parts of the protective system need to be considered as it is important that all parts of the system are adequately rated.

Specifiers often expect a short-time current rating on the earth bar equivalent to that of the neutral busbar. However, unless there are large outgoing circuits using definite minimum time protection, this is not a requirement of the standard.

2.5 Incorporation of switching devices and components

Constructional requirements: Subclause 8.5
Design Verification: Subclause 10.6

The general objective of this Subclause is to ensure safety in installation and operation of the installed devices. Fixed and removable parts are covered. The main difference is the possibility to safely connect or remove removable parts when the circuit is live (although not necessarily under load). The standard regards a withdrawable part as a type of removable part. The selection of devices and components must consider their suitability for the application. Devices and components must be installed in accordance with the device manufacturers' instructions and with due regard to the accessibility necessary to ensure proper and safe operation in service.

2.6 Internal electrical circuits and connections

Constructional requirements: Subclause 8.6
Design Verification: Subclause 10.7

The standard requires that the PSC-assembly design should minimize the possibility of short-circuit in the arrangement of internal busbars. These main internal circuits are fundamental to the operation of many PSC-assemblies and must be sufficiently robust to be able to withstand the thermal, electrical and mechanical stresses of a short-circuit fault at the maximum prospective short-circuit current at the incoming terminals of the assembly. (See 2.10)

In addition, other parts of the internal power distribution system within the assembly (distribution busbars, auxiliary circuits etc.) must comply with dimensional (cross-sectional area) and spacing requirements prescribed within the standard and verified by means of test or other methods as permitted by the standard.

The capability of internal connections is considered with emphasis on the need to cope with vibrations, heat rise and ageing of materials in normal service. It is important to note that mains frequency oscillations introduce a mechanical vibration in connected equipment which will almost certainly affect the installation over time. Ageing of cables and insulating materials, slackening of terminal bolts and consequent accelerated heating at the connection point are typical consequences and must be considered when planning a maintenance regime.

Identification of internal connections and conductors is also considered, and apart from specific requirements for protective conductors (green-and-yellow), and (in most cases) neutral (blue), the selection of cable colours inside the assembly is the responsibility of the assembly manufacturer but MUST be in accordance with the documentation (wiring diagrams) of the assembly. However, note that interfacing terminals for the connection of external conductors may also have particular demands (see 2.7).

The Subclause also covers conductors in what is commonly termed the 'fault-free zone' where a conductor providing direct connection from a distribution or main busbar, for example, to a short-circuit protective device (SCPD) protecting an outgoing load circuit, may be rated in accordance with the SCPD, not the upstream device (see 4).

2.7 Terminals for external conductors

Constructional requirements: Subclause 8.8
Design Verification: Subclause 10.8

The standard requires the manufacturer to declare the suitability of the terminals provided for external connections for either copper or aluminium conductors or both.

Subclause 8.8 of the standard states '*In the absence of a special agreement between the ASSEMBLY manufacturer and the user, terminals shall be capable of accommodating copper conductors from the smallest to the largest cross-sectional areas corresponding to the appropriate rated current (see Annex A).*'

Terminals provided have to be suitable for the current rating and short-circuit strength of the system and must be able to accommodate cables from the smallest to the largest cross-sectional areas for the corresponding current rating (unless otherwise agreed), in accordance with Table A.1.

Terminals for electronic circuits carrying very low current and voltage are not subject to these requirements.

Unless otherwise stated marking of the terminals for external conductors must follow the requirements of BS EN 60445 which prescribes phase, neutral and protective conductor colours and labels.

Verification of the terminals (Subclause 10.8 of the standard) is via a visual inspection only.

2.8 Dielectric properties

Performance requirements: Subclause 9.1
Design Verification: Subclause 10.9

For design verification the standard requires confirmation of capability to withstand transient and temporary (short term) overvoltages.

Resistance to transients is proven as 'impulse withstand' capability. In accordance with the standard this may be verified by means of an impulse test, power frequency or d.c. voltage test equivalent to the impulse test, or measurement of clearances. If the latter option is selected, the nominal minimum clearances defined in the standard have to be increased by a margin of 50%. In the absence of more application specific information, Table G.1 in the standard details the appropriate value for a particular voltage and place in the electrical distribution system.

A power frequency dielectric test is carried out to verify short-term overvoltage capability. These are popularly referred to as "Flash Tests" and involve the application of specified test voltages between all live parts and the interconnected exposed conductive parts of the PSC-assembly.

The standard sets out values for the test voltage in subclauses 9.1.2. For main power circuits, for example, the dielectric test voltage should be 1890 V a.c. when the insulation voltage of the equipment is between 300 - 690 V a.c. Auxiliary circuits typically have a test voltage of 1500 V a.c. minimum. The test voltage is required to have a practically sinusoidal waveform and a frequency between 45 Hz and 65 Hz. Care has to be taken to ensure that the a.c. power source is capable of maintaining the test voltage irrespective of any leakage currents.

2.9 Temperature rise limits

Performance requirements: Subclause 9.2
Design Verification: Subclause 10.10

Verification in this category is one of the most critical in determining the reliability and long service capability of a PSC-assembly and must not be overlooked. Excessive temperatures result in premature ageing of components and insulation, and ultimately failure. Current ratings of components are valid only when the temperature around them is within the limits specified by the component manufacturer. Safety aspects are also of significance although they may arise mainly as a secondary effect through the touching of hot covers or operating handles. The design of an assembly should take into account a number of factors which will affect the assembly's ability to meet the temperature rise limits set by the standard. The limits for the various parts of an assembly are summarised in Figure 4.

From Figure 4, it is clear that temperature rise and therefore temperature limits are set for the external interfaces, cable terminals, covers and handles. However, internal temperatures are the manufacturer's responsibility. There is a differentiation between operating handles which need to be held and covers, etc., which might be touched, as well as recognition of the effects of different materials. Maximum permissible temperatures are however quite high, for example a plastic cover at a temperature of 75° C (temperature rise of 40 K plus daily average ambient temperature of 35° C) is considered acceptable.

Other parts within the assembly are essentially limited to temperatures which will have no detrimental effects. This does not mean temperatures are unlimited. The manufacturer must ensure the temperatures within the assembly do not exceed the specified ratings of the components, materials and in particular the insulation, used.

Predicting or calculating temperatures within an assembly is difficult and has to take into account current load and component operating temperatures. Each component may have a different temperature operating capability. Due to close coupling one component may transfer heat to another. Adjacent circuits will have a mutual heating effect. Different levels of ventilation have significant effects. As the level of ingress protection increases (see section 2.2 above) so does the potential for overheating and de-rating of components may need to be applied in order to overcome the problem.

With the introduction of the BS EN 61439 series, the manufacturer must now verify that each circuit within the assembly can individually carry its rated current. This will ensure de-rating of devices as appropriate to suit their connections and enclosure conditions.

In order to reflect most practical applications without over-engineering, the standard assumes that all the outgoing circuits will not be fully and constantly loaded simultaneously. A diversity (loading) factor for the assembly as whole or individual sections is assumed. In the absence of more application specific information from the purchaser, the diversity (loading) factor is assumed and is given in BS EN 61439-2, Table 101, *'Values of assumed loading'*. (See Figure 5)

Part of assemblies	Temperature rise (K)
Built-in components [(a)]	In accordance with the relevant product standard requirements for the individual components or, in accordance with the component manufacturer's instructions [(f)], taking into consideration the temperature in the assembly.
Terminals for external insulated conductors	70 [(b)]
Busbars and conductors,	Limited by [(f)]: • mechanical strength of conducting material [(g)]; • possible effect on adjacent equipment; • permissible temperature limit of the insulating materials in contact with the conductor; • effect of the temperature of the conductor on apparatus connected to it • for plug-in contacts, nature and surface treatment of the contact material
Manual operating means: • of metal • of insulating material	 15 [(c)] 25 [(c)]
Accessible external enclosures and covers • Metal surfaces • Insulating surfaces	 30 [(d)] 40 [(d)]
Discrete arrangements of plug and socket-type connections	Determined by the limit for those components of the related equipment of which they form a part [(e)]

a) The term "built-in components" means:
- conventional switchgear and controlgear;
- electronic sub-assemblies (e.g. rectifier bridge, printed circuit);
- parts of the equipment (e.g. regulator, stabilized power supply unit, operational amplifier).

b) The temperature-rise limit of 70 K is a value based on the conventional test of 10.10. An ASSEMBLY used or tested under installation conditions may have connections, the type, nature and disposition of which will not be the same as those adopted for the test, and a different temperature rise of terminals may result and may be required or accepted. Where the terminals of the built-in component are also the terminals for external insulated conductors, the lower of the corresponding temperature-rise limits shall be applied. The temperature rise limit is the lower of the maximum temperature rise specified by the component manufacturer and 70 K. In the absence of manufacturer's instructions it is the limit specified by the built-in component product standard but not exceeding 70 K

c) Manual operating means within ASSEMBLIES which are only accessible after the ASSEMBLY has been opened, for example draw-out handles which are operated infrequently, are allowed to assume a 25 K increase on these temperature-rise limits.

d) Unless otherwise specified, in the case of covers and enclosures, which are accessible but need not be touched during normal operation, a 10 K increase on these temperature-rise limits is permissible. External surfaces and parts over 2 m from the base of the ASSEMBLY are considered inaccessible.

e) This allows a degree of flexibility in respect of equipment (e.g. electronic devices) which is subject to temperature-rise limits different from those normally associated with switchgear and controlgear.

f) For temperature-rise tests according to 10.10 the temperature-rise limits have to be specified by the Original Manufacturer taking into account any additional measuring points and limits imposed by the component manufacturer.

g) Assuming all other criteria listed are met a maximum temperature rise of 105 K for bare copper busbars and conductors shall not be exceeded.

Figure 4: Temperature rise limits (derived from BS EN 61439-1, Table 6)

The standard permits several methods of verifying temperature rise capability:

i) for single-compartment PSC-assemblies of 630 A or less, ensuring the total power loss of the assembly does not exceed the heat dissipation capability of the enclosure

ii) calculation in accordance with a recognized standard such as IEC 60890 for assemblies rated 1600 A or less, and

iii) temperature rise test.

Number of main circuits	Assumed loading factor
Distribution - 2 and 3	0.9
Distrbution - 4 and 5	0.8
Distribution 6 to 9	0.7
Distribution10 and more	0.6
Electric actuator	0.2
Motors ≤100 kW	0.8
Motors > 100 kW	1.0

Figure 5: Values of assumed diversity (loading) (derived from BS EN 61439-2, Table 101)

In the case of methods (i) and (ii) a margin is added by insisting that all devices are de-rated to 80% of their free air rating and that all current carrying conductors have a cross-section as detailed in the standard.

When temperature rise verification is carried out by test, the manufacturer can select from three options to suit the design and the total time to be devoted to testing;

Option 1 The incoming circuit and at least one outgoing circuit of each rating are loaded to their rated current. If a circuit of each basic type is not included in the test, further tests are carried out until one outgoing circuit of each type has been included. This approach is suitable where a specific arrangement and design of assembly is to be verified with the minimum amount of testing. As the outgoing circuits are tested with a diversity (loading) factor of unity, it does, however, result in a more onerous test than necessary for most applications.

Option 2 Outgoing circuits are temperature rise tested individually to verify they are capable of carrying their rated current. The incoming circuit is then supplied to its rated current. This is distributed through as many outgoing circuits as practical, including one outgoing circuit of each basic type and in the most onerous configuration, with each circuit loaded to its rated current multiplied by the rated diversity (loading) factor. Again, this test regime is only suitable for a specific arrangement and design of assembly, but it does better reflect the normal loading of an assembly.

Option 3 This alternative has been included to enable modular assembly systems to be fully verified. Horizontal busbars, vertical busbars and outgoing functional units are tested individually. The assembly as a whole is then verified as in Option 2. Whilst this method of temperature rise testing involves a lot of testing, once it is completed it covers all the possible arrangements available in a flexible modular system, and avoids any concerns that may previously have arisen due to the specific arrangement supplied not being exactly as that tested.

Temperature rise tests are time consuming. A lot of time is required to connect all the circuits to be included in the test, balance the current and insert the thermocouples. Current is applied until conditions stabilise, usually around eight hours, and, in the final hours, temperatures are monitored, normally with thermocouples. Critical areas for temperature measurement are covers, operating handles, busbars and joints, insulators, cable terminals, device and/or internal air temperatures.

In order to reduce the time spent testing, the standard allows derivation of the rating of similar variants without testing, assuming the ratings of 'critical variants' have been established by test. For example, if the rating of a 250 A moulded case circuit-breaker (MCCB) circuit is verified by test, subject to rules defined in the standard, the rating of a circuit comprising a 200 A MCCB of the same frame size can be assigned. Similarly, if the rating of double lamination busbar has been determined by test, a current rating of 50% of the double lamination busbar can be assigned to a single lamination busbar.

This derivation of ratings for similar variants is pragmatic and conservative. When it can be used, any margins to be applied and design specific rules to be applied are all defined in the standard.

As a guide to the potential power loss within a PSC-assembly some typical test results for watts loss are shown in Figure 6.

1000 A Horizontal busbar section
114 W

15 kW DOL Starter - fuse protected
32 W

315 A Fuse Switch Disconnector
130 W

2000 A Air Circuit Breaker
365 W

Figure 6: Typical watts losses

A section of a typical PSC-assembly may have an available capacity to dissipate 400 watts. With circuits having losses as indicated in Figure 6, this can be readily exceeded.

If circuits which generate a lot of heat are incorporated, or the assembly's ability to dissipate heat is reduced, e.g. as a result of a high ambient temperature, the problems are even more acute. Natural ventilation may not be sufficient and forced ventilation may be the only alternative.

Temperature directly affects equipment life. The effective use of temperature rise verification is the key to ensuring long life and reliability in this respect.

2.10 Short-circuit protection and short circuit withstand strength

Performance requirements: Subclause 9.3
Design Verification: Subclause 10.11

Short-circuit withstand verification is necessary to verify the ability of electrical equipment to withstand the thermal, electrical and mechanical effects produced by short-circuit currents.

Verification can be achieved via test, comparison with a reference design or assessment, but the latter two methods is very restricted.

Short circuit withstand verification is not necessary when; (i) the prospective short-circuit current at the incoming terminals does not exceed 17 kA cut-off/10 kA r.m.s, or, (ii) the assembly or the circuit within the assembly is protected by a current limiting device having a cut-off current not exceeding 17 kA, with the maximum prospective short circuit current at the incoming terminals of the assembly. If these values are exceeded then verification by short-circuit test or comparison with a reference design with a capability at least equal to that required, which has been verified by test, is essential.

Verification by test

Where testing is employed, it is often carried out at an accredited third-party testing station which will issue a certificate detailing the tests that have been completed satisfactorily.

- Major structural changes to the assembly.
- Reductions in busbar cross-sections, changes in busbar profiles and spacing.
- Changes to the type or quantity of busbar supports or the support structures.

  Since any of the above deviations could affect the mechanical strength of the busbar system, these would cause unpredictable, and possibly adverse, changes to the short-circuit withstand rating of the busbars.
- Exclusion of or changes to major short-circuit protective devices taken account of in the programme of reference design verification.

  The effective short-circuit coordination between a major protective device, e.g. incoming fuse-switch or circuit-breaker, and an assembly or section thereof cannot be established other than by test. By removing a protective device, or installing protective devices not included in the verification programme, there is the risk of major damage to the assembly under conditions of short-circuit.
- Reductions in compartment sizes.

  Some short-circuit protection devices discharge ionized gases with force when interrupting short-circuit currents. A smaller compartment space to that tested could result in a short-circuit to earth via these gases or the inability of the smaller compartment to withstand the associated mechanical force.

The effects of other deviations may not be so self-evident but here it is reasonable to expect that assembly manufacturers, on the basis of their verification data, will be able to define very closely in their associated engineering procedures the limits of their application design parameters.

Figure 7: Variations that can affect performance

The verifications must be carried out in accordance with the requirements laid down in BS EN 61439-2. The nature of tests are such that they are not repeated for every piece of equipment supplied and are thus carried out on equipment manufactured specifically for testing purposes. For subsequent equipment to be covered by the test certificate it must be without significant variation in design. Variations that **could** significantly affect the performance include those in Figure 7.

In order to completely verify an assembly, it is necessary to verify a sample of each significant variation of circuit and busbar system within that assembly. Individual component parts such as contactors and MCCBs should have been tested by the component manufacturer. Within a range of equipment, this normally includes verification of short-circuit withstand strength on each type of:

- Main busbar system
- Distribution busbars
- Outgoing circuits
- Incoming and bus-section units.

In order to achieve the above, the verification is carried out in accordance with Subclause 10.11 of the standard and, where verification by test is undertaken, (Subclause 10.11.5) the test sequences would typically comprise the following:

a) Outgoing circuits

Each basic type of outgoing circuit which has not previously been tested is through-fault tested in turn.

For this test the circuit being considered is closed and a bolted short-circuit applied to its outgoing terminals. A 3-phase test supply having a voltage equal to 105% of the operational voltage of the equipment being tested, and capable of delivering the specified short-circuit current, is connected to the incoming terminals of the assembly. Usually with outgoing circuits this ‘prospective’ short-circuit current is allowed to flow until interrupted by a SCPD (fuse or circuit-breaker).

b) Incoming circuits and busbars

Generally, the incoming circuits and busbars (plus bus-section units) are tested together. The test supply is connected to the incoming terminals and a short-circuit applied to the remote end of the busbar system being considered. If the incoming circuit contains a SCPD, then the fault current may be interrupted after a short duration as described for outgoing circuits above. Alternatively, and more likely with larger rated PSC-assemblies, the fault current will be required to persist for a definite time (short-time withstand current). As for outgoing circuits, tests are carried out for 3-phase and single-phase and neutral, again with the prospective neutral current equal to 60% of the 3-phase value. Where different busbar designs (horizontal and vertical) are included within the assembly, each must be tested.

On completion of any short-circuit tests, at least the following must be maintained:

- minimum IP protection
- creepage and clearance distances
- insulation integrity and mechanical integrity

Slight deformation of enclosures and busbars is acceptable.

If the construction, mounting and spacing of the neutral conductor is identical to that of the phase bars this test is not necessary and need not be undertaken.

Verification by comparison with a reference design

Short-circuit verification by comparison to a previously tested reference design is permitted. The stringent checklist in the standard (Table 13 of the standard) demands very clear consideration of the salient differences from the reference design before verification can be assumed. Should any requirement not be fulfilled, then an alternative route to verification must be employed. This may be a calculation to determine the suitability of the busbar support system in accordance with Annex P of the standard.

Verification other than by test is very strictly controlled. Other than the 10 kA r.m.s./17 kA cut-off exclusion detailed above it must be from a tested base. Verification by comparison with a reference design does not, for example, give license to change the size and style of busbars, or even to change from one make of SCPD to another. Any risks incurred by this approach must be negligible.

Under no circumstances must the derived short-circuit rating exceed that of the tested reference design.

2.11 Electromagnetic compatibility (EMC)

Performance requirements: Subclause 9.4
Design Verification: Subclause 10.12

The EMC performance of a PSC-assembly is usually verified via assessment. This requires all components to be themselves compliant with the requirements for the stated environment AND their installation and wiring into the assembly to be undertaken in accordance with the component manufacturers' instructions. By these means, it is usually possible to avoid the need for EMC testing (a complex and exacting process) on PSC-assemblies, which, by their nature, are often one-off bespoke designs.

2.12 Mechanical operation

Design Verification: Subclause 10.13

The standard is brief and concise in defining requirements for verification of mechanical operations.
Those parts incorporated into a PSC-assembly that have already been type tested in accordance with their own product standards (for example, operating handles of switching devices) do not need to be verified again unless the method of mounting has affected the device's operation.

Where parts do need to be verified, 200 operating cycles are used to prove effective operational capability. At the same time, the operation of any mechanical interlocks associated with the part's movements are checked to ensure continued effectiveness of other operational aspects of the apparatus, such as the degree of protection, are not impaired and the effort required for the operation is almost the same as before the test.

Where withdrawable parts are employed, the action of moving the withdrawable part from the connected position to the isolated position and back to the connected position has to be verified.

3. Routine Verification

This chapter gives a brief introduction to routine verification.

The introductory text in BS EN 61439-1, Clause 11 clearly states that the basic intent of Routine Verification is to detect faults in manufacture and workmanship and to verify the proper functioning of the manufactured assembly.

The timing of the specified routine verifications is a decision of the manufacturer and can be completed at any time during and/or after the manufacturing process. Every manufactured assembly has to be subjected to the routine verification process.

Routine verification on devices and components already verified in accordance with their own product standards and installed in accordance with manufacturer's instructions is not required. The routine verification tests comprise of those in Figure 8.

1) Construction (see subclauses 11.2 to 11.8)
   - a) degree of protection of enclosures
   - b) clearance and creepage distances
   - c) protection against electric shock and integrity of protective circuits
   - d) incorporation of built-in components
   - e) internal electrical circuits and connections
   - f) terminals for external conductors
   - g) mechanical operation
2) Performance (see subclauses 11.9 to 11.10)
   - a) dielectric properties
   - b) wiring, operational performance and function

Figure 8: Routine verifications

These requirements are further amplified in subclauses 11.2 to 11.10 of the standard but as the standard covers a broad range of equipment, it is very general. It is up to each manufacturer to establish, within their Quality Assurance System, procedures which will ensure they are fully satisfied the equipment they are providing complies with the standard, and that the equipment is fit for purpose. In addition, the user may also have included within the contract further specific routine verifications they believe are necessary to confirm the assembly is suitable for their applications, e.g. measuring the resistance of busbar joints.

In order to carry out routine verification in a controlled, logical and efficient manner it is usual for a manufacturer to have detailed procedures with limits of acceptance for measured results.

However, it should be noted that wide variations in absolute values can be obtained, dependent on the context of the verification undertaken.

For example, if in the case of an assembly rated not more than 250 A, measurement of resistance is used instead of power frequency dielectric test, the insulation resistances measured in the various verifications will depend on the size of the assembly, its contents and the climatic conditions. Usually manufacturers will set their own minimum values. This may be of the order of 10 megohms but the standard only requires a minimum of 1000 ohms/volt per circuit. It is also important to recognise that values obtained in a clean, dry factory can be considerably reduced when the equipment is installed on site.

It is now general practice for the results obtained during routine verification to be formally recorded on documents that form part of the supplier's Quality Plan and, as such, an inherent element in their quality assurance procedures.

4. Considerations for Small Assemblies

The verification requirements of the standard are extensive and cover a wide variety of PSC-assemblies from large high current distribution boards to small control panels for individual machines. To undertake a complete programme of design verification to assure compliance with the standard via the testing route will often be an expensive and time consuming approach. However, alternatives to testing are available to reduce this potentially onerous burden.

Manufacturers of small assemblies such as control panels, subject to specific conditions, can take advantage of the alternative routes to verification. Whilst this approach does require the inclusion of the safety margins prescribed in the standard, it can avoid the time and cost associated with conducting many of the design verification tests detailed in Figure 3.

For example, the use of an enclosure verified in accordance with BS EN 62208:2011, Empty enclosures for low-voltage switchgear and controlgear assemblies - General requirements, provides an exemption from repeating the verification requirements of BS EN 61439-1 Subclause 10.2, '*Strength of materials and parts*', and Subclause 10.3, *'Degree of protection of assemblies'*.

When using a pre-verified enclosure in accordance with BS EN 62208, the assembly manufacturer must not modify the enclosure in any way that degrades the performance of the enclosure. For example, to maintain the IP rating of an enclosure when fitting a device that requires punching a hole through the cover, the IP rating of the device must be at least equivalent to that of the unmodified enclosure. In addition, measures should be taken to maintain any anti-corrosion treatments when punching or drilling holes, for example.

BS EN 61439-1 Subclause 10.11.2 also details exemption criteria from short-circuit verification requirements, subject to assembly characteristics as follows:

a) *Assemblies having a rated short-time withstand current or rated conditional short-circuit current not exceeding 10 kA r.m.s.*

b) *Assemblies, or circuits of assemblies, protected by a current-limiting devices having a cut-off current not exceeding 17 kA at the maximum allowable prospective short-circuit current at the terminals of the incoming circuit of the assembly.*

c) *Auxiliary circuits of assemblies intended to be connected to transformers whose rated power does not exceed 10 kVA for a rated secondary voltage of not less than 110 V, or 1,6 kVA for a rated secondary voltage less than 110 V, and whose short-circuit impedance is not less than 4%.*

In these specific cases, manufacturers of small assemblies are able to apply a combination of design rules, calculations and a much reduced and simplified test regime to verify the assembly in accordance with the standard.
It can be seen from a cursory view of Figure 3 that, once the above two major issues have been effectively resolved, the majority of the remaining verification requirements have a 'verification by design rules' option and can thus be completed without the significant costs of testing.

There remain two characteristics that require tests to be undertaken; item 5 in Figure 3, Subclause 10.5.2, where confirmation of effective continuity of exposed conductive parts and the protective conductor must be proven to be 0,1 ohms or less. This is normally completed via a simple resistance measurement.

The other is in item 9, Figure 3, Subclause 10.9.2, where the dielectric properties of the assembly must be tested. The power frequency withstand voltage test is normally undertaken at the final inspection stage using simple and readily available equipment.

The standard details the design verification compliance criteria for all other requirements where options for verification via comparison to a reference design or assessment are provided.

So, for small assemblies that fall within the exemption criteria and when using a pre-verified enclosure to BS EN 62208, manufacturers can greatly reduce the requirements for testing and simplify the route to compliance to BS EN 61439-2.

5. The So-Called 'Fault-Free Zone'

Introduction

The main busbars and the connections between them and the supply side of functional units share the same upstream short-circuit protection. Therefore, in the absence of any relaxation to the contrary, these connections would need to have the same short-circuit withstand strength as the main busbars themselves.

However, in practice it may be impossible or, at least, impractical or uneconomic to achieve this short-circuit strength because the rated currents of some functional units may be of a much lower order than that of the busbars and this may have to be reflected in the dimensioning of the associated conductors and, indeed, in the dimensioning of related circuit parts such as plugs and sockets (e.g. in the case of withdrawable functional units).

The solution

In such cases, the dilemma is resolved by part of Subclause 8.6.1 of the standard which allows that the conductors between the main busbars and the supply side of functional units may be rated on the basis of the reduced short-circuit stresses occurring on the '*load side*' of the respective short-circuit protective devices in the functional units. This relaxation is subject, of course, to certain provisos. For example, the conductors have to be arranged '*…so that under normal operation an internal short-circuit ... is not to be expected*'.

The term *'fault-free zone'* is used colloquially to describe this interface zone between the main busbars and the functional units, although it is not actually a term which is used in the standard, which refers to *'non-protected live conductors'*.

Distribution busbars are particular examples of conductors which may be rated on the basis of down-stream SPD. The standard defines a distribution busbar to be *'a busbar within one section which is connected to a main busbar and from which outgoing units are supplied'*.

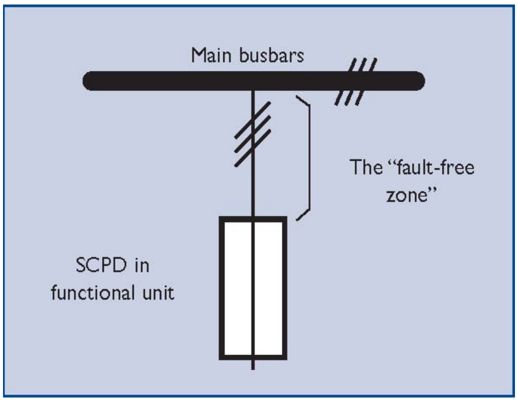


Figure 9: The 'fault-free zone'

Subclause 8.6.4 provides guidance on the selection and installation of conductors in order to satisfy the objective that a short-circuit between the conductors, or between the conductors and earth, should be only a *'remote possibility'*. At the same time it encompasses certain other circuits in a PSC-assembly where it may not be possible to provide upstream short-circuit protection. For example, auxiliary circuits, where danger could arise if the supply were to be interrupted through the operation of an upstream protective device.

Subclause 8.6.4 provides this guidance in the form of a table (see Figure 10). It gives examples of conductor types and associated installation requirements. Conductors installed, as detailed in this table and having a short-circuit protective device connected on the load side may be up to three metres in length.

Type of Conductor	Requirements
Bare conductors or single-core conductors with basic insulation, for example cables according to IEC 60227-3	Mutual contact or contact with conductive parts shall be avoided, for example by use of spacers
Single-core conductors with basic insulation and a maximum permissible conductor operating temperature of at least 90° C, for example cables according to IEC 60245-3, or heat-resistant thermo-plastic (PVC) insulated cables according to IEC 60227-3	Mutual contact or contact with conductive parts is permitted where there is no applied external pressure. Contact with sharp edges shall be avoided. These conductors may only be loaded such that an operating temperature of 80 % of the maximum permissible conductor operating temperature is not exceeded
Conductors with basic insulation, for example cables according to IEC 60227-3, having additional secondary insulation, for example individually covered cables with shrink sleeving or individually run cables in plastic conduits	No additional requirements
Conductors insulated with a very high mechanical strength material, for example Ethylene Tetrafluoro Ethylene (ETFE) insulation, or double-insulated conductors with an enhanced outer sheath rated or use up to 3 kV, for example cables according to IEC 60502	
Single or multi-core sheathed cables, for example cables according to IEC 60245-4 or IEC 60227-4	

Figure 10: Examples of conductor types and associated installation requirements - conductors not protected by short-circuit protective devices (derived from BS EN 61439-1)

6. Forms of Internal Separation (Forms 1 – 4)

Introduction

The internal compartmentalisation of PSC-assemblies, being a specific characteristic of PSC-assemblies, is dealt with in BS EN 61439-2, Subclause 8.101.

This Subclause refers to Table 104 and is concerned with the ways in which the busbars and 'functional units' in an assembly may be separated from one another - either by fitting interposing barriers or by locating them in separate compartments, and classifies some typical arrangements into four groups - the so called 'Forms of internal separation, Forms 1-4' (see Figure 12).

The Subclause is only concerned with this one aspect of internal separation and does not otherwise preclude the use, for whatever purposes, of other barriers, partitions, shrouds or compartmentalisation. It should already be emphasised at this stage that the standard also does not impose a requirement on the manufacturer to adopt any of the Form 1-4 separation classifications. Indeed, for some assemblies it can be inappropriate or impossible to do so. For example, since each classification (except Form 1) relates to the separation of functional units from busbars, then it would clearly be difficult to declare any of the other classifications in the case of an assembly having no busbars. Nevertheless, such an assembly can still conform fully with the standard and the manufacturer is entirely free to discuss alternative or synonymous separation arrangements with the client. This is just one reason why the standard makes it clear that the form of separation has to be subject to agreement between the manufacturer and user.

The elements to be separated

The Subclause is concerned solely with the separation of busbars and functional units.

By busbars is meant the main busbars as well as any associated distribution busbars.

A functional unit is defined as a '*part of an assembly comprising all the electrical and mechanical elements including switching devices that contribute to the fulfilment of the same function*.' Typical examples of functional units would be incomers, distribution outgoers, individual starters, and the like.

Special consideration is given to those terminals which are required for the connection of external conductors to a functional unit and which are treated as an integral part of that unit. These may have to be separated from the terminals of other functional units and/or from the busbars. In some cases there may be advantages in separating the outgoing terminals from the main body of the associated functional unit.

Conductors which are connected to a functional unit but which are external to its compartment or associated individual terminal box (e.g. control cables to a common marshalling compartment) would not be considered to form part of the functional unit. This particular issue is covered by the National Annex (Annex NA) to the standard, specifically directed to PSC-assemblies manufactured in accordance with BS EN 61439-2.

Separation objectives

The standard only considers the two objectives detailed in Figure 11. Either one or both of these objectives may be used as the basis of a classification of the Form of internal separation.

- Protection against contact with hazardous parts. The degree of protection shall be at least IPXXB.
- Protection against the passage of solid foreign bodies. The degree of protection shall be at least IP2X.

Note: The degree of protection IP2X covers the degree of protection IPXXB

Figure 11: The possible objectives of internal separation (derived from BS EN 61439-2

The purpose of the first of these objectives is to ensure that there will be at least '*fingerproof*' (IPXXB) protection between adjacent functional units. This, subject to national legislation, is to enable an individual functional unit to be disconnected (isolated) from the supply and for its interior to be accessed while the rest of the assembly remains in service. The aim here is to reduce the risk that accidental contact could be made with the live parts of adjacent units or busbars.

Similarly, if the functional unit in question is of the removable or withdrawable type and has been removed from the PSC-assembly, then access to live parts via the vacated compartment interior must also be restricted.

The second objective is to reduce the risk that loose parts, tools or debris, for example, could fall or otherwise pass into an adjacent compartment. This could occur either while the assembly is in service or, as above, while work is being carried out on an individually isolated functional unit. The requirement that the degree of protection must be at least IP2X means that objects greater than 12.5 mm diameter are unable to pass into adjacent functional units.

The requirement for at least IP2X or IPXXB protection also makes it clear, subject to certain provisos, that gaps between compartments can be allowed. Higher degrees of protection may be demanded for certain applications and these are permitted by the standard subject to agreement between the manufacturer and user.

It should be clearly noted that these two objectives are not concerned with separation in terms of arc-fault containment. Arc-fault containment is not specifically addressed in the standard and might need to be the subject of a special agreement between the manufacturer and user.

The means of separation

The standard states that separation may be achieved by means of partitions or barriers (metallic or non-metallic), insulation of live parts or by the integral housing of a device itself (e.g. MCCB).

It can be seen then that the standard is not solely concerned with compartmentalisation in the strictest sense, i.e. the confinement of a number of functional units within their own discrete and virtually sealed housings, but also with their separation through the interposition of simple partitions or barriers.

A barrier is defined as a *'part intended to provide protection against direct contact from any usual direction of access.'*

Because of the wide variety of PSC-assemblies which this standard covers - from small control panels to large motor control centres and distribution boards, and not least because of the variety of constructional possibilities which may be available even within a given assembly type - the standard does not attempt to impose detailed design requirements.

It does not dictate, for example, how the partitions or barriers are to be constructed or from what materials they are to be made. Nor has it been found practicable to lay down performance criteria apart from the IPXXB or IP2X verification requirements.

The manufacturer is, therefore, allowed considerable freedom in his choice of constructional techniques and materials and may indeed be able to offer the user several possible solutions, even for a given assembly type.

This freedom is yet another reason for the standard to state that *'the form of separation ...shall be the subject of an agreement between ASSEMBLY manufacturer and user.'* (BS EN 61439-2 Subclause 8.101).

The Forms of separation (Forms 1- 4)

The basic descriptions of the Forms of separation are set out in Figure 12.

The standard explains that these Forms of separation are to be regarded as <u>typical only</u>. In other words, it is not an exhaustive list and <u>does not preclude</u> other arrangements.

Furthermore, just as there is flexibility in the choice of construction techniques and materials for the barriers and partitions, so there is also wide flexibility in the design solutions which can be offered for each Form of separation. There are no definitive solutions!

For a given Form, the actual design solution which is chosen is likely to depend on several factors. For example, if the intention of deciding on a Form 4a or 4b arrangement is to allow maintenance staff to access the interiors of individually isolated functional units or their terminals while the rest of the PSC-assembly remains live, then the decision may also depend on the likely frequency of access and the qualifications/experience of the persons involved in such activities. It will depend also on the solution possibilities offered by the particular assembly type and, last but not least, it will almost certainly depend on the cost!

For example, the user may wish for a Form 4a arrangement in which the terminals are accommodated in the same compartment as the associated functional unit. However, space and other factors may hinder or preclude this option. If, therefore, consideration has to be given to a Form 4b solution in which the terminals are separately accommodated, then a choice of constructions for the terminal housings may be available for a given PSC-assembly type ranging from simple flexible shrouds to individual rigid insulated or steel casings. Each solution has its place - and this is yet another reason for the Form of separation to be the subject of agreement between the manufacturer and user.

Form 1 No internal separation.

Form 2a Separation of the busbars from the functional units. The terminals for external conductors are not separated from the busbars.

Form 2b As 2a but the terminals for external conductors are separated from the busbars.

Form 3a Separation of the busbars from the functional units and separation of all the functional units from one another. The terminals for external conductors and the external conductors are separated from the functional units, but not from each other or from the busbars.

Form 3b As 3a but the terminals for external conductors are separated from the busbars.

Form 4a Separation of the busbars from the functional units and separation of all functional units from one another, including the terminals for external conductors which are an integral part of the functional unit. Separation of the terminals for external conductors associated with a functional unit from the terminals of any other functional unit and the busbars. Separation of external conductors from the busbars and separation of the external conductors associated with a functional unit from other functional units and their terminals. External conductors need not be separated from each other. The terminals for external conductors are in the same compartment as the associated functional unit.

Form 4b As 4a but the terminals for external conductors are not in the same compartment as the associated functional unit, but are in individual, separate, enclosed protected spaces or compartments.

Figure 12: The Forms of separation (derived from BS EN 61439-2 Table 104)

National Annex to BS EN 61439-2:2009

A UK National Annex to the standard has been published in order to provide manufacturers, specifiers and users with a means of specifying some of these possible solutions. For ease of reference this describes and classifies various basic solutions based on typical UK practice. They are included, where appropriate, against the Forms 1-4 under the heading 'Types of construction'.

It should be noted, however, that these Types of construction do not preclude other constructional arrangements, nor is it necessary to adopt any of the included Types in order to comply with the requirements of the standard. Nevertheless, adoption of an included Type may assist in the process of achieving agreement between manufacturers and users.

Essentially, the 'Types of construction' consider three aspects of the PSC-assembly design:

- the arrangement of the terminals for external conductors, i.e. whether or not accommodated in the same compartment as the associated functional unit

- the material to be used for the barriers and partitions separating the busbars, functional units and terminals, i.e. whether this is to be of metal or insulating material (rigid or flexible)

- the location of the glanding arrangements, i.e. whether each functional unit has its own integral glanding facility.

When deciding on the required Type of construction and, indeed, when selecting between Forms 1-4, it is desirable to strike a sensible balance between the actual application requirements and the likely cost.

For example, taking some opposite extremes, in so far as a choice is available it is self-evident that a Form 1 PSC-assembly is likely to be significantly less expensive than its equivalent Form 4 version. Similarly, the cost of a Form 4 Type 5 PSC-assembly with its terminals merely separated by rubber 'boots', for example, is likely to be significantly less costly than Form 4 Type 7 PSC-assembly with its terminals installed in separate, integrally glanded and rigid-walled compartments.

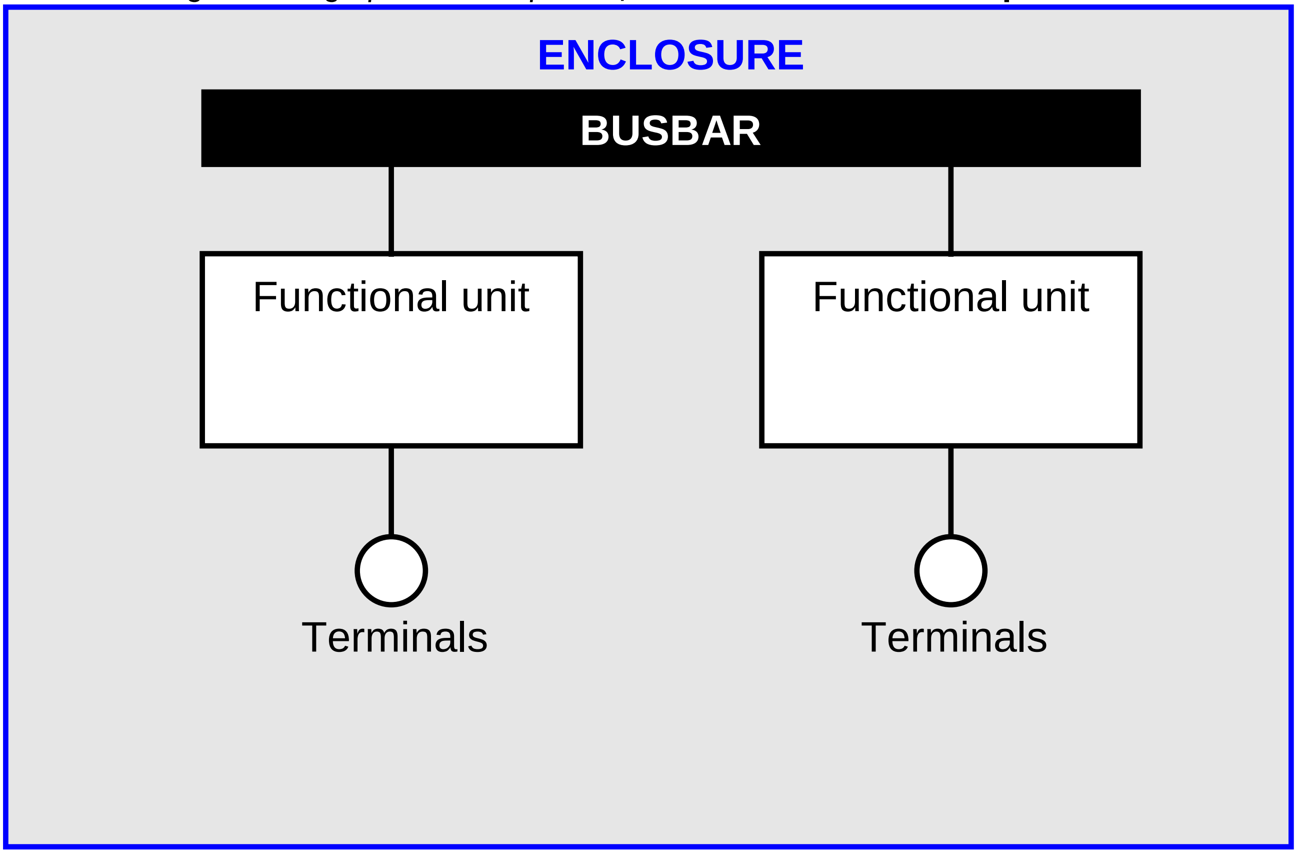
The latter solution (Form 4 Type 7) could be an appropriate choice in cases where cabling access to the terminals of functional units is needed at all times and it is impossible to disconnect the rest of the PSC-assembly from the supply when carrying out such work. On the other hand, a solution such as Form 4 Type 5 might be considered by the user to be adequate and more cost effective in cases where it would be only rarely necessary to access terminals while the PSC-assembly was live and where such access would only be required for simple inspection purposes by skilled and experienced personnel.

Forms of separation/Types of construction

The Forms of internal separation and the associated Types of construction are illustrated in Figures 13.1 through 13.9. The diagrams are simple schematics intended solely to illustrate the principles involved. They are not intended to represent or determine in any way the actual physical layouts of assemblies.

Form 1

Figure 13.1 graphical description of **Form 1: No internal separation**



Form 2

Separation of busbars from all functional units

Figure 13.2 graphical description of **Form 2a:** Terminals not separated from busbars

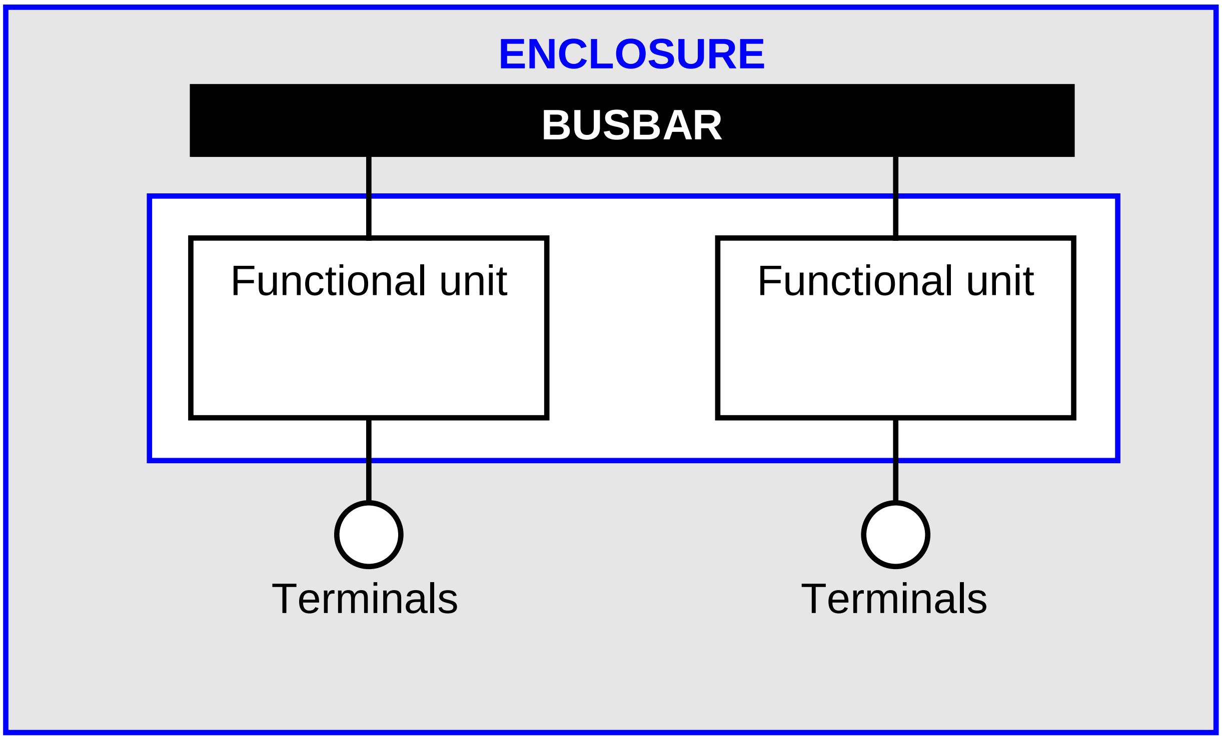
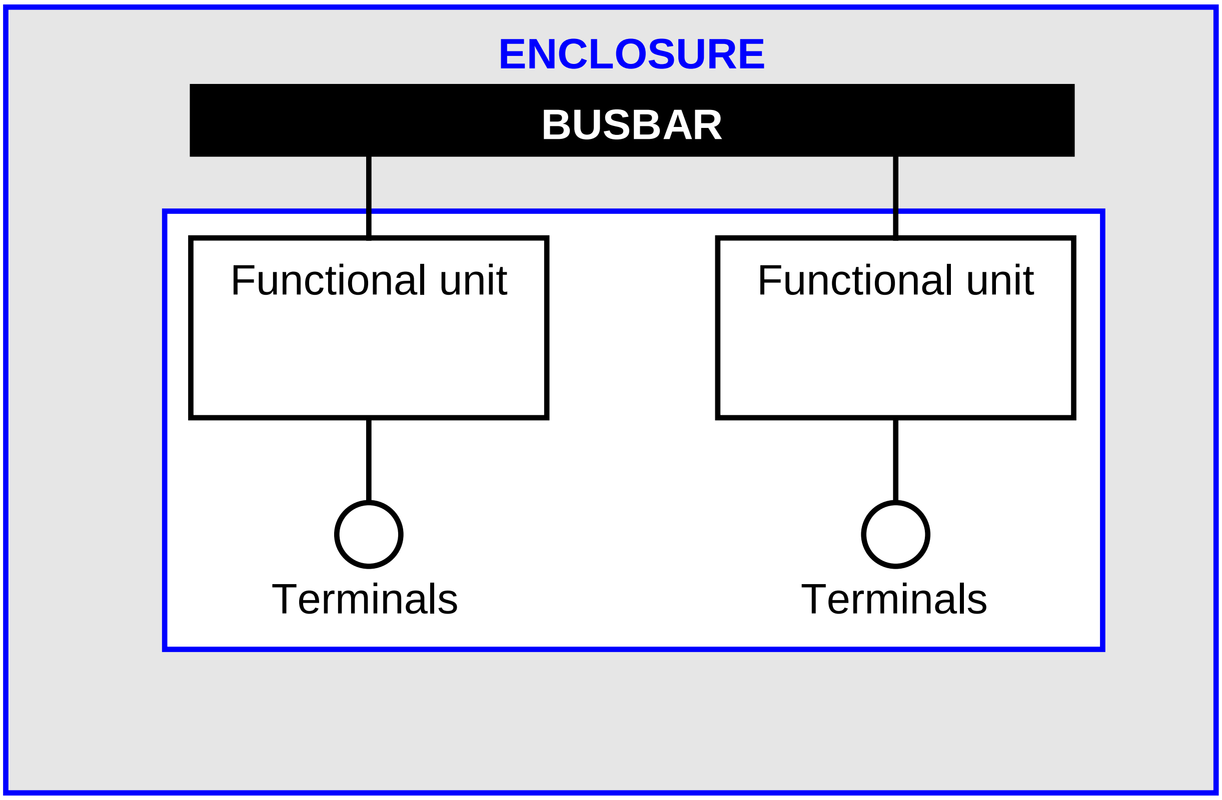


Figure 13.3 graphical description of **Form 2b:** Terminals separated from busbars



Typical **Form 2** solutions:

Type 1: Busbar separation is achieved using an insulated covering e.g. Sleeving or wrapping (BS EN 61439-1 §8.4.2.2 for more information on insulation of hazardous live parts).

Type 2: Busbar separation is achieved using metallic or non-metallic rigid barriers or partitions.

Form 3

Separation of busbars from all functional units
+
Separation of all functional units from one another
+
Separation of terminals for external conductors and external conductors from the functional units, but not from the terminals of other functional units

Figure 13.4 graphical description of **Form 3a:** Terminals not separated from busbars

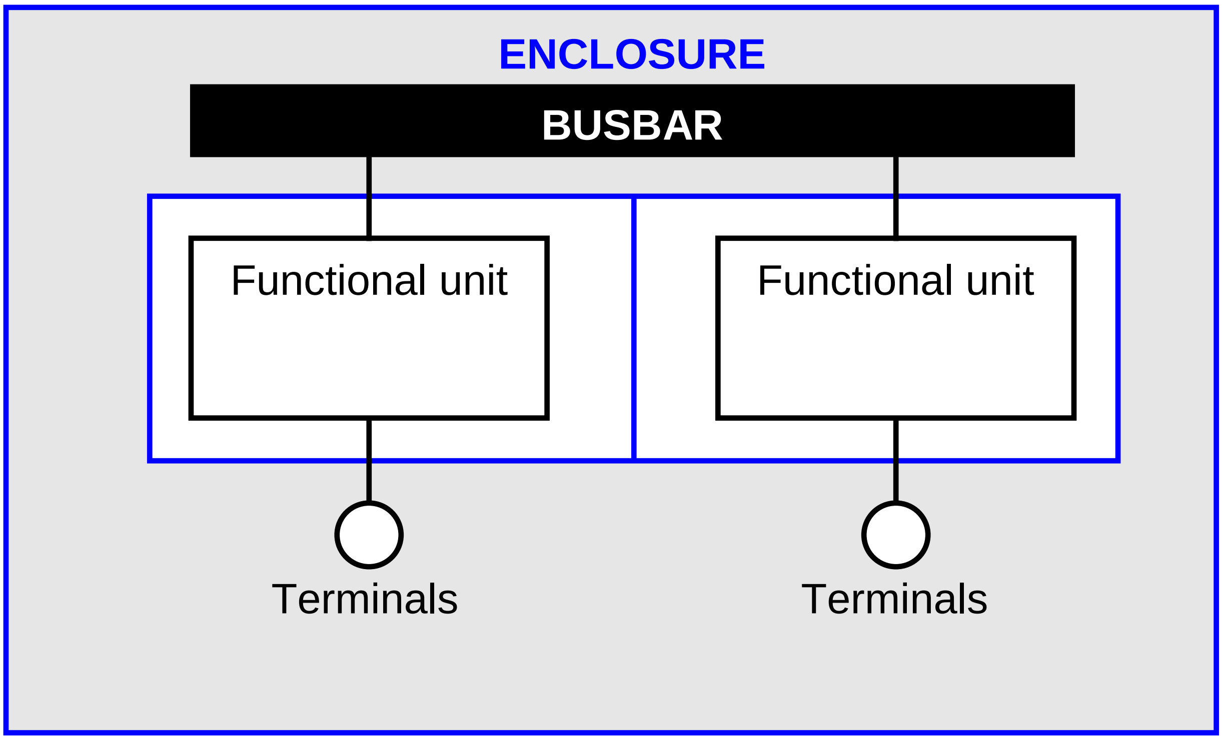
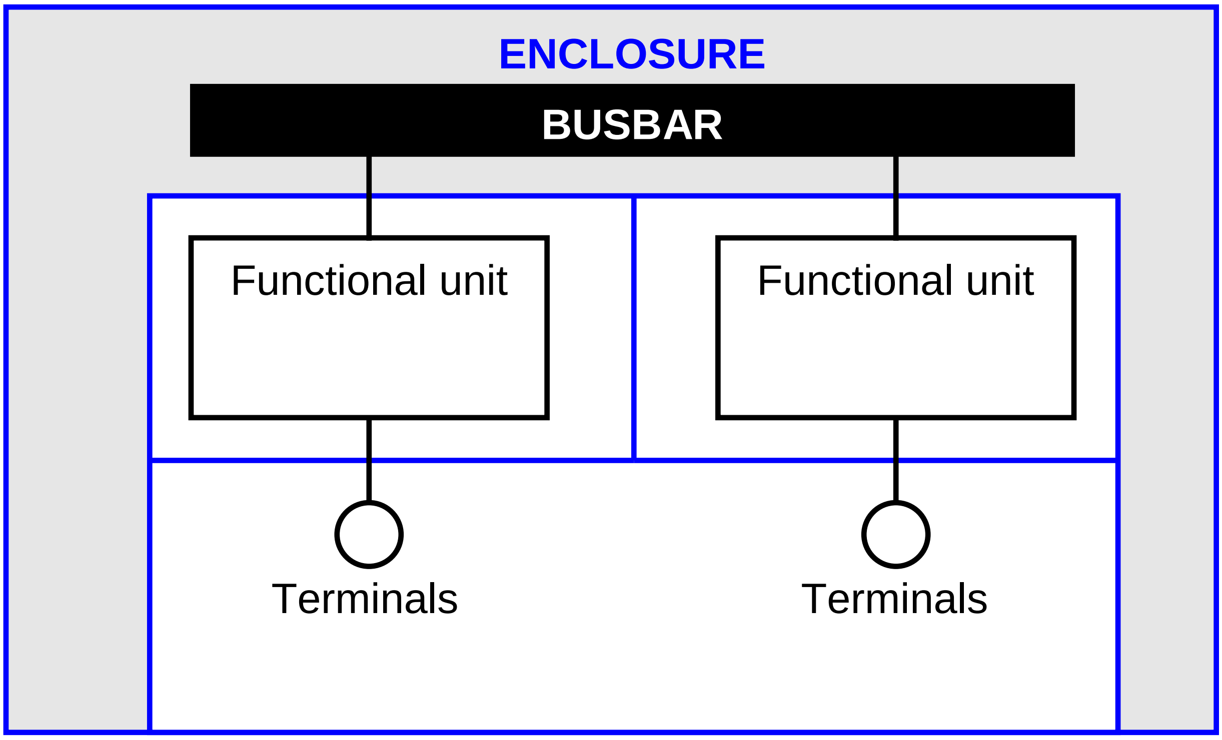


Figure 13.5 graphical description of **Form 3b:** Terminals and external conductors separated from busbars



Typical **Form 3** solutions:

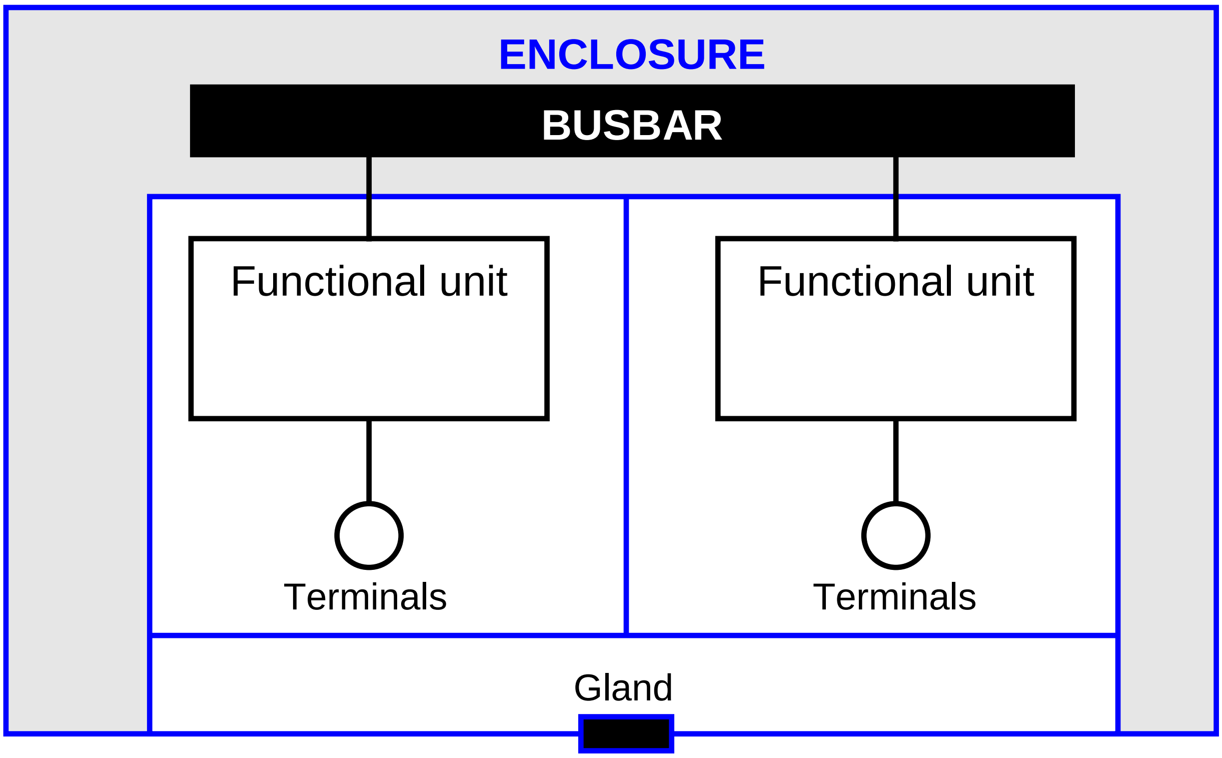
Type 1: Busbar separation is achieved using an insulated covering e.g. Sleeving or wrapping (BS EN 61439-1 §8.4.2.2 for more information on insulation of hazardous live parts).

Type 2: Busbar separation is achieved using metallic or non-metallic rigid barriers or partitions.

Form 4

Separation of busbars from all functional units
+
Separation of all functional units from one another
+
Separation of terminals for external conductors associated with a functional unit from the terminals of any other functional unit and the busbars
+
Separation of the external conductors from the busbars
+
Separation of the external conductors associated with a functional unit from other functional units and their terminals
+
External conductors need not be separated from each other

Figure 13.6 graphical description of **Form 4a:** Terminals in same compartment as associated functional unit (common glanding):

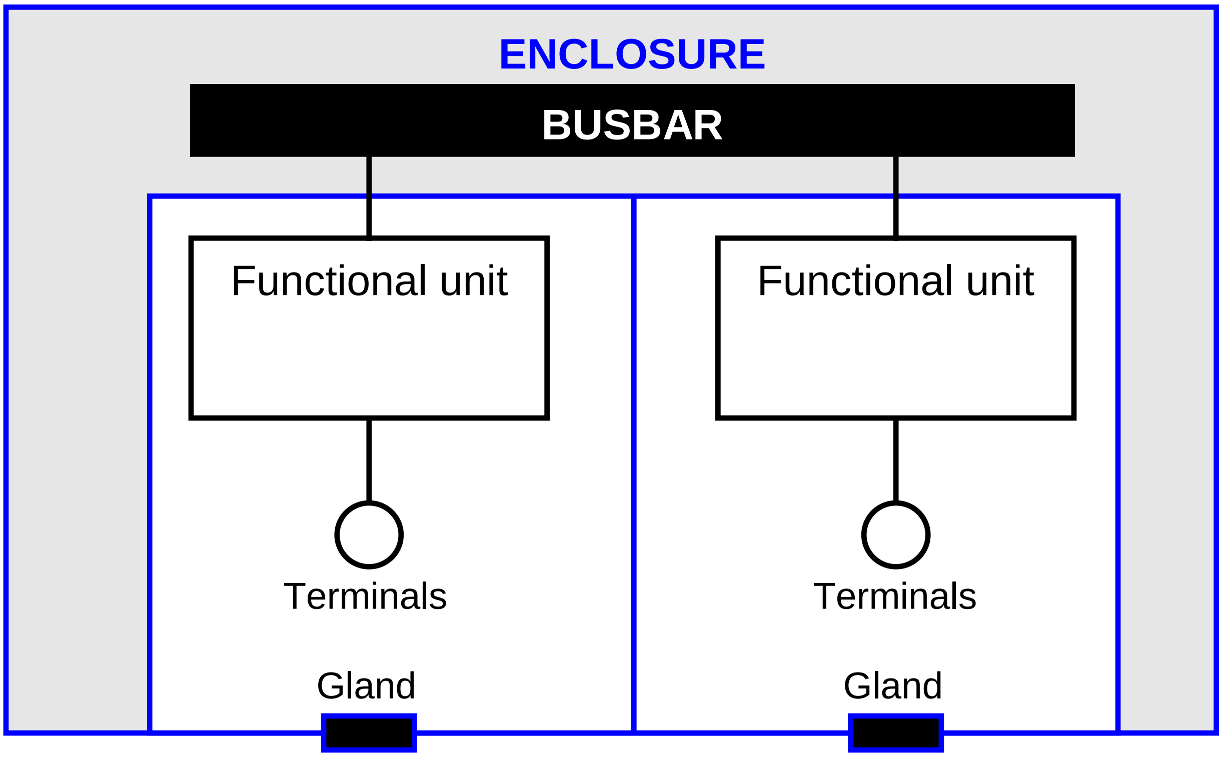


Typical **Form 4** solutions:

Type 1: Busbar separation is achieved using an insulated covering e.g. Sleeving or wrapping. (BS EN 61439-1 §8.4.2.2 for more information on insulation of hazardous live parts).
Cables may be glanded elsewhere.

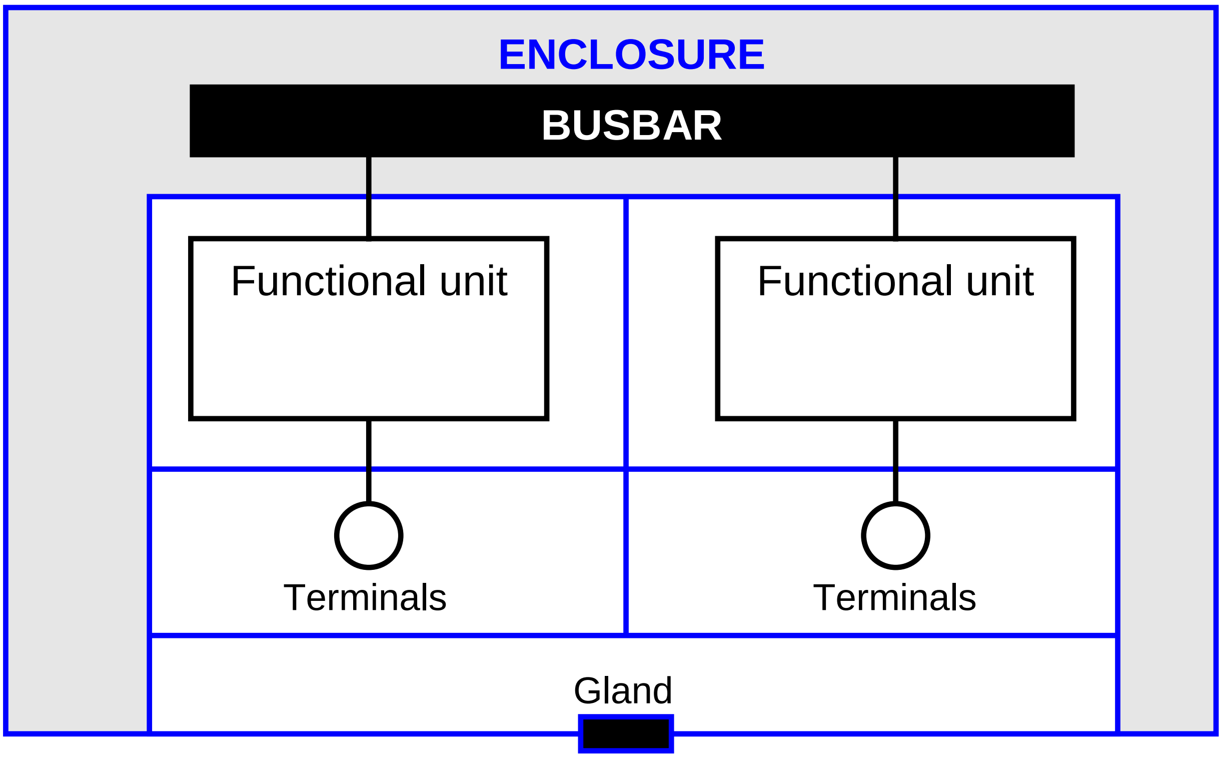
Type 2: Busbar separation is achieved using metallic or non-metallic rigid barriers or partitions.
Cables may be glanded elsewhere.

Figure 13.7 graphical description of **Form 4a:** Terminals in same compartment as associated functional unit (separate glanding):



Type 3: Busbar separation is achieved using metallic or non-metallic rigid barriers or partitions.
The termination for each functional unit has its own integral glanding facility.

Figure 13.8 graphical description of **Form 4b:** Terminals for external conductors NOT in the same compartment as associated functional unit (common glanding):

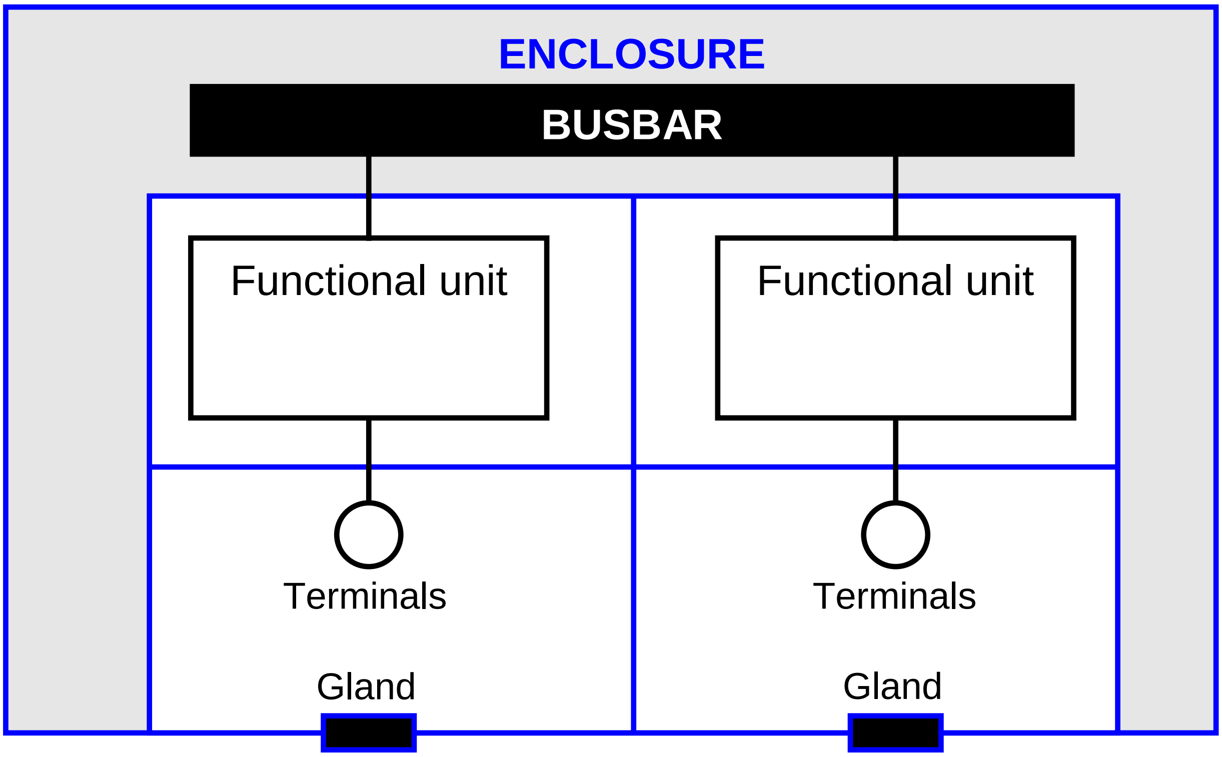


Type 4: Busbar separation is achieved using an insulated covering e.g. Sleeving or wrapping.
(BS EN 61439-1 §8.4.2.2 for more information on insulation of hazardous live parts).
Cables may be glanded elsewhere.

Type 5: Busbar separation is achieved using metallic or non-metallic rigid barriers or partitions.
Terminals may be separated by insulated coverings.
(BS EN 61439-1 §8.4.2.2 for more information on insulation of hazardous live parts).
Cables may be glanded in common cabling chambers.

Type 6: All separation requirements are achieved using metallic or non-metallic rigid barriers or partitions.
Cables are glanded in common cabling chambers.

Figure 13.9 graphical description of **Form 4b:** Terminals for external conductors NOT in the same compartment as associated functional unit (separate glanding):



Type 7: All separation requirements are achieved using metallic or non-metallic rigid barriers or partitions.
The termination for each functional unit has its own integral glanding facility.

Note: Conductors which are connected to a functional unit, but where they are external to its compartment or enclosed protective space (e.g. control cables connected to a common marshalling compartment) are not considered to form part of the functional unit.

7. European Directives

7.1 Introduction

Assemblies placed on the EU/EEA market are required to comply with all applicable legislation.

Some of the legislation (including the Low Voltage Directive and EMC Directive) requires that equipment is CE marked and has a Declaration of Conformity (DoC):

The CE marking affixed to equipment is a declaration by the manufacturer that:

- the equipment conforms to all applicable provisions, and
- the appropriate conformity assessment procedures have been completed.

The DoC is a statement by the manufacturer, intended for use by the regulatory authorities, declaring that he has fulfilled the requirements of the referenced directives.

The UK Government web site provides FAQ's on CE marking at:

http://www.berr.gov.uk/whatwedo/sectors/sustainability/regulations/cemark/page11646.html

Should investigations carried out by a national enforcement authority confirm that any of the requirements of any relevant directives have **not** been met it could lead to total banning of the assembly from the European market, and perhaps the fining and/or imprisonment of the responsible person. Misapplication of the CE mark could itself lead to the removal of the assembly from the market.

Although other directives may apply (see 7.4) the main directives to consider are the Low Voltage Directive (see 7.2) and the EMC Directive (see 7.3).

7.2 The Low Voltage Directive

The Low Voltage Directive is applicable to low-voltage electrical equipment operating at voltages from 50 - 1000V a.c. or 75 - 1500V d.c. It requires that LV equipment may be placed on the European market only if it satisfies certain basic ('essential') safety requirements. These requirements are intended to protect against hazards such as:

- direct and indirect shock hazard
- hazards arising from dangerous temperatures, arcs or radiation
- hazards arising from overloading
- hazards arising from insulation failures
- hazards arising from mechanical failures

- hazards arising from the expected environmental conditions
- hazards arising from non-electrical dangers

Naturally, there are certain provisos – for example, the equipment must be used in applications foreseen by the manufacturer, and must be adequately maintained.

The Directive itself does not go into detail of how these requirements are actually to be met but states that equipment is deemed to comply if it satisfies the safety provisions of relevant European harmonised standards.

This means that assemblies conforming to the BS EN 61439 series are considered to satisfy those essential requirements of the Low Voltage Directive to which the standard relates.

Furthermore, the Low Voltage Directive states that, if an assembly satisfies these safety requirements, then its free movement within the European market must not be impeded for reasons of safety.

The Low Voltage Directive (Directive 2006/95/EC on the harmonization of the laws of Member States relating to electrical equipment designed for use within certain voltage limits) is implemented in the UK through the Electrical Equipment (Safety) Regulations 1994 (SI 1994/3260).

7.3 The EMC Directive

The EMC Directive (EMC = Electromagnetic Compatibility) requires that equipment has an adequate level of immunity to electromagnetic disturbances, and does not generate excessive electromagnetic disturbances.

As well as addressing the safety requirements of the Low Voltage Directive the BS EN 61439 standards, following their listing in the OJ under the EMC Directive, can give a presumption of conformity to the EMC Directive.

It has to be recognised that the application of the EMC Directive to assemblies poses particular problems. For example, many assemblies are manufactured as one-off, customised units and, as such, incorporate a wide selection of devices and components which will, individually and/or in combination, exhibit particular EMC performance characteristics. It is difficult, therefore, to conceive of any system of sample testing which could accurately predict the EMC performance of all the possible assembly variations which could arise in practice. Also, on account of their physical size and ratings, meaningful EMC testing of assemblies, which would have to be carried out under conditions of full load, would in any case usually be quite impracticable.

Furthermore, each assembly forms part of an installation comprising incoming and outgoing power supply and load circuits, motors, cables and external wiring. All of these elements have an influence on the EMC performance of the assembly and might not be under the control of the manufacturer.

Therefore, BS EN 61439-1 adopts the approach that consideration can only be given to the EMC requirements for the individual products that are to be built into the assembly: BS EN 61439-2 does not require additional EMC requirements to those of Part 1 for PSC-assemblies.

It states that, unless subject to special agreement, an assembly is intended for use in one of the following electromagnetic environments A or B, which has to be agreed between the supplier and user:

Environment A: relates to a power network supplied from a high or medium voltage transformer dedicated to the supply of an installation feeding manufacturing or similar plant, and intended to operate in or in proximity to industrial locations, as described below. The standard also applies to apparatus that is battery operated and intended to be used in industrial locations. Both indoor and outdoor environments are encompassed. Industrial locations are additionally characterized by one or more of:

- industrial, scientific and medical (ISM) as defined in BS EN 55011:2009 + A1: 2010
- heavy inductive loads are frequently switched
- currents and associated magnetic fields are high

Note 1: Environment A is covered by the generic EMC standards BS EN 61000-6-2:2005 and BS EN 61000-6-4:2007 + A1: 2011

Environment B: relates to low-voltage public mains networks or apparatus connected to a dedicated DC source which is intended to interface the apparatus and the low-voltage public mains network. It also applies to apparatus which id battery operated or is powered by a non-public, but non-industrial, low-voltage power distribution system if this apparatus is intended to be used in the locations described below.

The environments encompassed are residential, commercial and light-industrial, both indoor and outdoor. The following list, although not comprehensive, gives an indication of locations which are included:

- residential properties, e.g. houses, apartments
- retail outlets, e.g. shops, supermarkets
- business premises, e.g. offices, banks
- areas of public entertainment, e.g. cinemas, public bars, dance halls
- outdoor locations, e.g. petrol stations, car parks, sport centres
- light-industrial locations, e.g. workshops, laboratories, service centres

Locations which are characterized by being supplied directly at low voltage from the public mains network are considered to be residential, commercial or light industrial.

Note 2: Environment B is covered by the generic EMC standards BS EN 61000-6-1:2007 and BS EN6000-6-3:2007 + A1: 2011.

The environmental condition A and/or B for which the assembly is suitable shall be stated by the assembly manufacturer.

BS EN 61439-1 goes on to state that no EMC immunity or emission tests are then required to be carried out on the assembly provided the following conditions are fulfilled:

a) the incorporated devices and components are designed for the specified Environment A or B in line with the relevant harmonised product or generic EMC standards, and

b) the internal installation and wiring is carried out in accordance with the instructions of the manufacturers of the devices and components (arrangement with regard to mutual influences, cable screening, earthing, etc)

In all other cases, BS EN 61439-1 specifies the EMC immunity and emission requirements that are to be verified by testing.

Many of the products which will be built into assemblies are already covered by the necessary product EMC standards, e.g. the BS EN 60947 series of standards covering low-voltage switchgear and controlgear. The EMC performance requirements laid down in these standards also relate to Environments A and B and thereby mirror the requirements of BS EN 61439-1.

So, provided an assembly is manufactured (and, where necessary, tested) fully in conformity with the EMC requirements of BS EN 61439-1, then that assembly can be presumed to satisfy the requirements of the EMC Directive and may have the CE marking.

Some assemblies are bespoke, are intended for incorporation in a specific fixed installation, and are not otherwise commercially available. In such cases, the conformity assessment procedure is not compulsory and the assembly need not have a DoC or bear the CE marking, but it must not compromise the conformity of the installation.

The EMC Directive (Directive 2004/108/EC on the approximation of the laws of the Member States relating to electromagnetic compatibility) is implemented in the UK through the Electromagnetic Compatibility Regulations 2006 (SI 2006/3418).

7.4 Other directives that address safety and/or EMC

Whilst the Low Voltage and EMC Directives apply to most assemblies, other directives that address safety and EMC aspects may apply for certain applications. These include:

- **The Machinery Directive (2006/42/EC)** The Machinery Directive applies to the design, construction, placing on the market or putting into service of machinery. In particular, it specifies requirements relating to the design and manufacture of machinery in order to help improve its safety.

  The Machinery Directive, 2006/42/EC, is implemented in the UK through the Supply of Machinery (Safety) Regulations 2008 (S1 2008/1597). All machinery placed on the EEA market from 29 December 2009 must comply with this Directive.

  Readers should also consult BS EN 60204-1: Safety of machinery – Electrical equipment of machines.

- **ATEX Directive (94/9/EC)** The objective of the ATEX ('ATmosphères EXplosibles') Directive is to help reduce the risks resulting from the use of certain equipment in, or in relation to, a potentially explosive atmosphere. It applies to both mechanical and electrical equipment capable of causing an explosion through their own potential sources of ignition, and protective systems intended to halt/limit incipient explosions.

  The ATEX Directive, 94/9/EC, is implemented in Great Britain by the Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations 1996 (SI 1996/192) and in Northern Ireland by the Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres (Northern Ireland) Regulations 1996 (SR 1996/247).

- **The Radio Equipment & Telecommunications Terminal Equipment Directive (1999/5/EC)** The R&TTE (Radio equipment and Telecommunications Terminal Equipment) Directive applies to radio equipment and to telecommunications terminal equipment that can be connected to public telecommunication networks.

  In addition to not disturbing radio services, the R&TTE Directive is concerned with both safety and EMC, and incorporates many of the requirements contained within the LVD and EMC Directives.

  The Radio & Telecommunications Terminal Equipment Directive (RTTED), 1999/5/EC, is implemented in the UK by The Radio Equipment and Telecommunications Terminal Equipment (RTTE) Regulations 2000 (SI 2000/730) as amended by The Radio Equipment and Telecommunications Terminal Equipment (Amendment) Regulations (SI 2003/1903) and The Radio Equipment and Telecommunications Terminal Equipment (Amendment No 2) Regulations (SI 2003/3144).

ORDER CHECK LIST

The aspects of design and construction here are just some of the items subject to agreement between manufacturer and user. For a complete list of all such items, refer to Table BB.1 in BS EN 614389-2

1. Supply voltage and current capacity of busbars including neutral rating:

____

2. System fault capacity:

________________ kA ________________ Seconds

3. Diversity (loading) factor (if other than that specified in standard):

____

4. Special installation conditions:

Temperature above 35ºC? ______________________

Other conditions including humidity/environment: ______________________

5. External degree of protection: IP ______________

6. Degree of internal protection: IP ______________

NOTE: IP2X is minimum within standard

7. Form of construction: Fixed / Withdrawable / Removable

8. Accessibility for maintenance: Front / Rear

9. Accessibility for cabling: Front / Rear
Top / Bottom entry

10. Form of separation: Form: ____________________

Type: ____________________

GAMBICA Technical Guide

AUTOMATION
INSTRUMENTATION & CONTROL
LABORATORY TECHNOLOGY

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