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PART 1 - INTRODUCTION

This document defines the relevant technical specifications, policies and procedures that must be complied with by all users connected to or seeking connection to the GB Transmission System as set out under the Connection Conditions Annex (a) of the Grid Code.

The Relevant Electric Standards seek to maintain an appropriate level of reliability and security for the GB Transmission System. Ensuring that User equipment connected to the System at least meets the same standard of construction, manufacturing and installation quality as that employed by National Grid where such equipment has a material impact on the overall reliability and security of the System. The Relevant Electric Standards apply to User equipment that is located, electrically or physically within the zone covered by National Grid's substation busbar protection.

The User shall demonstrate that its equipment connected to the GB Transmission System is fit for purpose, complies with statutory and Grid Code requirements and that it meets the manufacturers stated performance characteristics and the requirements of the User Specifications contained within these Relevant Electrical Standards. For the avoidance of doubt this includes evidence of commissioning processes and procedures that ensure that the above requirements are met.

In accepting the Connection Conditions, Users connecting to the GB Transmission System are required to comply with these requirements.

This document applies only to connection agreements where the User is connected/connecting to an extant National Grid substation or where the connection will be to a new substation that is being constructed by National Grid. Where the User elects to construct the substation to which it will connect and subsequently transfer the assets to National Grid the substation construction as a minimum shall meet in its entirety the standards used by National Grid.

The Relevant Electric Standard document is split into five Parts; Introduction, Administration, User Policy, User Specification and Guidance Notes.

> Administration covers roles and responsibilities with respect to issue, maintenance and administration of the document including the governance of changes to the document contents and/or requirements.
>
> User Policy covers National Grid's intentions with respect to the use of particular asset types on its System. Policies being based on, *inter alia*, safety, environmental implications, International policy, legislation and supplier market.
>
> User Specification covers the functional requirements of equipment connected to the GB Transmission System.
>
> Guidance Notes provide advice and guidance on how the User Policy is to be applied or the User Specification is used, referencing the User Policy, User Specification or other relevant documents as appropriate.

These Relevant Electrical Standards contain the technical specifications that National Grid currently requires Users to meet. However, it should be recognised that the requirements contained herein cannot be completely exhaustive and, in certain circumstances, there may still be specific scheme related reasons that will result in National Grid requesting a User to meet requirements that will not be described within these Relevant Electrical Standards.

The Relevant Electrical Standards detail, along with the Grid Code, certain of National Grid's requirements with respect to User equipment that is connected within the zone of the substation busbar protection system. Its scope does not extend to detailing requirements for User equipment outside the zone of the busbar protection that could nonetheless be subject to various electrical phenomena due to their connection to the GB Transmission System (e.g. voltage transients). The User is responsible for ensuring that its equipment is capable of withstanding the effects of such system phenomena. Details of the technical and operational characteristics of the GB transmission system are given in National Grid report CI01 *Technical and Operational Characteristics of the Transmission System.*

PART 2 - ADMINISTRATION

National Grid's Electricity Codes Manager is responsible for the issue, maintenance and administration of this document.

Changes to this document are subject to the provisions of the Grid Code Governance process - Governance of Electrical Standards and shall apply where National Grid or a User:-

a) proposes a change to a technical requirement;

b) proposes to add a new technical requirement;

c) proposes to delete a technical requirement.

d) The document amendment process is shown in Figure 1 below.

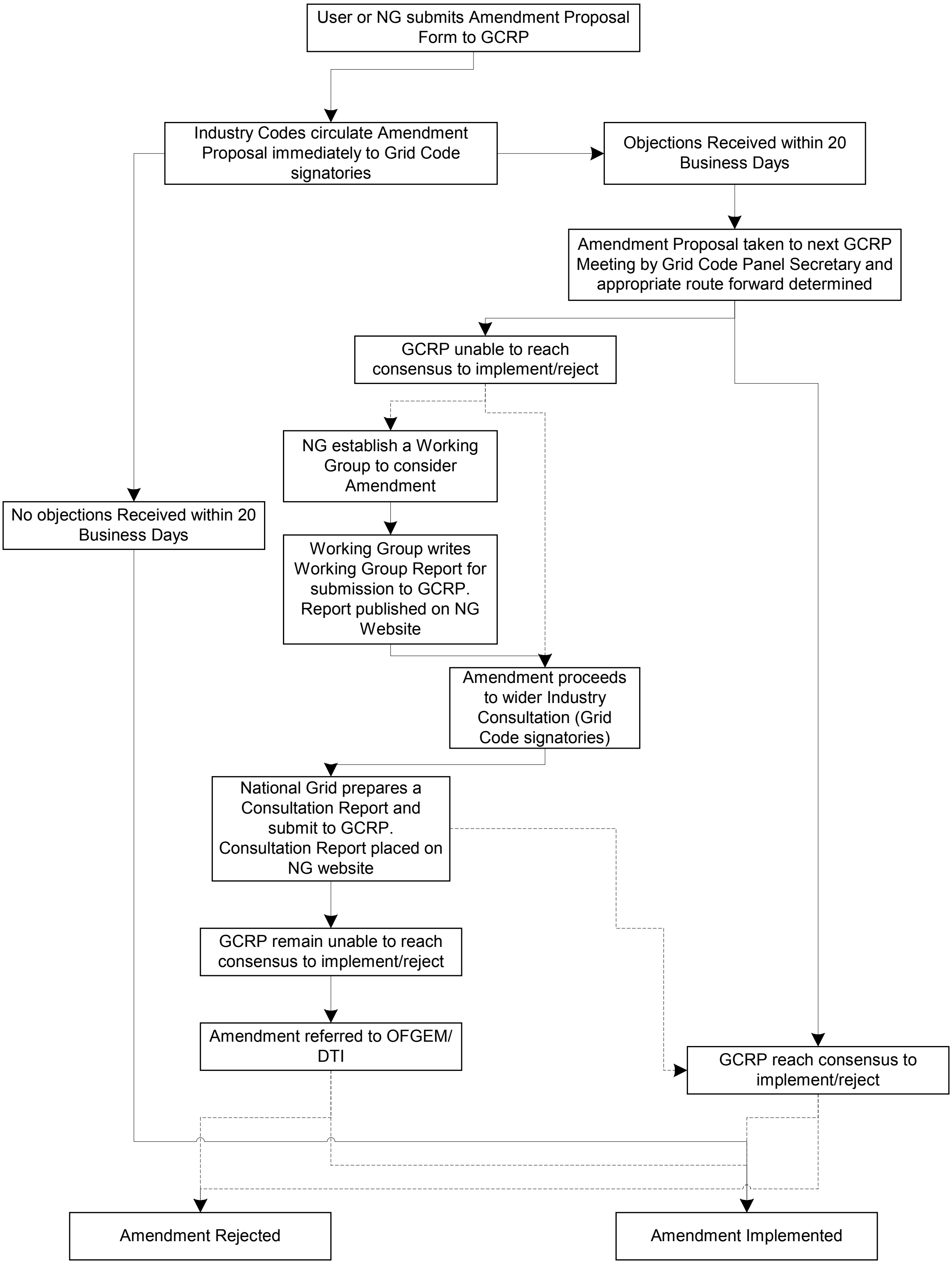


Figure 1 - Governance of Electrical Standards- Amendment Process

PART 3 - USER POLICY

Engineering Policy statements included in this document relate to particular types of technology assets and are a clear and unambiguous statement of need or intent, based on safety and/or environmental implications, business needs, international policy, legislation and supplier market.

Policy statements reference standards, National Grid Transmission engineering policy and other relevant documents as appropriate.

1 SECTION 1 - TYPE REGISTRATION

1.1 PURPOSE AND SCOPE

This policy defines National Grid's Type Registration Process for ensuring that solutions intended for use on, or connection to, the GB Transmission System are compliant with National Grid's technical/operational requirements and legal obligations. Health, safety, environmental impact and life cycle management issues associated with the solutions shall comply with the relevant National Grid UK Transmission (electricity) policies.

This policy applies to solutions, which have a direct or indirect impact on the strength, capability and reliability of the GB Transmission System. This can be taken to mean that the User shall ensure that only type-registered equipment is connected within the zone (physical and electrical) covered by National Grid's substation busbar protection system.

Further information regarding the Type Registration process is given in the guidance and notes section of this Relevant Electric Standard.

1.2 RESPONSIBILITIES

All Users wishing to connect to the GB Transmission System shall comply with this policy.

National Grid, Asset Strategy - Asset Policy has lead responsibility for management of the Type Registration Process.

1.3 REQUIREMENTS

Solutions shall not enter service (commence stage 2 commissioning) unless they have been Type Registered by Asset Policy. Ideally, Type Registration should be completed before the solutions are delivered to site.

Type Registration is a National Grid UK Transmission (electricity) process for verification of compliance of solutions with the relevant National Grid Technical Requirements, Operational Procedures, related Health, Safety and Environmental policies and National Grid legal obligations.

The Type Registration process is a documented and risk managed process based on self-certification of compliance against National Grid requirements by solution providers, with selective audit of the capability and performance of the solution provider and the quality of test evidence and technical submissions.

Test evidence offered by solution providers to support the Type Registration process shall be admissible only if it has been independently witnessed and/or verified by an independent and accredited organisation.

All necessary asset information, technical data and records required for asset life cycle management shall be codified and recorded in National Grid's Asset Register system.

Solutions and their components shall be assigned unique codes as required by National Grid's Asset Register System.

All submissions and supporting documentation arising from the Type Registration process shall be supplied in suitable electronic formats and recorded in National Grid's Document Management system.

National Grid shall apply the Type Registration process to solutions as the largest functional unit taking into account design, testing, procurement & lifetime management constraints.

1.4 FORMS AND RECORDS

The Type Registration Process and associated forms and records are available as a Network Strategy QMAP - Asset Specification.

1.5 DEFINITIONS

The following are defined terms used in this document:-

1.5.1 Component – A part of a solution that can have an impact on the strength, capability or reliability of the GB Transmission System.

1.5.2 Largest functional unit – this may include, but is not limited to, switchgear bays, light current bays, mechanically switched capacitor damped networks, power transformers, quad boosters, shunt reactors, overhead line insulator strings, overhead line conductor systems, cable systems.

1.5.3 Solution – An arrangement of plant, equipment and apparatus, which can be procured as a functional unit. It applies to:

a) All primary equipment connected directly to the Transmission System.

b) All secondary equipment directly monitoring, controlling or protecting the Transmission System.

c) All ancillary equipment supplying the primary and secondary equipment.

1.5.4 Solution Provider – typically a main project or contracting company whose processes and performance are monitored by National Grid Procurement - Supplier Development Group.

2 SECTION 2 - MANAGEMENT OF RISE OF EARTH POTENTIAL AT NEW AND REFURBISHED TOWERS

2.1 PURPOSE AND SCOPE

This policy defines the processes and procedures which need to be followed in order to determine the appropriate earthing requirements for new OHL tower routes and for existing legacy OHL tower routes that are to undergo structural analysis as part of a refurbishment or uprating scheme.

The purpose of this policy is to comply as far as is reasonably practical with BS EN 50341 [1] in the management of risks to 3rd parties associated with towers during a local earth fault condition. During this time it is expected that the tower and its surrounding ground will be subjected to a temporary rise of earth potential (ROEP).

Legacy OHL routes that are not subjected to tower load and strength assessments of its supports and foundations as part of a refurbishment or uprating scheme should not be considered as falling within the scope of this document. In cases such as this, identification, verification and implementation will be by other means.

2.2 POLICY STATEMENTS

The need for and design of mitigation measures to be applied to towers should be determined through consideration of predicted ROEP impact on third parties. Impact may occur through the mechanisms of touch, step and transferred potentials. For more details of these effects see EA TS 41-24 [2].

The impact of touch step and transferred potentials and its mitigation shall be determined by evaluation of third party risks using the methodology detailed in National Grid guidance documents.

Where more than one mechanism results in third party impact the most appropriate mitigation measures shall be chosen to minimise the overall risks e.g. BS EN 50341 requires that touch potentials are controlled at Often Frequented Towers. However, the installation of buried earth electrode to achieve this may conflict with the requirement to control transferred potentials affecting nearby third party property.

For new towers, careful consideration should be given to locating the tower such that third party risks are minimised i.e. avoid locations which is likely to be frequented.

Available mitigation options are detailed in National Grid guidance documents, which are available on request.

3 SECTION 3 – BACK-UP PROTECTION GRADING ACROSS NATIONAL GRID'S AND OTHER NETWORK OPERATOR INTERFACES

3.1 PURPOSE AND SCOPE

This section defines protection grading at interfaces between National Grid and other Network Operators to ensure that adequate discrimination of National Grid back-up protection with that of other Network Operators is achieved.

This section applies to Network Operators overcurrent and earth fault protections and it sets out the protection setting requirements that, when applied, will ensure compliance with the Grid Code with respect to protection discrimination.

a) Protection setting, and other information, that is to be used for protection the purpose of protection grading shall be exchanged between National Grid and the Network Operator as require to ensure the secure and reliable operation of the combined networks.

b) When the required grading stated in this section cannot be achieved reference should be made to National Grid.

3.2 SUPERGRID/132 KV AUTO-TRANSFORMERS

3.2.1 Overcurrent Protection on Outgoing Feeders and Transformers at 132 kV

a) Overcurrent protection shall be set to provide both current and time grading with National Grid back-up overcurrent protection installed at incoming Supergrid/132 kV auto-transformer on a 1:1 basis.

b) In cases where there is an overcurrent protection installed on the 132 kV side of an incoming auto-transformer the Network Operator protection shall be set to provide both current and time grading with that protection on a 1:1 basis.

c) Current grading shall be achieved to ensure that the current setting deployed on the Network Operator plant (e.g. outgoing feeder, transformer, reactor) protection is smaller than the supergrid transformer overcurrent protection. In cases where overcurrent protection is also installed on the 132 kV side of an auto-transformer the Network Operator current setting shall be smaller than the lower of the HV and LV supergrid transformer overcurrent protection. The Network Operator current setting shall take into account relay and CT errors.

d) Time grading shall be achieved by using an adequate minimum grading margin that should be calculated taking into account the following factors:

(i) The fault current interrupting time of the circuit breaker.

(ii) Relay timing errors – as a shift from the ideal characteristic as defined in IEC 60255 (IEC 255-4 or BS 142) – both (upstream and downstream) protection errors are included.

(iii) The overshoot time of the relay.

(iv) CT errors (on both protections).

(v) Safety margin (typically 0.1 s for electromechanical and 0.05 s for static and numeric relays). Factors ii) and iii) above depend on the relay technology used – an electro-mechanical relay, for instance, will have a larger overshoot time than a numeric relay.

e) The minimum grading margin shall be maintained throughout the protection characteristic curve (protection operating time versus fault), starting from the pick up fault current all the way through to the maximum allowable three-phase fault level.

f) National Grid policy is to set stage 1 of the 2-Stage HV overcurrent protection such that its operate time is not greater than 2.4 s for a three-phase fault on the 132 kV busbar/bushing (132 kV switchgear has a 3 s rating). The Network Operator overcurrent protection on a feeder or transformer shall be set such as to provide adequate minimum grading margin with the supergrid transformer overcurrent protection at the supergrid transformer maximum allowable let through fault. The grading shall be on a 1:1 basis.

3.2.2 Earth Fault Protection on the Outgoing Feeders and Transformers at 132 kV

a) Earth fault protection shall be set to provide both current and time grading with residually connected earth fault protection installed at the 132 kV side of the incoming supergrid/132 kV auto-transformer. Grading shall also be provided with National Grid's back-up overcurrent (stage 1 of the HV 2-Stage overcurrent protection), and with the supergrid transformer LV overcurrent protection, where installed. Grading shall be on a 1:1 basis.

b) Current grading shall be achieved to ensure that the current setting deployed on the Network Operator plant (e.g. outgoing feeder, transformer, reactor) protection is smaller than the supergrid transformer earth fault protection setting. In cases where overcurrent protection is also installed on the 132 kV side of an auto-transformer the Network Operator current setting shall be smaller than this lower of the HV and LV supergrid transformer overcurrent protection setting. The Network Operator current setting shall take into account relay and CT errors.

c) See clause d) section 3.2.1 (time grading principle).

d) Minimum grading margin shall be maintained throughout the protection characteristic curve, starting from the pick up fault current all the way through to the maximum allowable earth fault level.

e) National Grid policy is to set the 132 kV residually connected earth fault protection such that its operate time is not greater than 2.4 s for a 132 kV single-phase to earth fault at the transformer LV terminals. The Network Operator earth fault protection on a feeder or transformer shall be set such as to provide adequate minimum grading margin with the supergrid transformer earth fault protection at the supergrid transformer maximum allowable single phase to earth let through fault. The grading shall be on a 1:1 basis.

3.3 SUPERGRID/66 KV OR LOWER VOLTAGE DOUBLE-WOUND TRANSFORMERS

3.3.1 Overcurrent protection on the outgoing feeders and transformers at 66 kV or lower voltages

a) Overcurrent protection shall be set to provide both current and time grading with the supergrid transformer back-up overcurrent protection installed at incoming supergrid/66kV double-wound transformers on a 1:1 basis. See clause c) section 3.2.1 for current grading principle, clause d) section 3.2.1 for the time grading principle and clause e) section 3.2.1 for the minimum grading margin.

b) National Grid policy is to set stage 1 of the 2-Stage HV overcurrent protection such that its operate time is not greater than 2.4 s for a three-phase fault on the 132 kV busbar/bushing. The Network Operator overcurrent protection on a feeder or transformer shall be set such as to provide adequate minimum grading margin with the supergrid transformer overcurrent protection at the supergrid transformer maximum allowable let through fault. The grading shall be on a 1:1 basis.

3.3.2 Earth Fault Protection on the Outgoing Feeders and Transformers at 66 kV or Lower Voltages

a) Earth fault protection shall be set to provide both current and time grading with the supergrid transformer 2-Stage unrestricted earth fault protection (Standby Earth fault) on the LV side of the transformer. See clause d) section 3.2.1 for the time grading principle and clause e) section 3.2.1 for the minimum grading margin.

b) Current grading shall be achieved to ensure that the earth fault setting deployed on the Network Operator plant (e.g. outgoing feeder, transformer, reactor) protection is smaller than the stage 1 unrestricted earth fault setting and must take into account relay and CT errors.

c) National Grid policy is to set the supergrid transformer stage 1 unrestricted earth fault protection to achieve an operate time of 5 s (using long-time inverse characteristics – LTI) for an earth fault at the transformer LV terminals. Network Operator earth fault protection shall be set so as to provide adequate minimum grading margin with the supergrid transformer unrestricted earth fault protection on a 1:1 basis.

3.4 GRADING WITH NATIONAL GRID OWNED 132 KV OR LOWER VOLTAGE BUS SECTIONS AND COUPLERS

3.4.1 Overcurrent Protection on the Outgoing Feeders and Transformers at 132 kV or Lower Voltages

a) Overcurrent protection shall be set to provide both current and time grading with National Grid overcurrent protection on bus sections/couplers. See clause d) section 3.2.1 for the time grading principle and clause e) section 3.2.1 for the minimum grading margin.

b) Current grading shall be achieved to ensure that the current setting deployed on the Network Operator plant (e.g. outgoing feeder, transformer, reactor) protection is smaller than the overcurrent protection on National Grid’s 132 kV or lower voltage bus sections/couplers. The Network Operator current setting shall take into account relay and CT errors.

3.4.2 Earth Fault Protection on the Outgoing Feeders and Transformers at 132 kV or Lower Voltages

a) Earth fault protection shall be set to provide both current and time grading with National Grid earth fault protection on bus sections/couplers. See clause d) section 3.2.1 for the time grading principle and clause e) section 3.2.1 for the minimum grading margin.

b) Current grading shall be achieved to ensure that the current setting deployed on the Network Operator plant (e.g. outgoing feeder, transformer, reactor) protection is smaller than the current setting on National Grid’s 132 kV or lower voltage bus section(s)/coupler(s). The current setting shall also be smaller than the current setting of the bus section/coupler overcurrent protection. The Network Operator current setting shall take into account relay and CT errors.

PART 4 - USER SPECIFICATIONS

4 SECTION 1 - RATINGS AND GENERAL REQUIREMENTS FOR PLANT, EQUIPMENT AND APPARATUS FOR THE GB TRANSMISSION SYSTEM AND CONNECTION POINTS TO IT

4.1 SCOPE

The requirements of this document apply to all plant, equipment and apparatus, which is part of, or is directly connected to, The GB Transmission System. Requirements contained herein may be modified on a more specific basis by lower level specification however, unless such modifications are explicitly detailed, the requirements of this document apply.

Ratings are specified explicitly for plant with nominal voltages of 132kV and. Rating for other nominal voltages will be specified in the contract enquiry document.

Derogation from the requirements of the Relevant Electrical Standards will normally be permitted only where it can be demonstrated that the proposed derogation is not detrimental to the safety, reliability and availability of The GB Transmission System.

4.2 REFERENCES AND DEFINITIONS

4.2.1 Statutory and Legislative Documents

Many of the following documents are not explicitly referenced in the text of this Section however they are generally applicable and are listed here for information. This list is not exhaustive and it is the responsibility of all parties using this Section to ensure compliance with all relevant legislative documents.

4.2.2 UK Regulatory Documents

The Grid Code

4.2.3 UK Health and Safety Legislation

Category	Legislation	Year	Comments
General	Health and Safety at Work etc Act	1974	Umbrella Act
	Offices, Shops and Railway Premises Act	1963	Some remaining obligations.
	Factories Act	1961	Some remaining obligations.
The Workplace	The Health and Safety (First Aid) Regulations	1981	
	The Workplace (Health, Safety and Welfare) Regulations	1992	Part of 'The 6 pack'
	The Confined Spaces Regulations	1997	
Display Screen Equipment	The Health and Safety (Display Screen Equipment) Regulations	1992	Part of 'The 6 pack'
Fire	The Fire Precautions Act	1971	
	The Fire Precautions (Workplace) Regulations	1997/ 1999	
Handling and Transportation	The Manual Handling Operations Regulations	1992	Part of 'The 6 pack'

Category	Legislation	Year	Comments
	The Carriage of Dangerous Goods (Classification Packaging and Labelling) and use of Transportable Pressure Receptacles Regulations	1996	
	The Transport of Dangerous Goods (Safety Advisors) Regulations	1999	
Work Equipment	The Provision and Use of Work Equipment Regulations	1998	Part of 'The 6 pack'
	The Lifting Operations and Lifting Equipment Regulations	1998	
Personal Protective Equipment	The Personal Protective Equipment at Work Regulations	1992	Part of 'The 6 pack'
Electricity	The Electricity at Work Regulations	1989	
	The Electrical Equipment (Safety) Regulations	1994	
	The Electricity Safety, Quality and Continuity Regulations	2001	Concerned with Public Safety
Building/ Construction	The Construction (Head Protection) Regulations	1989	
	The Construction (Design and Management) Regulations	1994	
	The Construction (Health, Safety and Welfare) Regulations	1996	
Pressure Plant and Systems	The Pressure Systems Safety Regulations	2000	
	The Pressure Equipment Regulations	1999	
Harmful Substances	The Control of Asbestos at Work Regulations	1987	
	The Control of Lead at Work Regulations	1998	
	The Control of Substances Hazardous to Health Regulations	1994/ 1999	
Flammable and Explosive Substances	The Highly Flammable liquids and Liquefied Petroleum Gases Regulations	1972	
	The Petroleum-Spirit (Plastic Container) Regulations	1982	
Noise	The Noise at Work Regulations	1989	
Radiation	The Ionising Radiations Regulations	1999	
Consultation	The Safety Representatives and Safety Committees Regulations	1977	
	The Electricity Act	1989	
	The Health and Safety (Consultation with Employees) Regulations	1996	
Communication	The Health and Safety Information for Employees Regulations	1989	

Category	Legislation	Year	Comments
	The Health and Safety (Safety Signs and Signals) Regulations	1996	
HSE Reporting	The Reporting of Injuries Diseases and Dangerous Occurrences Regulations	1995	
Enforcement	The Health and Safety (Enforcing Authority) Regulations	1998	
Training	The Health and Safety (Training for Employment) Regulations	1990	
Management	The Working Time Regulations	1998	
	The Management of Health and Safety at Work Regulations	1999	Part of 'The 6 pack'
	The Control of Major Accident Hazard Regulations	1999	

4.2.4 Standards Referred to in the Text

IEC 60815 Guide for the selection of insulators in respect of polluted conditions.

IEC 60060 High-voltage test techniques.

BS EN 60507 Artificial pollution tests on high-voltage insulators to be used on a.c. systems

BS EN 60071 Insulation co-ordination.

BS EN 60529 Degrees of protection provided by enclosures (IP Code).

BS EN 60654-1 Industrial – Process Measurement and Control Equipment Operating Conditions; Part 1 Climatic Conditions.

BS EN 60694 Common specifications for high-voltage switchgear and controlgear standards.

Engineering Recommendation (ER) G5/4 - Levels of harmonic distortion

4.2.5 Definitions of Terms

For the purposes of the Relevant Electrical Standards the following are defined.

Directly (connected) Connected in such a way that performance of the connected equipment directly affects the performance of National Grid's System. Typically this is limited to equipment within the coverage of National Grid busbar protection.

Plant Primary (high voltage) elements of National Grid's System such as the circuit-breakers, transformers, overhead lines and cables.

Equipment Secondary (low voltage) elements of National Grid's System such as those for control, measurements, protection and auxiliary supplies.

Apparatus Physical components of, or associated with, National Grid's System which are required in support of the plant and equipment. Examples are substation structures, auxiliary plant and portable test equipment.

Contract Enquiry Doc — The commercial requirement document of National Grid for a specific application.

4.3 SERVICE (ENVIRONMENTAL) CONDITIONS

4.3.1 General

Plant, equipment and apparatus shall be suitable for operation under the following normal and special service conditions.

4.3.2 Normal Service Conditions

Normal service conditions, as defined in BS EN 60694, are applicable. The following sub-clauses define National Grid requirements where a choice of severity is required or where the requirements of BS EN 60694 are inappropriate.

a) Indoor

(i) Temperature class minus 5 indoor.

b) Outdoor

(i) Temperature class minus 25 outdoor.

(ii) Ice coating class 10 mm.

The operating environment for equipment, such as control and protection, is categorised in Table 1. Equipment shall be suitable for operation in its intended environment including the ability to maintain critical functions in the event of failure of environmental control facilities such as air conditioning.

Class	**Siting Conditions**	**Class according to BS EN 60654-1**	**Ambient Temperature Range (a) (b)**	**Relative Humidity Limits**
1	Rooms having a closely controlled environment	A1	+18 to +27°C	20 to 75%
2	Control rooms and equipment rooms not fully air conditioned	B3	-5 to +40°C	5 to 95%
3	Plant areas, rooms and block houses away from high temperature plant and subject to greater extremes than Class 2	N/A	-5 to +55°C	5 to 95%
4	Outdoors	C2	-25 to +55°C	10 to 100%

Table 1 - Temperature and Humidity Classes for Equipment

Notes to Table 1:

- The ambient temperature maxima assume negligible solar gain and negligible localised temperature excursions ie adequate ventilation. The validity of these assumptions must be considered, and confirmed, at the application stage.

- For ventilated equipment the ambient temperature is defined as being the free air temperature existing at a point level with the top of the equipment.

4.3.3 Special Service Conditions

Plant & equipment shall be suitable for operation in a pollution environment as defined in Table 2.

External insulation shall be in accordance with the relevant requirements and recommendations of IEC 60815.

For ceramic insulation, test conditions to prove this performance level shall be as defined in Tables 2 & 3. Service experience offered in lieu of artificial pollution testing shall identical to that detailed for composite insulation detailed in this clause.

Insulation, including composite insulation, shall have a minimum specific creepage of 25mm/kV for Class III pollution environments and 31mm/kV for Class IV pollution environments. Account shall be taken of the factor $k_{D.}$

Ceramic insulation for vertical application meeting the following criteria is deemed to meet the requirements of Tables 2 & 3 without further testing.

- Alternate Long Short (ALS) profile.
- (p1 – p2) ≥ 15 mm
- s ≥ 70mm

Insulation	IEC 60815 Pollution Class	IEC 507 Salt Fog Withstand Test Specification kg/m^3	National Grid Heavy Wetting Test Specification kg/m^3
Indoor	I	No test withstand required	No test withstand required
Outdoor	III	80	80
Outdoor (special)	IV	>160	> 160
Outdoor Horizontal	III & IV	80	80

Table 2 - Pollution, Salt Fog and Heavy Wetting Test Requirements

Informative: Pollution Class IV may be specified in the contract enquiry document for sites which are judged to be subject to severe coastal or industrial pollution.

Informative: Details of the heavy wetting specification can be found in 5.8.

Rated Voltage of Insulation	17.5	145	300	420
Test Voltage (phase-to-earth) kV	10	84	173	242
Test Voltage (phase-to-phase) kV	17.5	145	300	420
Test Voltage for other insulation	The maximum power frequency voltage to which the insulation may be stressed in service. For insulation enclosing a switchgear interrupting gap, or if insulation is specified for enclosures for isolating gaps, or for insulation connected in parallel with such an interrupting or isolating gap, this test voltage shall be the out-of-phase voltage.			

Table 3 - Test Voltage Levels for Pollution, Salt Fog and Heavy Wetting Tests

Phase-to-phase AIS solid external insulation is not acceptable.

The application of an anti-pollution palliative coating to the external surface of ceramic insulation in order to satisfy the requirements of this specification is not acceptable.

Products consisting of internally graded insulation contained within an external AIS insulating enclosure or weather-shield, such as bushings, instrument transformers or grading capacitors, shall be considered a single item for the purposes of pollution and heavy wetting tests.

Phase to earth insulation connected in parallel and having a shed-to-shed separation distance of less than 0.5 times the phase-to-earth clearance, shall be considered as a single item for the purposes of pollution and heavy wetting tests.

Horizontally oriented insulation and insulation intended for mounting > 15^0 from the vertical shall meet the pollution and heavy wetting requirements in its intended orientation.

The insulation shall be mounted at the orientation intended for service during pollution and heavy wetting tests.

Composite external insulation shall be supported by satisfactory service experience equivalent to at least two years in a heavily polluted environment similar to that experienced at UK coastal locations. All relevant aspects of this experience shall be fully documented.

Informative: Typically 2 to 5 years test station experience or 5 to 10 years power system experience will be sufficient to meet this requirements depending on actual severity of climatic conditions during the test period. Where such evidence is unavailable, monitoring of initial installations on National Grid's System may be considered. Such consideration will be in the form of a risk assessment taking into account factors such as expected pollution levels at the proposed location, system risks associated with failure and predicted population.

4.4 SYSTEM REQUIREMENTS

4.4.1 System Voltage

Plant and Equipment shall satisfy their specified functional and performance requirements over the range of primary voltages given in Table 4.

Plant and equipment for use on the 400kV system shall also operate safely and without any degradation in performance when operated in the range 420kV to 440kV for not longer than 15 minutes.

Plant and equipment shall satisfy their specified functional and performance requirements with phase voltage unbalance up to a maximum of 1%.

Informative: Phase voltage unbalance up to 2%, on an infrequent, short duration basis, may be specified at some sites.

Plant and equipment shall satisfy their specified functional and performance requirements when exposed to harmonic distortion levels in the voltage waveform up to the compatibility levels specified in Appendix A of ER G5/4.

Nominal System voltage (phase to phase)	400 kV	275 kV	132 kV	13 kV tertiary
Maximum continuous System voltage	420 kV	303 kV	145 kV	16.9 kV
Minimum continuous System voltage	360 kV	247 kV	119 kV	10.4 kV
Rated voltage of plant	420 kV	300 kV	145 kV	17.5 kV

Table 4 - System Voltage

4.4.2 System Frequency

Plant and Equipment shall satisfy their specified functional and performance requirements over the range of frequencies given in Table 5.

Plant and equipment shall also operate safely and without any degradation in performance within the following frequency ranges:

a) 47Hz to 47.5Hz for at least 20 seconds

b) 50.5Hz to 52 Hz continuous

Rated frequency	50 Hz
Maximum continuous frequency	50.5 Hz
Minimum continuous frequency	47.5 Hz

Table 5 - System Frequency

4.4.3 Earthing of System Neutral

Plant and Equipment shall satisfy their specified functional and performance requirements under the neutral earthing condition given in Table 6.

Nominal Voltage (kV)	Maximum Earth Fault Factor	Earthing Type
400, 275, and 132	1.4	Multiple direct
13 (tertiary)	Site specific	Site specific

Table 6 - Earthing of System Neutral

4.4.4 Fault Clearance

Plant and Equipment shall be suitable for operation under the conditions detailed in Table 7.

Nominal Voltage(kV)	Target fault interruption time of main in-feeding circuit (ms)	Target total fault clearance time (all infeeds) (ms)	Target back-up clearance time (ms)
400	80	140	500 (1000*)
275	100	160	500 (1000*)
132	120	N/A	<1500
13	75 (of which 35ms max' protection time)	N/A	N/A

Table 7 - Target Fault Clearance Requirements.

**Informative: Fault clearance times for zone 3 distance protection and residual earth fault protection on feeder circuits of 1 second are acceptable.*

In the event of a circuit-breaker failure, circuit-breaker fail protection shall trip all necessary contiguous circuit-breakers, capable of supplying a fault infeed, within a target fault clearance time not exceeding 300 ms.

4.4.5 Multi-pole Opening/Tripping and Auto-reclosing

Plant and equipment shall be suitable for operation under the following circuit-breaker operating conditions:

a) Simultaneous three-phase opening/tripping.

b) Simultaneous three-phase auto-reclosing on overhead line feeder circuits.

4.5 RATING REQUIREMENTS

4.5.1 Primary Currents

Substation Plant and Equipment shall be suitable for operation under the condition detailed in Table 8.

System Voltage kV	Normal Current A	Short-circuit Current (3- and 1-phase) kA	Duration of short-circuit ** s	DC Time Constant ms
400	4000	63	1	45
275	2500	40	1	45
132	2000	40	3	45 and 135*
13	4000	50	1	96

Table 8 - Rated Normal and Rated Short-circuit Currents

*The alternative value may be required at bulk supply points and a coincident reduction in RMS current rating from 40kA e.g. to 31.5kA, may be acceptable.

**The rated duration of short-circuit at system voltages between 132kV and 13kV is 3 seconds.

4.5.2 Rated Insulation Level and Protective Gap Settings

Plant shall meet the requirements of Tables 9 and 10 with regard to its rated insulation level and protective gap settings (if any).

	Nominal System Voltage	kV	400	275
	Rated Voltage for Plant	kV	420	300
(a)	Rated lightning impulse withstand voltage to earth (1.2/50 µs wave)	kV peak	1425	1050
(b)	Rated lightning impulse withstand voltage between poles (1.2/50 µs wave)	kV peak	1425	1050
(c)	For switching devices (including disconnectors) rated lightning impulse voltage withstand between terminals on one pole when open (impulse waveshape 1.2/50 µs)		1425 kV impulse plus 240 kV peak power frequency voltage	1050 kV impulse plus 170 kV peak power frequency voltage
(d)	Rated switching impulse withstand voltage to earth (250/2500 µs wave)	kV peak	1050	850
(e)	Rated switching impulse withstand voltage between poles (250/2500 µs wave)	kV peak	1575	1275
(f)	For switching devices (including disconnectors) rated switching impulse withstand voltage between terminals of one pole when open (impulse waveshape 250/2500 µs)		900 kV Impulse plus 345 kV peak power frequency voltage	700 kV Impulse plus 245 kV peak power frequency voltage
(g)	Overhead Line Arcing Gaps (Mid-line)	m	2.80	2.13
(h)	Overhead Line Arcing Gaps (First 1.6 km from the substation)	m	2.50	1.90
(i)	Transformer and Reactor Co-ordinating Gaps (screened gap) (see (k))	m	1.50	1.20
(j)	Cable Sealing Ends Arcing Gaps	m	2.54	1.90
(k)	Existing transformers and reactors may have un-screened loop-loop gaps where the gap is.	m	1.68	1.22

Table 9 - Rated Insulation Levels 420 kV and 300 kV Plant

Nominal System Voltage	kV	132	13

	Rated Voltage for Plant	kV	145	17.5
(a)	Rated lightning impulse withstand voltage to earth (1.2/50 μs wave)	kV peak	650	95
(b)	Rated lightning impulse withstand voltage between poles (1.2/50 μs wave)	kV peak	650	95
(c)	For switching devices other than disconnectors and switch-disconnectors rated lightning impulse withstand voltage between terminals on one pole when open (1.2/50 μs wave)	kV peak	650	95
(d)	For disconnectors and switch-disconnectors rated lightning impulse withstand voltage between terminals on one pole when open(1.2/50 μs wave)	kV peak	750	110
(e)	Rated power frequency dry withstand voltage (1 minute)	kV	275	38
(f)	For open type equipment rated power frequency wet withstand voltage (1 minute) *(preferred method is BS923)*	kV	275	38
(g)	Across the isolating distance of disconnectors rated power frequency dry, and where applicable wet, withstand voltage (1 minute)	kV	315	45
(h)	Overhead Line Arcing Gaps (Mid-line)	m	1.10	N/A
(i)	Overhead Line Arcing Gaps (first 1.6 km from the substation)	m	1.00	N/A
(j)	Transformers and Reactor Co-ordinating Gaps (see (l))	m	0.66 screened gap	0.10 arcing gap
(k)	Cable Sealing Ends Arcing Gap	m	1.00	0.10
(l)	Existing 132 kV transformers and reactors may have un-screened loop-loop gaps	m	0.66	–

Table 10 - Rated Insulation Levels for 145 kV Plant & for 13 kV Tertiary Connected Plant

4.6 GENERAL REQUIREMENTS

4.6.1 Equipment orientation

Plant shall be type tested in the orientation in which it is intended to be applied. Applications in orientations other than that which was tested are unacceptable.

4.6.2 Health, Safety and Environment

Products supplied for installation on the GB Transmission System or property, and owned and operated by or on behalf of National Grid, shall comply with all relevant UK Health and Safety and Environmental legislation.

Products shall comply with the requirements of National Grid's Safety rules.

A suitable & sufficient environmental assessment covering all stages of the product life-cycle shall be submitted for all products.

Details of any materials or components requiring special precautions or handling shall be submitted for all products.

Equipment containing SF_6 shall, as far as reasonably practicable, be leak free. Where leak free operation is not achievable the leak rate shall be minimised and, in the extreme, shall not exceed 0.5% per annum.

4.6.3 Degree of Protection

Controlgear and other equipment housed outdoors in association with high voltage plant shall have a degree of protection of at least IP54 as defined in BS EN 60529.

All plant, equipment and apparatus shall have a degree of protection of at least IP2X under normal operating conditions.

Informative: For these purposes "normal operating conditions" includes activities such as local operation that may require cabinet doors to be opened.

4.6.4 Date Proofing of Systems Used in Plant, equipment and apparatus

All products shall be immune to failure or malfunction due to the presence of date sensitive elements.

4.6.5 Product Identification

All products shall be provided with a suitable & sufficient means of identification, such as a nameplate.

Provision shall be made for all products to be clearly marked with their operational identity using a consistent methodology across the substation site.

4.7 MANUALS, SUPPORT DOCUMENTATION AND DRAWINGS

All products shall be supported by suitable and sufficient documentation including, but not limited to, Type Test Certificates or Reports of Performance, installation and operation manuals, commissioning schedules, testing recommendations and drawings.

All manuals and drawings shall clearly indicate the product manufacturer, type and model that they refer to, and also indicate the issue date of the document/drawing.

Manuals shall, as a minimum, address the following: a technical description and specification of the product, requirements for transportation, storage, installation, operation, commissioning, maintenance, de-commissioning and disposal. Particular attention shall be paid to aspects such as access for maintenance, inspection and/or testing (internal and external to the product), lifting and handling facilities for heavy or awkward parts and/or covers, and prevention of access to parts that might represent a hazard due to, for example, voltage levels, temperature or mechanical movement etc.

Details shall be provided of spares requirements to achieve the agreed service life and of any additional equipment or software required in support of the product during its expected service life.

Informative: It is preferable for installation manuals to be physically separate from operation and maintenance manuals.

4.8 GUIDANCE NOTES - HEAVY WETTING TEST SPECIFICATION

4.8.1 General Test Requirements

The Heavy Wetting Test is used to establish the performance of a polluted insulator when exposed to the sudden application of heavy wetting.

The general test requirements are as in BS EN 60507 Clauses 5 and 6.

4.8.2 Preconditioning Process

The insulator shall be preconditioned as required by BS EN 60507 Clause 10 before performing the test.

4.8.3 Heavy Wetting Test

The intention of the test is to confirm the specified heavy wetting withstand salinity of the insulator at the specified test voltage.

Referring to clauses in BS EN 60507 the test shall start when the test insulator and the chamber conditions fulfill the requirements of Clause 9, and after the preconditioning of the insulator according to Clause 10.

A series of tests shall be performed on the insulator as detailed below. Each test consists of three stages.

a) Stage 1 Salt Fog

The specified test voltage, in accordance with Table 3 of this document shall be applied to the insulator which shall be exposed to a salt fog using a salt solution having the specified test salinity in accordance with Table 2 of this document. Flashovers during this stage do not constitute a failure of the heavy wetting test. After a flashover, the insulator shall immediately be re-energised at a voltage level 5% below the flashover voltage. This process may be repeated if further flashovers occur. The total period of application of salt fog shall be 15 minutes.

b) Stage 2 Drying

The insulator is allowed to dry initially at the voltage level reached at the end of Stage 1. During the drying period the test voltage shall be increased if necessary to the specified test voltage. Flashovers during this stage do not constitute a failure in the test. After a flashover the insulator shall be immediately re-energised to continue the drying process. The total drying period shall be 15 minutes.

c) Stage 3 Heavy Wetting

Immediately following Stage 2 and at the specified test voltage, the insulator shall be sprayed with water as specified in the IEC 60060-1 Standard Wet Test Procedure except that the water conductivity shall be 100 µS.mm-1. The wetting shall continue until flashover or until the discharge activity has decreased to a stable level at which flashover cannot occur. If this cannot be determined then the wetting shall continue for 15 minutes.

d) Acceptance Criteria for the Heavy Wetting Test

The insulator complies with this specification if no flashover occurs during the Stage 3 Heavy Wetting tests in a series of three consecutive tests. A single test consists of the complete sequence of all 3 stages in accordance with the above procedure. If only one flashover occurs, a fourth test shall be performed and the insulator then passes the test if no flashover occurs in this final test.

5 SECTION 2 - SUBSTATIONS

5.1 TECHNICAL REQUIREMENTS FOR SUBSTATIONS CONNECTED TO THE GB TRANSMISSION SYSTEM

This Section covers all types of substations with equipment installed for use on 132, 275 and 400 kV 50 Hz systems. Substations operating at other voltages are expected to comply with the general provisions of this document. It is applicable to both open-terminal air-insulated (AIS) and metal-enclosed gas-insulated (GIS) substation constructions and covers equipment operated at lower voltages on the same substation site. It is applicable to new construction and extensions to existing installations.

All National Grid plant and apparatus wholly within the substation and not covered more specifically by other technical requirements is within the scope of this document.

5.2 GENERAL REQUIREMENTS (INCLUDING HEALTH & SAFETY)

5.2.1 Designing For Safety

It is intended that National Grid substations are as safe an environment as is reasonably practicable. This specification contains many detailed requirements intended to facilitate this however, due to the complex nature of substation design and construction, no single specification, or suite of specifications, can guarantee to address all potential dangers in the optimum way. As part of a collaborative approach it is vital that National Grid and its substation suppliers take a “best practice” approach to substation design safety at all times. In particular constructional issues such as tripping hazards, sharp edges, labelling and poor access which are difficult to specify effectively should be eliminated wherever possible in the design.

5.3 STATUTORY REQUIREMENTS

The manner in which plant and equipment is designed and installed as a system shall allow that system and its components to be operated and maintained in accordance with all relevant statutory requirements.

5.4 ENVIRONMENTAL IMPACT

The siting and design of new substations shall take into account the guidelines presented by the Horlock Rules.

5.5 DESIGN LIFE OF INSTALLATION

The substation installation including busbars, connections, insulators, structures foundations and all other infrastructure shall be designed for a life of 40 years subject to periodic preventive maintenance being carried out in accordance with manufacturers or suppliers instructions.

5.6 OPERATIONAL ACCESS

Access shall be provided to the isolation facilities of each disconnector and earthing switch including any locking device. Access shall be suitable for use by an unaccompanied person.

The isolation facilities or locking devices shall be between 1 m and 1.8 m above either the floor level or a platform provided for access and shall be not further than 750 mm horizontally from the edge of a platform.

Access above ground level shall be from mobile or fixed platforms (though the latter may be accessed by ladder). Where movement of equipment within the substation would be restricted by the presence of ladders it is acceptable that these are removable. Removable ladders and mobile platforms shall be easily handled and used on the finished substation surface by one person.

Ladders and permanent platforms shall comply with relevant parts of BS 5395 and their arrangement shall be agreed with National Grid to suit site requirements.

Informative: Fixed platforms need not be provided for preventive or corrective maintenance requirements so long as access can be gained by the use of pre-formed scaffolding, portable ladders or powered access equipment.

5.7 REQUIREMENTS FOR MAINTENANCE

The substation layout and surfaces shall be adequate to allow the access and use of any powered access equipment, cranes or similar equipment which may be required for foreseeable maintenance activities

Access suitable for gas handling equipment shall be provided to all equipment containing SF_6.

Roads shall be provided to access substation main buildings, relay rooms and heavy items of plant (e.g. transformers) and shall be to a standard consistent with that of the rest of the substation site. All other surfaces shall also be constructed to a standard consistent with the rest of the substation site.,

5.8 INTERLOCKING

Substations shall be provided with a full interlocking scheme as detailed in Part 4, Section 7 - Substation Interlocking.

5.9 CURRENT TRANSFORMERS

The accommodation of current transformers shall be as specified in 5.26 of this Section.

The location of current transformers shall be as specified in 5.27 of this Section.

5.10 SWITCHGEAR SECONDARY ISOLATION

Isolation facilities shall be accessible from ground level or from fixed platforms and shall permit the application of isolation procedures defined in National Grid's Safety Rules.

5.11 VOLTAGE TRANSFORMER SECONDARY ISOLATION

Voltage transformer secondary isolation links, or equivalent means of positive isolation, shall be provided in a separate isolation box mounted between 1 m and 1.8 m above substation floor or access platform level.

The door of the isolation box shall be padlockable by means of National Grid's standard padlock type.

5.12 EARTHING

The User's earthing system shall be integrated with that of National Grid's substation earthing system and shall, as a minimum, meet the same design and installation standards as National Grid's earthing system.

Informative: Particular attention should be paid to requirements for high frequency earthing

5.13 PLANT AND EQUIPMENT IDENTIFICATION

Labels shall be provided to allow unambiguous identification of all plant and equipment and of associated operating facilities and points of isolation. The following are required:

a) Each circuit-breaker, disconnector and earthing switch mechanism box shall carry a label giving the operational reference of the device.

b) Each pressure gauge or pressure readout device shall carry a label identifying the parameter it is monitoring.

c) Each valve (including self-sealing gas filling valves) shall carry a label identifying its function.

d) Each SF6 filling valve shall be provided with a label identifying the mass of gas contained within the gas compartment to which it is fitted (at normal filling density). The volume of the compartment and normal filling density shall also be marked.

e) Each control handle or switch for plant operation shall carry a label identifying its function.

f) Each point of LV isolation associated with plant shall carry a label identifying its function.

g) Each cabinet, cubicle or kiosk shall carry a label identifying all of the equipment contained within it.

Labels shall be sufficiently durable for the application and the environment in which they are to be used taking account of the expected operational lifetime of the equipment. They shall remain in place and legible for the design lifetime of the equipment.

Informative: Experience indicates that this requirement can be met by the use of UV resistant engraved labels with mechanical fixings. National Grid will require demonstration that alternative labelling systems are adequate

The fixing of labels shall not compromise the degree of protection (IP rating) of the equipment.

All pipework shall be identified in accordance with BS 1710.

5.14 LIGHT CURRENT EQUIPMENT

Electronic equipment shall be located in accommodation commensurate with its environmental performance, which is classified in Part 4 -Section 16.

Light current accommodation shall meet the requirements of Part 4 - Section 16, Class 3 under all ambient conditions.

Fixed heating shall be thermostatically controlled.

Where no fixed heating is provided, provision shall be made for raising the air temperature in the vicinity of all equipment associated with any one circuit to 16°C without causing condensation on the equipment.

All panels housing secondary equipment which are sited in equipment rooms or accommodation shared with equipment owned by other users shall be padlockable.

5.15 SUBSTATION AUXILIARY CABLING

All substation auxiliary cabling between substation buildings, relay rooms, common marshalling points and substation primary equipment shall, as far as reasonably practicable, be installed in buried cable ducts. Where cable trays (or similar) are used these shall not present a risk of injury and shall be suitably finished to prevent degradation due to environmental conditions. Auxiliary cables shall be installed such that they do not present a tripping hazard.

Informative: The installation of substation auxiliary cabling should minimise hazards such as tripping and sharp edges (cable trays). Cables between dispersed relay rooms or circuit marshalling points and local plant may be buried direct where armoured cables are used. In all other circumstances cable ducts may be used.

The location of all buried cables and ducts shall be clearly recorded on site.

All metallic cables shall be of low smoke, low fume, zero Halogen, armoured design. Installation shall be in accordance with BS 7671.

Substation auxiliary supplies shall be designed and installed in accordance with Part 4, Section 5.

5.16 SEGREGATION OF EQUIPMENT OWNED BY NATIONAL GRID & OTHER USERS

Protection relays and circuits associated with equipment owned by Users (e.g. generating companies, distribution companies or directly connected entities as defined in Part 4, Section 1) shall be accommodated in separate panels from those associated with equipment owned by National Grid. This requirement shall also apply to multicore cable terminations, marshalling facilities and jumper fields.

Informative: Ideally all National Grid owned equipment should be physically segregated from that owned by Users however it is accepted that this is not always possible/practical in which case the following clauses are applicable.

Where switchgear local controls are grouped on a bay control panel (or similar) then control of National Grid owned plant shall be segregated from that of User owned plant. Separate individually lockable local/remote control selector switches shall be provided for National Grid and User equipment such that staff with authority to operate only User equipment are unable to access control of National Grid owned equipment.

Facilities provided for substation level control of Users equipment shall have no facilities to operate National Grid owned equipment.

Any electrical/mechanical supplies which are provided by National Grid to Users equipment shall be equipped with segregated, clearly labelled isolation facilities.

48V dc, 110V dc and 400/220V ac auxiliary supply isolation facilities shall be located in the equipment local control cubicle (LCC) or, where installed in a common panel, shall be clearly segregated from isolation facilities for National Grid owned equipment. LCC's and common panels should be sited in areas to which access will be permitted to non-National Grid staff.

400V ac supplies to significant User loads, such as transformer coolers, shall be supplied from separate circuits on the substation LVAC supplies board and provision shall be made for the installation of metering. Isolation facilities shall be provided at the load end of the circuit such that isolation at the LVAC board is not normally required during maintenance.

Common compressed air, hydraulic or other motive power systems supplying both National Grid and Users equipment are unacceptable.

The ownership of equipment shall be clearly labelled particularly where National Grid and Users equipment or isolation facilities are located in close proximity.

5.17 CRANES & LIFTING EQUIPMENT

Lifting beams or fixed overhead travelling cranes of adequate capacity shall be provided where their use is required to assist with maintenance, repair or dismantling of switchgear. Fixed cranes shall not be provided in outdoor substations or indoor AIS substations except where specifically required for maintenance or repair purposes.

Provision shall be made to inspect beams or cranes for insurance purposes and to fit lifting tackle.

5.18 FACILITIES

As a minimum the following facilities shall be provided at all new 400 kV, 275 kV and National Grid owned 132kV substations.

Informative: The extent to which this Clause shall apply to extensions to existing installations shall be specified by National Grid in the Contract Enquiry.

a) Adequate toilet and washing facilities for operation and maintenance staff taking into account National Grid's equal opportunities policies.

b) Adequate lighting in accordance with HS(G)38.

c) Standby control room(s) with provision to be equipped as a permit office and to be used for on-site drawing/record storage.

Informative: At indoor GIS substations access to the control room shall not be through the switchgear hall and the room shall prevent ingress of SF6 decomposition products in the event of a switchgear fault.

d) At sites where SF6 gas-filled equipment is installed a standing area and suitable water and drainage connections for a mobile changing/shower facility. Where large volumes of SF6 are installed e.g. GIS substations, a fixed installation is required.

Informative: These facilities are required to comply with National Grid safety codes of practice for work on SF6 filled equipment that has been exposed to power arcing (NS-C2).

e) A small mess room with sink, worktop, electrical outlets and facilities for the supply of drinking quality water.

f) An equipment store (including earth storage facilities) / small workshop.

g) Vehicle parking.

5.19 SITE SECURITY

No equipment within the substation shall be installed within 2 m of the security fence.

5.20 FIRE PROTECTION

Fire protection shall be installed on the User bay(s) to a standard consistent with that of National Grid's substation site.

5.21 GENERAL REQUIREMENTS SPECIFIC TO AIS SUBSTATIONS

5.21.1 Electrical Clearances

The layout of AIS equipment shall ensure the integrity of the air space between live parts and other conductors (whether earthed or at different potential) for the rated voltage conditions for which the substation is designed.

Where equipment configurations have not been dielectrically tested in accordance with BS EN 60694 then minimum operational electrical clearances in accordance with Table 11 shall be applied.

Nominal System Voltage	**BIL/SIL**	**Phase-to-Earth Clearance**	**Phase-to-Phase Clearance**
kV (rms)	kV (p)	m (Notes 1,2)	M
33	170	0.5	0.43
66	325	0.7	0.78
132	650	1.1	1.4
275	1050/850	2.1	2.4
400	1425/1050	2.8	3.6

Table 11 - Substation Electrical Clearances

Informative: [Note 1] Minimum clearance of 500 mm specified to cover vermin and bird interference.

Informative: [Note 2] Under some circumstances temporary infringement of phase to earth clearances during earthing switch operation may be permitted. Such circumstances must be agreed with National Grid during the design phase.

Informative: It should be noted that Table 11 lists MINIMUM clearances and an appropriate additional allowance should be made for constructional tolerances, effects of short-circuit, wind effects etc.

5.21.2 Safety Clearances/Distances

Safety to persons shall normally be achieved by the provision of adequate safety clearance to live parts taking into account the need for maintenance, vehicular and pedestrian access.

Where adequate safety clearances to live parts cannot be maintained without limiting access, barriers or fences shall be provided.

The safety clearances to be maintained in AIS installations are listed in Table 12.

Nominal System Voltage	Safety Distance (From National Grid Safety Rules)	Design Clearance for Safety (vertical) D_S	Design Clearance for Safety (horizontal) D_{SH}	Insulation Height (pedestrian access)
kV	M (Note 1)	M (Note 2)	M (Note 3)	M (Note 4)
≤ 33	0.8	3.2	2.3	2.4
66	1.0	3.4	2.5	2.4
132	1.4	3.8	2.9	2.4
275	2.4	4.8	3.9	2.4
400	3.1	5.5	4.6	2.4

Table 12 - Substation Safety Clearances/Distances

Informative: It should be noted that Table 12 lists MINIMUM clearances and an appropriate additional allowance should be made by the Supplier for constructional tolerances.

Informative: [Note 1] Persons should not allow any part of their body or any object to infringe this distance to exposed conductors operated at high voltage.

Informative: [Note 2] The minimum clearance from a live conductor to a point to which pedestrian access is permitted. These figures are derived by adding the 'personal reach' (the vertical reach of a person with upstretched hand), which is taken to be 2.4 m, to the appropriate Safety Distance.

Informative: [Note 3] It is general practice, where possible, to apply the vertical design clearance in all directions.

Informative: [Note 4] The minimum clearance from the lowest insulation part of a support insulator to a point to which pedestrian access is permitted.

5.21.3 Clearances to Perimeter Fences

Exposed live conductors that cross perimeter fences shall, under worst-case conditions, be at a height no less than the minimum height above ground of overhead lines as defined in the Electricity Safety Quality and Continuity regulations, 2002.

Informative: Designers must allow for the specified maximum ambient temperature and temperature rise due to passage of rated normal current when determining maximum conductor temperature.

Informative: Subject to agreement with National Grid a reduced horizontal clearance may be acceptable provided clearances of DS and DSH (as appropriate) are maintained from the top of the perimeter fence (but excluding any electrified wires). See Figure 2 based on 400kV clearances.

Exposed live conductors that do not cross perimeter fences shall be a distance of at least D_S (measured horizontally) from a substation compound perimeter fence.

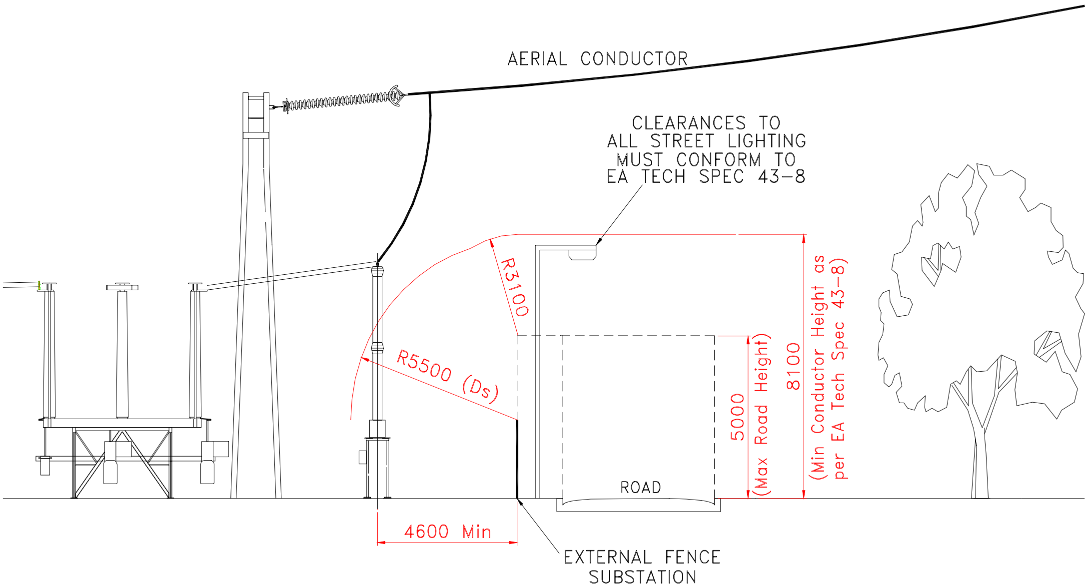


Figure 2 - Reduced Clearance to Substation Perimeter Fence (400kV Clearances Shown)

5.21.4 Clearance to Roadways

a) The minimum vertical clearance from exposed live conductors to internal substation roadways or recognised maintenance access routes to which vehicular access is required shall be the greater of:

(i) Minimum height above ground of overhead lines as defined in the Electricity Safety Quality and Continuity regulations, 2002.

or

(ii) Max vehicle height + 0.5m margin + Safety Distance

Where the latter criterion is used the maximum vehicle height used for the design shall be clearly marked at all vehicular access points.

b) The horizontal clearance from defined roadways to exposed live conductors shall be sufficient to ensure that:

(i) Safety distance is not infringed by any part of a vehicle.

and

(ii) D_{SH} (Table 12, above) is maintained from the driving and/or riding position of any vehicle.

Informative: The second of these requirements caters for the case where the driving and/or riding position falls outside (above) the envelope of the vehicle.

Lockable height barriers shall be provided at entrances to the substation and/or within the substation to restrict access for vehicles exceeding the maximum height for which unrestricted access is allowable.

5.21.5 Oversailing Conductors and Conductors in Proximity

Informative: Designers are obliged to comply with all relevant health and safety legislation, particularly the designers' duties under the Construction (Design and Management) Regulations 1994 (CDM). In applying the principles of prevention and protection in the reduction of risk designers' considerations particular attention is drawn to the hazards of working in proximity to exposed live HV conductors (including 'oversailing' conductors) during construction, operation, maintenance, repair, replacement or demolition of electrical/mechanical equipment and civil structures.

If the designer does not eliminate hazards presented by exposed live HV conductors from the design, there is an obligation on said designer to demonstrate, by risk assessment, that the design has complied with the principles of prevention and protection, as required by CDM. The hierarchy of risk control should be considered when selecting alternative control measures.

Oversailing conductors shall be eliminated from the design as far as is reasonably practicable.

Informative: Oversailing conductors are exposed HV conductors above or in proximity to any reasonably foreseeable work area and which would normally remain energised during such work activities..

Conductors in proximity shall be eliminated from the design.

Informative: Conductors in proximity are exposed HV conductors with insufficient clearance to a reasonably foreseeable work area to avoid danger and which would normally remain energised during work activities.

Situations where work activities must be carried out above exposed HV conductors that are live shall be eliminated from the design.

5.21.6 Substation Profile

The height of the highest component of outdoor substations should be kept to a practical minimum to achieve a low substation profile.

On new sites the maximum height of equipment shall not exceed the values listed in Table 13.

At existing sites the height of existing equipment shall not be exceeded.

Nominal System Voltage (kV)	Maximum Equipment Height (m)
132	7.5
275	10
400	12.5

Table 13 - Maximum Equipment Heights in Substations

5.21.7 Earthing Devices

Substations shall have sufficient earthing provision to enable the safe maintenance of any item of primary equipment including fixed earthing switches. In particular, it shall be possible always to apply an earth between the point of work and all potential fault infeeds.

As a minimum, earthing switches in accordance with Part 4, Section 10 shall be provided at circuit entries ('line' earth switches) and at one position on each section of busbar.

Line earth switches shall be power operated.

Sufficient earthing devices shall be installed such that the "*9 metre rule*" for AIS and the "*30 metre rule*" for GIS, as defined in National Grid's Safety Rules, can be complied with.

Further earthing provision may be by means of other types of interlocked earthing device which meet the specified rating.

5.21.8 Portable Earthing

Provision shall be made to employ National Grid's standard portable earthing equipment.

Informative: This equipment is designed for use with tubular conductors with diameters in the range 10-90 mm, 127 mm, 140 mm or 190/200 mm.

Where flexible conductors are used as substation conductors or where tube sizes are incompatible with the existing earthing equipment then earthing stubs shall be provided.

Points for attachment of the earth end of portable earthing leads shall be provided at each switchgear structure.

Each portable earthing lead attachment point shall be connected to the substation earthing mat by a fully rated conductor system.

Allowance shall be made for the attachment of sufficient leads at each attachment point to match the switchgear rating

For primary earthing National Grid require fully rated earthing capability to be applied in a single operation. Where primary earthing is to be achieved using portable earthing leads, consideration should be given to safe application positions and compliance with the Manual Handling Regulations.

5.22 GENERAL REQUIREMENTS SPECIFIC TO GIS SUBSTATIONS

5.22.1 Buildings

GIS installations comprising two or more circuit breakers shall be housed in a building. The building shall be of minimum life cycle cost construction consistent with environmental and planning requirements.

Fixed crane(s) shall be provided in indoor GIS substations unless the supplier can demonstrate that they are not required for dismantling or removing any part of the substation for maintenance or repair purposes.

5.22.2 AIS Connections

AIS connections associated with GIS substations shall meet the requirements of detailed in General Requirements Specific to AIS Substations, above.

Line earth switches shall be of AIS design where reasonably practicable.

5.22.3 Portable Maintenance Earthing Devices (PMEDs)

Two three-phase sets of each type of PMED employed shall be supplied.

5.22.4 Gas service connections

A diagram of the gas system shall be displayed at the Local Control Cabinet or at any point where gas service connections are grouped together.

5.22.5 Pressure/Density Indication

All displays of pressure/density shall be readable from the substation floor level or from access walkways.

5.22.6 SF6 Gas Alarm Scheme

An audible alarm scheme to warn operators of a major loss of SF_6 gas shall be provided in indoor substations. This shall operate at the low pressure alarm setting of each gas zone.

Controls shall be provided at the substation control point to reset and isolate the audible alarm.

Visual indication(s) shall be provided in the switchhouse to show that the audible alarm is in service.

Visual indication(s) shall be provided outside the main entrances to the switchhouse to indicate that the alarm has operated.

Consideration should be given to the installation of SF_6 detection and alarms in substations where a slow leak may foreseeably result build up of gas e.g. in basement areas.

5.22.7 Location of Light Current Equipment

Equipment panels may be located in the switchgear building either adjacent to the switchgear or in an annexe. Such equipment, together with its accommodation, shall meet the requirements of Class IP 54 of BS EN 60529.

5.23 PERFORMANCE REQUIREMENTS FOR ALL SWITCHGEAR

5.23.1 Jointing of Current Carrying Conductors

Guidance is presented in the Guidance Notes of this Relevant Electric Standard.

5.23.2 Primary Equipment

Calculations or tests shall be performed to demonstrate the mechanical capability of terminals for specified loading combinations of the conductor system in which the equipment is to be applied.

5.24 ROUTINE TESTS AT SITE

5.24.1 Current Carrying Conductors

Where joints between current carrying conductors are made on site then the joint electrical resistance shall be measured and recorded.

5.25 REFERENCES

BS EN 60694	Common specifications for high-voltage switchgear and controlgear standards
BS EN 60865-1	Short-circuit currents. Calculation of effects. Definitions and calculation methods
BS EN 60529	Specification for degrees of protection provided by enclosures (IP code).
BS EN 60335-2-76	Specification for safety of household and similar electrical appliances. Particular requirements for electric fence energisers.
BS 1710	Specification for Identification of Pipelines and Services.
BS 5395	Stairs, ladders & walkways.

BS 7671	Requirements for electrical installations. IEE Wiring Regulations. Sixteenth edition.
HS(G)38	Lighting at Work
National Grid Safety Rules	
The Horlock Rules	NGC substations and the environment :Guidelines on siting and design.

5.26 GUIDANCE NOTE - CURRENT TRANSFORMER (CT) ACCOMMODATION

5.26.1 Integrated Digital Protection/Control

The requirements specified in sections 5.26.2 to 5.26.6 of this Appendix are applicable to substations where conventional protection & control equipment is installed.

The introduction of integrated digital protection & control equipment has eliminated the requirement to provide separate CT cores for busbar and feeder protections and to segregate metering functions from protection. There is still, however, a requirement to maintain two independent measurement and communication systems for analogue data.

The minimum provision shall be:

a) Two independent current sensors per phase on each circuit. These shall be designed and constructed in such a way that the risk of common mode failure is, as far as reasonably practicable, minimised.

b) Two independent communication channels for transmitting analogue data to protection and control equipment. These shall be designed and constructed in such a way that the risk of common mode failure is, as far as is reasonably practicable, minimised.

c) Where the measurement or transmission of analogue data is dependent on an auxiliary power supply then each sensor/communications channel shall be supplied from an independent source (e.g. 110V DC supplies 1 and 2).

d) Where transmission of analogue data relies on the operation of active components to process this data (e.g. integrators, A/D converters, opto-electric converters) then facilities shall be provided for protection relays to use a secondary data source in the event of failure of the primary source. Typically, relays using data channel 1 would revert to data channel 2 in the event of failure and vice versa.

e) In designing the changeover system, the following hierarchy of preference shall be considered (most preferred first, least preferred last):

   (i) Automatic changeover on failure of primary data channel.

   (ii) Manual changeover by unskilled staff on failure of primary data channel.

   (iii) Manual changeover by skilled staff on failure of primary data channel.

f) Changeover facilities shall be designed so that, as far as is reasonably practicable, they do not introduce any additional risks of common mode failure.

5.26.2 Current Transformer Mounting and Polarity Requirements

The following conventions shall be adopted for the physical mounting of current transformers with respect to their terminal markings:

a) For CT's which are integral to circuit-breakers and for separately mounted CT's which are directly associated with circuit-breakers all P1 markings shall be electrically nearer to the circuit-breaker than the corresponding P2 markings.

b) For CT's which are integral to transformers, reactors or generators the P1 markings shall be electrically nearer to the windings than the corresponding P2 markings.

c) For separately mounted current transformers which are not associated with the circuit-breakers the P1 markings shall be electrically nearer to the junction of the primary connections or busbars than the corresponding P2 markings.

d) In the run of busbars, and not associated with a circuit-breaker, the current transformers will usually be in the same housing or chamber. In this case the P1 marking should be electrically nearer the section of busbars with the higher number. If there are two housings or chambers (per phase) the P1 markings of each shall be electrically nearer the adjacent housing or chamber.

The current transformer accommodation normally available for use is as detailed in 5.26.3 to 5.26.6 below. In each case the current transformer cores are listed in the preferred order with the housing, core 1 being positioned nearest to the P1 terminal.

5.26.3 Post Type Current Transformers and Through Wall Air/Air Bushings
All 420, 300 and 145 kV post type measurement/protection CTs and through wall air/air bushings shall have accommodation for the arrangements listed below
The following 'standard' configurations of CT cores are commonly used by National Grid. Alternative configurations may be accepted or specified on a contract basis:

a) Five Core Arrangement

A full complement of five secondary windings as follows:

Core 1 Protection Type A

Core 2 Protection Type A

Core 3 Measurement/Protection

Core 4 Protection Type B

Core 5 Protection Type B

This arrangement will be required where older types of high-burden protection/instrumentation are installed.

b) Four-Core Arrangement

A complement of four secondary windings as follows:

Core 1 Protection Type A

Core 2 Protection Type A

Core 3 Measurement/Protection

Core 4 Protection Type B

This is the preferred arrangement for circuit CT’s in new substations with digital protection/instrumentation systems.

5.26.4 AIS Dead-Tank and Gis Circuit-Breakers

Circuit-breaker bushings, bushing turrets or CT enclosures on the line side of the circuit-breaker shall be capable of accommodating four or five secondary windings in arrangements 5.26.3 a) or 5.26.3 b), as required by the application. For busbar coupler and section applications CT accommodation shall be provided on each side of the circuit-breaker.

5.26.5 GIS Back Parts

In switchgear making up a mesh or single switch substation additional accommodation is required for four or five current transformers in each feeder circuit connection, the arrangement being as 5.26.3 a) or 5.26.3 b).

5.26.6 Slip-Over, Neutral and Other Separately Mounted Current Transformers

Accommodation requirements for such applications are to be examined individually to establish that sufficient accommodation exists for the current transformer types required.

5.27 GUIDANCE NOTE - LOCATION OF CURRENT TRANSFORMERS ASSOCIATED WITH 420, 300 AND 145 KV CIRCUIT BREAKERS

5.27.1 General

In all installations where current transformer housings are associated with circuit-breakers such housings shall be mounted as close as possible to the circuit-breaker concerned.

5.27.2 Busbar Stations

Circuits Other than Bus Section or Bus Coupler - All current transformers associated with a given circuit-breaker shall be installed on the circuit side of the circuit-breaker.

5.27.3 Mesh Type Stations

Current transformers for feeder protection, feeder instrumentation purposes and for system back-up protection shall be installed in the line current transformer housing.

Current transformers for bus section instrumentation purposes and circuit-breaker fail protection shall be installed in the bushings or housings on the side of the circuit-breaker which connects to the mesh corner having the corresponding number e.g. mesh corner four side of S40 etc.

Current transformers for mesh-corner protection shall be installed in the line current transformer housing, in the HV bushing turrets of the associated transformer(s) and on both sides of the circuit breakers. The current transformer for a particular zone of protection shall be located on the side of the circuit breaker remote from that zone.

5.27.4 Single Switch Stations

Current transformers for feeder protection and for feeder instrumentation purposes shall be installed in the line current transformer housings.

Current transformers for system back-up protection shall be installed in the line current transformer housings and in the bushings or housings on the higher numbered side of the bus section circuit-breaker. The current transformer for system back-up protection shall also be used for circuit-breaker fail protection.

Current transformers for bus section instrumentation purposes shall be installed in the bushing or housings on the lower numbered zone side of the bus section circuit-breaker.

Current transformers for mesh corner protection shall be installed in the line current transformer housings, the HV bushing turrets of the associated transformer(s) and in the bushings or housings on both sides of the bus section circuit-breaker. The current transformer for a particular zone or protection shall be located on the side of the circuit-breaker remote from that zone.

6 SECTION 3 - SWITCHGEAR

6.1 TECHNICAL REQUIREMENTS FOR SWITCHGEAR CONNECTED TO THE GB TRANSMISSION SYSTEM

This document defines the technical requirements for switchgear connected to National Grid’s System at 400kV, 275kV, 132kV and 13kV (tertiary). The principles of this document also apply to equipment connected at other voltages.

This Section applies to all switchgear for use on, and for connection to, National Grid’s 132, 275, 400 kV and 13kV tertiary connected 50 Hz systems. It specifies the requirements for items of switchgear but does not cover application, protection and automatic switching requirements; neither does it cover fixed ancillary installations where they have no direct bearing on the service operation of the switchgear specified. For switchgear for use on the GB Transmission System at other voltages exceeding 1 kV detailed requirements will be defined in the Contract Enquiry Document. However, the general principles of this document apply to all switchgear connected to National Grid’s System.

6.2 GENERAL REQUIREMENTS

6.2.1 General

All mandatory requirements of IEC 60694 shall be met.

Switchgear shall have an anticipated asset life of not less than 40 years.

The Supplier shall indicate the maintenance requirements (both time based and duty based), and any mid-life refurbishment activity required to achieve the anticipated asset life.

Provision shall be made for condition monitoring, diagnostics and site testing. Where these facilities are integral to the switchgear they shall not reduce the integrity of the prime function of the switchgear or that of neighbouring switchgear.

6.2.2 Compressed Gas

Where compressed gas is used for arc extinction or operation, abnormal gas system condition alarms shall be provided. The alarms shall indicate falling gas density/pressure and shall operate at a higher level than any low gas density/pressure lockout devices.

Provision shall be made for remote indication or alarm of density/pressure recharging equipment failure, abnormal gas system conditions and low density/pressure lockout.

Provision shall be made for the connection of equipment for monitoring of the rate of change of gas density/pressure of insulation and interruption systems.

The function of the various components of the gas system shall be clearly identified at the switchgear. Different gases or different conditions of the same gas shall be identified by colour on pipework, vessels and diagrams. The colour shall conform to BS 1710 standard colours for gases.

Informative: If white is specifically required to reduce the effect on the equipment of radiated heat from adjacent apparatus or excessive solar gain then unambiguous and clear marking shall indicate the gas contained.

Instruments and alarms shall be provided to ensure safe and reliable operation of all compressed gas systems.

6.2.3 Operating Mechanisms, Ancillary Equipment and their Enclosures

The local control and monitoring apparatus shall be accommodated at the switchgear which it controls (This is termed the local control point). Such accommodation shall be clearly labelled to indicate the apparatus it contains and the switchgear controlled.

The local control point shall be located at ground (floor/fixed access) level.

Indication of the operational position of the switchgear being controlled shall be unambiguous and clearly visible from ground (floor/fixed access) level.

Switchgear with power operated mechanisms shall be provided with means of initiation of closing and opening, and selection of local/remote control, at the local control point.

Three phase switching devices with separate phase mechanisms shall be controllable from a single point, the local control point.

The supplier shall clearly state the maximum available number of auxiliary switches and the number normally pre-allocated for use within the switchgear itself.

Auxiliary switches shall be positively driven in both directions.

Where anti-condensation heaters are fitted in cubicles of switchgear, they shall be physically and electrically shrouded to protect operators of the switchgear from danger.

6.2.4 Sulphur Hexafluoride Gas (SF6)

New SF_6 gas shall conform to IEC 60376.

Recycled SF_6 gas shall conform to IEC 60480 and Appendix A of this document.

At the time of commissioning of switchgear containing SF_6 gas, the gas shall have a moisture content of no greater than 25 mg/kg (approximately -35°C dew point at atmospheric pressure).

National Grid reserves the right to require reprocessing where the differential between the moisture content of the filling gas and final moisture content is greater than 10 mg/kg (approximately a 5°C dew point change).

6.3 PERFORMANCE REQUIREMENTS

6.3.1 Gaseous Insulation

The Supplier shall state the minimum density of the gaseous insulating medium at which circuit breakers and disconnectors can withstand two fully asynchronous power frequency voltages applied to the opposite terminals of the same pole when in the OPEN position. Each voltage to be equal to the rated phase to earth power frequency voltage.

The Supplier shall state the density of the gaseous insulating medium at which all gas insulated equipment can withstand 1.5 times the rated phase to earth power frequency voltage between its conducting parts and earth and where appropriate between phases.

Means shall be provided to enable gas systems to be safely replenished whilst the equipment is in service.

6.3.2 Rated Voltage of Closing and Opening Releases and Operating Devices

a) Direct Current Systems

The rated supply voltage of the dc system at National Grid substations is 125 V. Closing and Opening releases and operating devices shall operate over the voltage ranges, measured at their terminals, given in Table 14.

The Supplier shall declare the characteristics of the current required by the closing and opening releases and operating devices when operating at the minimum operating voltage.

		dc System	Closing and Opening Releases and Operating Devices	
			Close	Open
Maximum Operating Voltage	Volts	137.5	137.5	137.5
Minimum Operating Voltage	Volts	93.5	87.5	77

Table 14 - Rated Supply and Operating Voltage Range for dc Systems and Operating Devices

b) Alternating Current Systems

Alternating current control systems are not acceptable for the control of circuit-breakers, switches, disconnectors or earthing switches.

6.4 TEST REQUIREMENTS FOR SWITCHGEAR

6.4.1 Dielectric Tests

a) Gas Insulated Switchgear (GIS)

Dielectric tests shall be to the requirements of IEC 60694. Where doubt exists regarding the path of any breakdown during testing it shall be assumed that the breakdown involved non-self restoring insulation.

b) Atmospheric Air Insulated Switchgear (AIS)

Dielectric tests shall be to the requirements of IEC 60694. Where doubt exists regarding the path of any breakdown during testing it shall be assumed that the breakdown involved non-self restoring insulation.

6.4.2 Mechanical Strength of Hollow Ceramic and Composite Pressurised Insulation

Ceramic hollow support pressurised insulation shall be designed and tested according to IEC 61264 for pressure and bending stresses.

The Supplier shall state the type test withstand bending moment, routine test bending moment and the bending moment equivalent to the design pressure. In addition the Supplier shall state the bending moment, above that required to satisfy the total loading requirements of the switchgear itself, which is available for the connections to adjacent switchgear.

Informative: The total loading requirement includes consideration of the 100% wind pressure without ice accretion, 100% short-circuit forces, equipment internal pressure, equipment mass and mechanical operation.

Hollow composite insulation for unpressurised and pressurised applications shall be designed and tested according to the rules prescribed in IEC. The Supplier shall self-certificate that the insulator materials and insulator design satisfy the design test criteria IEC 61462.

The supplier shall state the following insulator mechanical cantilever and internal pressure loads:

a) Cantilever

Maximum mechanical load (MML), i.e., the equipment design load; the routine cantilever bending load; the damage limit; the type test cantilever bending load and the specified mechanical load (SML).

b) Internal Pressure

Maximum service pressure (MSP), i.e., the equipment design pressure; the routine test pressure; the damage limit; the type test pressure and the specified internal pressure (SIP).

The Supplier shall self certificate the compliance of the routine tests with Clause 10 of IEC 61462.

In addition the Supplier shall state the cantilever bending load, above that required to satisfy the total loading requirements of the switchgear itself, which is available for the connections to adjacent switchgear. The total loading requirement includes consideration of the 100% wind pressure without ice accretion, 100% short circuit forces, equipment internal pressure, equipment mass and mechanical operation.

6.4.3 Routine Tests

Routine Tests shall normally be performed at the point of manufacture.

Commissioning tests and routine tests that are performed at site shall be fully documented.

Power-operated switchgear shall be operated mechanically 50 times with each operation initiated as per in service operation.

Informative: This number may include routine tests.

Commissioning procedures and acceptance values shall be detailed by the Supplier.

Diagnostic tests shall be incorporated into the commissioning test programme and be performed on all equipment to establish its correct operation.

Informative: Such tests may include, but are not restricted to, the measurement of operating coil currents, contact timing, speed of operation, travel characteristics, contact engagement, synchronous operation of poles, primary circuit resistance, checks for gas and liquid leakage, checks for the correct operation of monitoring devices and checks on the quality of the insulating and arc- quenching media.

6.5 REFERENCES

6.5.1 International, European and British Documents

This Specification makes reference to the documents listed below.

BS EN 60694	Common Specifications for High Voltage Switchgear and Controlgear Standards
BS 1710	Specification for Identification of Pipelines and Services
IEC 60376	Specification for Sulphur Hexaflouride for Electrical Equipment
IEC 61264	Ceramic Pressurised Hollow Insulators for High-Voltage Switchgear and Controlgear.
IEC 61462	Composite Insulators for use in Outdoor and Indoor Electrical Equipment.

7 SECTION 4 - EARTHING

7.1 PURPOSE AND SCOPE

This Section defines the functional performance and test requirements for earthing systems forming part of National Grid's System and protected by fast acting protection systems*. It supports the more general conditions defined in Part 4 Sections 1 and 2.

The requirements of this Section shall apply to new substations, cable sealing end and tower constructions and where reasonably practicable to extensions or modifications of existing substations and cable sealing ends and tower refurbishment.

Where a substation, cable sealing end or tower is being extended or modified, National Grid will state if it is necessary to control the rise of earth potential in accordance with 7.2.2 of this Section. If not stated, this requirement need not be applied.

*Note: Fast acting protection systems are those designed to achieve a target total fault clearance time of less than 200 ms.

7.2 GENERAL REQUIREMENTS

The earthing system shall comply with EA TS 41-24 and BS 7430, unless otherwise stated.

7.2.1 Statutory Requirements

The earthing system shall be designed and installed to comply with all relevant statutory instruments.

Specifically, The Electricity Safety, Quality and Continuity Regulations 2002 require that:

"A generator or distributor shall ensure that, so far as is reasonably practicable, his network does not become disconnected from earth in the event of any foreseeable current due to a fault".

Further requirements are contained in the Electricity at Work Regulations and Management of Health and Safety at Work Regulations 1999.

7.2.2 Rise of Earth Potential

The safety of all persons on high voltage sites, as well as in the immediate environs of such sites, and persons who may contact any conducting services to, or passing through such sites, is dependent on the design of the earthing system and its associated electrical isolation. The design of the earthing system at substations shall limit the step and touch potentials to safe levels given in Table 15.

	Maximum Voltage for Touch	Maximum Voltage for Step
Chippings surface (150 mm)	1.4 kV	4.6 kV
Soil surface	1.0 kV	3.1 kV

Table 15 - Touch and Step Potential Limits

The limits in Table 15 assume a 200 ms clearance time, a 1 m step distance and a footwear resistance of 2 kΩ per shoe. They are based on curve c_1 of Figure 14 of IEC 479-1.

In the event that an insulating coating is required to be applied to the tower legs in order to manage the risks associated with touch potentials, then the coating specification shall comply with the minimum requirements below:

a) Minimum Rated voltage withstand: 50kV

b) Coverage: From ground level to 2.5m above ground level

c) Minimum Service Life: 10 years

d) The coating shall not serve to aid climbing of the tower

e) The coating shall not prevent the fitting of step bolts

f) The coating shall be resistant to minor impact damage

g) The coating shall be dark or light grey and shall generally be unobtrusive

Cable sealing ends shall be treated as substations unless otherwise agreed by National Grid.

Critical third party ROEP impact voltage thresholds via proximity effects are given in Table 16.

Third Party Infrastructure	Threshold Limit Voltage
Domestic residence or commercial property	1700
Large hazardous process plant e.g. refinery	650
Railways	1150

Table 16 - Third Party Impact Threshold Voltages via Proximity Effect *

* Proximity effect refers to ROEP conduction via the ground

Where a National Grid substation provides a HV connection to a third party, the applicable threshold limit values via conduction are given in Table 17.

Third Party Infrastructure	Threshold Limit Voltage
Domestic residence or commercial property	Not Applicable
Large hazardous process plant e.g. refinery	650
Railways	430

Table 17 - Third Party Impact Threshold Voltages via Conduction *

* Conduction refers to electrical conduction via metallic conductors.

The design of the earth electrode system (whether this is as a result of adding to an existing system or the installation of new system), shall be optimised in so far as is reasonably practical to ensure third party impact threshold voltages are within the limits in Tables 16 and 17. In particular, consideration shall be given to the arrangement of the electrode system and the use of all land within the substation boundary. It is only necessary to use land outside the substation boundary (within National Grid's ownership) if stated by National Grid. The earth electrode depth and geometry shall be optimised to make use, as far as practicable, of lower resistivity ground strata.

Where reasonably practicable, the earthing system shall be designed using an earth return current which is 20% greater than that calculated by National Grid, to allow for future increases in system fault current.

Calculations to design the main earth system shall be carried out using CDEGS software package (Current Distribution, Electromagnetic Fields, Grounding and Soil Structure Analysis). The design models produced shall be made available once completed and becomes the property of National Grid as part of the connection agreement.

Communication cables connecting to all National Grid substations must be fitted with appropriate electrical isolation.

7.2.3 Earth Electrodes

Earth electrodes shall be designed to operate satisfactorily during faults, taking into account the area of the electrodes in contact with earth, the soil resistivity and earth electrode current magnitude and duration, in accordance with BS7430. The fault duration times to be used for rating the electrodes are 1 second for 275 kV and 400 kV and 3 seconds for all other voltages.

Buried bare copper horizontal earth electrodes shall be installed at around 500 mm depth. If the indigenous soil is hostile to copper, see clause 7.4.1 b), the electrode shall be surrounded by 150 mm of non-corrosive soil of fine texture, firmly rammed. Where there is a likelihood of soil migration and leaching, alternative materials may be used as described in BS 7430. Conductors installed in ploughed farmland shall be buried at least 1 m deep, at all points, measured from undisturbed ground level.

Where horizontal earthing conductors are exposed to indigenous soils that are hostile to copper, stranded copper conductors are not permitted within the earthing design.

Driven rod electrodes in accordance with EA TS 43-94 shall be used to exploit lower resistivity ground strata where present to reduce the site rise of earth potential in accordance with 7.2.2. Where the ground is hard and rods cannot be driven, consideration shall be given to drilling holes to install the rods and back filling with a suitable low resistance fill material.

Buried conductors and electrodes shall be at least 3 m away from buried cables with uncovered metallic sheaths, unless the sheaths are used as part of the earthing system.

Where beneficial, reinforcing steelwork incorporated within piling shall be utilised as an earth electrode. However, care must be taken to ensure that the current carrying capacity of the steelwork is not exceeded. Connections shall be made to each vertically steel bar within the pile cap. Connections brought out through the pile cap shall be provided with appropriate means to prevent moisture ingress into the cap. Current carrying connections to and within the steelwork shall be in accordance with Part 4, Section 2. Fortuitous connections must not be relied upon.

Where sheet steel piles of the interlocking kind are used as an earth electrode, connections shall be made to each pile.

7.2.4 Earth Electrode Arrangement

Unless otherwise agreed by National Grid, the earthing electrode arrangement shall be based on a peripheral buried main bare earthing conductor generally encompassing the plant items to be earthed, with buried spur connections, from the main conductor to the items of plant. The main earthing conductor shall be augmented with inter-connected buried bare cross-connections to form a grid. In addition, where beneficial, groups of earth rods distributed around the periphery shall be connected to this main earthing conductor.

For indoor substations the earthing grid shall be installed with spur connections to the steel reinforcing mat of the concrete floor, every 20 m. Additionally, a second peripheral main earthing conductor shall be buried at 1 m distance from the building, which shall be bonded to the first main conductor, and to the building if it is metalclad, both at 20 m intervals. Earth rod groups shall be connected to the second peripheral conductor as previously described in in the paragraph above.

7.2.5 Test Facilities

In order to facilitate testing of all earth electrode groups, a section of conductor connecting to each group shall be made accessible and shall have dimensions that would fit inside 25 mm diameter circular clamp meter jaws (min length 75 mm). An example of how this can be achieved is shown in 7.10, figure 8 of this Section. This section of conductor shall be a part of a spur connection to the rod group ie so that all the test current flows into the rod group and is not diverted into the main earth system.

Disconnectable links must not be fitted in the connections from the main earth system to terminal towers or rod groups or in the connections between main earth systems, e.g. between earth systems on joint sites.

7.2.6 More Than One HV Substation

Where there is more than one National Grid substation on the same site a separate earth grid shall enclose each substation and these grids shall be connected together at the extremities by at least two fully rated conductors ideally taking secure separate physical routes. In order to facilitate testing of the interconnections, the conductors connecting the systems together shall each be made accessible at a designated point. At this point the conductors shall have dimensions which would fit inside a 25 mm diameter circular clamp meter jaws (min length of conductor 75 mm). An example of how this can be achieved is shown in 7.10, figure 6 of this Section.

Where a National Grid substation is located on the same site as another users substation, the earthing systems shall be interconnected as defined by National Grid.

Measures shall be taken to ensure that persons can not come into contact with hazardous transferred potentials between substations or directly connected customers, particularly where sites are separated. Where control of these potentials requires measures to be taken by a third party, National Grid shall be informed by the supplier at the time of production of the earthing design.

In all cases where HV earthing systems are connected together, disconnectable test links shall not be fitted.

7.2.7 Equipment Connected to the Main earth system

The following items of equipment shall be connected to the main earth system by a fully rated conductor:

a) All points which may form the earth of a high voltage fault path.

b) Transformer winding neutrals required for HV system earthing. For 66 kV and below, the connection may be via earthing resistors or other current limiting devices.

c) In the case of a manually operated earthing or HV switch, a dedicated fully rated conductor shall be run from the handle or mechanism box to the main earth system as directly as possible and this conductor shall pass under the stance position of the person operating the switch. The conductor runs to any fault points associated with the switch shall, where practicable, be maintained separate from the handle or mechanism of the switch and connecting metalwork.

All metalwork e.g. panels, cubicles, kiosks etc, including the steelwork of buildings, shall be bonded to the main earth system by a conductor of no less than 70 mm^2 cross section. Strip conductor shall be no less than 3 mm thick.

Mechanical linkages, e.g. turnbuckles, shackles etc, which could form part of the earth connection shall be shunted across using fully rated flexible conductor to prevent damage by the passage of fault current.

Metallic trench covers shall be earthed to cater for the possibility of an earth fault on cabling in the trench and to cater for the possibility of induced or transferred potentials. To achieve this, metal trench covers may be laid on conducting support(s) that shall each be connected to the main earth system by a conductor as specified above.

7.2.8 Installation

Earth conductors in trenches containing power and/or multicore cables shall be fixed to the walls approximately 100 mm from the top to maintain separation from the cables.

Due regard shall be given to the possibility of mechanical damage to buried conductors and, where necessary, either marker tapes and/or mechanical protection shall be installed. A separation of at least 500 mm to civil works such as drainage pits, shall be maintained. Conductor runs above ground shall be designed to minimise the possibility of mechanical damage.

When laying stranded conductors, care shall be taken to avoid distorting individual strands.

Conductors shall be fixed firmly and tidily to structures at a spacing of no more than 1 m. The fixings shall not allow galvanic corrosion to occur and shall not require the conductor to be drilled unless otherwise agreed by National Grid.

Where earth conductors cross they shall be jointed (other than in the case of rod groups where these must be maintained separate to permit testing).

Where earth conductors connect to equipment the connections shall as far as practicable be made onto vertical surfaces only. Connections to the metal cladding of buildings shall be inside the building.

Aluminium conductor shall only be installed at least 250 mm above ground level.

All conductor joints shall be in accordance with the Guidance Notes given in this Relevant Electrical Standards document.

Where specified, buried earth tape shall be protected from theft by measures such as concrete anchors or securing to driven earth rods.

Bolted joints are not acceptable below ground other than for earth rod screw couplings which shall be thoroughly greased. Connections to buried earth rods shall be welded in accordance with the Guidance Notes given in this Relevant Electrical Standards document.

7.2.9 Portable Earthing

Loops for portable earths shall be provided on the earthing conductor at each location where portable earths may be required to be applied. The loops shall be fully rated and suitable for National Grid standard portable earthing equipment, and shall be made of copper or aluminium. The loops shall be not less than 230 mm long and shall be 75 mm clear of the earthing conductor. Loops for portable earths shall be installed at a convenient height and shall be separately formed, ie not by bending the earthing conductor.

The rating of multiple portable earth leads shall be as listed in Table 18

Number of leads (150 mm^2 aluminium)	Rating
1	17.5 kA
2	31.5 kA
3	47.25 kA
4	63 kA

Table 18 - Ratings for multiple portable earth leads

7.2.10 Steel Support Structures

Where the current carrying capacity of steel support structures is at least equal to the switchgear rating, it is preferred that the structure is utilised to form part of the connection to the main earthing system, in which case there is no need to fix an earth conductor along this section.

Where a steel structure is relied upon to provide an earth connection for supported equipment, current carrying joints within 2.4 m of ground level shall be in accordance with the Guidance Notes given in this Relevant Electrical Standards document. Above 2.4 m the normal structural joints are considered adequate for electrical integrity during fault conditions.

Steel structures shall not be relied upon to conduct high frequency currents or for earth connections to earth switches.

Where post insulators, other than those forming part of shunt connected equipment (eg CTs, VTs, SAs) are supported by a steel structure the insulator base does not require a bridging connection to the structure.

7.2.11 Fences

Measures shall be taken to ensure that dangerous touch or transferred potentials cannot arise on substation fences.

Perimeter fences may be independently earthed using 5 m long rod electrodes in accordance with BS7430. Alternatively, perimeter fences may be connected to the main earth system in accordance with BS7430.

Where a perimeter fence is independently earthed, 2m separation must be maintained between the fence and the main earth system and equipment connected to it.

Unless otherwise agreed by National Grid, where a perimeter fence is connected to the main earth system an additional buried bare conductor shall be installed 1 m outside the fence buried at a depth of 0.5 m to control touch potentials. This conductor shall be connected to the main earth system and fence at 50 m min intervals.

Internal fences within the curtilage of the main earth system shall be connected to it at 50 m min intervals and at changes of direction and where power lines cross overhead. Unless otherwise agreed by National Grid, internal fences not within the curtilage of the main earth system shall have an additional buried bare conductor installed 1m on either side of the fence buried at a depth of 0.5 m connected to the fence at 50 m intervals to control touch potentials.

Where a fence, which is connected to the main earth system, abuts an independently earthed fence they shall be electrically separated using either a non-metallic fence panel or an insulating section having 5 cm (approx) creepage at each end of a 2 m section which is not connected electrically to either of the fences. A suggested method of installation using insulating bushes is shown in 7.10, figure 7 of this Section.

A cable having a metallic covering effectively in contact with the ground or a bare conductor which passes underneath an independently earthed fence shall be covered with insulation for a distance of 2 m on either side of the fence. For example this may be achieved by running the conductor in an alkethene pipe 2 m either side of the fence.

Where galvanised steel chain link internal fencing is used, a separate earth conductor shall be installed along the fence (min 70 mm2) and shall be connected to each section of fence every 10 m or less and to the main earth system at 50 m intervals.

Where plastic coated steel chain link internal fencing is used, connection to the main earthing system shall be made at all fence guide wire anchor points (min 70 mm2).

Connections to the fence shall be via a conductor which shall be accessible and shall have dimensions which would fit inside 25 mm diameter circular clamp meter jaws. Where bolted joints are used to connect to the fence, these shall be protected with Denso Mastic and Tape.

7.2.12 Access/Egress Gates

Access/egress gates are not required to be bonded to its supporting post. Note that this should not be confused with the requirement to cross bond between gate supporting posts, and that this requirement should still be met.

7.2.13 Temporary Fences

Temporary metallic fences shall be installed with appropriate measures to limit touch or transferred potentials to safe levels.

An internal metallic fence within the curtilage of the main earth system shall be connected to the main earth system at 50 m intervals, at changes of direction and where power lines cross overhead.

Where a temporary metallic fence which is connected to the main earth system abuts an independently earthed fence they shall be electrically separated in accordance with BS7430.

A fence outside the curtilage of the main earth system may present a greater hazard where it crosses the ground voltage profile. In this case, in order to limit the transferred potential, the fence shall either be non-metallic or shall have its sections electrically insulated from each other at intervals depending on the ground voltage profile at the site.

7.2.14 Terminal Towers

Where the earth wire of an incoming line terminates on a tower it shall be connected to the top of the tower.

The tower shall be connected to the adjacent substations main earth system (not rod groups) at two separate points by two spur copper strap conductors following secure separate routes. The copper strap shall have a cross section no less than 50 mm x 6 mm. There shall be no disconnectable links in these connections. These conductors shall be connected to different legs of the tower and shall be adequately protected to prevent damage and deter theft. Where these conductors cross or come close to rod groups they shall be insulated to maintain an electrical separation between bare conductors of 2 m min.

Where a terminal tower leg is within 2 m of an independently earthed fence, the affected sections of fence shall be connected to the tower and insulated sections fitted either side of the affected sections.

7.2.15 LV Distribution Transformers

The earthing and isolation of LV distribution transformers associated with National Grid substations shall be designed assuming that the substation ROEP is greater than 650 V rms.

Where an LV distribution transformer is used to provide LV auxiliary supplies to the substation and is supplied externally, the following requirements shall apply:

a) Where the transformer is sited within National Grid’s substation, the transformer steelwork and LV neutral shall be connected to the substation main earth system. The incoming HV supply shall be electrically isolated from the main earth system at a minimum level of 10 kV rms. The HV cable sheath and any metalwork connected to it shall be insulated at a minimum level of 10 kV rms and the cable termination shall be clearly labelled to indicate a transferred potential hazard. The transformer must not be used to provide LV supplies external to National Grid’s substation. This arrangement is illustrated in 7.10, figure 4 of this Section.

b) Where the transformer is sited outside National Grid’s substation, the transformer LV neutral and LV cable sheath shall be connected to the main earth system and electrically isolated from the external HV supply, including its associated earth, at a minimum level of 10 kV rms. The LV cable sheath insulation shall be rated at 10 kV rms min. At the transformer end, the LV cable sheath and any metalwork connected to it shall be insulated at a minimum level of 10 kV rms and the cable termination shall be clearly labelled to indicate a transferred potential hazard. The transformer must not be used to provide LV supplies external to National Grid’s substation. This arrangement is illustrated in 7.10, figure 5 of this Section.

Where an LV distribution transformer, sited within National Grid’s substation, is used to provide LV supplies external to the substation, the following requirements shall apply:

c) The transformer steelwork shall be connected to the main earth system. The transformer LV neutral shall be electrically isolated from the main earth system and the HV winding of the transformer at a minimum level of 10 kV rms. The LV cable sheath and any metalwork connected to it shall be insulated at a minimum level of 10 kV rms and the cable termination shall be clearly labelled to indicate a transferred potential hazard. This arrangement is illustrated in 7.10, figure 6 of this Section.

7.2.16 Gas Insulated Substations

Gas insulated substations with single phase enclosures have specific earthing requirements to reduce circulating currents in supporting steelwork.

The main earth system shall be well integrated in the regions close to equipment with short spur connections taken to specific points. Connections to this system, together with direct connections between phases shall be made at all line, cable and transformer terminations, at busbar terminations and at approximately 20 m intervals in busbar runs. Inter-phase connections shall be rated to carry induced currents resulting from the flow of rated normal current in the primary conductors.

7.2.17 Anti-climbing Precautions Along the Tops of Walls

Where barbed wire or other metal anti-climbing devices are erected along the tops of brick walls etc these shall be connected to earth using the same procedure as with fencing.

7.2.18 Substation Lightning Protection Systems

Where required, lightning protection systems shall be in accordance with BS 6651. All lightning protection system conductors shall be connected to the substation main earthing system.

7.2.19 Design Life of Installation

All parts of the earthing installation, both below and above ground, shall have a design life of 40 years taking into account the anticipated corrosion of the conductors resulting from site chemical pollution.

7.3 PERFORMANCE REQUIREMENTS

7.3.1 Conductors

All conductors which may carry fault point current shall be fully rated. Earth conductors shall be rated so as not to exceed the maximum temperatures given in Table 19. Duplicate or loop connections shall be derated by a minimum of 20% to allow for unequal current sharing.

Type of conductor	Maximum recommended conductor temperature during a short circuit
Bare conductors, solid or stranded: Cu	405^{o}C
Bare conductors, solid or stranded: Al or Al alloy	325^{o}C
Bare conductors, solid or stranded: steel	300^{o}C

Table 19 - Highest Temperatures for Non-Mechanically Stressed Conductors During a Short Circuit

7.4 DESIGN INFORMATION

7.4.1 The designer of the earth electrode system should consider the following:

a) The site soil resistivity profile and suitability for driving earth rods (see 7.9 of this Section for measurement methods).

b) The chemical and/or physical nature of the site soil structure. For example, the presence of corrosive soils (acids, nitrates, sulphides, sodium silicates, ammonium chlorides, sulphur dioxides) should be considered in the design of an earthing system with a 40 years life design requirement

c) Details of the civil engineering structures existing, or to be built on site shall be ascertained to determine if the reinforcing steelwork incorporated within the structures or piling can be used as an earth electrode.

d) For existing sites, the latest site earthing survey.

e) The earth return current and the switchgear rating.

f) Existing third party infrastructure, including future known developments, in the vicinity of the substation.

If available, National Grid will provide the supplier with some or all of the above information. The availability of this information will be stated in the tender document.

7.5 TEST REQUIREMENTS

Validation by electrical measurement of any design is required for all installed systems to confirm the satisfactory installation and design of the system. National Grid reserves the right to witness all tests. The measurement methods are outlined in 7.9 of this Section.

The resistance to earth of all individual rods and rod groups shall be measured and recorded. Where the measured resistance of an individual rod is more than 50% higher than the average for the site the reason shall be investigated and the rod(s) re-installed if necessary.

The total substation earth electrode impedance shall be measured using the AC Fall of Potential Method and the result recorded. The measured result shall be compared with that predicted by calculation and any significant difference investigated. On some sites it may not be practicable to carry out this measurement due to the surrounding environment and it may be necessary to rely on calculation alone. In this case, careful attention must be given to establishing accurate data for the calculation, e.g. the soil resistivity profile and the layout of the main earth system.

For transmission towers, as far as is reasonably practicable, both the footing resistance and the chain impedance shall be measured.

Tests of all electrical joints shall be made in accordance with the Guidance Notes given in this Relevant Electrical Standards document.

The supplier, at the request of National Grid, may be required to excavate in order to reveal earth conductor joints for testing, or to demonstrate correct installation to drawing.

7.6 ACCEPTANCE PROCEDURE

The supplier shall provide evidence that the tests described in this document have been carried out satisfactorily.

The supplier shall provide evidence that the necessary precautions have been taken to prevent unsafe touch, step and transferred potentials from arising.

The supplier shall provide documentation to demonstrate that the earthing installation complies with this document and includes with it ROEP contour plots showing 430V, 650V, 1150V and 1700V contours overlaid onto an OS map (see also 7.2.2 of this Section).

The map accuracy should be checked during site assessment to include all 3rd party properties within the proximity with detail of its occupation.

7.7 REFERENCES

This document makes reference to or should be read in conjunction with the documents listed below:

The Health and Safety at Work Act, 1974.

The Electricity At Work Regulations, 1989.

The Electricity Safety, Quality and Continuity Regulations 2002

Electricity Supply Regulations 1988, Statutory Instrument No 1057.

Electricity Supply (Amendment) Regulations 1990, Statutory Instrument No 390.

The Management of Health and Safety at Work Regulations, 1999.

IEC 479-1 International Electrotechnical Commission, Technical Report, Effects of Current on Human Beings and Livestock - Part 1 General Aspects.

BS 6651, Code of practice for protection of structures against lightning, 1999

BS 7430 Code of practice for Earthing 1998 (Formerly CP 1013: 1965).

BS 7354 Code of Practice for Design of High Voltage Open Terminal Substations.

EA TS 41 24, Guidelines for the Design, Installation, Testing and Maintenance of Main Earthing Systems in Substations, Issue 1: 1992.

EA S 34 A Guide For Assessing the Rise of Earth Potential at Substation Sites, May 1986.

EA S 36, Procedure to Identify and Record hot□ Substations, December 1988.

EA TS 43-94 Earth Rods and their Connectors, Issue 3, 1990.

ITU-T K.33 Limits for people safety related to coupling into telecommunications system from a.c. electric power and a.c. electrified railway installations in fault conditions (previously CCITT Recommendation).

CCITT Directive, Volume VII, Protective Measures and Safety Precautions.

Earth Resistances, G F Tagg, George Newnes, London, 1964.

7.8 DEFINITIONS

Cold Site A site at which the **rise of earth potential** is less than or equal to 650 V rms (based on a 200 ms clearance time).

Earth The conductive mass whose electric potential at any point is conventionally taken as zero.

Earth Electrode A conductor or group of conductors in intimate contact with, and providing an electrical contact to **earth.**

Earth Electrode Area The area contained by the **earth electrode** system.

Earth Electrode Current The maximum value of current which the total substation **earth electrode resistance** may be required to conduct. In single earthed neutral systems fitted with current limiting devices the maximum **earth electrode current** is limited by that device unless there are secure parallel circuits offering an alternative current path to that provided by the **earth electrode resistance**.

Earth Return Current The proportion of **fault point current** which returns to source via the ground.

Earth Electrode Resistance The resistance of an **earth electrode** with respect to **earth**.

Fault Point Current The maximum value of current which could flow at any fault point. This shall be taken as the single-phase short-circuit rating (or three-phase if higher) of the installed switchgear, unless otherwise specified by National Grid.

Fully Rated Rated to carry 63 kA for 1 s at 400 kV, 40 kA for 1 s at 275 kV and 31.5 kA or 40 kA (special application) for 3 s at 132 kV.

Ground Voltage Profile The radial ground surface potential around an earth electrode referenced with respect to earth.

Hot Zone The internal area encompassed by a contour representing points at which the rise of potential is greater than 650 V rms (based on a 200 ms clearance time).

Main Earth System The complete interconnected assembly of earthing conductors and earth electrodes which are intended to carry HV equipment fault current.

Other Earth System Earth conductors which are part of the System (as defined in National Grid Safety Rules) but which are not part of the Main Earth System.

Earthing System Earth conductors which are part of either the Main Earth System or Other Earth System.

Rise of Earth Potential (ROEP) or Substation Potential Rise or Ground Potential Rise The voltage difference between the substation metalwork and earth due to fault current. It is calculated from the product of the total substation earth electrode impedance and the current flowing through it.

Step Potential The electrical potential between two points, on the surface of the ground, bridgeable between a person's feet, due to a ground voltage profile. The step distance is assumed to be 1 m.

Touch Potential The electrical potential between two points, bridgeable by a person's hands and feet, due to a ground voltage profile. The touch distance is assumed to be 1 m.

Total Substation Earth Electrode Resistance The resistance of the main earth system and other connected electrodes with respect to earth.

Total Substation Earth Electrode Impedance The impedance of the main earth system and other connected electrodes with respect to earth.

Transferred Potential An electrical potential between two points due to a ground voltage profile which is transferred to the points by a conducting

7.9 GUIDANCE NOTE - MEASUREMENT METHODS

7.9.1 Measurement of Earth Rod and Earth Rod Group Resistance

Unless otherwise agreed by National Grid, individual earth rod and rod group resistances shall be measured. The measurement may be made using the circulating current method with respect to the main earthing system, provided the main earth system has a very much lower resistance compared with the rod or rod group. Care must also be taken to ensure that the voltage profile overlap of the main earth system and the rod or rod group does not significantly affect the measurement.

7.9.2 Measurement of Total Substation Earth Electrode Impedance

The total substation earth electrode impedance shall be measured using the ac Fall of Potential Method [1]. The 61.8% rule or the Slope Method must not be used.

7.9.3 Measurement of Tower Footing Resistance or Chain Impedance

Where the OHL earth wire is not connected to the tower, the tower footing resistance shall be measured using the Fall of Potential Method [1]. The 61.8% rule or the Slope Method must not be used.

Where the OHL earth wire is connected to the tower, the tower chain impedance shall be measured using the ac Fall of Potential Method [1]. The 61.8% rule or the Slope Method must not be used.

7.9.4 Measurement of soil resistivity

Sufficient resistivity measurements shall be made to determine a suitably accurate soil model. The number of measurements will normally depend on the homogeneity of the ground.

Soil resistivity shall be measured in accordance with BS7430. The method described is also known as the Wenner Method. Resistivity shall be measured up to a depth of 60 m where reasonably practicable. No less than two pairs of measurements shall be made at separate locations on site (each pair consists of two traverses at 90 o to each other).

REFERENCE

[1] Earth Resistances, Tagg G F, George Newnes, London 1964.

7.10 GUIDANCE NOTE - FIGURES

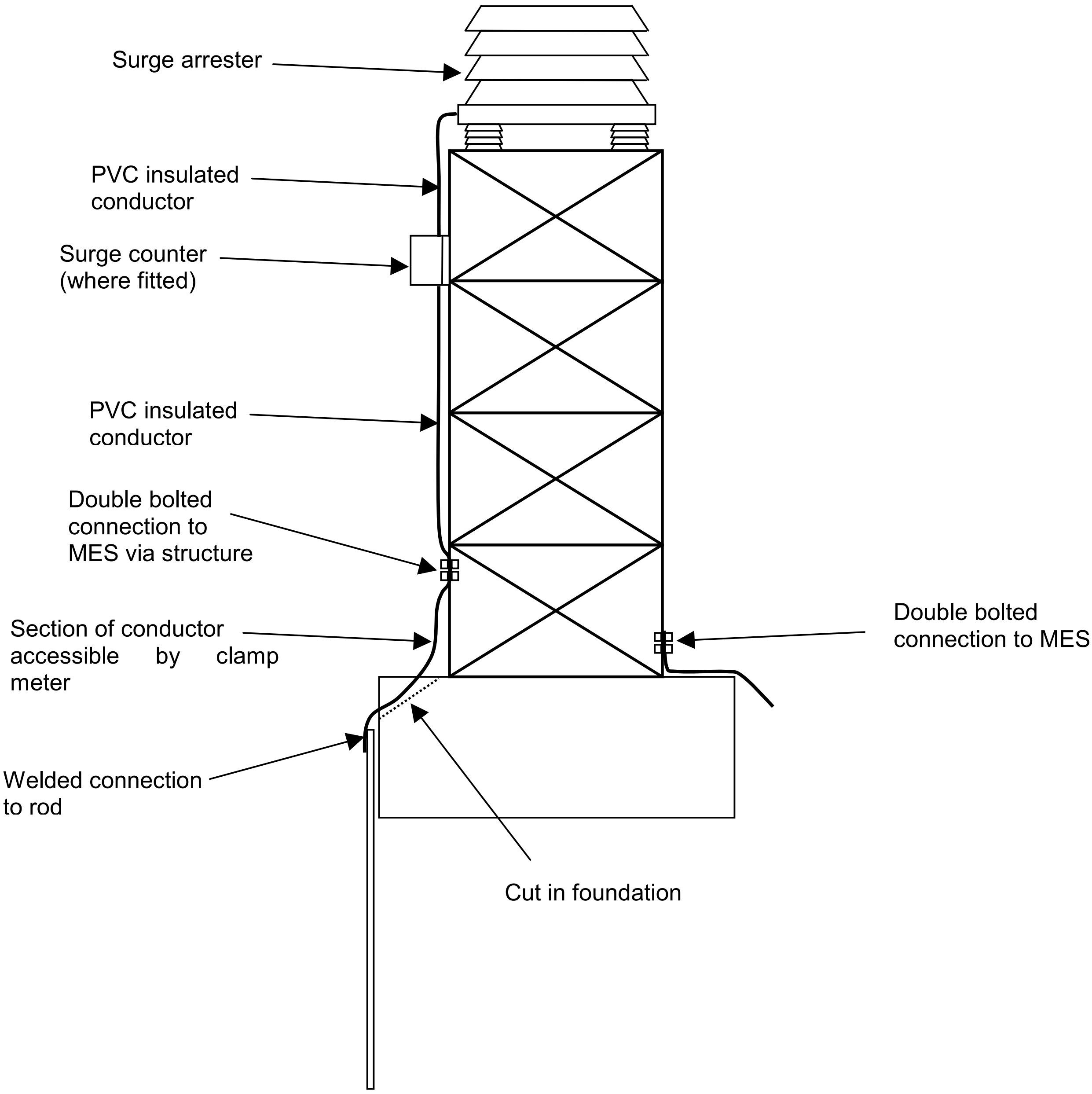


Figure 3 - Example High Frequency Earth Installation for Surge Arrester

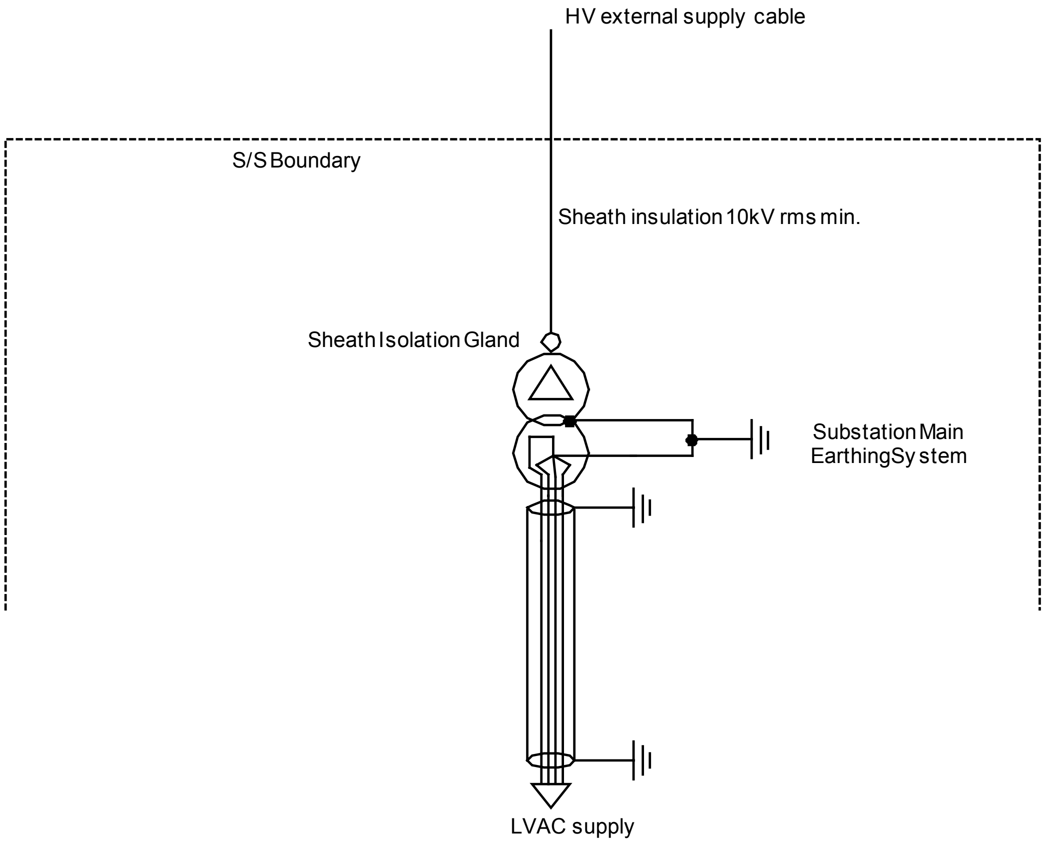


Figure 4 - Incoming supply transformer sited within National Grid substation

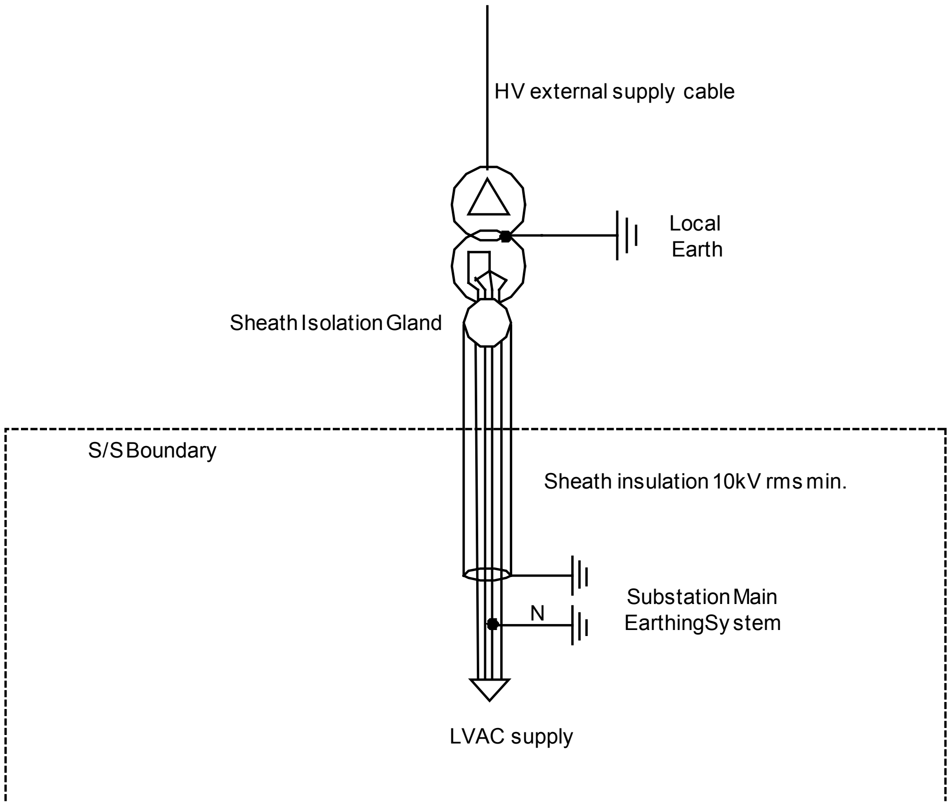


Figure 5 - Incoming supply transformer sited outside National Grid substation

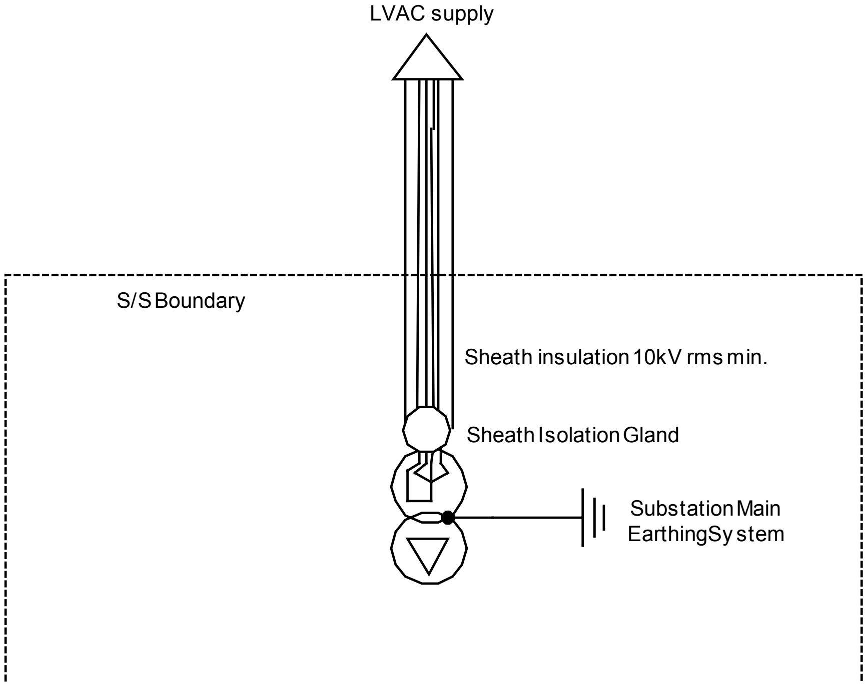


Figure 6 - Outgoing supply transformer sited within National Grid substation

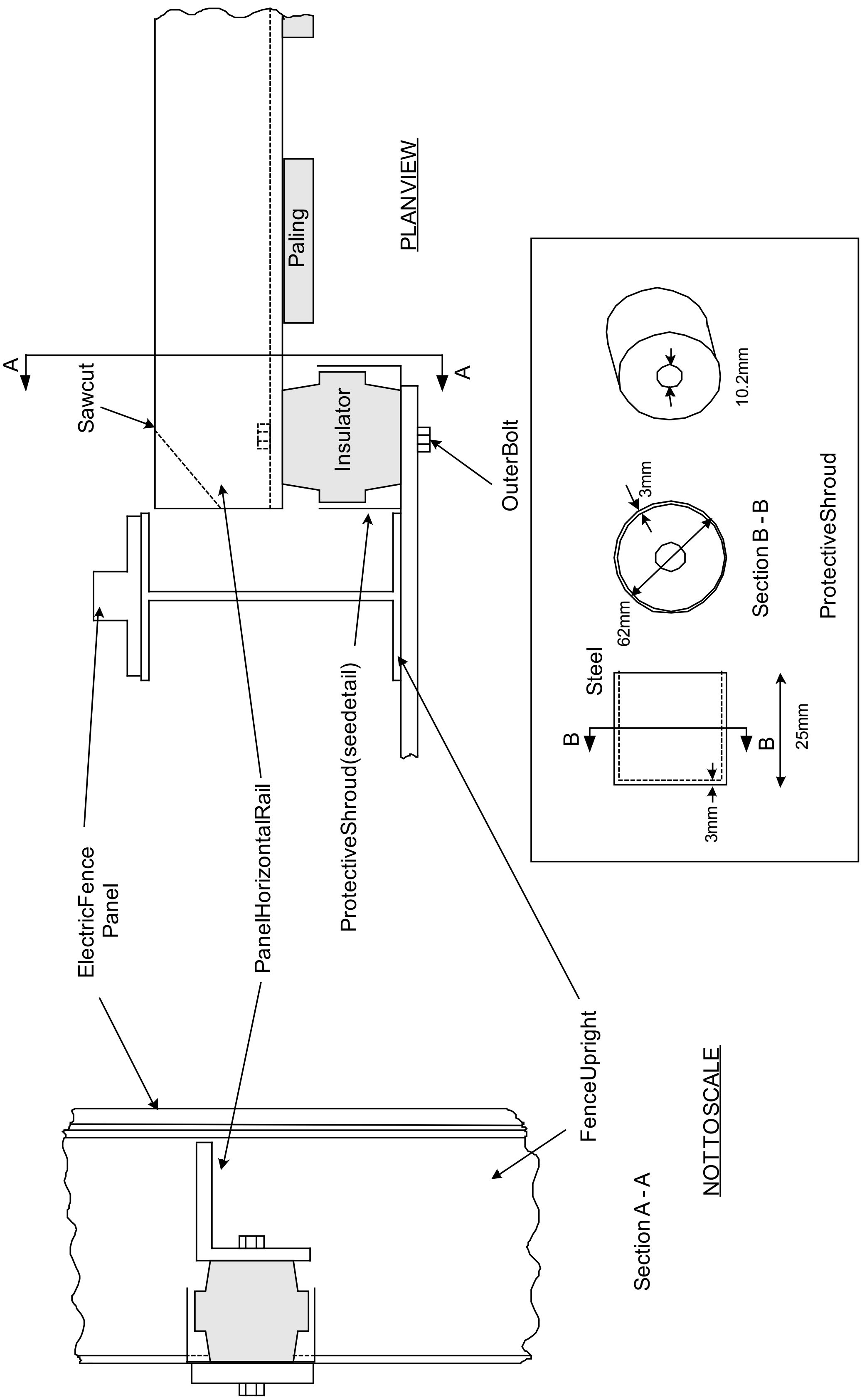


Figure 7 - Example installation of insulating bushes on palisade fence

Figure 8 – Example of earthing connection box with test facility*

*Note – The image shown above is without lid and is meant to simply depict a surface accessible earth test box. This box example is from Omega Red and is suitably dimensioned to allow the testing of earth rod groups without disconnection in accordance with clauses 7.2.5 / 7.2.6.

8 SECTION 5 - SUBSTATION AUXILIARY SUPPLIES

8.1 PURPOSE AND SCOPE

This Section defines National Grid's technical requirements for the application of substation auxiliary equipment. This section describes the functional and performance requirements for both ac and dc auxiliary power supplies for equipment in National Grid substations.

8.2 GENERAL REQUIREMENTS

Informative: The operational security of National Grid substations and the availability of the high voltage plant and secondary equipment within the substation is dependent upon reliable and secure auxiliary supplies.

8.2.1 Manufacture

Manufacturing facilities shall be certified by a recognised accreditation organisation to BS EN ISO 9001.

Manufacturers shall preferably have in place or be working towards installation of management systems compatible with the international environmental management system standard ISO 14001.

8.2.2 Equipment

In order to provide as safe an environment as is reasonably practicable in National Grid substations the User shall, where appropriate, liase with National Grid and equipment suppliers to ensure current 'best practice' safety standards and / or methodologies are incorporated into equipment design, layout and installation. Consideration should be given, in particular, to 'general' safety issues such as, but not limited to, tripping hazards, sharp edges, equipment identification and ease of access for the performance of routine maintenance, repair or replacement.

No-break supplies for protection, control, measurements, telecommunications and other electronic equipment shall normally be fed from 48 V (dc) and/or 110 V (dc) supplies.

Informative: The preferred choice of supply for light current equipment is 110 V (dc)

Alternating current supplies may be used where a short duration supply interruption is tolerable (typically 0-2 mins arising from the time taken for a supply to change over or for a diesel standby generator to run up to speed). Where a break is not acceptable and the equipment requires a no-break ac supply such as for a computer and monitor then it shall be fed from a dc supplied inverter or a stand-alone uninterruptible power supply (UPS).

Informative: The use of an UPS to power single items of equipment is not desirable and the preferred option is to provide PC's and monitors powered directly from a dc supply.

For safety reasons, the use of 230 V (ac) supplies for control systems should be avoided where reasonably practicable. If ac supplies must be used for general control purposes, a suitable transformer providing 110 V with centre tapped earth is recommended to derive an acceptable control voltage.

8.2.3 Alternating Current Supplies

The LVAC power supply shall be designed to provide a voltage maintained within the limits of 400/230 V + 10%, - 6% and 50 Hz ± 1%.

All components of the LVAC supply should be capable of operating correctly at the levels of harmonics specified in BS EN 50160.

8.2.4 Direct Current Supplies

Both the 48 V and 110 V (dc) supply systems at 400 kV and 275 kV substations shall be provided by two independent dc supply systems.

Interconnection facilities between the independent dc supply systems for each voltage level shall be provided at each substation. Common mode faults shall be minimised wherever possible.

Cross connections of dc supply systems between adjacent dispersed relay rooms, where the relay rooms belong to primary 400/275 kV circuits carried on the same route, shall be arranged to avoid common mode faults.

Each independent system shall be designated for a 6 hour standby period with the maximum load of the associated distribution board.

8.3 PERFORMANCE REQUIREMENTS

8.3.1 Alternating Current Supplies

All equipment supplied shall be provided with the following degrees of protection against ingress of objects and moisture, as specified in BS EN 60529.

Outdoor Equipment: The level of protection during normal operation shall be IP54. With access doors open, without the use of tools, the level of protection of live electrical conductors shall be IP20.

Indoor Equipment: The level of protection during normal operation shall be IP31. With access doors open, without the use of tools, for the level of protection of live electrical conductors shall be IP20.

8.3.2 Direct Current Supplies

Direct current systems shall provide no-break supplies at all times up to the end of the specified standby period.

The power supply systems and cabling shall be sized to ensure that the battery is capable of supplying the load requirements at the end of the 6-hour standby period.

At the end of the 6-hour standby period the voltage measured at the distribution board , with an ambient temperature of 5ºC, shall not be less than 46 V in the case of 48 V nominal systems, 102 V in the case of centralised 110 V systems and 93 V for dispersed 110 V systems.

The 110 V battery shall be capable of supplying the maximum tripping load at the end of the 6 hour standby period. This is defined as the tripping of all the required plant associated with that battery for a primary busbar fault.

The battery/charger system shall at all times maintain the voltage at the distribution board(s) within the following levels (taking into account the permissible statutory variance in alternating current supply voltage at the charger):	Normal	Max.	Min.[1]	Min.[2]
Voltage Envelope for 110 V nominal system[3]	125	137.5	102	93
Voltage Envelope for 48 V nominal system	54	60	46	--

1 For centralised distribution boards

2 For distribution boards in dispersed relay rooms

3 For smaller capacity batteries where 6 V or 12 V monoblocs are provided eg 100 Ah or less normal and nominal voltages are 122.6 V and 108 V respectively.

8.4 REFERENCES

This section makes reference or should be read in conjunction with the following documents:

BS EN 50160 Voltage Characteristics of Electricity Supplied by Public Distribution Systems

9 SECTION 6 - ANCILLARY LIGHT CURRENT EQUIPMENT

9.1 PURPOSE AND SCOPE

This Section describes the overall functional and performance requirements for ancillary light current equipment to be used with light current systems provided for protection, control, monitoring and metering. It covers the requirements for:

a) Light current equipment, auxiliary switches and indicators,

b) Cubicles, boxes, and kiosks,

c) Marshalling,

d) Earthing,

e) Marking and labelling,

f) Components and accessories,

g) Interposing relays,

h) Testing Facilities.

9.2 GENERAL REQUIREMENTS

Ancillary light current equipment in substations shall conform to the relevant International or British Standards for its application and be fit for purpose.

The constructional requirements and tests for controlgear assemblies shall comply with BS EN 60439-1.

Electrical installations shall comply with the appropriate requirements of BS 7671.

The use of auxiliary energising voltages above 110 V (ac) shall be avoided, the preferred voltage for suchac circuits is 110 V, the use of centre tap earthed 110 V is preferred. Supplies for test purposes above 110 V (ac) shall be labelled as such. Heating and lighting circuits in cubicles and kiosks shall comply with the requirements of BS 7671. Electrical hazard labels shall be fitted to all plug and sockets connected to systems with nominal voltages above 125 V (ac) or(dc) warning labels shall be in accordance with BS 5378.

All equipment shall be marked to identify the Manufacturer and the Manufacturer's reference.

Equipment with elements that can be withdrawn shall have marking on both the fixed and removable portions, to assist the correct replacement of equipment.

Covers shall be easily removed and replaced without risk of damage to, or inadvertent operation of, equipment. They shall be constructed and fastened so that they cannot be replaced incorrectly, or damaged or distorted by their fastenings.

All materials shall be non-ignitable or resistant to flame propagation (tested in accordance with BS EN 60695).

All materials shall be dimensionally stable i.e. shall be distortion-free to the extent necessary for the correct functioning of the equipment in service.

Protective finishes shall be of such a standard that they shall not require renewal during the life of the equipment in the specified ambient conditions.

All contacts and mechanisms that are not in a dust-proof enclosure shall be protected from dust.

Equipment shall be designed to operate satisfactorily over the range of voltages and frequencies specified in Part 4, Section 1.

The design shall be such that all maintenance operations may be carried out with ease and safety and shall comply with the statutory requirements quoted in Part 4, Section 2.

Equipment that has to be removed from a panel or cubicle for maintenance purposes shall be readily removable without disturbing other equipment or wiring.

9.2.1 Power Supply Isolation

Where fuses, links and their holders are used for power supply isolation they shall comply with the requirements of BS EN 60269 - 1.

Where Miniature Circuit-Breakers (MCBs) are used for power supply isolation purposes they shall either be removable or facilities shall be provided such that they are lockable in the open position. MCBs shall have an auxiliary contact such that operation may be alarmed.

The rating of the fuse or MCB shall be clearly identified.

9.2.2 Switchgear Auxiliary Switches

Auxiliary switches in HV switchgear shall comply with the requirements of BS EN 60694.

9.2.3 Indicators

Indicators of plant-state must be clearly visible from the point of operation. Indicator colours shall be: Closed - Busbar colour (see below)

a) Open - White (steady)

b) DBI - White (steady)

c) Running White - (flashing)

(Note: The colours specified for the *Open*, *DBI* and *Running* states are not prescriptive but shall be varied only in agreement with National Grid).

Colour Scheme to Distinguish Busbar Voltage Levels

VOLTAGE (kV)	COLOUR	BS381C: 1988 ref.
400	Blue	166
275	Red	537
132	Black	
66	Brown	414
33	Green	221
25	Yellow	309
22	Yellow	309
11	Red	537
6.6	Blue	166
6.25	Blue	166
3.3	Violet	796

9.2.4 Indoor Equipment Cubicles

Cubicles shall normally be manufactured, equipped, wired and tested in the manufacturers or contractors works before delivery to site.

Cubicles shall comply with the dimensions stated in IEC 60297 Part 2. The cubicle shall be rigid, free standing and capable of being fixed down. All equipment cubicles, shall have 19" rack mounting arrangements.

On cubicles where equipment is mounted on a swing door, stops to limit the travel of the equipment frame shall be provided. When closed, the equipment door shall be secured against vibration.

The cubicle, by its construction, shall minimise the spread of fire from any cubicle to its neighbour.

Cubicles shall meet rating IP 44 as a minimum requirement as specified in BS EN 60529. Where individual equipment e.g. relays, have an IP rating less than that specified in the appropriate National Grid Technical Requirements, consideration shall be given to increasing the cubicle IP rating to meet the requirement of National Grid's Technical Requirement.

Facilities shall be provided to maintain the air temperature and humidity within the levels detailed in Part 4, Section 1, without condensation. Equipment shall be suitable for operation in its intended environment including the ability to maintain critical functions in the event of the failure of environments control facilities such as air conditioning.

All cubicles shall be provided with locking facilities.

Equipment on panel fronts shall be flush mounted.

All equipment requiring access for test or adjustment shall be not more than 2.0 m above permanent access ways.

9.2.5 Outdoor Kiosks

Outdoor kiosks shall be of rigid construction and suitable for the life of the associated plant without any maintenance. Kiosks shall meet Environmental Class 4 conditions, (see Part 4, Section 1), without any condensation forming and shall meet IP 54 as specified in BS EN 60529.

All equipment, terminals and wiring shall be readily accessible. Doors shall be weatherproof.

An unrestricted view of the instruments without opening the doors shall be provided. Instruments which are required to be read accurately shall not be more than 1.7 m above access ways, and where vibration is to be expected the instruments shall be on resilient mountings.

The cable entry (eg gland plates) shall be at least 450 mm above ground level and shall be vermin proof and shall project above the inside of the kiosk base to prevent water entering the cable.

Kiosks shall be provided with locking facilities.

9.2.6 Termination Boxes

Termination boxes shall be of rigid construction and suitable for the life of the associated plant without any maintenance. Termination boxes shall not collect condensation.

All terminations and connections shall be readily accessible.

Cable entries (eg glands) shall project above the inside of the termination box base to prevent water entering the cable.

For outdoor termination boxes, cable entries shall always be from below.

When vibration is expected, termination boxes shall be fitted on anti-vibration mountings.

Termination boxes for Ambient Class 1, 2 and 3 as detailed in Part 4, Section 1 may be provided with sliding covers. Other types of covers shall be secured with captive fasteners. Alternatively, doors secured as for cubicles may be provided.

Termination boxes for use outdoors shall be suitable for Ambient Class 4 conditions as detailed in Part 4, Section 1, mounted so as to prevent pockets or spaces which can collect water shall meet the requirements of BS EN 60529 with classification IP 54. Indoor termination boxes shall be to IP 44 as specified in BS EN 60529.

Padlocks and locking facilities are required on mechanism and terminal boxes of HV plant for locking-off purposes.

9.2.7 Marshalling

Marshalling cubicles or racks in relay or equipment rooms shall be arranged with external cables entering the cubicle at the bottom and inter-panel connections entering from the top. External cables shall be glanded above the floor of the cubicle or rack and cores shall be terminated on terminal blocks in number order. Inter-panel connections shall be terminated on terminal blocks in number order. All cores on both external cables and inter-panel connections shall be terminated. A jumper field, which shall be installed in the factory whenever possible, shall be used to interconnect the external cables and the inter-panel connections.

9.2.8 Earthing

Cubicles, racks, kiosks, and termination boxes shall be connected to the station earth system by a 25 mm wide by 3 mm thick copper or aluminium bar, or equivalent. Where a copper earth bar is employed, the stud connection to the earth bar shall be phosphor bronze or high tensile brass. Where an aluminium earth bar is employed, the stud shall be of galvanised steel.

A radial type earthing system with a single connection point to the substation earth mat shall provide earthing of equipment within a cubicle. As a minimum a cubicle shall be fitted with an earth terminal or stud as specified below, for kiosks and termination boxes.

Kiosks and termination boxes shall be provided with a 10 mm diameter, low resistivity earth terminal or stud. This termination shall be in an accessible position, clear of obstruction.

Electrical continuity shall be maintained between cubicles and associated termination boxes. If electrical continuity is not inherently provided between the cubicles and associated termination box then a copper earth wire of cross-section not less than 2.5 mm^2 shall interconnect the equipments. Doors, covers, subracks etc shall be similarly interconnected to ensure electrical continuity to earth.

The disconnection of any one piece of equipment from earth shall not disconnect any other equipment.

Where earth connections are made to metal work, paint shall be removed to ensure a good electrical contact, and the connection protected against corrosion.

All current transformer (CT) secondary circuits shall be connected to earth at one point of the circuit only. This connection shall be a secure link and shall be labelled as an earth link. The link shall be of a captive type. All circuit earth connections and links shall be readily accessible in the relay cubicle or associated terminal box.

The secondary circuits of interposing transformers shall not normally be earthed.

A notice warning of dangerous voltage shall be provided adjacent to the CT secondary circuit link.

9.2.9 Marking and Labelling of Equipment

Labels shall be provided for identifying all equipment requiring operation and maintenance.

Additional warning labels shall be supplied where specified.

All labels and inscriptions shall be resistant to wear or deterioration in the ambient conditions prevailing and shall be suitable for the life of the equipment.

Adhesives for instruction labels and identification labels within enclosures shall be tested in accordance with BS EN 28510-2.

All terminals of equipment shall be marked. Wire end terminations shall be identifiable by the use of 'dependent local-end marking' in accordance with IEC 391 Sections 3.4.a.1 and 5.1.2 except for telecommunications equipment where marking may be omitted where the design and arrangement of the equipment is such that marking is unnecessary (e.g. colour coding and wire schedules etc).

Marking and labelling of equipment shall provide a logical and convenient means by which the lifetime management of the equipment can take place.

Where identification labels are affixed to doors or covers, a similar label shall be provided and sited so that it is visible when the door or cover is opened or removed.

Labels shall be consistently sited and not obscured by any other equipment. There must be no ambiguity as to the equipment to which the labelled parts refer.

Circuit labels shall be provided on the front of cubicles and on the back for rear access cubicles.

Each rail/group of terminals shall be identified with an appropriate rail/group reference. Terminals within each rail/group shall be individually sequentially numbered. The labels shall be mounted such that they are not disassociated from the mouldings when access to terminals is required.

9.2.10 Terminal Blocks

Terminal blocks shall be adequately rated for their duty and conform to the appropriate requirements of BS EN 60947-7-1.

Terminal block labels shall be of insulation material.

All terminal blocks shall be demonstrated to provide reliable and secure wiring terminations and shall be suitable for the life of the primary equipment without maintenance.

Terminal blocks in outdoor kiosks or equipment cubicles shall have separate terminals for incoming and outgoing connections, not more than two terminations being permitted on any one terminal excluding any purpose made interconnectors.

Wire ends shall be marked as specified in Section 9.2.9.

All terminal blocks shall by virtue of their design prevent accidental short-circuiting between adjacent terminals.

Terminal covers shall be provided where terminal blocks are used at nominal voltages above 125 V (ac) or (dc). , or where high transient over-voltages may occur, eg current transformer circuits. They shall be to IP20 as specified in BS EN 60529. They shall preferably clip onto the mouldings, with warning labels as necessary where hazardous voltages could be present.

No live metal shall be exposed at the back of terminal blocks.

For screw type terminal blocks associated with CT wiring in panels, the design shall be such that loosening off of the primary captive arrangement e.g. the terminal screw shall not lead to a change in the current carrying capability. Alternatively, the terminal block manufacturer shall demonstrate that by virtue of the design of the terminal block, loosening off of the primary captive arrangement through vibration or other environmental factors, cannot occur.

Test sockets, where provided, preferably shall be suitable for test plugs of 4 mm diameter, but a smaller size may be acceptable where the terminal block dimensions make 4 mm impractical.

9.2.11 Terminations

The application and conditions of use for conductor terminations shall be in accordance with the terminal manufacturers requirements. The design of conductor termination or the means by which a conductor is terminated shall be appropriate to the application, taking into account the lifetime management of the equipment.

Where insulation displacement type terminations are used conductors shall have sufficient excess length to permit a minimum of four re-connections during the life of the equipment.

a) Crimps

Crimps shall meet the requirements of BS 4579 Part 1.

Barrel sizes shall suit the sizes and forms of conductor supplied. Barrels that take a range of conductor sizes are acceptable.

Where conductor insulation support is required (flexible stranded conductor below 0.5 mm^2 and single strand conductor of 1 mm^2 and below), this shall be provided by an extended sleeve over the barrel.

Each crimped termination shall be fitted with one conductor only.

Crimping shall be carried out in accordance with the crimp manufacturers instructions.

b) Heavy Duty Plug and Socket connectors

Plug and socket connectors shall be equipped with a coding facility to avoid incorrect connections being made. The design of connector used shall ensure correct alignment of the pins on connection.

Each plug and socket shall be identified. Where the connector contains current transformer circuits the plug body shall be coloured yellow unless specific design features are provided to prevent inadvertent open circuiting of the current transformer circuit, in the event of the connector being split. The socket body shall carry a warning label "CAUTION CURRENT TRANSFORMER CIRCUITS".

The degree of protection provided on plug and socket connectors for use in protection and control cubicles sited in relays rooms shall be to IP 50 as specified in BS EN 60529. Outdoor types shall be a minimum of IP 54 and shall be suitable for the environment in which they are applied over the life of the associated primary equipment.

Cable strain relief shall be provided at the cable gland, such that the integrity of the plug/socket housing IP rating is not affected.

Male and female electrical contacts for use in protection and control systems shall not be of the stamped metal design.

9.2.12 Small Wiring

The colouring of small wiring shall comply with Table 20.

Function	Colour
Protective Conductor	Green-and-Yellow
Functional Earthing Conductor	Cream
ac power circuit (motor/fan drives, power socket outlets, lighting, etc)	
Single-phase	Brown (L), Blue (N)
Three-phase	Brown (L1), Black (L2), Grey (L3), Blue (N)
ac control circuits and other applications (including VT/CT secondaries)	White*
dc control circuit	White

Table 20 - Small Wiring Colours

*CT secondaries ferruled in red coloured ferrules at termination blocks; VT secondaries ferruled in yellow coloured ferrules at termination blocks.

Current transformer small wiring shall have a cross sectional area of not less than 2.5 mm^2unless specifically agreed with National Grid. For other applications the general wire size shall be 1 mm^2, smaller wire sizes may be acceptable with the agreement of National Grid. Wiring sizes shall always be designed for electrical requirements such as volt drop, current etc, and take into account mechanical integrity.

PVC insulated small wiring shall be in accordance with BS 6231 with general-purpose insulation to BS 6746 suitable for service between -25 0C and +55 0C. For ambient temperatures in excess of +55 0C, other types of heat-resisting compound to BS 6746 shall be used.

All wiring accessories of plastics materials, such as cleats, troughs, conduits, strapping, etc, shall be non-ignitable (tested in accordance with BS EN 60695) or resistant to flame propagation.

9.2.13 Relays

a) General

(i) Reliability Requirements

An adequate standard of reliability is required and will be defined in the individual equipment specification.

Reliability may be demonstrated in one or more of the following ways:

- Where identical equipment is already in use, the supplier may quote in-service failure rates, with adequate certification.
- Where the equipment is an amended version of equipment already in use, the supplier may quote in-service failure rates, as above. In addition the supplier must provide details of design changes and show how these could affect reliability.
- When required, the supplier shall provide a reliability assessment based on agreed component failure rate figures. A component count assessment, such as that described in MIL-HDBK-217F Appendix A, will generally be acceptable. (Normally the appropriate generic failure rate figures for the Ground Fixed environment should be used). Other methods may be supplied in the individual equipment specification.

(ii) Environmental Requirements

The equipment shall be subjected to environmental factors such as electrical interference, supply voltage variations, nuclear radiation, dust, vibration, temperature, and salt mist. Where special equipment enclosures are required to satisfy these requirements, the supplier shall define its Degree of Protection by stating its IP Code as given in BS EN 60529 (IEC 60529).

The following clauses define the conditions which the equipment needs to withstand without either the performance being degraded or the life being shortened.

- Temperature and Humidity
  - Equipment shall operate within its functional specification over the range of the specified atmospheric environmental classes, as detailed in Part 4, Section 1.
  - Where any item of equipment is to be mounted within an enclosure housing other items of equipment, it shall be capable of normal operation at a temperature 15°C higher than the upper temperature limit of the environmental class.
  - The temperature rise above ambient within an enclosure, when the equipment is operating normally, shall not exceed 10 °C.

(iii) Mechanical

- Shock and Vibration
- The Drop and Topple Test (Part 4, Section 16) shall not affect performance life.
- Where specified, equipment shall conform to the requirements of Part 4, Section 16, Vibration Test.
- Where responsible for installation, the contractor shall ensure that harmful levels of vibration do not reach the equipment through mountings and external connections.
- Protection equipment shall conform to the requirements of Part 4, Section 16, shock, bump and seismic tests.

- Self-generated Vibration

  Equipment shall not generate vibration at a level which could be damaging to its performance or that of other equipment or personnel.

(iv) Electrical

The equipment shall meet its specified functional performance under the supply and electrical environmental parameters detailed below.

(v) Supply Parameters

Equipment may operate from a variety of supplies. The supply parameters are defined in Part 4, Section 5.

(vi) Interference Immunity

The interference suffered by a 'victim' equipment is dependent not only on the interference levels to which the equipment itself is directly subject but also the levels existing in the areas through which the cables connected to it pass. This concept is defined in BS EN 50082-1 Section 4 and Figure 1 is based on this definition.

When a plug-in relay is utilised it shall have a device to retain the relay or element in place. It shall not be possible to insert a plug-in relay into its base incorrectly.

The relay shall have an enclosure specification to IP 50 as specified in BS EN60529 and have transparent covers.

It shall not be possible to replace a cover incorrectly.

The contact performance for relays used for local control purposes shall be in accordance with the requirements stated in the Table 21 below, where relevant. However a lower rating may be used where it can be shown that the contacts are suitable for the particular application.

Make and Carry Capacity			
dc (L/R >10 ms)	200 ms	1 s	continuous
	3000 W (with a maxima of 20 A and 300 V)	2000 W (with a maxima of 10 A and 300 V)	1000 W (with a maxima of 4 A and 300V)
Continuous Current Carrying Capacity (contacts already closed)			
dc minimum current	200 ms	1 s	continuous
	35 A	20 A	4 A
Breaking Capacity			
dc inductive (L/R > 40 ms)	30 W (with a maxima of 2 A and 300 V)		
dc resistive	60 W		

Table 21 – Contact Performance Requirements

Interposing relays shall comply with the requirements of IEC 60255-7.

The relay will be required to operate either from a 48 V nominal dc supply as or from a 110 V (dc) supply with voltage envelopes as specified in Part 4, Section 5.

(vii) In/Out Switching Relays for Protection and Auto-Reclose Equipments

The relay shall be of the latched type with an operate and reset coil. The operate coil shall perform the 'Out' function. A contact in series with each coil shall break the coil current during, or at the end of the mechanical travel. Nine further contacts shall be provided. A self resetting indicator on the relay that displays the words 'IN' and/or 'OUT' when applicable and masks the inapplicable word shall be provided.

A hand resetting mechanism shall not be fitted.

b) Control Interposing Relays

The contacts of interposing relays for control purposes shall be suitable for controlling inductive circuits associated with the operating gear of the equipment to be controlled.

48 V (dc) control interposing relays shall be double pole switched.

110 V control interposing relays shall be Class 2 in Table 22 or shall be double-pole switched.

9.2.14 Testing Facilities

Facilities shall be provided to enable all routine maintenance testing to carried out from the front of the equipment.

9.3 PERFORMANCE REQUIREMENTS

9.3.1 Enclosures and Equipment

Enclosures, equipment and ancillary components etc, shall be designed to operate under the appropriate general ambient conditions specified in Part 4, Section 1 – Table 1.

9.3.2 Terminal Blocks

Terminal blocks for use on CT circuits shall have a rated insulation voltage of 1 kV and be tested with a test voltage selected from BS EN 60947-7-1 Table V (3500 V rms). The terminal block shall also meet the requirements of the impulse voltage test in IEC 60255-5 with a test voltage of 5 kV.

Terminal blocks for use in 110 V and 48 V (dc) systems shall have a rated insulation voltage up to 300 V and be tested with a test voltage selected from BS EN 60947-7-1 Table V.

9.3.3 Plug and Socket Type Connectors

The rated insulation and impulse voltage shall be accordance with the requirements for terminal blocks.

9.3.4 Control Interposing Relays

Relays associated with the direct operation of switchgear shall have Class 1 or Class 2 performance as specified in Table 22.

Class	1		2
dc System Nominal Voltage (V)	110	48	110
Relay rated voltage (V)	125	48	125
Normal Working Voltage (V)	125	54	125
Operative Voltage Range (V)	87.5 to 137.5	37.5 to 60	87.5 to 137.5
Energising current at or below which the relay shall not operate (mA)	25	10	50
Capacitance discharge test *	N/A	N/A	10 μF at 150 V
Thermal withstand voltage at 40 ^{o}C ambient (V)	137.5	60	137.5

Table 22 - Control Interposing Relays

9.3.5 48 V dc Control Interposing Relays

The relay shall function correctly with 200 Ω in series with each coil and with a battery voltage of 46 V.

9.3.6 110 V dc Control Interposing Relays

Interposing relays energised at 110 V (dc) shall operate within their declared specification with 100 Ω in series with the operate coil.

9.4 TEST REQUIREMENTS

Equipment offered to meet this specification shall have passed the test requirements laid down in applicable International or British Standards.

9.5 TECHNICAL DATA

The equipment supplier shall provide technical data to support the general, performance and test requirements where required by National Grid to demonstrate compliance with this specification.

9.6 REFERENCES

This Section makes reference to, or should be read in conjunction with, the following documents:-

BS EN 28510-2 Adhesives - Peel Test for a Flexible Bonded to Rigid Test Specimen Assembly. 180 Peel

BS EN 60269-1 Low Voltage Fuses Part 1: General Requirements

BS EN 60439-1 Low-Voltage Switchgear and Controlgear Assemblies - Part 1 Requirements for Type Tested and Partially Type Tested Assemblies

BS EN 60529 Degrees of Protection Provided by Enclosures

BS EN 60694 Common Clauses for High-Voltage Switchgear and Controlgear Standards

BS EN 60695	Fire Hazard Testing for Electrotechnical Products
BS EN 60947-7-1	Terminal Blocks for Copper Conductors
IEC 391	Marking of Insulated Conductors
IEC 60255-5	Electrical Relays - Insulation Tests for Electrical Relays
IEC 60255-7	Test and Measurement Procedures for Electromechanical All-or-Nothing Relays
IEC 60297	Dimensions of Mechanical Structures of the 482.6 mm Series
BS196	Plugs, Socket-Outlets Cable-Couplers and Appliance-Couplers
BS 4579 Part 1	Compression Joints on Copper Conductors
BS 5378	Safety Signs and Colours
BS 6121	Mechanical Cable Glands
BS 6231	PVC-Insulated Cables for Switchgear and Controlgear Wiring
BS 6746	Specification for PVC Insulation and Sheath of Electric Cables
BS 7671	Requirements for Electrical Installations

10 SECTION 7 - SUBSTATION INTERLOCKING SCHEMES

10.1 PURPOSE AND SCOPE

This document defines the technical requirements of interlocking schemes for National Grid equipment and for Users equipment directly connected to The GB Transmission System.

This functional Specification is applicable to interlocking for air (AIS) and gas (GIS) insulated switchgear at substations connected to the GB Transmission System with equipment rated at 145, 300 or 420 kV.

10.2 GENERAL REQUIREMENTS

10.2.1 Common Requirements

So that operators do not compromise the integrity of the GB Transmission System by incorrect or inadvertent operation of equipment.substations shall be provided with a full interlocking scheme to ensure that all disconnectors, fixed earthing switches (or other interlocked earthing devices) and where required circuit-breakers, are operated in the correct sequence.

In substations where National Grid is a joint occupier and/or has operational responsibility for switchgear then the interlocking shall also be designed with consideration of personnel safety.

10.2.2 Interlocking schemes shall cover the following conditions:-

a) Interlocking between circuit breakers and disconnectors to ensure disconnectors do not make or break load currents.

b) Interlocking between disconnectors and earthing switches to ensure that earthing switches cannot be closed on to a locally energised circuit and cannot be energised, when closed, by operation of disconnectors.

c) Interlocking between disconnectors and adjacent earthing switches to permit operation of the disconnector when earthing switches are closed on both sides of the disconnector. Such interlocking is not required for equipment rated at 145 kV and below.

d) To ensure correct sequence of on load busbar transfer switching operations at multiple busbar substations.

e) To ensure that a bus-coupler or bus-section circuit breaker is only closed with its associated disconnectors both open or both closed.

f) For equipment at sites where National Grid is the Occupier, to restrict access to areas of the substation where safety clearances may be infringed unless appropriate safety measures, such as isolation and earthing, have been taken.

The interlocking of switching sequences involving only power operated switchgear shall be by electrical means. The correct interlocking status shall be confirmed automatically on initiation of an operation from any control position or from auto-switching or sequential-isolation equipment.

The interlocking of switching sequences involving manually operated switchgear may be by electrical or mechanical means. The interlocking shall be designed such that the correct interlocking status must be confirmed immediately before an operation.

Interlocking systems shall, where reasonably practicable, be fail-safe. They shall not be defeated without the use of tools, clip leads etc or a purpose designed override facility.

Interlock override facilities shall be lockable with a unique lock or shall be lockable by means of a safety padlock.

Partial interlocking of earthing switches at circuit-entries to the substation is acceptable where it is not reasonably practicable to extend the interlocking to the remote end disconnectors. Any partially interlocked earthing switch shall be provided with a warning label stating 'WARNING, THIS EARTHING SWITCH IS NOT FULLY INTERLOCKED'.

Interlocking shall be effective for switching and operating sequences when they are being followed in either direction (for example; if an earthing switch must be closed before an access gate can be opened then the gate must be secured closed before the earthing switch can be opened).

Interlocking schemes shall, where reasonably practicable, provide the maximum operational flexibility and shall not unnecessarily impose fixed operating sequences.

Where an interlocking scheme is being supplied for an extension to an existing substation at the same operating voltage then, unless otherwise agreed by National Grid, the interlocking philosophy shall match that existing.

Interlocking for a substation extension shall be fully interfaced with the existing interlocking scheme to achieve the functional requirements specified in this document.

10.2.3 Mechanical Interlocking

Mechanical interlocking systems shall be designed to provide a level of security and reliability comparable with equipment specified in 10.2.4.

10.2.4 Mechanical interlocking shall be by key operated systems.

Interlock keys shall be of a non-masterable design (ie no master key can be supplied or manufactured). Differs shall not be repeated on the same substation site.

Note: Differ is the term for the difference in a key that prevents it being interchangeable with another.

Interlock keys shall be engraved with an identifying reference which shall be unique to that substation site. The identifier shall, where appropriate, include the system number of the switching device where the key is located during normal operation. Key locations shall be marked with the identifier of the required key.

Where key exchange boxes are provided they shall be located in convenient positions with regard to normal substation operating sequences.

Where mechanical key interlocking is fitted to disconnector and earthing switch mechanisms the requirements specified in Part 4, Section 10 shall apply.

10.2.5 Electrical Interlocking

A facility shall be provided to allow the interlock system of each disconnector or earthing switch to be defeated without disturbing wiring. The facility shall meet the requirements of clause 10.2.2.

Note: This may take the form of a self-resetting switch or push-button to bypass electrical circuits.

Disconnector and earthing switch mechanisms which form part of electrical interlocking schemes shall meet the requirements of Part 4, Section 10.

10.3 Performance Requirements

Mechanical and hard-wired electrical interlocking schemes shall operate satisfactorily under the full range of environmental conditions specified for the associated primary equipment.

11 SECTION 8 – SYNCRONISING

11.1 SCOPE

This Section details the functional, performance and interface requirements for synchronising associated with the qualification of circuit breaker closure on the GB Transmission System. It is also applicable to those associated circuit breakers not owned by National Grid but where such qualification is necessary in order to ensure the safety of personnel, plant and equipment

It defines the operations to be undertaken by the synchronising equipment in undertaking either the automatic or manual closure of a circuit breaker or switch with synchronising. This Section is applicable to the interfacing to all synchronising facilities for control actions undertaken from either the Remote or Substation control points.

11.2 DEFINITIONS

Informative: When voltages are present on both sides of an open circuit breaker it is necessary to ensure that these voltages are reasonably in synchronism before closure of the circuit breaker. Two possible conditions apply:

a) More usually, the voltage vectors are static in relation to each other with a fixed phase angle between them and;

b) Rare occasions when the voltage vectors are at different frequencies because the system has become split.

In addition to the two synchronising conditions above, one or both of the voltages may be unavailable in which case the circuit breaker must be closed to energise a dead line, dead busbar or to close a circuit breaker in a dead system.

11.2.1 Check Synchronising

Check Synchronising is the term which has historically been used by National Grid to check that the voltage vectors across an open circuit breaker are within preset limits of magnitude, phase angle and practically zero slip. This condition is the most common when closing circuit breakers with voltages on either side.

11.2.2 DAR

Delayed Automatic Reclose as applied by National Grid to feeder circuits usually comprising or mainly comprising overhead line whereby, following the operation of a main protection and subsequent trip of a circuit, the circuit is automatically switched back into service after a minimum period of 10 seconds. The first circuit breaker to close energises the feeder by performing a Dead Line Charge (DLC). The second circuit breaker to close requires that the voltages across its open contacts are reasonably in synchronism. DAR is also applied to certain transformer LV circuit breakers when the transformer is banked on its HV side with a feeder that has DAR.

11.2.3 Incoming Voltage

The incoming voltage is the voltage on the opposite side of an open circuit breaker from the running voltage. At busbar-type substations the incoming voltage is on the feeder or transformer side of the circuit breaker. In those cases where the distinction between incoming and running voltages is not clear, for example bus section circuit breakers, the voltages may be identified as ‘A’ and ‘B’ voltages where the ‘A’ voltage is normally associated with the main busbar or the lowest numbered busbar or mesh corner.

11.2.4 Phase Angle

Phase angle is the angular difference in degrees between the incoming voltage vector and the running voltage vector across the open contacts of a circuit breaker.

11.2.5 Power System Synchronising

Power system synchronising, or simply System Synchronising, is the term which has historically been used by National Grid to cover the situation in paragraph 11.2 b) above. This is when a circuit breaker is being closed to re-parallel a part of the transmission system that has become separated from the main part of the transmission system i.e. islanded. It is necessary to check that the voltage vectors across this open circuit breaker are within acceptable limits of magnitude, phase angle and slip when the two parts of the transmission system are running asynchronously.

11.2.6 Running Voltage

The running voltage is the voltage on the substation side of an open circuit breaker across which synchronism is to be checked.

11.2.7 Slip

Slip is the frequency difference between the two voltage vectors across the contacts of an open circuit breaker and is measured in Hertz (Hz).

11.3 GENERAL REQUIREMENTS

The system shall be arranged such that synchronising under manual control can only take place on one circuit at a time on each voltage level at any one substation.

11.3.1 Synchronising Scheme and Voltage Selection Facilities

The voltage supplies for synchronising on systems operating at 400 kV, 275 kV and 132 kV shall be derived from a single phase-to-earth (usually yellow phase) primary voltage by means of single phase VT.

The synchronising scheme shall be able to cater for substation extensions

Two basic schemes of synchronising are required to cover the substation layouts used by National Grid:

a) Busbar Stations - The standard scheme shall be based on the use of either busbar VTs or individual circuit VTs with a suitable voltage selection scheme for selection of the appropriate supplies for synchronising purposes.

   Informative: Where busbar VTs are not provided a simple priority scheme is preferred so that circuit VT supplies are not connected in parallel and the busbar running voltage is derived from only one VT from the circuit having the highest priority.

b) Mesh Type Stations - The standard scheme shall be based on a ring system with a suitable voltage selection scheme for selection of the appropriate supplies for synchronising purposes.

   The synchronising equipment shall be capable of selecting the appropriate running voltage for synchronising by checking the position of disconnectors and circuit breakers.

11.3.2 Voltage Parameters and Burdens

The ac measuring system shall be designed to be earthed and use interposing voltage transformers (IVT) supplied from the 63.5 V secondary side of voltage transformers connected to the primary plant.

11.3.3 Interposing Voltage Transformers

The rating shall be designed to suit the requirements of the scheme.

The synchronising facilities shall incorporate suitable means to interface the voltage outputs from main VTs, providing adequate isolation and having an adjustable means of ratio error correction.

11.3.4 Synchronising Function

The equipment is required to operate for check synchronising, system synchronising and dead line/dead bar conditions and shall automatically select the appropriate method of closure dependant on settings and from measurement of the incoming and running voltages.

The equipment shall automatically select check or system synchronise, from measurement of the relative frequency between the incoming and running voltages.

The normal or default mode shall be as a check synchroniser. On initiation, the equipment shall operate in the check synchronise mode.

Upon receipt of a close control input and subsequent initiation of the synchronising function an output shall be provided to indicate that synchronising is in progress. The output shall remain active until either the Circuit Breaker has closed or the synchronising sequence has timed out.

A facility shall be provided to inhibit the operation of the synchronising function for the failure of either incoming or running VT supplies. This may be achieved by the use of either:

a) Appropriate auxiliary switch contacts from each VT MCB

b) A suitable algorithm within the equipment

c) A combination of (a) and (b) above

Circuit breaker closure shall be prevented and operation inhibited for either an under-voltage or differential voltage condition outside the settings chosen within the range stated in Table 24.

Receipt of the close command shall initiate the Synchronising timer. This timer defines the maximum duration for attempting to close the circuit breaker and the sequence shall abort and reset if the circuit breaker has failed to close at the end of this period.

Upon receipt of the close control and subsequent circuit breaker close indication the Synchronising timer shall be reset and the synchronising sequence cleared down.

Outputs shall be initiated without any appreciable delay and any delay shall be constant and quantified.

If the dc supplies or incoming and running voltages are removed the synchronising close output shall be prohibited except when DLLB, LLDB and DLDB modes have been pre-selected and the conditions have been detected.

11.3.5 Energising Check

The energising check facility shall be selectable and shall be configurable for all combinations of the following:

a) Dead line live bus (DLLB)

b) Dead bus live line (DBLL)

c) Dead bus dead line (DBDL)

The voltage levels, which define both live and dead conditions, shall be configurable separately and within the ranges shown in Table 24.

11.3.6 Check Synchronising

Pre-set selectable values of phase angle shall be provided in the range shown in Table 24.

Whilst in check synchronising mode the equipment shall prevent closure in the event of slip being in excess of a pre selected value in the range defined in Table 24. This shall be irrespective of the phase angle setting.

If during the period when the function is verifying the system phase angle the voltage vectors move out of the phase angle setting and system synchronising conditions are not detected, circuit breaker closure shall be prevented.

11.3.7 System Synchronising

The System Synchronising mode of operation shall commence automatically upon detection of a close control and detection of slip within pre-set selectable values.

The initiation of the system synchronising function shall result in the following actions:

a) Check Synchronising closure shall be inhibited whilst asynchronous conditions are detected.

b) The System Synchronising mode of the device is primed to permit closure of the circuit breaker to proceed within the limits specified for the System Synchronising function.

c) An output is initiated to provide external indications that the mode of closure has changed. The output shall remain active until either; the Circuit Breaker has closed, asynchronous conditions are no longer detected or the synchronising sequence has timed out.

When the system synchronising mode is activated the close output shall be initiated with the minimum delay, provided the following requirements are met:

d) The phase angle between the incoming and running voltages is decreasing and measures less than a pre-set selectable value in the range defined in Table 24.

e) The slip frequency is within the pre-selected values defined in Table 24.

f) The under-voltage or differential check facilities have not operated.

The circuit breaker operating time and measured slip should be taken into account when operating in System Synchronising mode to ensure that circuit breaker closure occurs within the phase angle window of closure.

Informative: The preferred method for System Synchronising closure shall include compensation for the measured slip and the circuit breaker closing time to ensure that when the closing command is issued the breaker closes at zero degrees.

If during a system synchronising sequence the system conditions change such that the criteria for check synchronising closure are met the equipment shall be capable of reverting to check synchronising mode of operation and attempt closure of the Circuit Breaker under these conditions. This feature shall be selectable and included in the setting sheet.

11.4 FUNCTIONAL INTERFACES

Informative: The functional interfaces for the Synchronising function are depicted in Figure 9.

The Synchronising function shall provide the functional interfaces as detailed in Figure 9. The User bay(s) synchronising facility shall meet the same design and functional requirement as National Grid's site synchronising scheme that it interfaces with Figure 9:

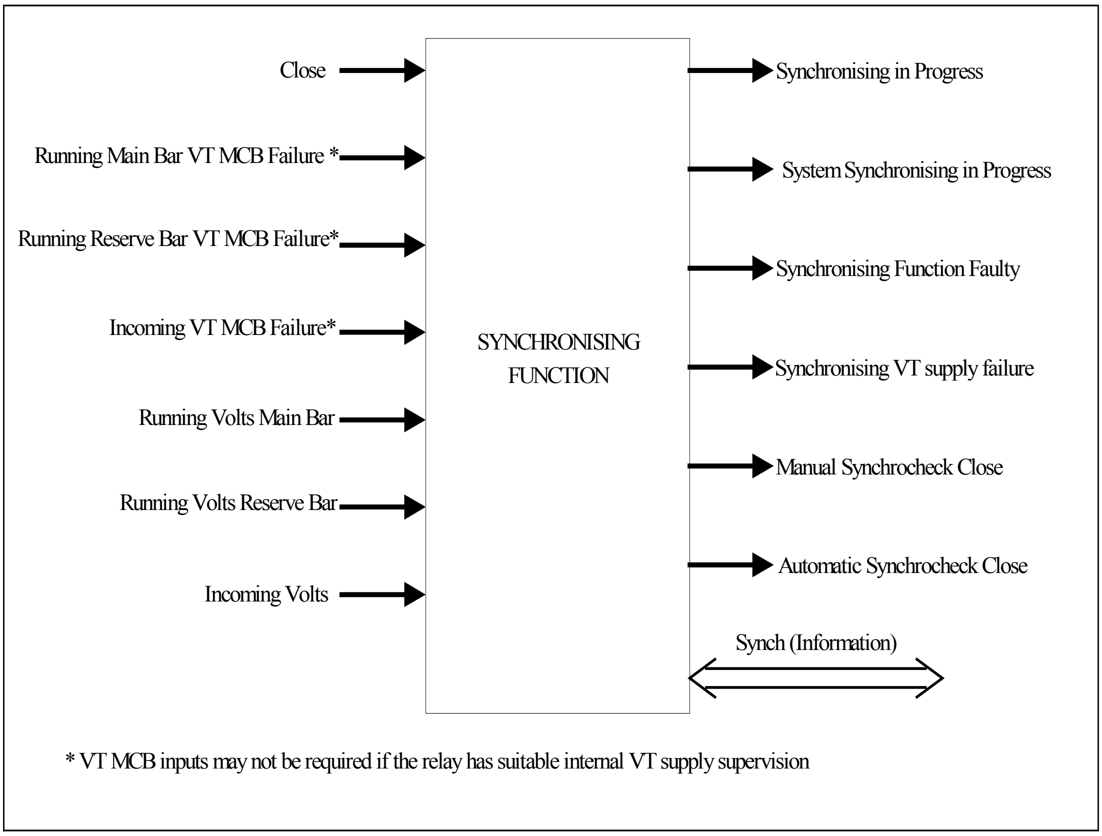


Figure 9 - Synchronising Functional Interfaces

Interface	Interface Function	Type of Interface
Close Control	This input shall accept a control output signal initiated at the control point and shall result in the closure of the selected power system circuit breaker via the check synchronising, system synchronising or Dead line/Dead bus modes.	Single Point Digital Input:
Manual Synchrocheck Close	A Manual Synchrocheck close control output shall be initiated when all criteria are met for a manual synchronising close.	Double Pole Control Output
Automatic Synchrocheck Close	An Automatic Synchrocheck close control output shall be initiated as part of an automatic close sequence such as Delayed Automatic Reclosure when all criteria are met.	Double Pole Control Output
Synchronising in Progress Indication	This indication shall be active for transmission to the control point when the synchronising function has been activated and shall remain on until the conditions in 11.3.4 paragraph 4 are met.	Single Point Digital Output
System Synchronising Indication	This indication shall be active for transmission to the control point when the synchronising function has been activated and has detected asynchronous system synchronising conditions and shall remain on until any of the conditions in 11.3.7 (c)met.	Single Point Digital Output
Synchronising VT Failure	This indication shall be active for transmission to the control point when a failure of a synchronising VT supply is detected.	Single Point Digital Output
Synchronising Function Faulty	This alarm shall be active for any detectable fault within the synchronising function.	Single Point Digital Output
Synchronising Information Port	The information available on this port shall include: Settings, Alarm and Indication Logs, Firmware/Software Revision and circuit Ids.	Informati on Port

Table 23 - Details each interface's ID, function and type.

11.5 SETTINGS

The Synchronising facility function settings as detailed in Table 24 shall be provided as a set of settings that the user can change.

Setting	Minimum Setting Range	Maximum Setting Resolution
VT Ratio Error Correction	1:1 - 5000:1	10
Under-voltage Check Facility	80% – 90% of Rated Voltage	2.5%
Voltage Difference	10% – 50% of Rated Voltage	5%

Setting	Minimum Setting Range	Maximum Setting Resolution
Check Synchronising Phase Angle	20º - 90º	5º
Check Synchronising Slip Speed	0.01 – 0.1Hz	0.01Hz
System Synchronising Phase Angle	10º - 20º (or less)	5º
System Synchronising Slip Speed	0.02Hz - 0.3Hz	0.01Hz
Energising Check dead volts	10% – 50% of Rated Voltage	5%
Energising Check live volts	60% – 100% of Rated Voltage	5%
Synchronising Sequence Timer	0 – 15 minutes	1 minute

Table 24 - Synchronising Settings

11.6 PERFORMANCE REQUIREMENTS

11.6.1 Voltage Transformers and Burdens

The burden of the synchronising system on the primary voltage transformers shall not normally exceed 5 VA.

Selection of the IVT voltage tap shall ensure that with nominal system voltage, the voltage at the synchronising equipment from any switchgear circuit is 63.5 V ±1%.

The IVT shall withstand 2 kV ac (rms) between windings and between windings and frame and earth screen for 1 minute.

11.6.2 Accuracy

The synchronising equipment shall maintain the accuracy given below over the frequency range given in Part 4, Section 1 and the dc power supplies range given in Part 4, Section 5 and an input voltage range of 80% to 120% of nominal.

The accuracy of the under-voltage and differential voltage check facilities shall be not greater than ± 5% of the set value under all specified environmental and power supply variations.

Phase angle accuracy at 50 Hz shall be ± 1º at each setting. The alteration of phase angle settings on site shall not require any re-calibration.

The total variation from actual setting shall not exceed 2º under the worst combination of voltage, frequency and auxiliary supply deviation.

If power supply conditions outside those specified should be encountered then, either accuracy shall be maintained by the synchronising equipment, or circuit breaker closure shall be inhibited.

Circuit- breaker closure should not be initiated with a phase angle greater than the nominal setting angle plus tolerance stated above.

The interposing voltage transformers shall meet the accuracy requirements of Class B of BS 3941.

Timers shall have an accuracy of ± 2% or better.

The slip measurement accuracy shall be 0.01 Hz or better.

12 SECTION 9 - CIRCUIT BREAKERS

12.1 PURPOSE AND SCOPE

National Grid's specification of circuit breakers is primarily by reference to IEC 62271-100 and associated documents. This document defines the required enabling parameters and additional technical requirements for circuit breakers connected to National Grid's System and rated at 145 kV, 300kV and 420 kV

This Document defines the performance requirements and testing for circuit breakers connected to National Grid's system. It supports the more general conditions defined in Part 4, Sections 1, 2, 3 and 6.

12.2 GENeRAL REQUIREMENTS

12.2.1 General Requirements for Circuit breakers

All mandatory requirements of IEC 62271-100 and BS EN 60694 shall be met for the specified rating.

The circuit breaker shall satisfactorily complete all initiated close and open operations.

In the event of a failure to latch in the closed position the circuit breaker shall open fully and shall be capable of performing all switching and fault interrupting duties during this opening operation.

In the event of opening immediately following a close operation and a continuous close signal being maintained there shall not be repeated attempts to close the circuit breaker.

All circuit breakers shall be fitted with a robust and reliable indicating drive system capable at all times of giving a clear and unambiguous representation of the position of the main contacts of the device. The indicating system shall be positively driven in both directions.

Informative: National Grid accept the internationally agreed indication I/O in contrasting colours. Alternatively, indicators inscribed CLOSED in white letters on Signal Red (BS 381C Code 537) background and OPEN in white letters on Grass Green (BS 381C Code 218) background are acceptable.

The density of the arc extinguishing and insulating media shall be monitored and discrete low density alarm (or close lockout) and low density lockout levels shall be set. These lockouts shall ensure that operation is prevented if the density is outside its specified design criteria. Provision for local and remote indication of significant reduction in density of arc extinguishing and insulating media shall be provided. This indication shall be at a level in excess of the open (or general) lockout level however it is acceptable for this indication to coincide with a close lockout level. The monitoring system shall be such that any closing operations are only permitted if a subsequent opening operation remains possible. These requirements may be modified where a requirement for forced tripping is identified.

Provision shall be made for low density, close lockout and open lockout levels, as appropriate, to be remotely alarmed.

Provision shall be made for routine diagnostic monitoring, site testing and condition monitoring.

The circuit breaker in its normal operational state (i.e. with all access doors etc closed) shall meet the pollution performance criteria associated with a degree of protection of IP54. All moving parts which are readily accessible during normal operation of the circuit breaker, including from the local operating position, shall have a degree of protection of at least IP2X such that they are adequately guarded to prevent injury.

Where isolation facilities are provided between the main volume of any insulating or arc extinguishing media and the associated monitoring equipment this isolation shall fail to safety and it shall not be possible to put the circuit breaker into service with the monitoring isolated.

12.2.2 General Requirements for Mechanisms and Stored Energy Systems

Circuit breakers shall be arranged for three-pole operation by powered mechanism or mechanisms.

The rated operating sequence in accordance with IEC 62271-100 shall be O - 0.3s - CO - 3 min - CO.

Since, for certain applications, National Grid requires the operating sequence O - 10s - CO - 15s - CO the Supplier shall confirm the mechanical suitability of the mechanism to achieve this requirement with replenishment operations as necessary.

Provision shall be made for local and remote indication that the stored energy system has less than the specified minimum stored energy for a normal operating cycle, close-open (CO). The close lockout shall be initiated. This 'stored energy system incorrect' indication shall not be initiated due to normal operation of the circuit breaker.

Provision shall be made for local and remote indication that the stored energy system has less than the specified minimum stored energy for normal opening. The open lockout or, where required, a forced open operation, shall be initiated. This 'stored energy system incorrect' indication shall not be initiated due to normal operation of the circuit breaker.

Operating system lockouts shall be arranged such that if it is possible to close the circuit breaker normally then opening is not prevented as a result of the energy consumed during the preceding close operation.

In satisfying the above paragraph the maximum tolerance on setting of monitoring devices and an allowance for drift and short time adiabatic change together with either an ambient temperature change of up to 10 °C or the normal loss of stored energy during a two hour period, whichever has the greater effect, shall be taken into account. Where practical the close lockout setting shall be equal to or less than 85 per cent of the rated working pressure.

Where a hydraulic system utilizes a compressed gas for energy storage, the precharge pressure of this gas related to the ambient temperature at the time of precharging shall be sufficient to prevent the initiation of a low gas alarm under normal operating conditions when the ambient temperature falls to the minimum specified in Part 4, Section 1. Where such systems initiate lockouts following loss of the pre-charge they shall also initiate appropriate alarms indicating the conditions.

Changes in ambient temperature of 20 °C shall not initiate more than two operations of any self contained stored energy replenishment systems as numerous operations under such conditions may mask the presence of genuine energy loss.

A replenishment system excessive running time alarm, or equivalent, shall be fitted.

The operating level of safety/relief valves fitted to replenishment systems shall be set with sufficient margin above the system replenishment cessation level to accommodate an ambient temperature rise of 10 °C.

Facilities shall be provided to permit manual slow closing and slow opening of the interrupter assembly and its drive mechanism. These facilities shall enable the state (open or closed) of a circuit breaker to be changed following isolation from the high voltage system. These facilities must be capable of being secured such that they can only be used for maintenance purposes.

Means shall be provided to allow the stored energy system to be charged and discharged when the circuit breaker is either closed or open without causing operation of, or damage to, the circuit breaker. This requirement is waived for springs connected directly to moving contacts, such as opening springs.

Loss of stored energy from the mechanism shall not cause the primary contacts to part. See 12.2.3 paragraph 15.

Stored energy systems shall not be released due to vibration caused by normal operation or other normal service phenomena.

Mechanisms incorporating springs for energy storage shall be provided with an unambiguous indication of spring state (charged or discharged). National Grid does not accept the internationally agreed graphical symbols since they are open to mis-interpretation. “Spring charged” and “spring discharged” inscriptions are preferred either as a primary indication or as clarification of other indications.

12.2.3 General Requirements for Control Schemes and Circuitry

Where individual poles have separate operating releases the control scheme shall be such that the requirements of 12.2.3 paragraph 10 are met.

If the opening circuit is initiated the closing circuit shall be rendered inoperative.

Operating mechanisms shall be provided with local, lockable initiation facilities for closing and opening and for selection of local/remote control. These facilities shall be in the immediate vicinity of the circuit breaker.

In the event of a failure to complete a closing operation involving poles having independent drive mechanisms provision shall be made for automatic opening of poles which have closed. Provision for a remote alarm indicating non-simultaneity of poles shall be provided. This requirement shall take account of any intentional non-simultaneity of poles.

Indications associated with the various monitoring requirements of this specification shall be provided adjacent to the circuit breaker. These devices shall be capable of being reset at this location. Provision shall be made for initiation of remote monitoring.

300 kV and 420 kV circuit breakers shall be provided with two opening releases per operating mechanism. The opening releases shall be arranged for supply from independent battery systems and shall have segregated circuits such that failure of one device in a circuit does not prevent opening of the circuit breaker. The logic diagrams in Appendix A illustrate the requirements.

Provision shall be made for opening circuit duplication on 145 kV circuit breakers to enable such circuits to be specified for site specific purposes.

Other Users adopting an approach other than the use of independent battery systems must satisfy the requirements of Part 4, Section 1 with regard to the safety and security of National Grid’s System at the point of direct connection.

If the dc power supply is removed from either opening circuit of a circuit breaker control scheme the closing circuit or mechanism shall be rendered inoperative.

Circuit-breaker opening coils and their associated opening circuits shall be provided with a continuous supervision scheme that is functional regardless of the circuit-breaker positional state (i.e.open or closed). This shall apply to both phase segregated and three phase operated circuit breakers. The system shall be self-monitoring and shall provide an alarm if the supervision system fails. The design of the supervision scheme shall be such that failure does not cause the circuit breaker to operate. As well as the circuit-breaker trip coils the system shall monitor all series connected links, auxiliary switches and other components between the protection trip initiation contacts and the trip coils. It shall be possible to remove a complete tripping circuit from service by use of suitable isolation facilities. Such isolation facilities shall be monitored by the trip circuit supervision scheme and be clearly and concisely labelled.

The alarm output of the supervision scheme shall not operate under normal circuit-breaker operation or transient conditions (to overcome this, a delayed alarm output is acceptable). The scheme shall not alarm for a persistent trip initiation signal with the circuit-breaker open.

The trip circuit supervision installation must satisfy the requirements of Part 4, Section 1 with regard to the safety and security of the GB Transmission System at the point of direct connection.

For circuit breakers with independent pole operating mechanisms it is preferred that a single supervision circuit monitors the whole of each opening circuit or circuits where duplicated. The alarm output shall not operate due to normal circuit breaker operations. The system shall be self-monitoring and failure of a single component shall not cause the circuit breaker to operate. The system shall be supplied as part of the circuit breaker control equipment or be available as separate equipment for mounting on or in another control cubicle.

Isolation facilities shall be provided for circuit breaker opening coils. These shall be labelled appropriately. These facilities shall be such that the open circuit supervision system shall detect isolation of the opening coils. In addition, the isolation facilities shall be such that they can be secured against unauthorised reinstatement, preferably by a lock and removable key system.

Provision shall be made to select the forced opening of a closed circuit breaker in the event of the loss of stored energy to below the limiting conditions of the operating system. Site specific application of such provision shall negate the need of any device required to lock the mechanism closed under such loss of stored energy.

Electrical connectors used within the mechanism cabinet of a circuit breaker shall be suitable for the mechanical duty imposed upon them and their integrity shall not be compromised by operation of the mechanism.

12.2.4 Additional General Requirements for Special Purpose Circuit breakers for Capacitor Bank Switching

The control circuitry of all circuit breakers intended for capacitor bank switching shall be capable of the addition of an approved controlled closing facility to facilitate minimisation of closing transients when energising an earthed star connected capacitor bank.

145kV circuit breakers shall be mechanically suitable for controlled closing with an intentional 1/6th cycle (3.3 ms) delay between poles without compromising their basic performance.

12.2.5 Additional General Requirements for Special Purpose Circuit breakers for Shunt Reactor Switching

The control circuitry of all circuit breakers intended for shunt reactor switching shall be capable of the addition of an approved controlled opening facility to facilitate the minimisation of re-ignition transients.

The circuit breaker shall be mechanically suitable for independent pole controlled opening without compromising its basic performance.

12.3 PERFORMANCE REQUIREMENTS

Electronic equipment shall comply with the relevant requirements of Part 4, Section 16.

The Supplier shall state the density of the gaseous insulating medium at which the circuit breaker can withstand two fully asynchronous power frequency voltages applied to the opposite terminals of the same pole when in the OPEN position. Each voltage shall be equal to the rated phase to earth power frequency voltage.

The Supplier shall also state the density at which the gaseous insulation can withstand 1.5 times the rated phase to earth power frequency voltage between its terminals and earth.

Circuit breakers shall give a no-load sound pressure level of not greater than 90 dB (linear) measured at a distance of 25 metres from the centre line of the circuit breaker in the most disadvantageous direction. In addition, impulse and steady state noise levels shall not exceed the Action Levels specified in the UK Noise at Work Regulations.

When switching capacitive currents within declared rating the circuit breaker shall exhibit a very low probability of re-strike as defined by Class C2 of IEC 62271-100.

The short-circuit ratings specified apply to both three phase and single phase fault conditions including the relevant arc duration considerations.

The maximum short-circuit break time required to comply with Section 12.2 is 50 ms for 420 kV circuit breakers, 60 ms for 300 kV circuit breakers and 70 ms for 145 kV circuit breakers. This break time shall be determined as described in IEC 62271-100 with due regard to the rated voltage of the operating releases as defined in Part 4, Section 3.

The Supplier shall declare the circuit breaker opening and closing times at the maximum, rated and minimum operating voltage of the opening and closing releases.

The maximum Make-Break time shall be 80 ms for 420 kV circuit breaker, 100 ms for 300 kV circuit breakers and 120 ms for 145 kV circuit breakers.

The Supplier shall declare the minimum Make-Break time at rated conditions and shall demonstrate the ability of the circuit breaker to perform all switching and fault interrupting duties under these conditions.

Operating tolerances, including those for simultaneity of poles, shall be as specified in IEC 62271-100 unless separately specified for special purpose applications such as capacitor bank switching, single phase auto-reclose or shunt reactor switching.

12.3.1 Performance Requirements for Special Purpose Circuit breakers for Capacitor Bank Switching

The circuit breaker shall be capable of at least 2000 service operations without maintenance and at least 10,000 mechanical operations prior to major maintenance activities.

The short-circuit current rating in accordance with the requirements of this specification shall be 63 kA at 420 kV, 40 kA at 300kV and 40 kA at 145 kV in order to cater for the possible need for such installations at any point on National Grid’s System.

The circuit breaker shall be capable of its rated capacitor bank switching duty when unaided by the addition of controlled switching facilities.

The circuit breaker shall be capable of operating satisfactorily under abnormal short-circuit conditions which may result from intentional non-simultaneity of the poles.

Circuit breakers with mechanically staggered poles shall close satisfactorily when subjected to fully asymmetric fault current in each phase sequentially at 3.3 ms intervals.

The controlled switching system shall be capable of controlling the closing operations of the circuit breaker such that the point of current initiation coincides with system voltage zero in each phase with a tolerance of +/-1 ms around the target voltage zero. Where this is not reliably achievable, and at National Grid's discretion, a wider tolerance of ± 2 ms may be deemed acceptable provided that exceedance of the ± 1 ms requirement is a rare event and can be demonstrated to occur in less than 2% of cases.

The controlled switching system shall operate consistently and within the tolerances given in the preceding clause under the following conditions and under any combinations of these conditions:

At any temperature within the temperature range -100 to +300 C. Separately the Supplier shall state the deviation in performance when operating at temperatures between -100 and -250 C and between +300 and +400 C.

Between consecutive operations at temperatures differing by not more than 200 C within the rated ambient temperature range.

At any supply voltage within the range of supply voltages given in Part 4, Section 3.

At any operating mechanism and arc extinguishing medium condition between the close lockout condition and the maximum normal operating condition.

12.4 TEST REQUIREMENTS

12.4.1 Control System Test Requirements

Control system testing shall be in accordance with the requirements of Part 4, Section 16.

12.4.2 Type Test Requirements for Circuit breakers

For general application, asymmetrical current short-circuit interruption tests shall be undertaken with a time constant of 45 ms or greater.

145kV circuit breakers shall also be demonstrated to be capable of operation at a dc time constant of 135ms.

Informative: 135ms may be required at bulk supply points and a coincident reduction in RMS current rating e.g. from 40kA to 31.5kA may be acceptable.

Short-circuit testing shall be demonstrated at the minimum operating conditions (lockout) appropriate to the commencement of the duty, i.e. C, O or O-0.3sec-CO. This demonstration shall confirm the interrupting ability, at open lockout conditions, throughout the full range of arc duration related to single phase fault conditions.

Short-circuit testing shall be demonstrated at the minimum (lockout) conditions of arc extinguishing and insulating media

In addition to the transient recovery voltage requirements of IEC 62271-100 the following 30% short-circuit (T30) TRV characteristics shall be met by 145 kV and 300 kV circuit breakers.

Rated Voltage (kV)	Current (kA)	TRV peak, U_c (kV_p)	Time, t_3 (µs)	Time delay, t_d (µs)	First ref= voltage, U_1 (kV_p)	Time, t_1 (µs)	Rate of rise, U_c/t (kV/µs)
145	As T30	285	38	7.6	89	19.5	7.5
300	As T30	415	42	6.0	138	20	10

Proof of ability against the non-mandatory Short Line Fault and Out of Phase requirements of IEC 62271-100 is required.

General purpose circuit breakers shall be tested for overhead line and cable switching duties in accordance with IEC 62271-100. These tests shall demonstrate that the circuit breaker can be categorised as having a very low probability of re-strike (Class C2). The voltage factor during testing shall be 1.4 for overhead line application and 1.0 for cable applications. Cable switching testing may be waived where circuit breakers are separately tested for capacitor bank switching.

Informative: Capacitive current switching tests shall preferably be performed using full pole, direct test methods.

In order to demonstrate compliance with 12.3, paragraph 4 a no-load sound pressure measurement shall be made at a height of 1.2 m above ground level. A pressure transducer shall be used in conjunction with a precision sound level meter which is set to its fastest response and linear scale. This will allow direct determination of the overall sound pressure level. Because of its short duration the noise is to be recorded on tape so as to enable detailed harmonic analysis and a check on the instrument reading to be made. The maximum rms sound pressure levels for each 1/3 octave band is to be determined either by successively playing back the recorded noise through a 1/3 octave band analyser or by use of a real time 1/3 octave analyser.

Since 90 dB measured by the above technique can be achieved with varying frequency spectra the maximum rms sound pressure level in any 1/3 octave band below a frequency of 1 kHz shall not exceed the maximum rms value in any 1/3 octave band above 1 kHz.

12.4.3 Routine Tests

Routine testing shall comply with IEC 62271-100.

The initial units of circuit breaker/controller systems supplied to National Grid for controlled switching applications shall be subjected to a minimum of 100 operations at a variety of operational conditions such that a limited statistical evaluation of expected performance can be made.

12.4.4 Site Commissioning Tests

The Supplier shall provide a schedule of site commissioning tests, broadly in accordance with, and sufficient to show compliance with, IEC 62271-100. The site commissioning programme shall include a complete functional check of the control features.

Site commissioning tests on the first 5 units of a design type produced and installed on National Grid’s System shall conclude with satisfactory demonstration of 50 operations at rated conditions. Condition monitoring shall be used to confirm that the final 10 operations show no deterioration in performance.

Following commissioning, but prior to energisation, all circuit breakers shall be subjected to a series of 25 operations at rated operating conditions.

Circuit breakers intended for switching shunt capacitors and shunt reactors shall be subjected to a series of live switching tests as part of their final commissioning.

12.5 DEFINITIONS

12.5.1 General purpose circuit breaker

A circuit breaker for application or connection to the GB Transmission System operating in a normal system role covered by the requirements of IEC 62271-100. Typically this refers to circuit breakers applied to lines, cables, transformers, bus sections and bus couplers.

12.5.2 Controlled switching

A method whereby the timing of the operation of a circuit breaker is precisely controlled in relation to the power frequency supply. Also known as "point-on-wave" switching.

12.5.3 Controlled switching system

The combination of a circuit breaker, controller (relay) and control scheme which, in combination, achieves controlled switching.

12.6 REFERENCES

12.6.1 International, European and British National Documentation

This Document makes reference to the documents listed below.

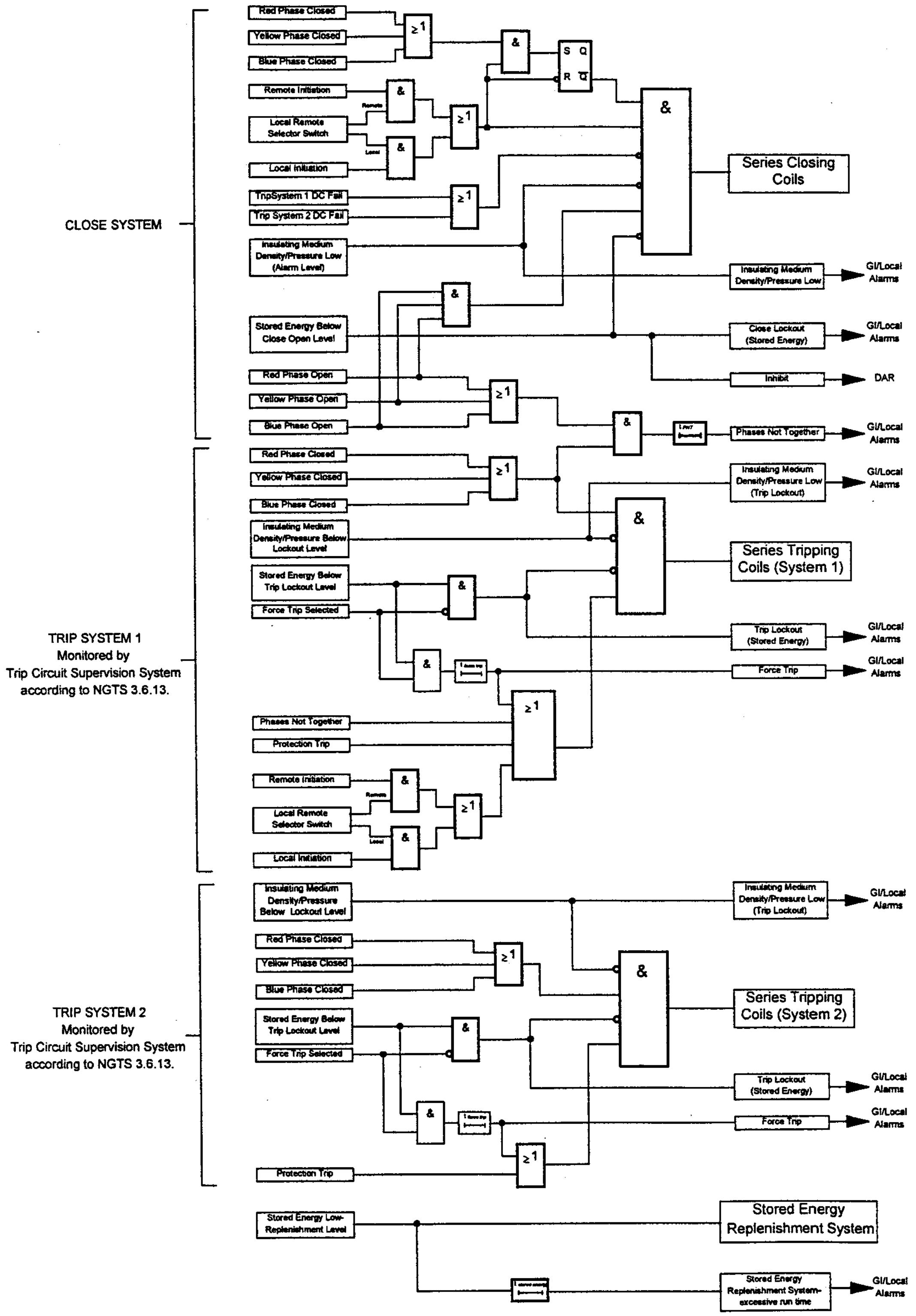
Noise at Work Regulations 1989.

IEC 62271-100	High-voltage Alternating Current Circuit breakers
BS EN 60694	Common Clauses for High-voltage Switchgear and Controlgear Standards.
IEC 61233	High voltage alternating current circuit breakers - inductive current switching.
BS 381C	Specification for Colours for Identification, Coding and Special Purposes.

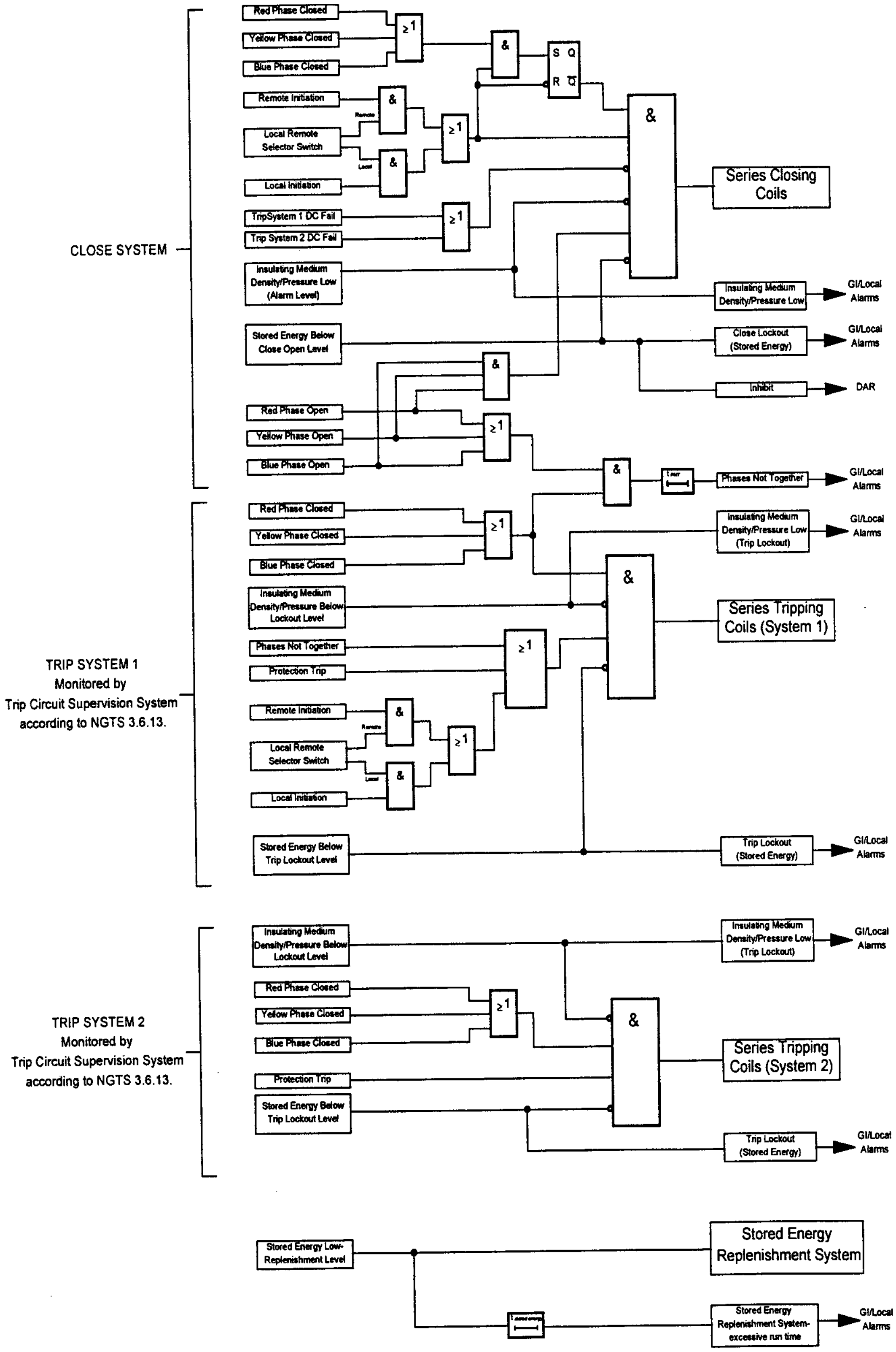
12.7 GUIDANCE NOTES - OPENING AND CLOSING RELEASE LOGIC DIAGRAMS

The following logic diagrams detail the circuit segregation requirements applicable for the double opening release and series closing control schemes for circuit breakers and switches.

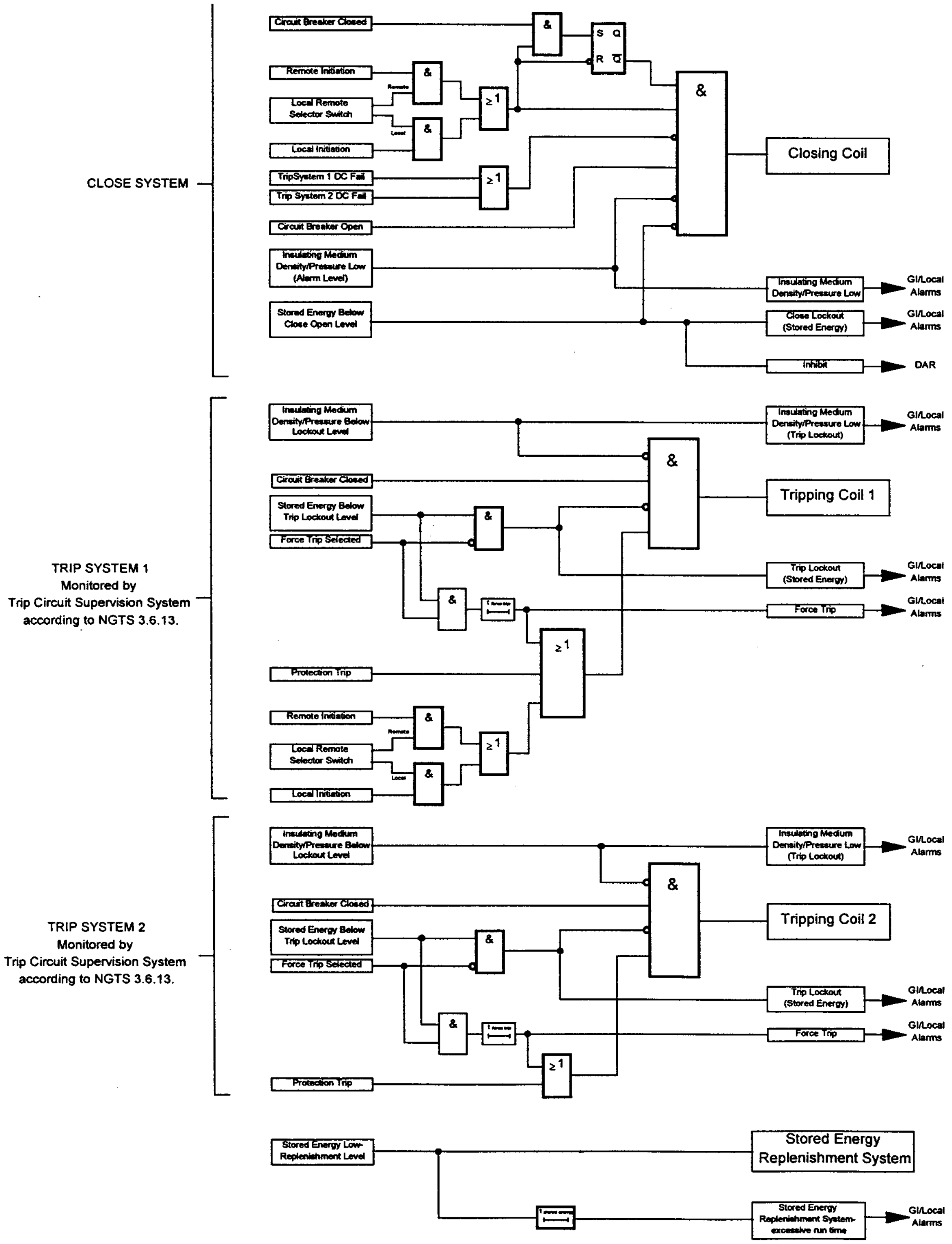
Attachment 1	Segregated phases with forced open facility
Attachment 2	Segregated phases with open lockout
Attachment 3	Three phase mechanism with forced open facility
Attachment 4	Three phase mechanism with open lockout



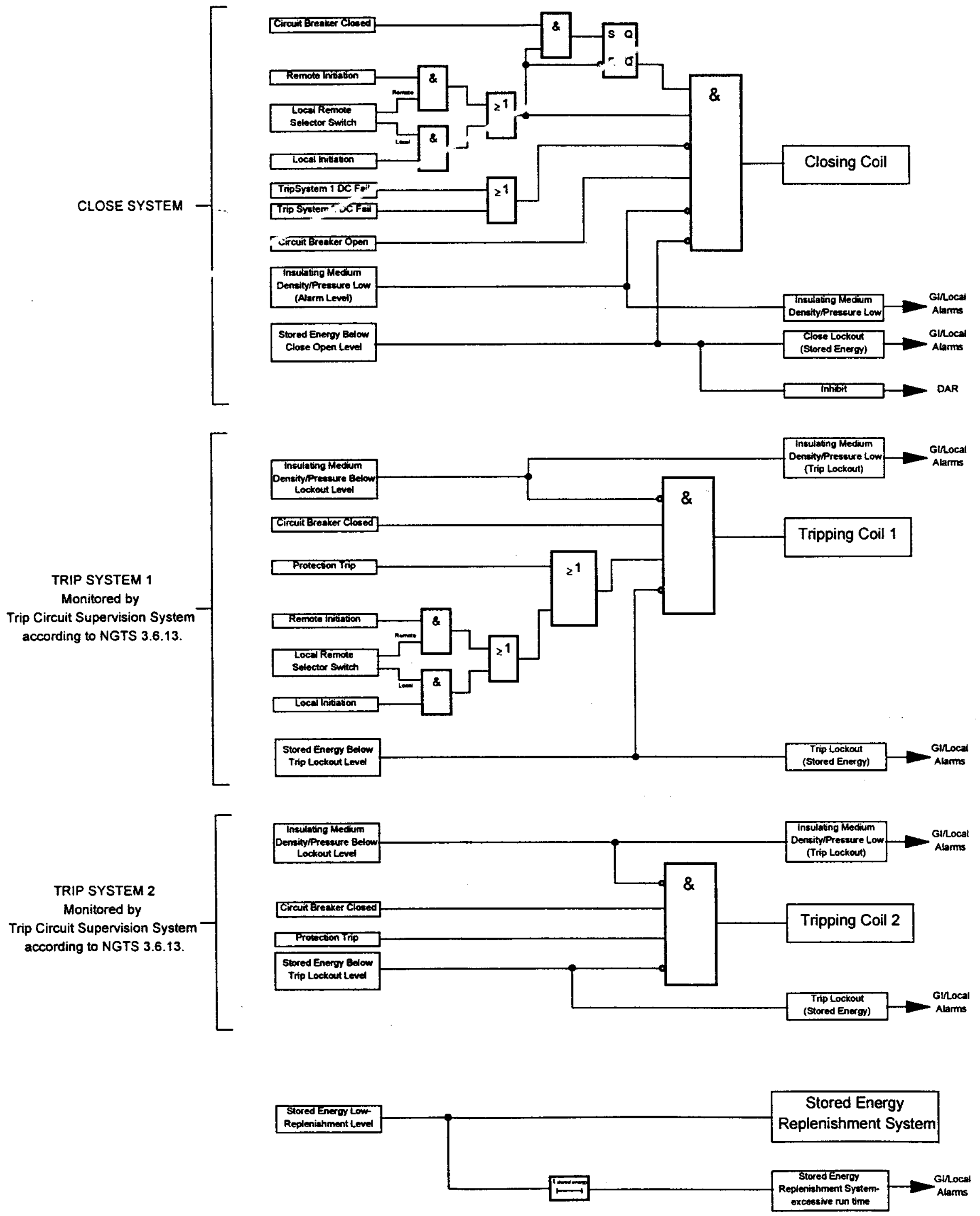
Attachment 1 - Segregated Phases with Force Trip Facility



Attachment 2 - Segregated Phases with Trip Lockout



Attachment 3 - Three Phase Mechanism with Force Trip Facility



Attachment 4 - Three Phase Mechanism with Trip Lockout

13 SECTION 10 - DISCONNECTORS AND EARTHING SWITCHES

13.1 PURPOSE AND SCOPE

This Section for disconnectors and earth switches is by reference to IEC 62271-102, BS EN 60694 and associated documents. This document defines the required enabling parameters and additional technical requirements for disconnectors and earth switches for use on, and directly connected to, the GB Transmission System, rated from 145 kV to 420 kV.

This document defines the functional performance requirements for disconnectors and earth switches connected to the GB Transmission System. It supports the more general conditions defined in Part 4, Sections 1 and Section 3.

13.2 RATINGS AND PERFORMANCE REQUIREMENTS

In addition to the general ratings and performance requirements defined in Part 4, Sections 1 and 3, the following ratings apply to disconnectors and earth switches.

Disconnectors and Earth Switches shall satisfy the requirements of IEC 62271-102.

Disconnectors rated at 420 kV and 300 kV shall be motor/power operated.

13.2.1 Rated Short-Time Withstand Current

If an earth switch is combined with a disconnector as a single unit, the rated short-time withstand current of the earth switch shall be at least equal to that of the disconnector.

13.2.2 Divided Frame Disconnectors and Earthing Switches

Divided frame disconnectors and earth switches shall be capable of operating to the limits of their rated contact zone as detailed in Tables 1 and 2 of IEC 62271-102.

13.2.3 Bus-transfer Duty

Disconnectors intended for bus-transfer or mesh-corner switching shall comply with the bus transfer requirements of IEC 62271-102 Annex B.

Bus transfer switching contacts fitted to disconnectors which can be operated in service from a manual mechanism, shall be designed so that their operation is independent of the speed of operation of the main contacts.

The design of the disconnector shall ensure that the operator is not endangered by arc debris during bus-transfer switching.

Disconnectors intended for bus-transfer or mesh-corner switching shall comply with the auxiliary switch requirements for disconnectors with bus transfer duty, as per clause 13.4.6.

13.2.4 Rated Values of Mechanical Endurance for Disconnectors

Disconnectors shall be rated to Class M1 as specified in IEC 62271-102.

13.2.5 Rated Values of Electrical Endurance for Earth Switches

Air Insulated Earth Switches shall be rated to Class E0 as specified in IEC 62271-102.

13.3 GENERAL REQUIREMENTS FOR DISCONNECTORS AND EARTH SWITCHES

13.3.1 Clearance Distances

Phase-to-phase and phase-to-earth clearance distances shall be as specified in Part 4, Section 2 unless the disconnector or earth switch has been type tested in accordance with the relevant requirements of IEC 62271-102 for the rated dielectric performance specified in Part 4, Sections 1 and 2. This shall apply to all clearance distances when a disconnector is in any position, including partially operated and for phase-to-phase clearance distance of earth switches in any position including partially operated.

13.3.2 Simultaneous Operation of Poles

The primary contacts of all poles shall operate (open or close) simultaneously, with a maximum spread of 0.5 seconds between first pole contact to open (or close) to the last pole contact to open (or close).

13.3.3 Flexibility of Design and Setting Adjustment Tolerances

All disconnectors and earth switches shall be designed and constructed with enough flexibility to cater for both coarse and fine adjustments associated with the dimensional tolerances required to achieve the correct settings under site conditions.

The Supplier shall provide adequate instructions to ensure that the installer is aware of any restriction associated with such adjustment. These instructions shall be included in the product operating manual.

13.3.4 Position Indication

A clear unambiguous open/closed indication (O/I) label/indicator shall be fitted, identifying the position of the main contacts when the operator is operating the disconnector or earth switch. This indication shall be visible following operation with the control cubicle secure.

For remotely operated disconnectors and earth switches incomplete operation of the main contacts shall be remotely indicated by a position-indicating device. The position-indicating device shall be a part of the disconnector or earth switch that enables a signal to be given, generally at a location remote from the disconnector or earth switch. It shall indicate that the contacts of the main circuit are in the closed or open position and that the mechanical movement is complete. This indication shall be repeated at the local control point when primary contacts are not readily visible to a local operator.

For GIS disconnectors and earthing switches, a reliable position indicating device (designed in accordance with IEC 62271-102, Annex A) may be provided as an alternative to the visible isolating distance or gap if easily accessible viewing windows are not provided.

13.3.5 Mechanical Key Interlocking

Where mechanical key interlocking is fitted to disconnector and earth switch mechanisms the following requirements shall apply.

Removal of a key shall, by means of an interference device, physically prevent operation of the mechanism. The interference device shall be so constructed that it will prevent operation when a normal operating force is applied by the recommended procedures, whether of power or manual means.

On power operated mechanisms with facilities for in-service manual operation the interlocking shall be effective for both power and manual operations.

Interlock keys shall be released when the mechanism is in either the fully open or fully closed position or both, as required by the interlocking scheme. The keys shall be trapped when the mechanism is in a partially operated position.

13.3.6 GIS Combined Disconnectors and Earthing Switches

Where a disconnector and earthing switch is combined within a single unit, the disconnector shall be capable of being opened, immobilised and locked before the earthing switch is closed. It shall not be necessary to unlock the disconnector in order to close the earthing switch.

Informative: This is to allow primary earths to be applied within the zone established by points of isolation in accordance with National Grid Safety rules.

13.3.7 Drive System Mechanical Interference Device

Where no mechanical key interlocking is provided, the drive system shall have a mechanical interference device. This device shall be used to physically prevent operation of the mechanism when in the open or the closed position. The interference device shall be effective when any reasonable operating forces are applied by the recommended means, whether by power or manual operation. For National Grid Operational and Safety (electrical) reasons facilities shall be provided to lock the interference device in the operated position using a padlock with a 5 mm diameter and 30 mm long hasp.

On power operated mechanisms, application of the interference device shall also prevent initiation of the power operation, unless it can be demonstrated no damage will occur as a consequence of the mechanism being stalled.

13.3.8 'Lockout' Interlock Keys

Lockout interlock keys shall be provided on all 420 kV, 300 kV and 145 kV disconnectors. These keys shall only be released when the disconnector is open.

Lockout interlock keys shall be provided on all 420 kV and 300 kV earth switches and shall only be released when the earth switch is closed.

Lockout keys shall be distinctively labelled and shall be unique to other keys in use on the substation site. The key shall also be unique from the other keys associated with the mechanism.

13.3.9 Earthing Switch Magnetic Bolt Device

Earth switches provided with a manual push button to release an electrical magnetic bolt device within the mechanism shall employ a time delayed magnetic bolt release.

13.3.10 Operations Counter

An operations counter shall be fitted to disconnector drive systems to record the total number of operating cycles (close-open) performed.

13.3.11 Construction Materials and Protective Coatings

The materials used in the construction of disconnectors and earth switches shall be demonstrated to be satisfactory for the environmental exposure detailed in the normal, special service and pollution conditions of Part 4, Section 1.

13.4 OPERATING MECHANISMS, ANCILLARY EQUIPMENT AND THEIR ENCLOSURES

13.4.1 General

The requirements of Part 4, Section 6 shall apply to disconnector and earth switch operating mechanisms, ancillary equipment and their enclosures.

13.4.2 'Sealing In' of Control Circuits

When an open or close operation is initiated, the mechanism control scheme shall be designed such that the open (or close) control circuit is not 'sealed in' to hold the supply voltage on to the drive motor for the duration of the Disconnector or Earth Switch travel, if the motor supply voltage is not available to operate the Disconnector or Earth Switch.

Informative: This is to prevent the condition where a motor supply may not be available, but an Open / Close instruction has been initiated and the control circuit has been latched or 'sealed in'. When the motor supply is reinstated, the Disconnector / Earth Switch may *unexpectedly operate without checking for valid interlock conditions being present at the actual time of operation.*

13.4.3 Drive Limit Switch

Power operated mechanisms shall be designed so that failures of the mechanism limit switches will not result in damage to the mechanism, drive linkages (with the exception of shear pins or mechanical protective devices) or the primary current path.

13.4.4 Control Switches

Local/Hand/Remote Close control switch shall be provided with a facility for locking in each position.

The Open/Neutral/Close control switch shall be provided with a facility for locking in the Neutral position.

13.4.5 Auxiliary Switches

Auxiliary switches shall comply with Part 4, Section 3 and IEC 62271-102. Auxiliary switches for disconnectors and earth switches are required to have a variety of different timings and senses with respect to the primary contacts.

The number of each type (i) to (vii) in 13.7 of this Section will be specified on a site-specific basis.

13.4.6 Auxiliary Switch Requirements for Disconnectors with Bus Transfer Duty

The auxiliary switch variant (vii) in 13.7 is only required on disconnectors for bus transfer duty. This contact timing is used for switching busbar protection CT and tripping circuits. The contact is made available for these specific secondary circuits. The auxiliary contact must close before the primary contacts start conducting current during a normal closing operation and must open after the primary contacts have stopped conducting current during a normal opening operation.

The disconnector positions marked ** in 13.7 shall be established at the time of type testing and recorded in the product operating manual. The setting shall be checked during routine (factory) tests and confirmed when the disconnector is completely assembled on site.

13.5 Test Requirements

The test requirements of Part 4, Section 1, 3 and IEC 62271-102 for disconnectors and earth switches are appropriate.

The following tests indicated as optional within IEC 62271-102 shall be considered as mandatory to meet the requirements of National Grid.

a) Tests to prove satisfactory operation under severe ice conditions.

b) Tests to prove satisfactory operation at minimum and maximum ambient air temperatures.

c) Tests to prove the bus-transfer current switching capability of disconnectors (where applicable).

d) Tests to prove the induced current-switching capability of earth switches (where applicable).

e) Tests to prove the reliable indicating device in accordance with IEC 62271-102 Annex A (where applicable).

f) Tests to prove the bus-charging capability of GIS disconnectors in accordance with IEC 62271-102 Annex F (where applicable).

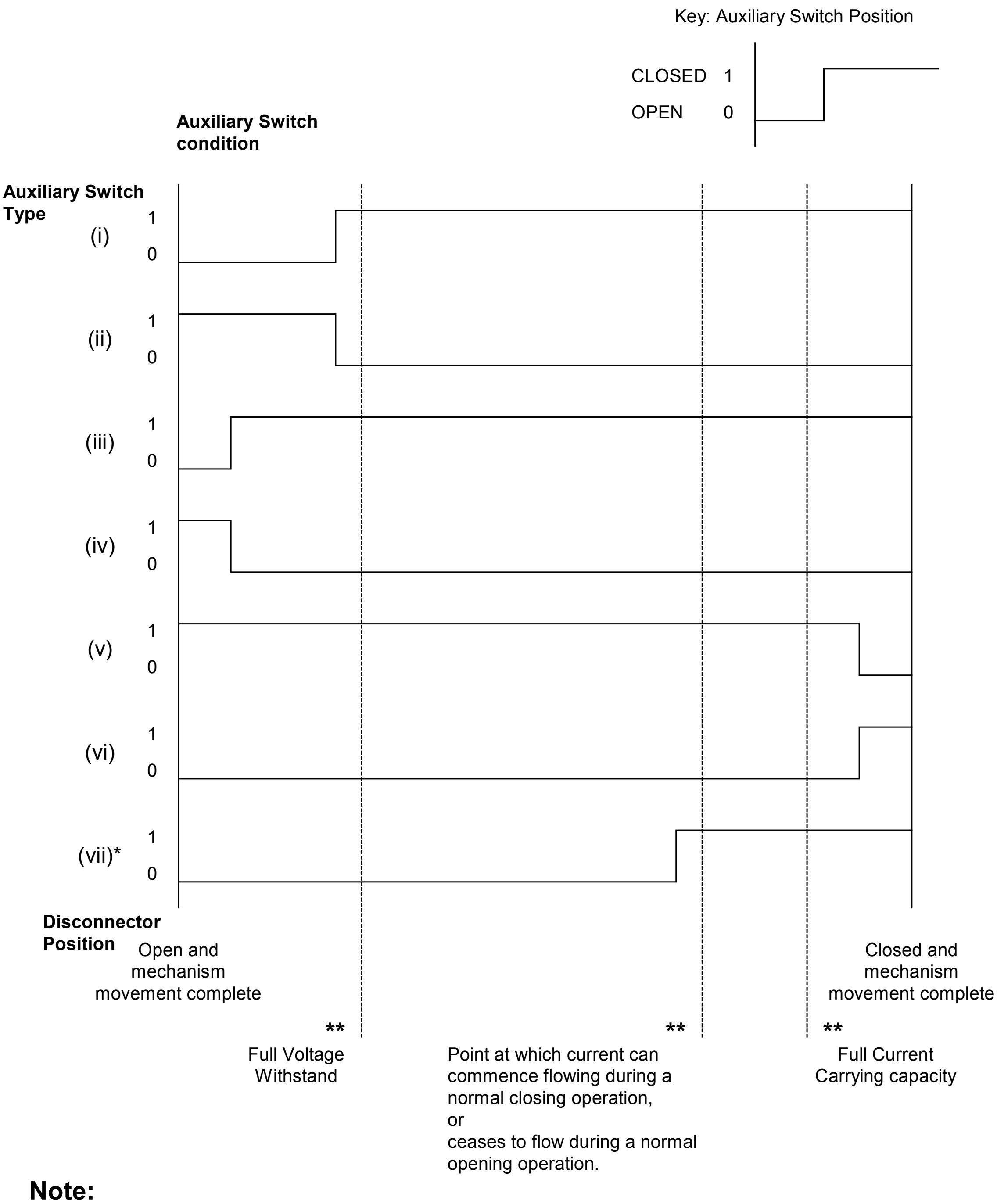
13.6 REFERENCES

13.6.1 International, European and British Standard Documents

This document makes reference to the documents listed below. Where a British Standard (BS) has been harmonised into a Euronorm (EN) only this BS EN reference is given. The issue date of these documents shall be that current at the time of the issue of this Technical Specification.

IEC 62271-102	High Voltage Switchgear and Controlgear. Part 102: High Voltage Alternating Current Disconnectors and Earth switches.
BS EN 60694	Common Specifications for High Voltage Switchgear and Control Gear Standards.

13.7 GUIDANCE NOTE - AUXILIARY SWITCH CONTACT POSITIONS IN RELATION TO THE DISCONNECTOR POSITION



Note:

* Bus transfer disconnectors only. This contact timing is used for switching Busbar Protection CT and Tripping circuits.

** These positions will be justified by the equipment manufacturer.

14 SECTION 11 - CURRENT TRANSFORMERS FOR PROTECTION AND GENERAL USE

14.1 PURPOSE AND SCOPE

This Section defines the functional and performance requirements for current transformers (CTs) for protection and general use on the GB Transmission System. It supports the more general requirements defined in Part 4, Sections 1, 2 and 3.

This is a functional and performance specification for CTs used for protection and measurement application.

14.2 GENERAL REQUIREMENTS

All CTs shall comply with Part 4, Sections 1, 2, 3 and IEC 60044-1. In addition, the following clauses apply:

14.2.1 General Requirements for all Current Transformers

Additional specification and testing requirements for protection Class PX cores are given in 14.8. For information, these requirements are identical to those given in the now obsolete BS 3938 Class X sections.

Secondary ratings and transformation ratios shall be selected from the attached Schedules and shall be specified in the contract Enquiry Document or Supplementary Agreement as appropriate.

A single secondary terminal box shall be mounted on the transformer to accommodate the necessary secondary terminal connections.

Secondary terminals and connections shall be suitable for their required purpose regarding rating, reliability and the effects of environmental conditions and corrosion.

Secondary terminal boxes shall comply with, as a minumum, the IP54 environment of BS EN 60529 as required in Part 4, Section 1.

Primary and secondary terminal markings, and rating plate markings shall be in accordance with IEC 60044-1

The rated continuous primary current of the current transformer shall be chosen to exceed the maximum continuous rating of the associated circuit and shall be selected from the standard values detailed in IEC 60044-1

A thermal short-time current rating (I_{th}) shall be assigned to all current transformers in accordance with IEC 60044-1. The value of I_{th} shall not be less than the corresponding value for the associated switchgear or transformer primary plant.

Current transformer secondary terminals should allow the application of shorting/earthing links or wiring for maintenance purposes. Separately, a terminal for earthing purposes shall be provided within the terminal box and shall be clearly marked.

For all oil filled CTs the supplier shall declare the type of insulating oil being used.

For oil-filled equipment fitted with an external oil expansion system, means shall be provided to give a permanent visual indication of the volume of the oil. The status of the indicator should be visible from ground level.

For oil filled CTs where the oil expansion system is wholly internal ie gas cushion or flexible diaphragm, the CT shall be fitted with a permanent internal pressure indicator. The status of the indicator shall be visible from ground level.

All oil filled CTs shall be fitted with an oil sample valve, situated at the base of the CT, suitable for taking oil samples for Dissolved Gas Analysis (DGA) in accordance with IEC 567. The sample valve shall be situated on the earthed base tank of the CT. Valves where the oil is extracted by using a hypodermic needle are not suitable.

Both ends of the CT secondary windings shall be earth free.

14.2.2 Additional Requirements for Post-Type Current Transformers

An insulation test terminal (test tap) shall be provided for the purpose of performing capacitance and dielectric loss (tan δ) measurements of the primary insulation during routine maintenance. The test terminals shall be suitably identified.

14.2.3 Additional Requirements for Current Transformers for GIS Application

Current transformers may be mounted internally or externally to the GIS enclosure.

Adequate protection against adverse environmental conditions shall be provided for externally mounted CTs as required in Part 4, Section 3.

14.2.4 Additional Requirements for Ring-Type Current Transformers

Current transformers supplied as loose equipment for power transformer application shall be equipped with secondary terminals or shall be supplied with leads of suitable length for this application. Such leads shall be capable of satisfying the test requirement of 14.4.3 (c).

Current transformers supplied with through-wall bushings can be mounted internally or externally to the bushing. Current transformers mounted internally shall be capable of operating within that environment. Current transformers mounted externally shall be suitably protected against the effects of adverse environmental conditions as required in Part 4, Section 3.

Current transformers supplied as loose equipment for other switchgear applications shall be capable of operating within that environment. Current transformers for other switchgear applications, mounted externally, shall be suitably protected against the effects of adverse environmental conditions as required in Part 4, Section 3.

14.2.5 Additional Requirements for Measurement/Protection and Class PX Protective Current Transformers

Measurement/Protection and class PX protective current transformers with a rated primary current of 2500 A or below and with untapped secondary windings shall have a rated secondary current of 1A (as selected from IEC 60044-1). The rated secondary current for current transformers of this primary rating with tapped secondary windings shall be 1 A corresponding to the highest transformation ratio.

Measurement/Protection and class PX protective current transformers with a rated primary current in excess of 2500 A shall have a rated secondary current selected from the values stated in IEC 60044-1

14.3 PERFORMANCE REQUIREMENTS

14.3.1 General

All current transformers shall comply with the performance requirements of IEC 60044-1 for the primary ratings detailed in Part 4, Sections 1, 2 and 3. The following requirements shall also apply as appropriate:

14.3.2 Protection Type PX-A Current Transformers

Protection type PX-A current transformers shall meet the additional requirements given in 14.8 providing accurate transformation up to the maximum fault current rating of the associated main plant. This performance shall be maintained under both fault and steady-state conditions without saturation

Type PX-A current transformers shall also meet the performance requirements of Schedule 2 of this Specification.

14.3.3 Protection Type PX-B Current Transformers

Protection type PX-B current transformers shall meet the additional requirements given in 14.8 providing accurate steady-state transformation up to the maximum fault current rating of the associated main plant.

Type PX-B current transformers shall also meet the performance requirements of Schedule 2 of this Specification.

14.3.4 Dual Purpose Measurement/Protection Current Transformers

Current transformers intended for the dual purpose of measurement and protection shall meet the performance requirements of IEC 60044-1, Clause 14.3.2 and Schedule 2 of this Specification.

14.4 TESTING REQUIREMENTS

14.4.1 Type Tests

All current transformers shall be type tested in accordance with IEC 60044-1 (type tests) and IEC 60044-1 (special tests). The additional requirements for protection class PX cores given in 14.8. Current transformers using a gas insulation system, a leakage test on the gas system shall be performed by the supplier to demonstrate compliance with Part 4, Section 3.

Radio interference voltage tests to IEC 60694 are to be performed on open-terminal current transformers.

A multi chopped impulse test shall be performed on all oil filled current transformers rated 72.5 kV and above. The test method is given in 14.7.

Temperature Rise - The thermal time constant of all equipment shall be determined on both rising and falling temperature.

For oil filled equipment oil samples for DGA shall be taken before and after the dielectric type tests and shall comply with 14.4.4.

Accuracy at Short-Term Continuous Current Levels - Current transformers which have a measurement specification shall have their errors determined at a current of 12000 A for 420 kV rating and 7500 A for 300 kV rating respectively. These currents shall be withstood for a period of 3 minutes.

Routine tests shall be performed before and after all type tests.

14.4.2 Routine Tests

All current transformers shall be routine tested in accordance with:

IEC 60044-1 (routine tests)

IEC 60044-1 (special tests)

The additional requirements for protection class PX transformers are given in 14.8.

14.4.3 Additional Routine Tests

a) Accuracy Tests

These shall be performed in a laboratory having traceability to National/International standards.

The overall accuracy and uncertainty of the measurement shall be demonstrated prior to testing and shall be commensurate with the accuracy class of the transformer under test.

Full accuracy routine tests to IEC 60044-1.

b) Capacitance and dielectric loss angle (tan δ) measurements of the primary insulation over the voltage range 10 kV to rated voltage shall be performed.

c) Leads for loose current transformers as detailed in Clause 14.2.4 of this Section shall withstand a power frequency test voltage of 5 kV (peak). For PXA application, the test levels shall be determined by tests in 14.8.

d) An oil sample for DGA shall be taken as described in 14.4.4 from all oil filled CTs. The sample shall be taken at least 24 hours after the final routine electrical testing has been performed. The results shall be included in the routine test report as detailed in Clause 14.4.4.

14.4.4 Routine Test Reports

Routine test reports shall include details of all routine measurements made in accordance with this specification. The information regarding the overall accuracy and uncertainty of the accuracy measurements shall also be recorded.

During the partial discharge (PD) test, the value of measured PD at the specified test voltage shall be recorded together with the value of the PD extinction voltage. Extinction voltage is defined as the voltage level at which measurable PD is completely extinguished upon decreasing test voltage. The background PD level at the time of the test should also be recorded in the report.

Where oil samples are taken for Dissolved Gas Analysis (DGA) the report shall contain the following information:

a) Name and Address of the laboratory where the analysis was performed

b) The Accuracy, Precision and Detection Limits for the individual gas measurement expressed in either parts per million (ppm) or percentage by volume.

c) The Sampling Procedure (stating the Standard Method IEC 567 if applicable).

d) The Gas Extraction Method used (stating the Standard Method IEC 567 if applicable).

e) Calibration Procedure adopted by the laboratory, including details of the number of points used over the range (f)and the gases used.

f) Accreditation Status of the laboratory for the purposes of DGA testing.

g) Date Sampled and Analysed.

h) Report the following:

Measurement	Units	No. Decimal Places
Oil Volume Tested	mls	0
Total Gas Content	%	2
Hydrogen	ppm	0
Methane	ppm	0
Ethane	ppm	0

Ethylene	ppm	0
Acetylene	ppm	0*
Carbon monoxide	ppm	0
Carbon dioxide	ppm	0
Oxygen	ppm	0
Nitrogen	ppm	0
Moisture	mg/l	0

*Note: For DGA samples associated with Type Tests, the acetylene value shall be quoted to one decimal place

14.5 SCHEDULES

14.5.1 Schedule 1- User Connection Points to The GB Transmission System

System Voltage	Rated Current of Switchgear	Class X Protection Current Transformers		Measurement/Protection Current Transformers		
		Rated Continuous Thermal Current	Turns Ratio	Extended Primary Current Rating %		Rated Transformation Ratio
			Busbar			
kV	A	A		Thermal	Accuracy	
275	2000	2000	1/600/1200	170	420	1200/600/1
275	2500	2500	1/600/1200	210	420	1200/600/1
400	4000	4000	1/1000/2000	200	500	2000/1000/1

14.5.2 Schedule 2 - Table Of Particulars For 420 kV, 300 kV And 145 kV Current Transformers

Ref Clauses	**CT Designation**	**Ratio**		**Knee-Point Voltage (V_k) or IEC Rating and Class**	**Magnetising Current (mA)**	**Max Sec Res (ohms)**
		Turns	**Current**			
14.3.2 to 14.3.4	420 kV, 4000 A					
	a) Prot A	1/1000/2000		300 (R_{ct} + 7.5)		
	b) Prot B	1/2000		60 (R_{ct} + 5)	40 at $\frac{V_k}{2}$	5.0 at 75°C
	c) Prot B Special Ratio	1/600/1200		82 (R_{ct} +3)	60 at $\frac{V_k}{2}$	2.4 at 75°C
	d) Measure-ment/Protection	1/1000/2000	2000/1	30 VA Class 1 5P20		
			1000/1	30 VA Class 1 5P10		
	300 kV, 2000 or 2500 A					
	a) Prot A	1/600/1200		160 (R_{ct} + 7.5)		
	b) Prot B	1/600/1200		82 (R_{ct} + 3)	60 at $\frac{V_k}{2}$	2.4 at 75°C
	c) Prot B Special Ratio	1/600/1200	1200/1	30 VA Class 1 5P20		
			600/1	30 VA Class 1 5P10		
	145 kV, 2000A					
	a) Prot A	1/600/1200 1/500/1000		50 (R_{ct} + 17) 60 (R_{ct} + 12)		
	b) Prot B	1/500/1000		95 (R_{ct} + 2.5)	60 at $\frac{V_k}{2}$	2.4 at 75°C
	c) Prot B Special Ratio	1/600/1200	1200/1	30VA Class 1 5P20		
			600/1	30VA Class 1 5P10		

Note - For tapped current transformers the knee-point voltage, magnetising current and secondary resistance are specified for the full winding, shown underlined.

14.6 REFERENCES

14.6.1 International, European and British National Documentation

This document makes reference to, or should be read in conjunction with, the documents listed below. Where a standard has been harmonised into a Euronorm, only this latter reference is given. The issue and date of the documents detailed below shall be applicable at the time of issue of this specification unless a specific issue date is given

IEC 60044-1	Instrument transformers- Part 1: Current Transformers
IEC 567	Guide for the sampling of gases and of oil from oil filled electrical equipment and for the analysis of free and dissolved gases.
IEC 60044-6	Requirements for protective Current Transformers for transient performance
BS EN 60694	Common specifications for high voltage switchgear and controlgear standards
BS 7626	Current Transformers

14.7 GUIDANCE NOTE - MULTICHOPPED IMPULSE TYPE TEST SPECIFICATION

All oil filled CTs rated at 72.5 kV and above, shall be subjected to a 600 chopped negative polarity impulse test at 60% of the rated BIL level for that equipment. The time to chop shall be between 2-5μs. A full set of routine electrical tests shall be performed, and oil samples for dissolved gas analysis shall be taken, both before and after this test.

The supplier shall submit to National Grid details of how the test will be conducted.

The three criteria, which must all be satisfied for the CT to pass the test, are:

a) The results of the routine electrical tests, performed before and after the chopped impulse test, are the same within the error specification for the test field.

b) No evidence of degradation is found when the CT is dismantled and examined after the test.

c) Any increases in the DGA levels are within the limits listed below.

Dissolved Gas	Allowable increase after 3 days (ppm)
Hydrogen (H_2)	5
Methane (CH_4)	3
Ethane (C_2H_6)	3
Ethylene (C_2H_4)	2
Acetylene (C_2H_2)	no detectable increase

The application of this test to CTs which have an ERIP or SRBP condenser core shall be subject to agreement between National Grid and the supplier.

14.8 GUIDANCE NOTE - ADDITIONAL REQUIREMENTS FOR PROTECTION CLASS PX TRANSFORMERS

Within the scope of IEC 60044-1 paragraph 5 additional requirements may be specified for certain protective systems. The specification and tests for Class PX transformers was addressed in BS 3938. This document was withdrawn in June 1998. The following amendment has been tabled by the United Kingdom BSI PEL 38 Instrument Transformer Technical Committee for inclusion IEC 60044-1 addressing these requirements.

The numbering of this section is identical to the submission made to IEC. When the amendment has been incorporated into IEC 60044-1 this document will be revised.

B1.1 Scope

Modify 5th paragraph

For certain protective systems, ...resonant earthed networks), additional requirements are given in Clause 14 for class PX transformers.

After 5th paragraph add

Clause 14 covers the requirements and tests in addition to those in clauses 3 to 10 that are necessary for current transformers for use with electrical protective relays, and in particular for forms of protection for which knowledge of the transformer secondary excitation characteristic, secondary winding resistance, secondary burden resistance and turns ratio is sufficient to assess its performance in relation to the protective relay system with which it is to be used.

B1.2 Normative references

Add

44-6 (1992) :instrument transformers, Part 6 : Requirements for protective current transformers for transient performance

B2 Definitions

B2.1 General definitions

Add

B2.1.32 ***rated resistive burden (R_b) :*** For definition see IEC Publication 60044-6 Clause 3.11.

B2.1.33 ***secondary winding resistance (R_{ct}) :*** For definition see IEC Publication 60044-6 Clause 3.12.

B2.3 Additional definitions for protective current transformers.

B2.3.10 ***Excitation characteristic :*** A graphical or tabular presentation of the relationship between the r.m.s value of the exciting current and a sinusoidal r.m.s e.m.f applied to the secondary terminals of a current transformer, the primary and other windings being open circuited, over a range of values sufficient to define the characteristics from low levels of excitation up to the rated knee point e.m.f.

B2.3.12 ***Rated knee point e.m.f (E_k) :*** That minimum sinusoidal e.m.f. (r.m.s) at rated power frequency when applied to the secondary terminals of the transformer, all other terminals being open-circuited, which when increased by 10% causes the r.m.s exciting current to increase by no more than 50%.

Note: - The actual knee point e.m.f will be ≥ the rated knee point e.m.f.

B2.3.13 ***Rated*** turns ***ratio :*** The required ratio of the number of primary turns to the number of secondary turns eg
Example 1: 1/ 600 (one primary turn with six hundred secondary turns)

Example 2: 2/1200 (a current transformer of similar ratio to example 1 but employing two primary turns).

B2.3.14 ***Turns ratio error:*** The difference between the rated and actual turns ratios. expressed as a percentage.

$$\text{Turns ratio error (\%)} = \frac{\text{actual turns ratio - rated turns ratio}}{\text{rated turns ratio}} \times 100$$

B6 Classification of tests

B6.1 Type tests

Modify as follows :

(f) determination of errors (see 11.4 and/or 12.4, 11.6, 12.5, 14.3)

B6.2 Routine tests

Modify as follows :

(d) power-frequency withstand test on secondary winding (see 8.3 or 14.4.4);

(e) power-frequency withstand tests, between sections (see 8.3 or 14.4.4);

(f) inter-turn over voltage test (see 8.4 or 14.4.5);

(g) determination of errors (see 11.5 and/or 12.4, 11.6, 12.6, 14.4)

B10.2 Rating plate markings

Modify as follows :

(e) The rated output and the corresponding accuracy class, together with additional information specified in the later parts of these recommendations (see 11.7 and/or 12.7, 13.8, 14.5).

B14 Additional requirements for Class PX protective current transformers

B14.1 Specification of performance for Class PX protective current transformers:

The performance of class PX current transformers shall be specified in terms of the following:

(a) rated primary current (I_{pn})

(b) rated secondary current (I_{sn})

(c) rated turns ratio. The turns ratio error shall not exceed ± 0.25%

(d) rated knee point e.m.f. (E_k)

(e) maximum exciting current (I_e) at the rated knee point e.m.f. and / or at a stated percentage thereof

(f) maximum resistance of the secondary winding at a temperature of 75°C (Rct)

(g) rated resistive burden (Rb)

(h) dimensioning factor (K_X)

Note - The rated knee point e.m.f. is generally determined as follows:

$$E_k = K_x \times \left(R_{ct} + R_b\right) \times I_{sn}$$

B14.2 Insulation requirements for class PX protective current transformers.

B14.2.1 *Insulation requirements for secondary winding*

The secondary winding insulation of class PX current transformers having a rated knee point voltage $E_k \geq 2$ kV shall be capable of withstanding a rated power frequency withstand voltage of 5 kV r.m.s for 60 s. For $E_k < 2$ kV the withstand voltage shall be 3 kV r.m.s for 60 s.

B14.2.2 I*nter-turn insulation requirements*

For Class PX transformers having a rated knee point e.m.f of 450 V or less the rated withstand voltage for inter-turn insulation shall be 4.5 kV peak. For those with a rated knee point e.m.f of greater than 450V, the rated withstand voltage for the inter-turn insulation shall be a peak voltage of 10 times the r.m.s value of the specified knee point e.m.f, or 10 kV peak, whichever is the lower. Note: For some EHV transmission systems a higher limiting value of peak voltage may be agreed between the manufacturer and the purchaser.

B14.3 TYPE TESTS FOR CLASS PX PROTECTIVE CURRENT TRANSFORMERS

Class PX current transformers shall in addition to the requirements of clause 7 be tested as below.

B14.3.1 *Proof of low reactance type*

An inspection of drawings shall be made in accordance with the requirements of IEC Publication 60044-6 Clause 7.3.1 a) in order to establish proof of low leakage reactance design. If compliance with the requirements of low leakage reactance design cannot be established to the mutual satisfaction of the manufacturer and purchaser by reference to drawings then the composite error shall be determined for the complete secondary winding using either of the direct methods of test given in Appendix A Clause A.5 or A.6 of this document, at a secondary current of K_x. I_{sn} and with a secondary burden R_b. Proof of low leakage reactance design shall be considered to have been established if the value of composite error from the direct method of test is less than 1.1times that deduced from the secondary excitation characteristic.

Note - The value of primary current required to perform direct composite error tests on certain transformer types may be beyond the capability of facilities normally provided by manufacturers. Tests at lower levels of primary current may be agreed between the manufacturer and purchaser.

B14.4 ROUTINE TESTS FOR CLASS PX PROTECTIVE CURRENT TRANSFORMERS

Class PX current transformers shall in addition to the requirements of clause 8 be tested as below:

B14.4.1 *Rated knee point e.m.f. (E_k) and maximum exciting current (I_e)*

A sinusoidal e.m.f. of rated frequency equal to the rated knee-point e.m.f. shall be applied to the complete secondary winding, all other windings being open-circuited and the exciting current measured.

The e.m.f. shall then be increased by 10% and the exciting current shall not increase by more than 50%. All measurement shall be performed using r.m.s. measuring instruments. Due to the non sinusoidal nature of the measured quantities the measurements should be performed using r.m.s measuring instruments having a crest factor ≥3.

The excitation characteristic shall be plotted at least up to the rated knee point e.m.f. The exciting current (I'_e) at the rated knee-point e.m.f. and at any stated percentage, shall not exceed the rated value. The number of measurement points shall be agreed between the manufacturer and the purchaser.

B14.4.2 Secondary winding resistance (Rct)

The resistance of the complete secondary winding shall be measured. The value obtained when corrected to 75°C shall not exceed the specified value.

B14.4.3 Turns ratio error ($_t$)

The turns ratio shall be determined in accordance with IEC publication 60044-6 Annex E. The turns ratio error shall not exceed the value given in Clause 14.1 (c).

Note - A simplified test involving measurement of the ratio error with zero connected burden may be substituted by agreement between the manufacturer and purchaser.

B14.4.4 Insulation tests

Tests shall be performed to demonstrate compliance with Clause 14.2.1 . For test method refer to Clause 8.3.

B14.4.5 Inter-turn insulation tests

Tests shall be performed to demonstrate compliance with Clause 14.2.2. For test method refer to Clause 8.4

B14.5 MARKING OF RATING PLATE OF CLASS PX CURRENT TRANSFORMERS

B14.5.1 Principal marking : See Clauses 10.2.

B14.5.2 Special marking

(a) rated turns ratio

(b) rated knee point e.m.f. (E_k)

(c) maximum exciting current (I_e) at the rated knee point e.m.f. and/or at the stated percentage thereof.

(d) maximum resistance of the complete secondary winding at a temperature of 75°C (R_{ct})

The following may also be required by the purchaser:

(e) dimensioning factor (K_X)

(f) rated resistive burden (Rb)

15 SECTION 12 - BUSHINGS

15.1 PURPOSE AND SCOPE

This Specification defines the functional and performance requirements for bushings on the GB Transmission System. It supports the more general requirements defined in Part 4, Sections 1 and 3.

This document details the functional performance and test characteristics for bushings for connection to the GB Transmission System.

15.2 GENERAL REQUIREMENTS

Bushings shall comply with the requirement stipulated in Part 4, Sections 1 and 3.

Bushings shall comply with BS EN 60137.

Bushings with capacitance grading shall be provided with a test terminal (test tap) as defined in BS EN 60137.

For bushings containing oil, an indicator to check the correct amount of oil is in the equipment should be provided (generally a sight glass).

All oil-filled equipment shall be fitted with an oil sample valve, situated on the earth flange, suitable for taking oil samples for Dissolved Gas Analysis (DGA) in accordance with IEC 567. Valves where the oil is extracted by using a hypodermic needle are not acceptable.

For oil impregnated paper bushings, the bushing design shall have sufficient oil capacity to allow 1 litre of oil to be extracted over the lifetime of the bushing for dissolved gas analysis purposes. Alternatively the supplier shall provide instructions on how to replenish the bushing with oil.

15.3 PERFORMANCE REQUIREMENTS

Bushings shall comply with the performance requirements of BS EN 60137 according to the relevant rating requirements detailed in Part 4, Sections 1 and 3.

15.4 TYPE TEST REQUIREMENTS

Bushings shall be type tested to BS EN 60137.

During the Temperature Rise Test the thermal time constant shall be determined on raising and lowering the temperature.

An oil sample for DGA shall be taken from all oil filled bushings, before and after the dielectric type tests. Acceptance criteria for the dissolved gas levels in oil will be agreed between National Grid and the bushing supplier. There shall be no change in the dissolved gas levels before and after type tests.

15.5 ADDITIONAL TYPE TEST FOR BUSHINGS OF THE CAPACITIVELY GRADED TYPE

Bushings for all switchgear applications shall have chopped impulse tests similar to those specified for transformer bushings in BS EN 60137. The bushings shall be subjected to 5 impulses of negative polarity, chopping of the impulse being made by means of an air insulated gap. The peak voltage level shall be 100% of the rated BIL. The time to sparkover of the chopping gap shall be between 1 μs and 6 μs.

Bushings for gas insulated switchgear shall also be subjected to 30 impulses of both positive and negative polarities with a chopping gap immersed in SF_6 and located adjacent to the SF_6 end of the bushing. The peak voltage level shall be 60% of the rated BIL. The time to sparkover of the chopping gap shall be between 1 µs and 6 µs.

Routine tests shall be performed before and after all type tests.

15.6 ROUTINE TEST REQUIREMENTS

All bushings shall be routine tested to BS EN 60137.

An oil sample for DGA shall be taken not less than 24 hours after the final routine electrical testing has been performed. The results shall be included in the routine test report.

Routine test reports shall include details of all routine measurements made in accordance with this specification.

Specifically for partial discharge (PD) tests, the values of measured PD at the specified partial discharge test voltage shall be recorded together with PD extinction voltages. The background PD level at the time of the test should also be recorded in the report.

Informative: Extinction voltage is defined as the voltage level at which measurable PD is extinguished upon decreasing test voltage

15.7 REFERENCES

15.7.1 International, European and British National Documentation

This document makes reference to or should be read in conjunction with the documents listed below. Where a Standard has been harmonised into a Euronorm, only this latter reference is given. The issue and date of the documents detailed below shall be that applicable at the time of issue of this specification unless a specific issue date is given.

BS EN 60137	Bushings for Alternating Voltages Above 1000V
BS EN 60694	Common Clauses for High-voltage Switchgear and Controlgear Standards
IEC 255-23	Electrical Relays - Part 23: Contact Performance
BS EN 60517	Gas Insulated Metal Enclosed Switchgear for Rated Voltages of 72.5kV and Above
IEC 60815	Guide for the selection of insulators in respect of polluted conditions.
IEC 60567	Guide for the sampling of gases and of oil from oil filled electrical equipment and for the analysis of free and dissolved gases.

16 SECTION 13 - SOLID CORE POST INSULATOR FOR SUBSTATIONS

16.1 PURPOSE AND SCOPE

These requirements for solid core post insulators are by reference to IEC 60273, IEC 60168 and associated documents. This document defines the required enabling parameters and additional technical requirements for solid core post insulators for use on, and directly connected to, the GB Transmission System, rated from 1kV to 420kV.

This document defines the functional performance requirements for solid core post insulators connected to the GB Transmission System. It supports the more general conditions defined in Part 4, Sections 1 and 3.

16.2 RATINGS AND PERFORMANCE REQUIREMENTS

In addition to the general ratings and performance requirements defined in Part 4, Sections 1 and 3, the following ratings apply to post insulators.

Post insulators shall satisfy the requirements in IEC 60273.

16.3 TEST REQUIREMENTS

16.3.1 Type Tests

Type tests shall be as required in Part 4, Sections 1and 3, together with the requirements of IEC 60168. Where the purchaser is presented with test options within IEC 60168, the following apply;

16.3.2 Dry Lightning-Impulse Withstand Voltage Test

Either test method described in IEC 60168 is acceptable.

16.3.3 Dry Or Wet Switching-Impulse Withstand Voltage Test

Either test method described in IEC 60168 is acceptable.

16.3.4 Mechanical Failing Load Tests

In addition to the bending test, the tensile and torsion tests shall be performed during type testing as described in IEC 60168.

16.3.5 Test for Deflection Under Load

This test shall be performed during type tests to establish the top flange deflection obtained as a result of applying 70% of the specified mechanical failing load.

16.3.6 Radio Interference Test

This special test shall be performed as described in IEC 60168 and IEC 60437.

16.3.7 Sample Testing

Sample testing requirements are dependant on production quantity and other commercial considerations. Where sample testing is required it shall be as detailed in IEC 60168 and Part 4, Section 1, with any site specific requirements being detailed in the Contract Enquiry Document or Supplemental Agreement.

16.3.8 Routine Testing

Routine tests shall be as required in Part 4, Sections 1 and 3 together with the requirements of IEC 60168.

16.4 REFERENCES

16.4.1 International, European and British National Documentation

This document makes references to, and should be read in conjunction with the documents listed below. Where a British Standard (BS) has been harmonised into a Euronorm (EN) only this BS EN reference is given.

IEC 60273	Characteristics of indoor and outdoor post insulators and post insulator units for systems with nominal voltages greater than 1000V.
IEC 60168	Tests on indoor and outdoor post insulators of ceramic material or glass for systems with nominal voltages greater than 1000V.
IEC 60437	Radio interference tests on high voltage insulators.
IEC 60694	Common Specifications for High Voltage Switchgear and Control Gear Standards.
IEC 815	Guide for the selection of insulators in respect of polluted conditions.

17 SECTION 14 - BUSBAR PROTECTION

17.1 SCOPE

This Section describes the functional and performance requirements and the facilities to be provided for the numerical protection of busbars at 400 kV, 275 kV and 132 kV double busbar switching stations.

17.2 REFERENCES

This Specification makes reference to a Domain Diagram showing relevant bay level specification functionality linked to the following documents:

IEC 255-1-00 - All or Nothing Electrical Relays.

IEC 255-6 - Measuring Relays and Protection Equipment.

IEC 255-13 - Biased Differential Relays.

17.3 FUNCTIONAL REQUIREMENTS

17.3.1 Busbar Protection System

Numerical busbar protection shall provide fully discriminative protection for phase-to-phase and phase-to-earth faults occurring within the substation.

Where the primary arrangement of the substation permits the substation to be split into a number of sections delimited by circuit breakers or disconnectors, the numerical busbar protection shall provide fully discriminative protection for phase-to-phase and phase-to-earth faults occurring within each section.

Separate protection zones shall be provided for each busbar section.

The numerical busbar protection shall discriminate between faults in the protected busbar section and faults elsewhere in the substation or the primary system.

The busbar protection shall employ a minimum of two different fault detection algorithms that must both be satisfied for tripping to occur.

If a biased differential principle is used, the protection shall comply with the requirements of IEC 255-13.

The operating current of the busbar protection shall be settable in the range 50 – 600% of 2000 amps at 400 kV or 50 – 600% of 1000 amps at 275 and 132 kV.

When a busbar fault occurs, all circuit breakers connected to the faulted busbar shall be tripped simultaneously, whether they can feed fault current or not.

The busbar protection shall be able to due correctly detect a fault condition occurring during an on-load busbar changeover and issue trip commands to the connected bays.

17.3.2 Switchgear Positional Information

Where a fault occurs in the overlap between two zones, e.g. at a Bus-section or Bus-coupler, with the circuit breaker closed, both zones shall be tripped simultaneously.

Switchgear positional information shall be used to determine the primary arrangement of each busbar section.

Where a discrepancy (DBI) in switchgear positional information occurs, the busbar protection shall have user selectable options either to remain in service using the last verified switchgear position or to block protection operation for the affected zone.

17.3.3 Differential Current Supervision

Differential current supervision shall be provided on each zone.

The differential current supervision shall be settable in the range 2 to 10% of 2000 amps at 400 kV, 2 to 10% of 1000 amps at 275 kV and 132 kV.

Where operation of the differential current supervision occurs, the busbar protection shall have user selectable options either to remain in service or to block protection operation.

Operation of the differential current supervision shall generate an alarm after a time delay settable in the range 0 - 10 s.

17.3.4 Physical Arrangement

The functionality shall be implemented in accordance with GB Transmission System requirements as applied to the site being connected to.

The system shall consist of a distributed set of bay units and a single central unit.

Informative: A typical arrangement of bay units and a single central unit is shown in Figure 10.

The protection shall collect current and switchgear positional information at the bay units.

Bay units shall preferably be mounted with the bay secondary equipment.

The central unit shall perform the busbar protection algorithm using the current and positional information transmitted from the bay units.

The central unit shall transmit tripping commands to the required bay units to operate the required outputs.

Communications between bay units and central unit shall be immune to electrical noise.

Separate multicore cables shall be employed and the wiring and terminals shall, as far as reasonably practicable, be segregated from other circuits.

The auxiliary supply to each bay unit shall be provided from the 110 V (dc) first tripping supply for the bay.

The auxiliary supply to each bay unit shall not be separately fused or protected.

The auxiliary supply to the central unit shall be taken from the 110 V (dc) supply.

Informative: It is preferred that the central unit have duplicated energising supplies with automatic changeover facility.

The equipment for busbar protection shall be electrically and physically independent from other equipment, as far as practicable.

17.3.5 Interfaces

Informative: Figure 11 shows the interfaces to a typical bay unit.

17.3.6 Current Transformer Inputs

There shall be one current transformer input for each bay except that bus section and bus coupler bays shall have a current transformer input from each side of the circuit breaker.

Informative: Figure 10 shows one bay unit for each three-phase set of current transformer inputs and, hence, two bay units are shown for a bus-section or bus-coupler bay.

The busbar protection system shall be capable of operating from Measurement/Protection current transformers as defined in Part 4, Section 11.

The busbar protection system shall be capable of accepting inputs from current transformers having different ratios in different bays.

There shall be no auxiliary switch contacts or relay contacts in the current transformer circuits.

17.3.7 In/Out Switching

A local in/out switching facility shall be provided to enable each bay unit to be taken out of service whilst the remainder of the busbar protection remains in service.

The in/out switching facility shall be activated by a control input as specified by National Grid and as used for the control of busbar protection at the connection site.

The in/out switching facility shall be common for all the functions resident in the bay unit.

A secure means shall be provided to activate the In/Out of service switching facility e.g. key switch.

Activation of the in/out switching facility shall set the bay unit outputs to the state programmed by the user as a setting.

In/Out switching functions shall be latched in the last selected position.

17.3.8 Switchgear Positional Information

Switchgear positional information shall be determined by double point inputs as specified by National Grid and as used for the control of busbar protection at the connection site.

Discrepancies in switchgear positional information shall generate an alarm after a time delay settable in the range 0 - 10 s.

17.3.9 Outputs

Each bay unit shall provide a minimum of three single point outputs as specified by National Grid and as used for the busbar protection outputs at the connection site., for tripping, two operating from the busbar protection and one from the circuit breaker fail protection.

Each bay unit shall provide the following alarm outputs:-

a) Disconnector Auxiliary Switch discrepancy alarm.

b) Equipment inoperative, for the loss of dc auxiliary energising supply and internal relay failures.

c) Bay unit out of service.

Informative: Figure 12 shows the interfaces to a typical central unit.

The central unit shall provide the following alarm outputs:-

a) Busbar protection zone operation.

b) Differential current supervision.

c) Disconnector Auxiliary Switch discrepancy alarm.

d) Equipment inoperative, for the loss of dc auxiliary energising supply and internal relay failures.

17.3.10 Informative Interface

In addition to the requirements for the Informative Interface specified by National Grid and as used for the interface at the connection site. the Bay Unit shall provide the following information:

a) Fault type, e.g. R – E or Y – B.

b) Phase currents.

c) Records of recent faults shall be stored and be available for downloading either locally or remotely.

In addition to the requirements for the Informative Interface specified by National Grid and as used for the central unit at the connection site. the Central Unit shall provide the following information:

a) Faulted zone.

b) Fault type, e.g. R – E or Y – B.

c) Current substation configuration.

d) Differential currents for each zone.

e) Records of recent faults shall be stored and be available for downloading either locally or remotely.

17.3.11 Man Machine Interface

The following indications shall be provided on the bay units;

a) Protection operated.

The following indications shall be provided on the central unit.

b) Protection operated.

17.4 PERFORMANCE REQUIREMENTS

The protection system shall perform correctly in accordance with the requirements of this Specification for the range of power system conditions specified in Part 4, Section 1 and the range of environmental conditions specified by National Grid and as used for the busbar protection at the connection site.

The protection system shall perform correctly under the conditions of current transformer saturation and magnetising inrush.

17.4.1 Accuracy

The accuracy of the busbar protection shall be such that, when set appropriately, and over the range of conditions referred to, it shall perform correctly and in accordance with this specification.

The accuracy shall not be affected by more than ± 10 % (± 2 % for auxiliary power supply variations) under the range of system and atmospheric conditions specified in Part 4, Section 1.

17.4.2 Reliability

Upon recovery of the input energising supply from a failure condition, the full discriminative protection system shall come into operation within 10 s.

17.4.3 Operating Time

The operating time of the busbar protection shall be not greater than 30 ms.

The resetting time of the busbar protection shall be not greater than 50 ms.

Where a change of setting, a configuration change or other software change requires the busbar protection to be switched out of service, the period of non-availability shall not exceed 15 minutes.

17.5 TESTING

17.5.1 Power System Conditions

The busbar protection shall be demonstrated to operate correctly for the range of system fault infeeds, X/R ratios, balanced and unbalanced load currents, offsets, voltage levels, shunt capacitance currents, harmonic currents, oscillatory currents, resonance conditions and travelling wave effects that are defined in Part 4, Section 1.

The busbar protection shall be demonstrated to operate correctly under the conditions of current transformer saturation and inrush.

17.5.2 Protection System Characteristics

The characteristics of the busbar protection and its accuracy and repeatability shall be demonstrated.

The presentation of these characteristics shall make it possible to verify that the performance meets the requirements as specified in 17.4.

17.5.3 Operating Time

The requirements of 17.4.3 shall be demonstrated for the range of influencing quantities as specified and over a reasonable range of settings.

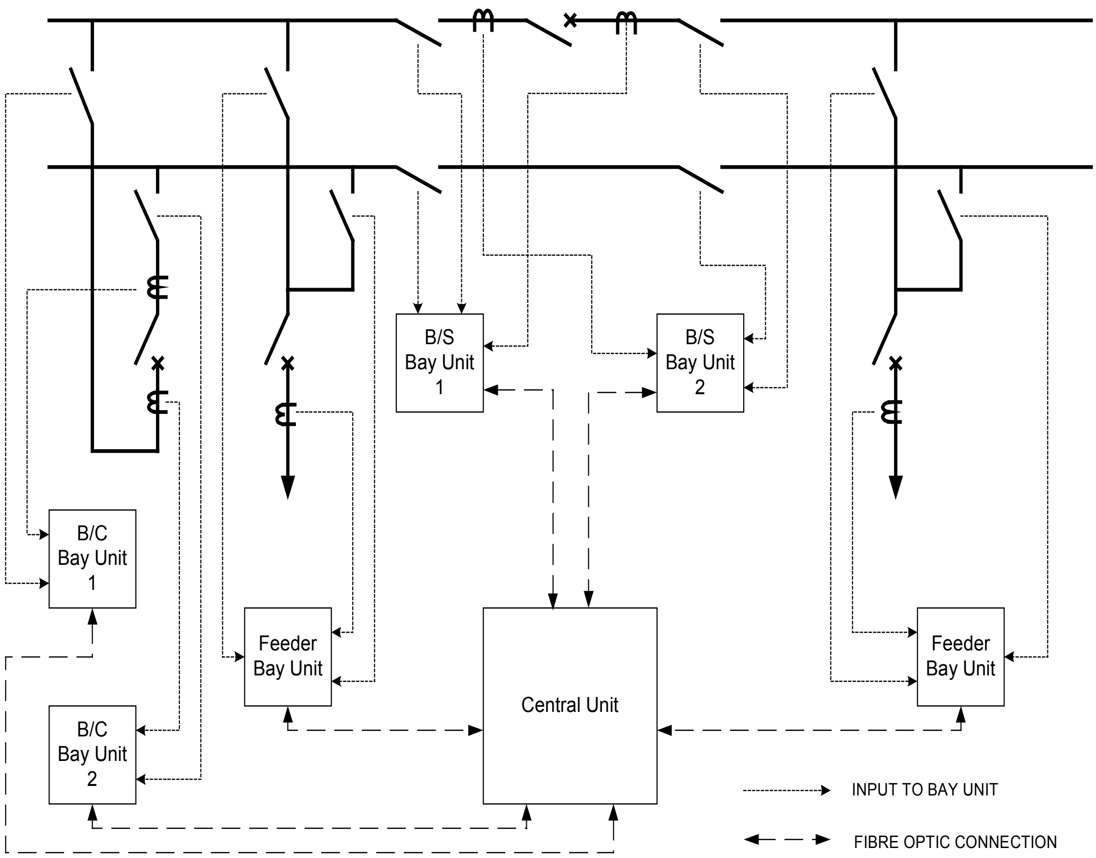


Figure 10 – Typical Block Diagram of Connections for Numerical Busbar Protection

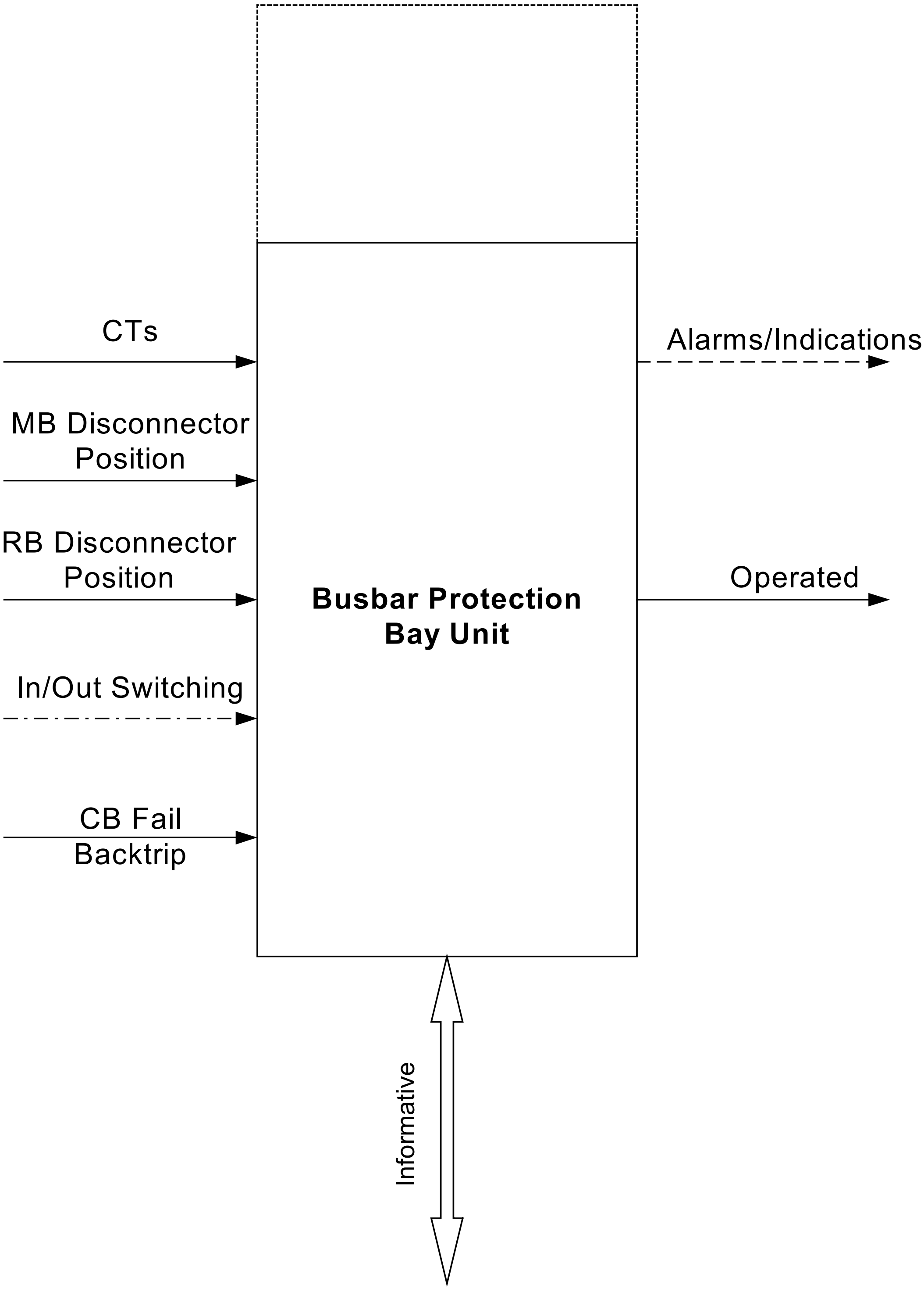


Figure 11 – Interface Diagram – Bay Unit

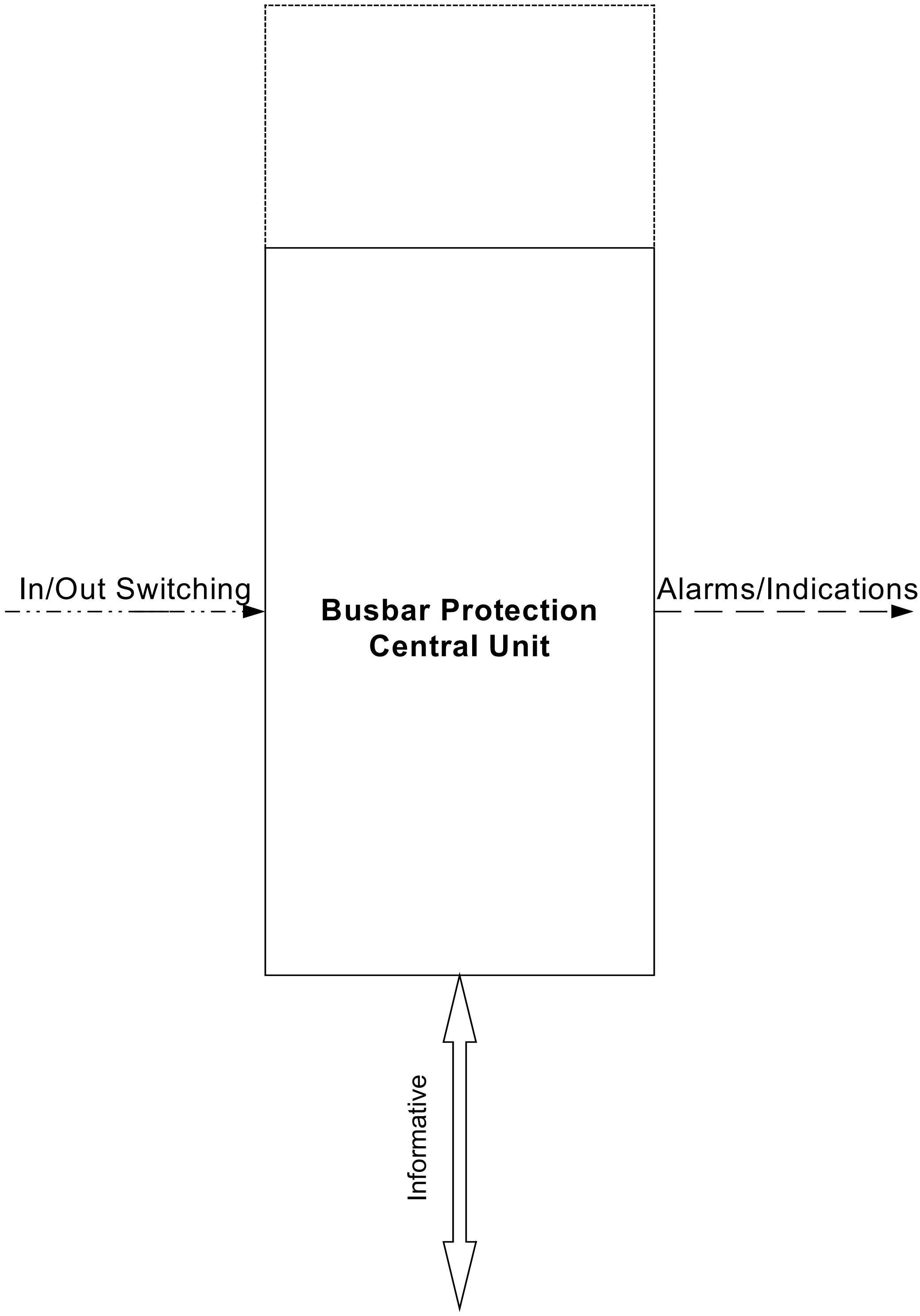


Figure 12 – Interface Diagram – Central Unit

18 SECTION 15 - CIRCUIT BREAKER FAIL PROTECTION

18.1 SCOPE

This Section describes the functional and performance requirements and the facilities to be provided for Circuit Breaker Fail Protection at 400 kV and 275 kV substations.

18.2 REFERENCES

IEC 255-1-00	All-or-nothing Electrical Relays
IEC 255-3	Electrical Relays – Single Input Energising Quantity Measuring Relays with Dependent or Independent Time
IEC 255-6	Electrical Relays – Measuring Relays and Protection Equipment
IEC 255-22-3	Electrical Relays – Electrical Disturbance Tests for Measuring Relays and Protection Equipment – Radiated Electromagnetic Field Disturbance Tests

18.3 FUNCTIONAL REQUIREMENTS

18.3.1 General

Circuit breaker fail protection shall cause cessation of fault current within 300 ms of inception of the original fault whose detection initiated tripping of the failed circuit breaker.

The functionality shall be implemented in accordance with the GB Transmission System requirements as applied to the site being connected to.

18.3.2 Circuit Breaker Fail Detectors

Circuit breaker fail detector(s) shall be enabled when the protected circuit breaker has been called upon to trip by operation of its associated protection systems.

The detector(s) shall not operate if the circuit breaker fails to open during a routine switching operation or automatic switching sequence unless such failure coincides with or precipitates the development of a system fault, resulting in the operation of its associated protection systems.

a) A detector shall comprise the following:

   (i) A current check element to check if current is still flowing in any phase of the circuit breaker following circuit breaker trip initiation.

   (ii) A timing element to delay tripping until the circuit breaker has had adequate time for normal extinction of fault current.

The Circuit Breaker Fail system for the substation the User is connecting to will be one of the options shown in Figures 15 and 16.

b) For Option A (see Fig. 15):

   (i) The current check element shall be enabled by the circuit breaker fail initiating inputs to monitor the current flowing through the circuit breaker.

   (ii) Detection of current in any phase of the circuit breaker above setting shall start and maintain the timing element.

   (iii) A trip output from the detector shall be initiated if the current is still above setting at the end of the timing period.

c) For Option B (see Fig. 16):

(i) The timing element shall be started directly from the circuit breaker fail initiating inputs.

(ii) The current check element shall be enabled by the timing element at the end of the timing period and shall monitor the current flowing through the circuit breaker.

(iii) If the current in any phase of the circuit breaker is above setting, then a trip output from the detector shall be initiated.

(iv) For applications using this arrangement, specific measures shall be taken to prevent unwanted back tripping for situations where the circuit breaker has been called upon to close when a trip relay (circuit breaker fail initiating contact) has been operated and not reset.

(v) One such measure would be to block circuit breaker closing for the duration of trip relay operation.

(vi) The method of preventing unwanted back tripping shall be declared by the supplier.

18.3.3 Current Check Function

The function shall comply with IEC 255-3.

The function shall have, as a minimum requirement, a current setting range of 5% to 25% in steps of 5% or 30% to 100% in steps of 10% depending upon the design of the circuit breaker.

Informative: The setting range specified is based on the assumption that the rating of the current check element is 1 A and that the ratio of the current transformer is 2000/1000/1 at 400 kV and 1200/600/1 at 275 kV.

18.3.4 Timing Function

The timing function shall comply with IEC 255-1-00.

The timing function shall have, as a minimum requirement, a time setting range of 50 ms to 250 ms in steps of 2 ms.

18.3.5 Circuit Breaker Fail System

Where the circuit breaker fail detector is a software function embedded in a multi-function numerical relay, such as busbar protection, one detector shall initiate tripping of contiguous circuit breakers.

Where the circuit breaker fail detector is effected by discrete conventional relays, two detectors operating in a two-out-of-two mode shall initiate tripping of contiguous circuit breakers.

18.3.6 Interfaces

Current transformer inputs of the User’s circuit breaker fail protection shall be capable of operating under the same environmental conditions as National Grid’s protection systems at that site.

Where the Circuit Breaker Fail Protection is not integrated with the busbar protection, it shall normally be supplied from a three-phase set of measurement/protection class current transformers.

The circuit breaker fail protection shall be initiated by a single point digital output from each of the protection systems that can initiate tripping of the protected circuit breaker.

Informative: The single point digital input is normally a trip relay contact.

Inputs to the Circuit Breaker Fail Protection shall be immune from mal-operation due to wiring earth faults.

Informative: Double pole switching is one accepted way of ensuring immunity from mal-operation.

18.3.7 Outputs – Busbar Stations

The Circuit Breaker Fail Protection shall initiate back tripping of all other circuit breakers connected to the same busbar via the tripping system of the busbar protection.

Where the Circuit Breaker Fail Protection is not integrated with the busbar protection, a minimum of two single point outputs shall be provided to initiate backtripping.

The back tripping initiations shall be immune from mal-operation due to wiring earth faults.

Informative: Double pole switching is one accepted way of ensuring immunity from mal-operation.

Where the protection system is associated with a feeder circuit breaker such that tripping of directly connected remote circuit breaker(s) is required, then initiation shall be provided for the DTT and PTT, as provided for the feeder.

A typical tripping logic diagram for a feeder circuit breaker fail protection system at a busbar substation is shown in Figure 17.

18.3.8 Outputs – Mesh Stations

The protection system shall be provided with single point outputs for each mesh corner to initiate back tripping of all associated local and directly connected remote circuit breakers.

Informative: An accepted way of initiating back tripping is to use the tripping system of both first and second mesh corner protections.

A typical tripping logic diagram for circuit breaker fail protection systems at a mesh substation is shown in Figure 18.

18.3.9 Alarm Outputs

The following single point outputs shall be provided for the circuit breaker fail protection system alarms as appropriate:

a) Circuit breaker fail protection operated.

b) Protection supply supervision.

c) Protection relay defective.

d) Trip relay operated indication, where a trip relay is provided.

18.4 PERFORMANCE REQUIREMENTS

18.4.1 Current Check Function

The operating time shall be not greater than 10 ms.

The drop off/pick up ratio shall be not less than 70 %.

For ‘Option A’ the resetting time shall be not greater than 12 ms for operating currents of up 30 times rating (ie 30 A) with a system X/R ratio of 40.

For ‘Option B’ the resetting time shall be not greater than 30 ms.

The error of the function shall be not greater than 5 %.

18.4.2 Timing Function

The reset or disengage time of the function shall be not greater than 30 ms.

For ‘Option A’, only the overshoot of the function shall be not greater than 10 ms.

18.5 TEST REQUIREMENTS

The current check function shall be tested in accordance with the requirements of IEC 255-3 to demonstrate that it meets the requirements of 18.4.1.

The timing function shall be tested in accordance with the requirements of IEC 255-1-00 to demonstrate that it meets the requirements of 18.4.2.

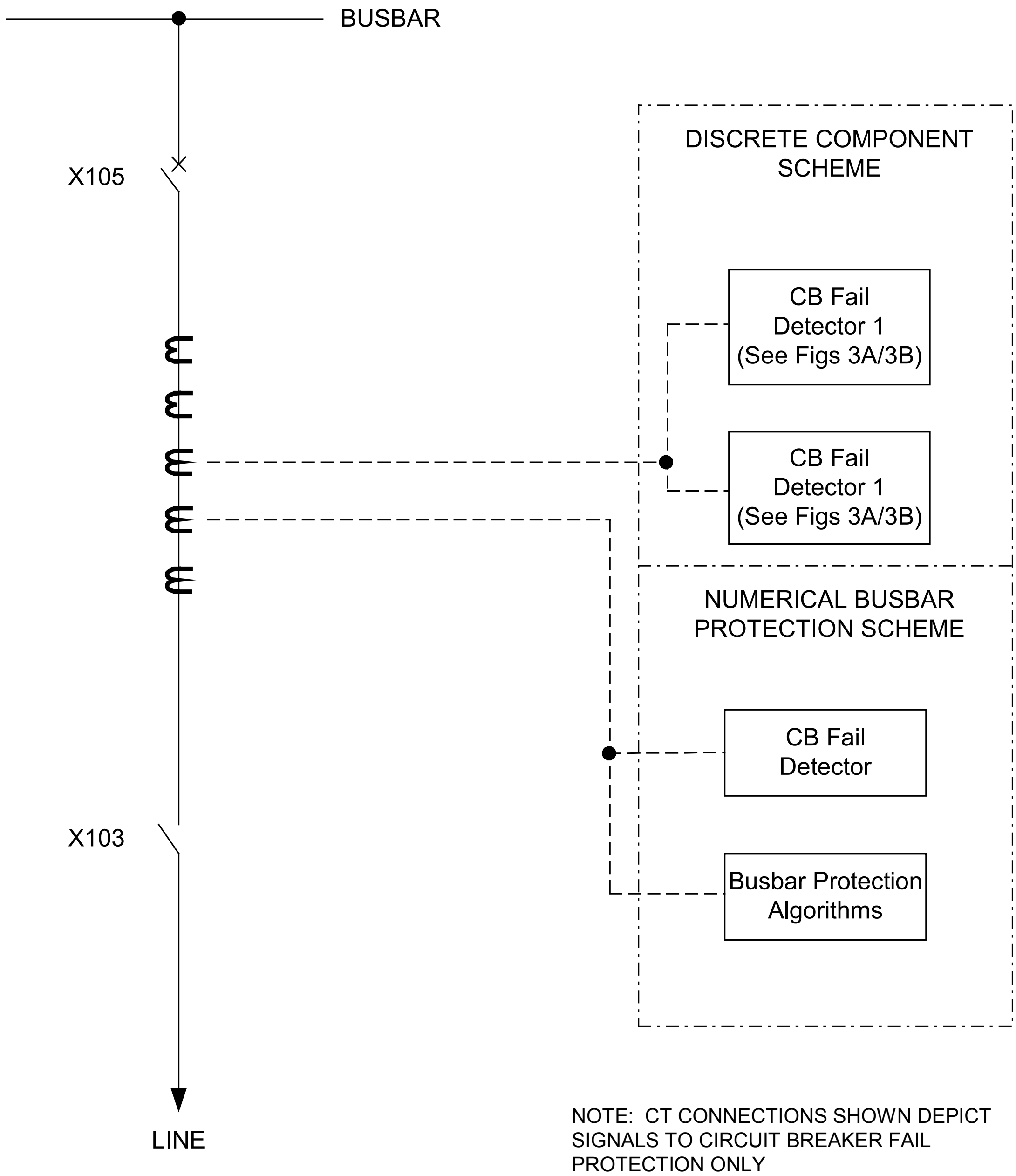


Figure 13 - Typical CT Arrangement for Circuit Breaker Fail Protection for Busbar Stations - Feeder Circuit

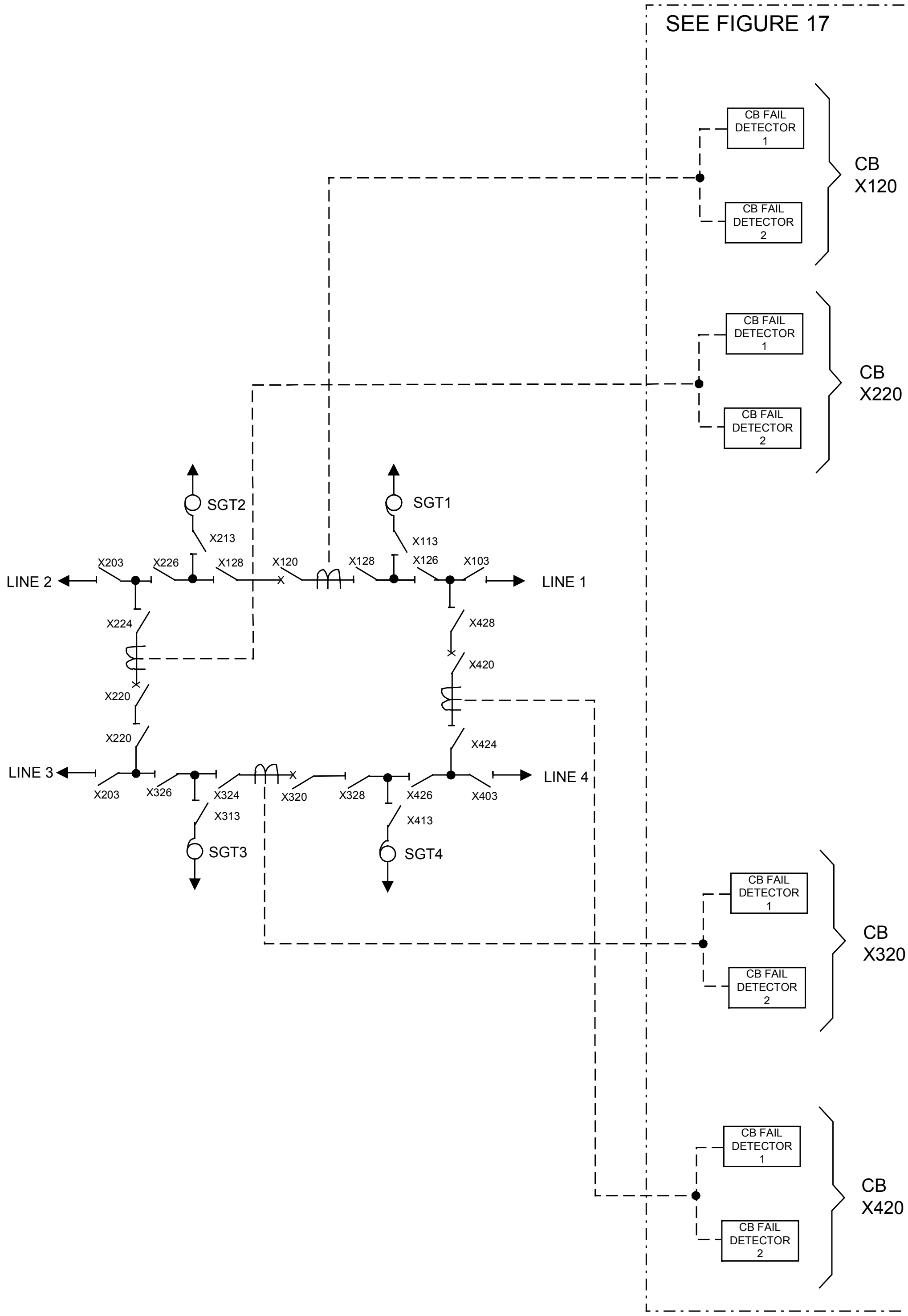


Figure 14 - Typical CT Arrangement for Circuit Breaker fail Protection for Mesh Stations

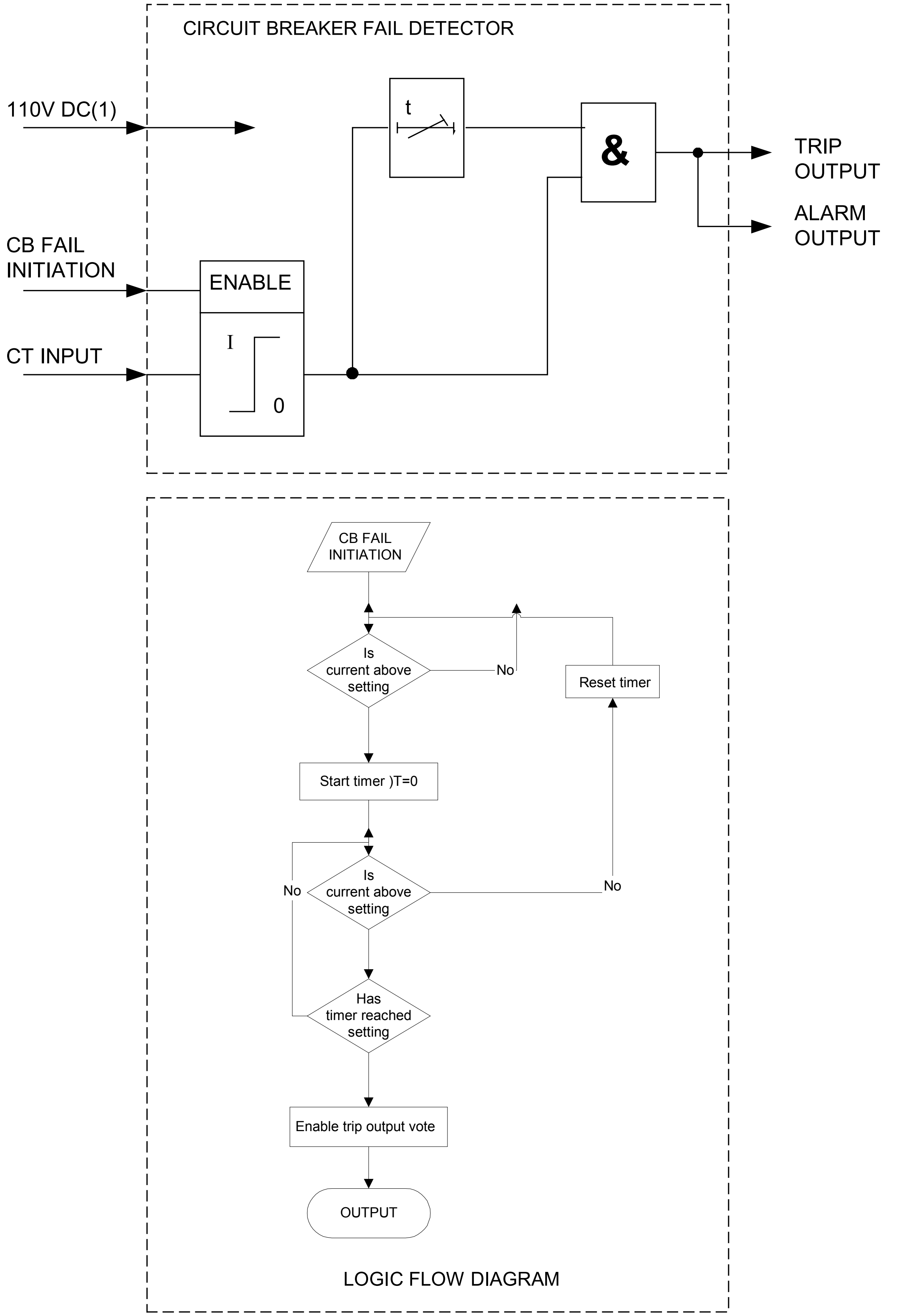


Figure 15 - Circuit Breaker Fail Detector - Option A

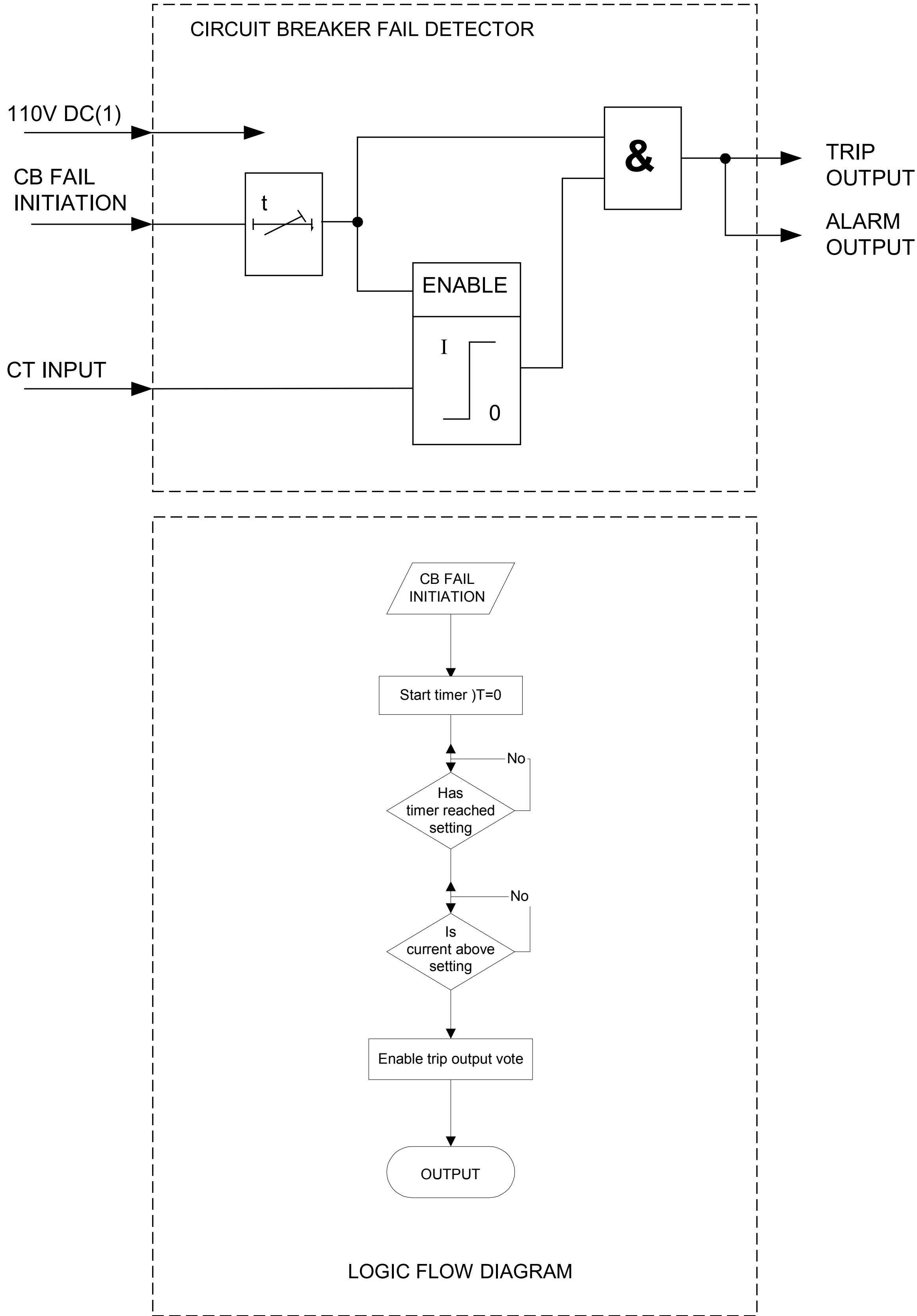


Figure 16 - Circuit Breaker Fail Detector - Option B

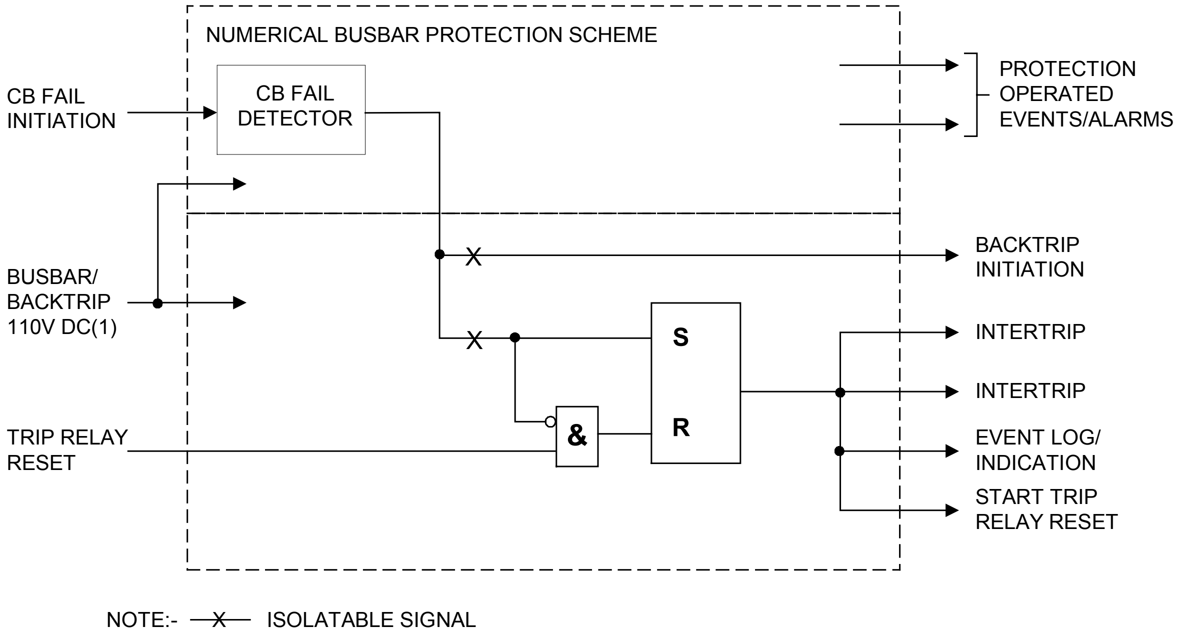


Figure 17 - Typical Tripping Logic Diagram for Circuit Breaker Fail Protection System for Busbar Substations - Feeder Circuit

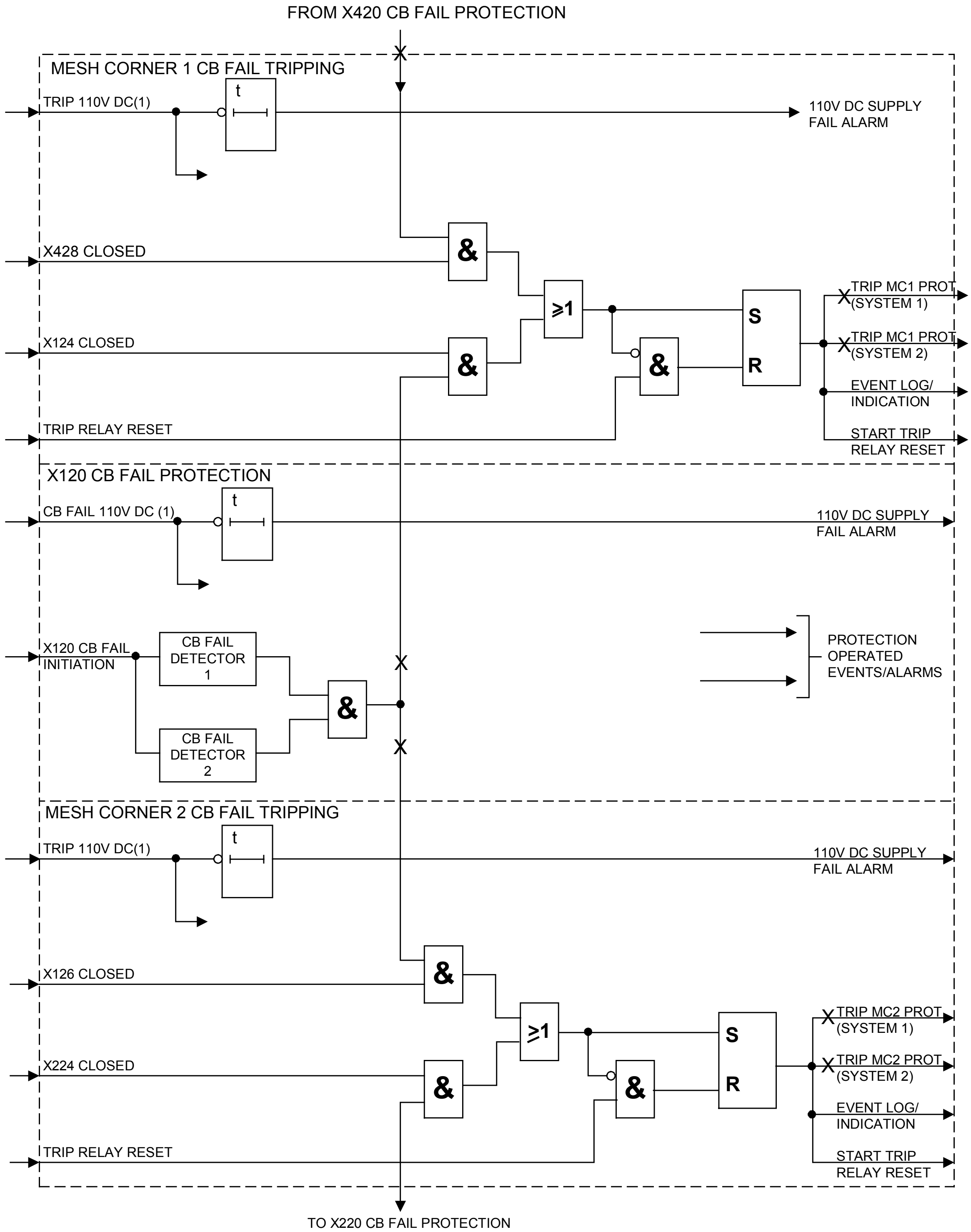


Figure 18 - Part of Typical Tripping Logic Diagram for Circuit Breaker Fail Protection System for Mesh Substations

19 SECTION 16 - ENVIRONMENTAL AND TEST REQUIREMENTS FOR ELECTRONIC EQUIPMENT

19.1 SCOPE

All electronic equipment supplied for operational use within National Grid's substation busbar protection zone of the User connection to National Grid's electricity transmission network must meet the required functionality and performance as set out in National Grid Required Electric Standards. These requirements must be met under the relevant environmental conditions stated in this Section.

19.2 INTRODUCTION

19.2.1 Relationship with European Standards

Informative: This Section generally references functional requirements and tests described in IEC or BS Standards. However, in some cases there are no standards that adequately cover the unique performance and functional requirements of an electricity supply system. In these instances specific requirements and tests are detailed in this document.

CENELEC document Electronic Equipment for use in Power Installations (EN 50178) gives minimum design and manufacture requirements with which control equipment within the scope of this specification must comply.

This Section specifies those performance requirements that must be met by electronic equipment to be used in National Grid transmission locations.

19.2.2 Guidance to Users

This Section is a generic requirement and therefore when used to specify requirements for equipment to be purchased, this Section must be supplemented by specific requirements relating to the equipment and application concerned. In most cases this will take the form, inter alia, of specifying which optional tests are to be applied and the test levels required for each port. This information will be contained in the corresponding functional specification or the contract documentation as appropriate.

19.3 DEFINITIONS

EUT	Equipment under test.
Port	A particular interface of the specified equipment with the external electromagnetic environment (see Figure 19). For interference immunity tests, the level of test to be applied is specified on a port by port basis.
Enclosure Port	The physical boundary of the equipment which electromagnetic fields may radiate through or impinge on.

19.4 REFERENCES

This Section makes reference to the following related specifications:

ISO 10012-1	Quality Assurance Requirements for measuring equipment. (BS EN 30012-1)

19.5 IEC STANDARDS

IEC 61000-4 series	Electromagnetic Compatibility Part 4:Testing and Measuring Techniques. (BS EN 61000-4- series)
IEC 60255 series	Electrical Relays (BS EN60255 series)
IEC 60068-2-10	Environmental testing. Part 2-10: Test J and guidance: Mould growth (BS 2011-2.1J)
IEC 60068-2-1	Part 2-1: Tests A: Cold (BS 60068-2-1)
IEC 60068-2-2	Part 2-2: Tests B: Dry heat (BS 60068-2-2)
IEC 60068-2-27	Part 2-27: Test Ea and guidance. Shock
IEC 60068-2-29	Part 2-29: Test Eb and guidance. Bump
IEC 60068-2-30	Part 2-20: Test Db and guidance: Damp heat, Cyclic (12+12 hour cycle) (BS 60068-2-30)
IEC 60068-2-31	Part 2-31: Test Ec: Drop and topple, primarily for equipment type specimens (BS 60068-2-31)
IEC 60068-2-42	Part 2-42: Test Kc: Sulphur dioxide test for contact and connections (BS 2011-2.1Kc)
IEC 60068-2-52	Part 2-52: Test Kb: Salt mist, cyclic (sodium chloride solution) (BS 60068-2-52)
IEC 60068-2-56	Part 2-56: and guidance: Damp Heat, Steady State (BS 2011-2.1Cb)
IEC 60068-2-6	Test 2-6: Test Fc and guidance: Vibration (sinusoidal) (BS 60068-2-6)

19.5.1 European Standards

EN 50082-1	Electromagnetic Compatibility – Generic Immunity standard
EN 50178	Electronic Equipment for use in Power Installations
EN 55022	Specification for limits and methods of measurement of radio interference characteristics of information technology equipment
EN 60529	Classification of degrees of protection provided by enclosures (IEC 529)
EN 60870	Telecontrol Equipment and Systems
EN 60870-2-1	Part 2 Operating Conditions Section 1 Power Supply and Electromagnetic Compatibility

ETS 300 132-2	European Telecommunications Standards Institute: Equipment Engineering; Power supply interface at the input to telecommunications equipment; Part 2: Operated by direct current (dc)
ETS 300 386-1	European Telecommunications Standards Institute: Equipment Engineering; Public Telecommunications network equipment Electromagnetic compatibility requirements; Part 1: Product family overview, compliance criteria and test levels

19.6 GENERAL REQUIREMENTS

Informative: Electronic equipment for operational use within National Grid is required to comply with specific environmental performance criteria. This Section sets out the essence of these criteria, with particular emphasis on the testing required. Clause 19.6 General Requirements states these criteria. Clauses 19.7, 19.8, 19.9 and 19.10 Test Requirements, define the tests required to prove that these requirements have been met under various ranges of environmental conditions.

19.6.1 Environment

The equipment shall be subjected to environmental factors such as electrical interference, supply voltage variations, nuclear radiation, dust, vibration, temperature, and salt mist. Where special equipment enclosures are required to satisfy these requirements, the supplier shall define its Degree of Protection by stating its IP Code as given in EN 60529 (IEC 529).

The following clauses define the conditions that the equipment needs to withstand without either the performance being degraded or the life being shortened.

19.6.2 Temperature and Humidity

Equipment shall operate within its functional specification over the range of the specified atmospheric environmental classes, as defined in the Part 4, Section 1 - Table 1, Temperature and Humidity Environmental Classes.

Where any Class 1 or Class 2 item of equipment is to be mounted within an enclosure housing other items of equipment, it shall be capable of normal operation at a temperature 15 °C higher than the upper temperature limit of the environmental class.

The temperature rise above ambient within an enclosure, when the equipment is operating normally, shall not exceed 10 °C.

Equipment which can directly cause the operation of a circuit breaker shall operate within its functional specification over the Class 3 range of the atmospheric environmental classes, as defined in the Part 4, Section 1 - Table 1, Temperature and Humidity Environmental Classes. The additional 15 °C enclosure factor need not apply.

19.6.3 Mechanical

19.6.4 Shock and Vibration

Performance life shall not be affected by the Drop and Topple Test, where specified.

Where specified, equipment shall conform to the requirements of the Vibration Test.

Where responsible for installation, the contractor shall ensure that harmful levels of vibration do not reach the equipment through mountings and external connections.

Protection equipment, or any hardware platform that is specified for use for a protection application, shall conform to the requirements of the shock, bump and seismic tests.

19.6.5 Self-generated Vibration

Equipment shall not generate vibration at a level that could be damaging to its performance or that of other equipment or personnel.

19.6.6 Electrical

The equipment shall meet its specified functional performance under the supply and electrical environmental parameters detailed below.

19.6.7 Interference Immunity

Informative: The interference suffered by a "victim" equipment is dependent not only on the interference levels to which the equipment itself is directly subject but also the levels existing in the areas through which the cables connected to it pass. This concept is defined in BS EN 50082-1 Section 4 and Figure 19 is based on this definition.

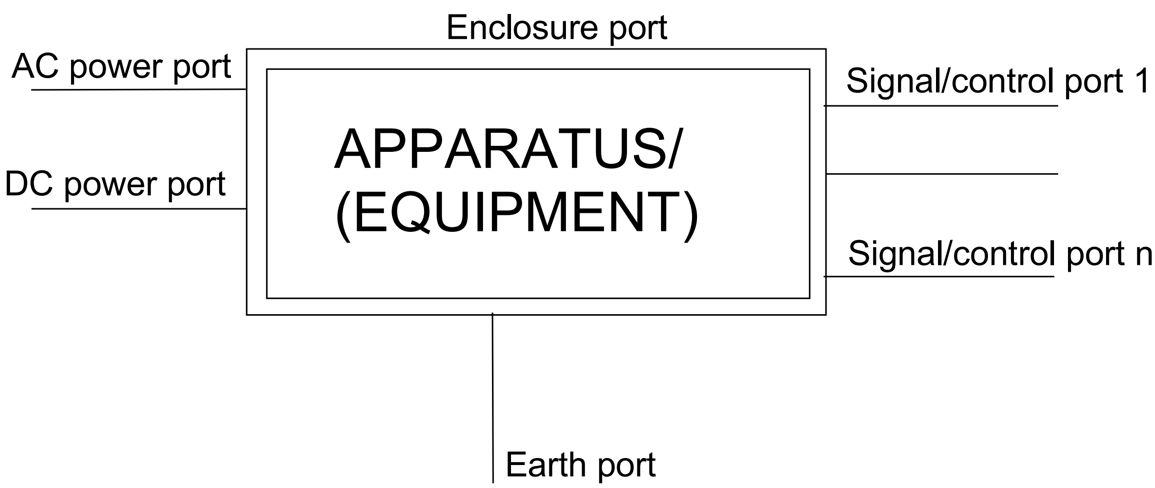


Figure 19 - Definition of Ports

For a given apparatus the test levels to be applied to each of the above ports will depend on the environment to which the port will be subjected. These are defined in Table 29 and Table 30.

Informative: Table 29 to Table , which refer to substation equipment and grid control centre equipment respectively.

19.6.8 Special Installation Measures

Where it is necessary to provide special installation measures, such as earthing or screening to improve interference immunity, details shall be submitted to National Grid for consideration.

Equipment shall operate in the presence of interference generated by portable radios/telephones without maloperation or significant error.

Where it is agreed that equipment may be supplied which does not meet National Grid's requirement for immunity from radio generated interference, then the supplier shall affix a label to the equipment stating this fact. The label shall also specify the minimum distance from the equipment that radio transmitters can safely be operated. The label shall be conspicuous at all times, including maintenance.

19.6.9 Conducted and Radiated Emissions

The level of conducted and radiated emissions produced by the equipment shall be quoted in its specification.

The earthing and cabling arrangements shall not exacerbate any interference caused by the equipment.

19.6.10 Supply Interruptions

Equipment shall be capable of accepting supply interruptions of up to and including 10 ms or otherwise specified without the performance being affected.

No damage shall be caused to the equipment by supply interruptions of any duration, nor shall the equipment respond to an interruption in a manner that could lead to a trip output or cause danger to other plant or personnel.

19.7 GENERAL TEST REQUIREMENTS

Informative: The tests specified in this section are intended to show that the equipment meets the general National Grid requirements for electronic equipment.

Table 25 - National Grid Test Classifications, shows the basic testing classifications for equipment supplied to National Grid. These tests shall be applied to electronic equipment in the manner defined in this document.

Test	Comments
Type	To be carried out on a sample standard production equipment. These may include factory acceptance tests, integration tests, and system tests. These tests are normally carried out by the supplier, but may be witnessed in whole or part by National Grid.
Routine & Sampling	Intended for each item of production equipment, these may include factory acceptance tests, integration tests, and system tests. Some of these tests may be witnessed by National Grid.
Site Pre-commissioning	These tests take place after the equipment has been fully installed.
Energisation	These tests are only applicable to turnkey projects.
Routine Maintenance Testing	These tests are performed during the life of the equipment.

Table 25 - National Grid Test Classifications

19.7.1 General

Informative: If national or international specifications or standards apply to equipment, these may contain different or additional tests. These tests will be taken into account in deciding the testing required for a particular contract.

19.7.2 Test Methods and Equipment

The test equipment and methods shall comply with ISO 10012-1.

19.7.3 Type Testing

Informative: Type tests are intended to show that electronic equipment meets the requirement of its specification.

19.7.4 Pre-test Information Requirements

A complete and detailed schedule of the proposed tests shall be submitted by the contractor and agreed by National Grid in reasonable time prior to their commencement.

19.7.5 Test Schedule

The following information shall be included in the test schedule:

a) A detailed timetable including time and place for all tests.

b) An itemised list of the test equipment to be used, with full performance specification and calibration details.

c) Specific details of the equipment to be tested including a block diagram showing all the ports of the equipment, specification, serial numbers etc.

d) A clear description of the arrangement for each test as applied to the specific equipment, including details of the test methods interconnection diagrams, grouping of i/o (where appropriate), measurements, observations required and Pass/Fail Criteria.

e) The forms on which the test results are to be recorded (see below).

f) A document setting out the procedures to be adopted if the tested item fails to meet its specification.

19.7.6 Test Result Forms

The test result forms shall include the following:

a) Contract reference.

b) Place, time and date of each test.

c) Type and serial numbers of equipment to be tested.

d) Diagram of the intended and actual test configurations.

e) Environmental conditions intended and existing at the time of the test.

f) Name, status, department and company of test engineer and test observers.

g) Parameters to be measured or observed and each measured or observed result.

h) Signature of test engineer and test observers.

i) Statement of whether the equipment has passed or failed the test, and reasons for failure if necessary.

j) Action taken as a result of a test failure.

If during the tests a failure occurs, adjustments are made, the test configuration is changed, alternative instrumentation is used instead of that agreed, the design of the Equipment Under Test (EUT) is changed, or any other change is made which could affect the test results in any way; the fact shall be noted in the test report.

Informative: Depending on the significance of the event or change, National Grid may require the repetition of any or all of the tests.

19.7.7 Reference Conditions

Unless otherwise specified in the appropriate source standard all type tests shall be carried out under the reference conditions quoted in Table 26 - Test Reference Conditions.

Variable	Limits
Ambient temperature	20°C ±2°C
Ambient relative humidity	≤70%
Supply voltage	Normal † ±1%
Supply frequency (for ac equipment)	50 Hz ±0.5% (no significant voltage waveform distortion)

Table 26 - Test Reference Conditions

† Normal may not be the same as nominal. Where normal voltage is not quoted, nominal may be assumed.

19.7.8 Measurement of Equipment Characteristics

Details of the equipment characteristics to be measured during the course of the test shall be given.

19.7.9 Routine and Sampling Testing

Informative: Routine and sampling testing confirms that each item of production equipment has been correctly manufactured and set up. Routine and sampling testing will be called for after a particular design has been type tested. National Grid reserves the right to witness any or all of the tests. Inspection of manufacturing processes and proof of adequate quality control may also be required.

The details of routine and sampling testing shall be agreed between the supplier and National Grid prior to its commencement.

National Grid shall be informed if the production equipment differs in any respect from type tested equipment; repetition of specific type tests may then be required.

Routine and sampling tests are listed in Table 27 - Routine and Sampling Tests. They shall be undertaken in the order given unless otherwise agreed.

Test to be Applied	Conditions
Soak test	Ambient environment and nominal voltage throughout
Dielectric and Insulation Resistance Test	
Performance test	
Visual inspection	
Enclosure tests (sealed equipment only)	

Table 27 - Routine and Sampling Tests

19.7.10 Site Pre-commissioning Testing

Site pre-commissioning testing shall be performed with the equipment correctly installed in its final location.

Details of tests shall be agreed between the supplier and National Grid.

The tests shall demonstrate that:

a) No damage to the equipment has occurred in transit and that it has been properly installed.

b) The equipment is suitable for and functions correctly in its environment.

c) The immunity to electromagnetic interference on site is satisfactory so that the equipment performs to its specification under site conditions.

d) The equipment is correctly earthed.

e) The equipment is capable of performing its specified function when connected to other equipment.

f) The equipment has sufficient range in its variable and interrelated controls.

Site pre-commissioning testing shall include tests from Table 28 - Site Pre-commissioning Tests.

The tests shall include a 72 hour unbroken operational run, after which a performance check shall be carried out.

Test to be Applied	Comment
Visual inspection	When finally installed
Performance tests	At actual site voltage
Supply variation and interruption tests†	With site supplies
Supply changeover tests†	With site supplies
Electrical noise tests†	With site supplies
Soak test	With site supplies

Table 28 - Site Pre-commissioning Tests

† Where site conditions allow.

19.7.11 Description of the Tests Required

Informative: The following clauses give general details of the tests discussed in Clauses: Type Testing, Routine and Sampling Testing, Site Pre-commissioning Testing.

Informative: Particulars of the performance requirements and pass/fail criteria will be included in the individual equipment specification.

19.7.12 Non Maloperation Tests

For Non Maloperation tests the Equipment Under Test (EUT) is required to perform to its specification in all respects while being subjected to the test conditions.

Informative: For some equipment which is not concerned with Control, Protection and other continuous service facilities, it may not be necessary that error free operation continues during primary plant operations.

Equipment for which error-free operation during primary plant operations is not a mandatory requirement shall be identified in the contract documentation (Type Registered List). For this equipment errors will be permitted during tests, however damage must not result and the EUT must revert automatically to error-free operation within 30 seconds of terminating the test without operator intervention.

19.7.13 Protection Equipment

Informative: The IEC 60255 series of Standards are the product specific standards for protection equipment. As such they often contain reference conditions and acceptance criteria specifically designed for protection. Generally the tests and test levels specified in Table 29 are compatible with the IEC 60255 tests. For each test in this specification the appropriate IEC 60255 standard, where it exists, will be indicated.

In the case of protection equipment or any hardware platform that is specified for use for a protection application, the method of application and acceptance criteria for the tests as defined in the appropriate IEC 60255 standard is definitive and shall take precedence.

In the case of protection equipment or any hardware platform that is specified for use for a protection application, the test levels required are stated in Table 29 and Table 30.

19.7.14 Substation Control Equipment

Informative: Substation Control Equipment comes within the scope of the BS EN 60870 series of standards. Specifically BS EN 60870-2-1 covers the power supply and electromagnetic compatibility requirements and BS EN 60870-2-2 defines the environmental requirements. They have been adopted by Cenelec as product family standards for this equipment. Table 29 relates the test levels called up by this Section with those required by BS EN 60870.

19.7.15 Visual Inspections

a) Initial Visual Inspection (Type Test)

The initial visual inspection shall be carried out to ensure that the equipment is of sound construction and appears to satisfy the specified requirements. Features that can be checked at this stage include labelling, maintenance accessibility, safety, correct supply voltages and output ranges.

b) Interim Visual Inspection (Type Test)

Interim visual inspections are carried out during the testing schedule to check that equipment has survived a particular test.

c) Final Visual Inspection (Type Test)

At the end of the test schedule a final visual inspection is required to check whether the test programme has harmed the equipment. Signs of component overheating, loosening of fasteners, damage to insulation and similar effects shall be noted.

d) Visual Inspection (Routine and Sampling Test)

Visual inspection shall be carried out to ensure that equipment complies with the specified requirements. National Grid shall be informed immediately of adverse inspection results, and will decide the action to be taken.

e) Visual Inspection (Site Pre-commissioning Test)

Visual inspections are required to establish that each item of the equipment has been delivered to site without damage.

19.7.16 Performance Tests (Type Test)

Performance tests shall demonstrate that the equipment functions correctly in all performance aspects of its functional specification as defined in the appropriatetechnical requirement.

With digital equipment, complete cycles of operation must be monitored, each cycle exercising each input and output and checking the correct operation of all performance characteristics.

It will be necessary not only to check that outputs change when they should, but also to ensure that they do not change spuriously due to the effects of an influence factor.

The number of performance characteristics checked with digital equipment needs to be assessed carefully to ensure that no aspect of the performance is overlooked; this requirement includes its operation under fault conditions such as operator error, faulty inputs, etc.

Where relevant, the effect of supply interruptions and the start-up/shut-down performance should be checked at various points in the performance cycle of the equipment.

a) Initial Performance (Type Test)

The initial performance type test shall consist of a comprehensive series of tests and observations to demonstrate that the equipment complies with its functional specification.

b) Final Performance (Type Test)

The final performance type test shall consist of a comprehensive series of tests and observations that will enable the current performance of the equipment to be compared with its initial performance.

c) Performance Check (Type Test)

A performance check may be required during and after type tests. It shall take the form of a simplified performance test and is intended to determine the effect a test has had on the operation of the equipment. The test procedures shall be agreed with National Grid.

d) Performance (Routine and Sampling Test)

The routine and sampling testing performance test confirms that the equipment performs its specified functions and is within calibration under normal voltage and environmental conditions.

e) Performance Test (Site Pre-commissioning Test)

The site performance test shall take place with the equipment fully installed and powered from site supplies. Associated plant and equipment must have undergone separate tests before the final site performance test takes place.

19.8 ELECTRICAL ENVIRONMENTAL TESTS

Informative: The tests to be applied are summarised in Table 29 and Table 30, substation equipment and Table , control centre equipment. They are required to establish that the equipment will perform in accordance with its specification in its working environment. The tables specify the levels of the tests to be applied to specific ports of the equipment. The port connections are more fully defined in Table 32 not all the tests will be appropriate to every item of equipment.

Informative: The tests in Table 29 are mandatory while those in Table 30 need only be called up if it is a specific requirement of the contract. However, it should be noted that certain of these tests are required in order to comply with BS EN 60870-2-1 (see Section on Substation Control Equipment). The test descriptions specify whether the equipment is required to function correctly during the test (non-maloperate) or whether the equipment is required to resist the specified test conditions without damage (withstand).

Unless otherwise stated in the appropriate Section for the EUT, equipment, when subjected to the non-maloperate tests, shall perform to specification during and after application of the tests. See also Section on Non Maloperation Tests.

Except where otherwise stated, the method of application for each test shall be as specified in the appropriate source standard as quoted in Table 29, Table 30 and Table 31.

The interference tests are designed to demonstrate that equipment is likely to be compatible with its environment. If specific measures on site are required to achieve the desired degree of immunity, full details of these measures shall be submitted to National Grid for assessment.

Table 29 - Substation Equipment – Port Test Levels – Mandatory Tests

Test	***Reference Information***			**Test Levels**							
	Source Standard	***Nearest Equiv IEC 60255 Standard (Product Standard for Protection)***	***Test and Relevant Levels Called up in EN 60870-2-1***	**Enclosure**	**Local Connections See Table 32 -**	**Cross-site Connections See Table 32 -**	**HV Equipment Connections See Table 32 -**	**Telecomms Connections** **Across Site**	**Telecomms Connections** **Up to 20 metres**	ac Power Supply i/p	dc Power Supply i/p
Electrical Fast Transient/ Burst N = coupling/decoupling network C = capacitive clamp	*IEC 61000-4-4 EN 6100-4-4*	*60255-22-4 Class A*	*61000-4-4 3 2 kV 4 4 kV*	N/A	2 kV, 5 kHz C	4 kV, 2.5 kHz N (for cables for analogue signals: C)	4 kV, 2.5 kHz N (for cables for analogue signals: C)	4 kV, 2.5 kHz C	2 kV, 5 kHz C	4 kV, 2.5 kHz N	4 kV, 2.5 kHz N
Damped Oscillatory Wave C = Common Mode D = Differential Mode	*IEC 61000-4-12 EN 61000-4-12*	*60255-22-1*	*61000-4-1 sic 3-4 2.5 kV*	N/A	N/A	1 MHz 2.5 kV C 1 MHz 1.0 kV D 0.1 MHz 1 kV C 0.1MHz 0.5 kV D	1 MHz 2.5 kV C 1 MHz 1 kV D 0.1MHz 2.5 kV C 0.1MHz 1 kV D	1 MHz 2.5 kV C 1 MHz 1 kV D 0.1MHz 2.5 kV C 0.1MHz 1 kV D See Note 2	N/A	1 MHz 2.5 kV C 1 MHz 1 kV D 0.1MHz 2.5 kV C 0.1 MHz 1 kV D	1 MHz 2.5 kV C 1 MHz 1 kV D 0.1MHz 2.5 kV C 0.1 MHz 1 kV D
Electrostatic Discharge Relay Rooms	*IEC 61000-4-2 EN 61000-4-2*	*60255-22-2*	*61000-4-2 3 6 kV (contact)*	6 kV contact 8 kV Air 6 kV HCP & VCP	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Electrostatic Discharge Substation Control Rooms and Telecomms Rooms	*IEC 61000-4-2 EN 61000-4-2*		*61000-4-2 4 8 kV (contact)*	8 kV contact 15 kV Air 8 kV HCP & VCP	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Radiated Radio Frequency Electromagnetic Field	*IEC 61000-4-3 EN 61000-4-3*	*60255-22-3*	*61000-4-3 3 10 V/m 4 30 V/m*	10 V/m 80% modulated 80 MHz-1GHz plus spot frequencies of 80, 160, 450 and 900 MHz See also 0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Conducted Disturbances Induced by RF Fields	*IEC 61000-4-6 EN 61000-4-6*		*Refers to 61000-4-6 10 VRMS*	N/A	150 kHz - 100 MHz 10 V plus spot frequencies of 27 & 68 MHz	150 kHz - 100 MHz 10 V plus spot frequencies of 27 & 68 MHz	150 kHz – 100 MHz 10 V plus spot frequencies of 27 & 68 MHz	150 kHz - 100 MHz 10 V plus spot frequencies of 27 & 68 MHz	N/A	150 kHz - 100 MHz 10 V plus spot frequencies of 27 & 68 MHz	150 kHz – 100 MHz 10 V plus spot frequencies of 27 & 68 MHz
Surge – Note that this is a non-maloperation test. See Note 1.	*IEC 61000-4-5 EN 61000-4-5*		*61000-4-5 1.2/50 μs 8/20 μs 3 2 kV 4 4 kV*	N/A	1.2/50 μs 1 kV L to E; 0.5 kV L to L Inst Class 2[1]	1.2/50 μs 2 kV L to E; 1 kV L to L Inst Class 3[1]	1.2/50 μs 4 kV L to E; 2 kV L to L Inst Class 4[1]	10/700 μs 4 kV L to E; 2 kV L to L Inst Class 5[1]	N/A	1.2/50 μs 2 kV L to E; 1 kV L to L Inst Class 4[1]	1.2/50 μs 2 kV L to E; 1 kV L to L Inst Class 4[1]

Test	***Reference Information***			**Test Levels**							
	Source Standard	***Nearest Equiv IEC 60255 Standard (Product Standard for Protection)***	***Test and Relevant Levels Called up in EN 60870-2-1***	**Enclosure**	**Local Connections See Table 32 -**	**Cross-site Connections See Table 32 -**	**HV Equipment Connections See Table 32 -**	**Telecomms Connections**		ac Power Supply i/p	dc Power Supply i/p
								Across Site	**Up to 20 metres**		
SMains Frequency Voltage	*EN 60255-22-7 Pending release – see below*	*EN 60255-22-7* *Class A*		N/A	300 V CM & 150 V Differential for 10 sec	300 V CM &150 V Differential for 10 sec	300 V CM & 150 V Differential for 10 sec	300 V CM for 10 sec OR 6A (60255-22-7)	N/A	N/A	300 V CM for 10 sec
Mains Frequency Voltage (levels to be used pending release of IEC 60255-22-7)	*EN 61000-4-16*			N/A	10V continuous\ 100V for 1 sec	30V continuous 300V for 1 sec	30V continuous 300V for 1 sec	30V continuous 300V for 1 sec	N/A	N/A	30V continuous 300V for 1 sec
Voltage Dips, Interruptions and Slow Variations	*IEC 61000-4-11 EN 61000-4-11 (ac supplies only)*		*61000-4-11 1 30% 0.5s & 100%10 ms 2 60%0.5 s & 100%0.5 s*	N/A	N/A	N/A	N/A	N/A	N/A	Interruption: 10 ms, 20, 100, 200, 500, 1000 ms	Interruption: 10 ms, 20, 100, 200, 500, 1000 ms
Supply Variation	*Not yet available*		*No method but classes: dc x (+25-10%) ac x (±15%)*	N/A	N/A	N/A	N/A	N/A	N/A	EUT to operate over range spec'd in 19.5. Pk in-rush ≤ 10x max load zero to pk current.	EUT to operate over range spec'd in 19.5
Dielectric and Insulation Resistance Test – Withstand	*IEC 60255-5 EN not available*		*Ref A.6.1 but no test or level*		See 19.7.18		2 kV for 1 minute	See Sections 0 to 0		2 kV for 1 minute	500 V/2 kV for 1 minute
Conducted and Radiated Emissions	*EN55022*			Class A						Class A	Class A
Note 1: For screened cables the method specified in IEC 61000-4-5 Fig 13 & 14 shall be used at a level to correspond with the installation class shown. Note 2: Applicable only to connections to Power Line Carrier											

Table 30 - Substation Equipment – Port Test Levels – Additional Tests

Test	Reference: Source Standard	Reference: Test and Relevant Levels Called up in EN 60870-2-1	When should test be called up?	Test Levels: Enclosure	Local Connections See Table 32 -	Cross-site Connections See Table 32 -	HV Equipment Connections See Table 32 -	Telecomms Connections: Across Site	Telecomms Connections: Up to 20 metres	ac Power Supply i/p	dc Power Supply i/p
ADDITIONAL TESTS TO BE CALLED UP AS REQUIRED											
Damped Oscillatory Wave – Additional Frequencies C = Common Mode D = Differential Mode	*Based on IEC 61000-4-12.*		See 19.7.17	N/A	N/A	10 MHz 2.5 kV C 10 MHz 1.0 kV D 10 kHz 1 kV C 10 kHz 0.5 kV D	10 MHz 2.5 kV C 10 MHz 1.0 kV D 10 kHz 1 kV C 10 kHz 0.5 kV D	10 MHz 2.5 kV C 10 MHz 1.0 kV D 10 kHz 1 kV C 10 kHz 0.5 kV D	N/A	10 MHz 2.5 kV C 10 MHz 1.0 kV D 10 kHz 1 kV C 10 kHz 0.5 kV D	10 MHz 2.5 kV C 10 MHz 1.0 kV D 10 kHz 1 kV C 10 kHz 0.5 kV D
Power Frequency Magnetic Field	*IEC 61000-4-8* *EN 61000-4-8*	*61000-4-8 continuous/short* *duration* *3 30/300 A/m* *4 100/1k A/m* *(no specific rqrmnt for CRT)*	See 19.7.15	30 A/m continuous 300 A/m for 1 sec 12.8 A/m for display equip	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Pulsed Magnetic Field	*IEC 61000-4-9* *EN 61000-4-9*	*N/A*	See 19.7.16	6.4/16 µs magnetic pulse 1000 A/m	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Damped Oscillatory Magnetic Field	*IEC 61000-4-10* *EN 61000-4-10*	*61000-4-10* *3 30 A/m* *4 100 A/m*	See 19.7.17	0.1 and 1.0 MHz 100 A/m.	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Radiated Electromagnetic Field from Digital Portable Telephones	*ENV 50204 (to be included in IEC 61000-4-3)*	*Not included*	This test is mandatory for any equipment which can directly cause the opening of a circuit breaker. But see 19.7.9	10 V/m 0.9 & 1.89 GHz	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Voltage Dips, Interruptions and Slow Variations	*IEC 61000-4-11* *EN 61000-4-11*	*61000-4-11* *1 30%* & 100% 10ms *2 60%* & *100% .5 s*	See 19.7.4	N/A	N/A	N/A	N/A	N/A	N/A	Dips: 30%: 10 ms & 20 ms 60%: 10, 50, 100, 250, 500 & 1000 ms	N/A
Voltage Dips, Interruptions and Slow Variations	*IEC 61000-4-11* *EN 61000-4-11*	*61000-4-11* *Fast variation* *1 ΔU = ± 8%* *2 ΔU = ± 12%*	This test is mandatory for any equipment which is intended for a protection application	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Ramping from 0% to 100% & 100% to 0% over 1 minute
Conducted Disturbances 15 Hz to 150 kHz	*IEC 61000-4-16* *EN 61000-4-16*	*Not included*	See 19.7.12	N/A	10-1-1-10 V	10-1-1-10 V	10-1-1-10 V	10-1-1-10 V	10-1-1-10 V	10-1-1-10 V	10-1-1-10 V

Table 31 - Grid Control Centre Equipment – Port Test Levels

Test	*Standard Reference*	Test Levels – Reference EN 50082-2			
		Enclosure	Signal Lines and Control Lines	ac Power Supply i/p	dc Power Supply i/p
Electrical Fast Transient/ Burst n = coupling/decoupling network, c = capacitive clamp	IEC 61000-4-4	N/A	0.5 kV, 5 kHz C	1 kV 5 kHz N	0.5 kV, 5 kHz N
Electrostatic Discharge	IEC 61000-4-2	4 kV contact 8 kV Air 4 kV HCP & VCP	N/A	N/A	N/A
Radiated Electromagnetic Field	IEC 61000-4-3	3 V/m 80% modulated 80 MHz-1 GHz	N/A	N/A	N/A
Conducted Disturbances	IEC 61000-4-6	N/A	150 kHz-100 MHz 3 V	150 kHz-100 MHz 3 V	150 kHz-100 MHz 3 V
Surge – Note that this is a non-maloperation test	IEC 61000-4-5	N/A	1.2/50 µs 2 kV common 1 kV diff	1.2/50 µs 4 kV common 2 kV diff	1.2/50 µs 500 V common and diff modes
Power Frequency Magnetic Field	IEC 61000-4-8	3 A/m CRT display interference allowed	N/A	N/A	N/A

Table 32 - Port Environment Definition

Name	**Environment/Source of Cable Connected to Port**
Remote:	Equipment and connections to it, located in a benign electromagnetic environment e.g. Grid Control Centre – See Table 31
Local:	Connected to cables running in moderate electromagnetic environments which are of relatively short length (no more than twenty metres) and are related to communications in the same building
Cross-site:	Connected to cables which are intended to be connected to the low voltage control/controlled equipment of the plant within the same earth network
HV a)quipment	Connected to cables which are connected to HV equipment such as circuit breakers, CTs, VTs, power line carrier or trip relays
Telecomms Across Site	Control, Protection and other continuous service facilities are required to continue operating, error-free throughout the duration of the test. Other facilities may maloperate but must resume error-free operation automatically within 30 seconds of terminating the test
Telecomms up to 20 metres	
ac Power Supply i/p	Supplied from normal site 230 V (ac) mains
dc Power Supply i/p	Supplied from site dc supply (normally 48 or 110 V)

19.8.1 Surge – Non-maloperate (Type Test)

Informative: The test is to be applied in accordance with IEC 61000-4-5 (BS EN 61000-4-5) including increasing test levels, application at various points on the voltage waveform etc. The impulse waveform is an aperiodic transient voltage without appreciable oscillations. There are two versions, the first, having a 1.2 μs risetime and an exponential decay to half amplitude of 50 μs (1.2/50 μs) is used on power supply inputs and all isolated i/o. The second version is for telecommunications connections across site which should be tested with a 10/700 μs version of the waveform.

Informative: The source impedance of the test equipment should be selected in accordance with the standard.

Informative: The test is to be applied both line to line and line to earth at levels as defined in Table 29, Table 30 and Table 31.

Informative: Where a large number of identical interface circuits are used, this test may be restricted to a representative sample, as agreed by National Grid's test observer.

19.8.2 Supply Variation – Non-maloperate (Type Test)

The performance of the equipment shall be checked over the full range of the supply voltage as specified. See clause 19.5.6.

The supply voltage shall be slowly and smoothly varied over the full supply voltage range.

Informative: Normally a gradual sweep over the range from minimum to maximum voltage for a period of one minute would suffice.

In the case of equipment that has two alternative sources of supply, the procedure in the 19.5.6 shall be followed with the other supply at each of its extreme values in turn.

Throughout these tests the equipment shall function in accordance with its specification.

A record shall be made of the maximum wattage and VA of the equipment when operating at normal voltage and frequency.

19.8.3 Voltage Dips, Interruptions and Slow Variations – Non-maloperate (Type Test)

19.8.4 Alternating Current Mains Powered Equipment

For ac mains powered equipment the following tests shall be carried out at the periods given and in accordance with IEC 61000-4-11.

The voltage dips and short interruption test shall be carried out in accordance with Table 1 of the standard at the 0% (ie 100% dip) test level for the durations listed in Table 29.

For equipment containing electro-mechanical devices such as disc drives, the 40% and 70% level tests (ie 60% and 30% dips) shall also be applied as in Table 1 of the standard for the periods listed in Table .

For the above “Voltage Dips, Interruptions and Slow Variations” tests two sets of Pass/Fail Criteria shall apply:

a) The EUT shall be required to operate without suffering any maloperation (ie perform entirely to specification) up to a predefined maximum test level/duration. This level/duration shall normally be 0 % / 10 ms unless otherwise stated in the contract documentation.

b) Beyond this level/duration and up to the maximum as defined in Table 29, Table 30 and Table 31, the EUT may maloperate but must recover spontaneously after the test and must not have suffered any permanent or temporary deleterious effect nor behaved in a manner which could have led to a trip output being generated.

Protection equipment shall not cause an unwanted trip output to be generated during, and shall operate satisfactorily following, the gradual ramping up and down from 0% to 100% and 100% to 0% of nominal supply voltage over a ramp period of one minute.

If the EUT is always to be used on a supply supported by a UPS these tests may be omitted. However this restriction must be stated on the Type Registration Documentation for the EUT.

19.8.5 Direct Current Powered Equipment

For dc powered equipment the following shall be carried out:

The supply to the EUT shall be interrupted three times at random for periods of 10, 20, 100, 200, 500 and 1000 ms. The combinations of the periods to be used will be related to the integrity required of the equipment when it operates within its working environment.

The minimum interval between interruptions shall be three times the period of the interruption.

For interruptions of 100 ms and above at least one minimum interval shall occur in the sequence.

The tests shall cover all modes of equipment operation.

The pass/fail criteria requirements as stated above shall apply.

19.8.6 Electrical Fast Transient/Burst – Non-maloperate (Type Test)

Informative: The test is intended to simulate the effects of transient disturbances such as those originating from switching transients (interruption of inductive loads, relay bounce etc).

The test shall be carried out in accordance with IEC 61000-4-4 and the levels to be applied to the various ports are defined in Table 29, Table 30 and Table 31.

Informative: Where the EUT has a large number of identical interface circuits, the test may be restricted to an agreed sample.

19.8.7 Damped Oscillatory Wave – Non-maloperate (Type Test)

Informative: This test is intended to simulate the effects of switching with restrike of the arc (eg disconnector operation).

The tests are to be applied in accordance with IEC 61000-4-12.

Informative: Where the EUT has a large number of identical interface circuits, the test may be restricted to an agreed sample.

The 100 kHz and 1 MHz damped oscillatory wave test is to be applied at levels and to ports as defined in Table 29 and Table 30.

Informative: It is understood that IEC 61000-4-12 may be modified to include versions of the test at other base frequencies. National Grid has evidence that 10 kHz and 10 MHz versions of this interference are often present in the interference emanating from primary plant (10 kHz in the case of AIS circuit breakers; 10 MHz from GIS disconnectors and circuit breakers and some AIS disconnectors).

When suitable test equipment is available the damped oscillatory wave test shall be extended to include the 10 kHz and 10 MHz versions of these tests.

19.8.8 Electrostatic Discharge – Non-maloperate (Type Test)

Informative: This test is particularly relevant as it simulates the effect of large transient currents flowing adjacent to susceptible equipment or in the casing of the equipment. Such common mode phenomena can occur in substations as a result of the operations of primary plant. For the substation environment therefore, the test should not just be regarded as a test that measures the susceptibility to discharges from personnel and furniture but as a test which gives an effective indication of the likely susceptibility of the equipment to the substation environment.

The test is based on IEC 61000-4-2. The level to be applied is dependent upon the environment in which the equipment is intended to be installed (see Table 29) and is to be applied while the EUT is energised.

The test shall be undertaken on fully installed items of equipment, within their enclosures.

The test is to be applied to all points which are accessible during normal use.

The test is also to be applied to all points which are accessible during maintenance by the user unless use of electrostatic precautions are provided for and mandated by an appropriate notice on the equipment.

Testing is to be carried out in accordance with the standard including the use of horizontal and vertical coupling planes where applicable.

The test voltage shall be increased from the minimum to the selected test level.

19.8.9 Radiated Radio Frequency Electromagnetic Field – Non-maloperate (Type and Site Pre-commissioning Test)

Informative: The objective of this test is to evaluate the performance of the equipment when subjected to electromagnetic fields, primarily the transient fields generated by electricity supply plant but also the permanent fields generated by portable and base station radio transceivers.

Informative: As the test applies the interference as a swept frequency its effectiveness in simulating the transient interference from primary plant is limited. However this is the only standard radiated interference test which is available from the majority of test houses.

The performance of the EUT shall be monitored throughout the test.

The frequency range to be covered shall be 80 MHz to 1 GHz which is chosen to complement (and slightly overlap) that covered by the Conducted Disturbances test (q.v.).

Informative: The standard test as defined in BS EN 61000-4-3 covers frequencies up to 1 GHz, modern digital cellular telephones (particularly the proposed Universal Mobile Telephone System) extend up to 2.2 GHz.

When assessing equipment for use in substations in the vicinity of a base station or where uninhibited use of mobile 'phones is allowed, a sweep test at 10 V/m from 1.7 to 2.2 GHz should be carried out in addition to the standard range of 80 MHz to 1.0 GHz.

The immunity to RFI is tested while the equipment is in its normal operating state with covers in place, and also with its covers removed for maintenance.

The testing shall be with the normal supply, input and output leads intended for the equipment.

The tests shall be conducted by persons experienced in the techniques involved and shall be carried out in a shielded room.

The test method shall be the radiating antenna method detailed in BS EN 61000-4-3 but with test limits as defined in Table 29, Table 30 and Table 31.

The sweep rate shall be as specified in BS EN 61000-4-3, except that for digital equipment the rate shall be such that the EUT can perform 10 full operational cycles per octave.

At certain spot frequencies the EUT shall be required to carry out two full operational cycles. These spot frequencies shall be 80, 160, 450 and 900 MHz.

The addition of a further spot frequency test at 1.89 GHz will obviate the requirement to carry out the "Radiated Magnetic Field from Digital Portable Telephones Test"

An operational cycle shall include at least one transition of the EUT from one operational state to another.

Informative: For example for protection equipment an operational cycle would include detecting a (simulated) fault condition and generating a trip output.

If the equipment is mounted in cubicles, the tests shall be conducted with the antenna in line with the centre of the back and then the front of the cubicle.

The testing shall initially be conducted with the cubicle doors open. If the equipment proves to be affected by RFI, the testing shall be repeated with the doors closed. If equipment in a cubicle is susceptible to RFI when the cubicle doors are open, a label shall be affixed to the cubicle warning that radio transmitters should not be operated near the cubicle when the doors are open.

The tests shall be conducted with the antenna in line with various faces of the equipment.

When an item of equipment is found to be susceptible to RFI, a note shall be made of the reduction of field strength which is required to reduce the susceptibility to acceptable limits. This need only be done at the most sensitive frequency.

19.8.10 Conducted Disturbances Induced by RF Fields – Non-maloperate (Type Test)

Informative: This purpose of this test is to determine the immunity of the EUT to electromagnetic fields which act on the cables connected to the EUT.

The test is to be applied in accordance with IEC 61000-4-6.

The frequency range shall be by agreement but shall normally be 150 kHz to 100 MHz. The test is to be applied at levels and to ports as defined in Table 29, Table 30 and Table 31.

The sweep rate shall be as specified in BS EN 61000-4-6, except that for digital equipment the rate shall be such that the EUT can perform 10 full operational cycles per octave.

At certain spot frequencies the EUT shall be required to carry out two full operational cycles. These spot frequencies shall be 27 and 68 MHz.

An operational cycle shall include at least one transition of the EUT from one operational state to another.

Informative: For example for protection equipment an operational cycle would include detecting a (simulated) fault condition and generating a trip output.

For equipment having a keyboard, mouse or similar manual interface unit, the test shall be carried out with and without an "artificial hand" as specified in IEC 61000-4-6

19.8.11 Mains Frequency Voltage

Informative: This test is intended to simulate the effect of an earth fault in the substation and to verify that the system is immune to any picked up mains frequency interference during non-fault conditions. The test method required is that specified in IEC 60255-22-7 which is currently in draft Ed.1. This standard is based on EN 61000-4-16 but includes a differential mode test, a current mode test for communication lines and uses different coupling capacitors and test voltages.

A test shall be applied to demonstrate that the EUT does not maloperate when a 50 Hz voltage (in phase with the equipment supply for ac powered equipment) is applied via a capacitor.

The method as specified in EN 60255-22-7 shall be used using test levels as specified in Table 29 and Table

The method of application shall be one of those illustrated in Figures 2 to 5 of EN 60255-22-7, selected to suit the type of port being tested.

It should be noted that this test is not applicable to circuits for which 50 Hz inputs are normal. Where the EUT has a large number of identical interface circuits, the test may be restricted to an agreed sample.

The test shall normally be restricted to 50 Hz unless additional frequencies are called up as a specific requirement of the contract. Note that this would normally be appropriate for equipment which is to be used in the proximity of power electronic equipment such as Static VAR Compensators.

In the interim period, before IEC 60255-22-7 is formally issued, the method as specified in EN 1000-4-16 shall be used unless otherwise agreed with National Grid. The required test levels are defined in Table 29.

19.8.12 Conducted Disturbance 15Hz to 150 kHz

Informative: This test simulates the effect of conducted disturbances which may be generated by power electronic equipment.

The test shall be carried out in accordance with IEC 61000-4-16 using the test profile as defined in Table 3 of that standard.

Application of the test should be considered for equipment to be installed on sites incorporating power electronics e.g. SVCs.

19.8.13 Conducted and Radiated Emissions (Type Test)

Informative: This test is intended to ensure that the EUT does not generate emissions at a level that could cause other equipment to maloperate.

A conducted and radiated emissions test shall be carried out to check that the equipment meets the requirements of EN 55022 (BS 6527). Normally the acceptable limits shall be taken as those applicable to Class A equipment.

In the specific case where equipment is to be powered from a 48 V (dc) communication supply, self generated interference requirements are described by ETSI (European Telecommunication Standards Institute) standards ETS 300 132-2 , and ETS 300 386-1 as follows:

a) Conducted emissions 25 Hz to 20 kHz ETS 300 132-2 Section 4.9

b) Conducted emissions 0.02 – 30 MHz ETS 300 386-1 Section 7.2.3

19.8.14 Inrush Current (Type Test)

Informative: Measurement of the inrush current shall preferably be made using a Hall effect current clamp having a frequency response up to at least 3 kHz. Alternatively, the current may be measured using a low value series resistor, such that at peak current the voltage across it does not exceed 5% of the supply voltage.

Informative: The tests shall be performed with the equipment operating under conditions of maximum power consumption.

Informative: An interval of several minutes shall be allowed to elapse between each test.

Informative: Every effort shall be made to ensure that the supply source impedance does not significantly limit the inrush current.

Informative: The current waveform shall be recorded after switch-on until it has reached a steady value, and a note shall be made on the trace of the points where peak and zero values of the waveform occur. For ac supplies, not less than ten measurements shall be recorded.

19.8.15 Power Frequency Magnetic Field Immunity – Non-maloperate (Type Test)

Informative: This test would normally only be applied to equipment which utilises an electron beam (eg Cathode Ray Tube Monitors, Electron Microscopes etc) or to certain measuring instruments. However the test is also called up in EN 60870-2-1 and is therefore available as an additional test for other equipment at levels as specified in Table 30.

The test shall be carried out in accordance with IEC 61000-4-8 in all three planes of the EUT.

The continuous and short duration tests shall be applied to equipment which is to be located within 5 metres of any grid transformer. The test levels are specified in Table 30.

For CRT monitors for use in a substation the level is specified in Table 30. No visible effect shall result at this level and below (Class 1 results as specified in IEC 61000-4-8).

19.8.16 Pulsed Magnetic Field – Non-maloperate (Type Test)

Informative: This test simulates the magnetic field generated by a) lightning strokes, b) initial fault transients and c) the switching of HV busbars and lines by circuit breakers. Research carried out for National Grid has concluded that the test is of most relevance in the case of a) above.

The test shall be carried out in accordance with IEC 61000-4-9 at test levels as specified in Table 30.

The Pulsed Magnetic Field test shall be applied to equipment which can directly cause the opening of a circuit breaker and is to be positioned in a high lightning risk area.

19.8.17 Damped Oscillatory Magnetic Field – Non-maloperate (Type Test)

Informative: Damped Oscillatory Magnetic Fields are generated by the switching of HV busbars by disconnectors. The test as specified in IEC 61000-4-10 requires oscillatory waves of 0.1 and 1.0 MHz. National Grid has evidence that 10 kHz and 10 MHz versions of this waveform are also often present in the spectrum of the interference emanating from primary plant (10 kHz in the case of AIS circuit breakers; 10 MHz from GIS disconnectors and circuit breakers and some AIS disconnectors). The field is confined to the vicinity of the current breaking device.

The Damped Oscillatory Magnetic Field test is required for equipment located within 10 metres of circuit breakers or disconnectors. When test equipment is available the test is also to be applied at 10 kHz and 10 MHz in addition to the 0.1 and 1.0 MHz specified in the standard. The test levels are specified in Table .

19.8.18 Dielectric and Insulation Resistance – Withstand (Type, Routine and Sample Test)

Informative: The objective of these tests which are based on IEC 60255-5 is to prove the integrity of the insulation and isolation between each circuit and exposed conductive parts (including earth) and between independent circuits. The tests involve the measurement of insulation resistance and the application of a dielectric withstand test as described below.

The type test is only to be applied to isolation and safety barriers.

Other items (eg PSUs) are to be tested during the manufacturing process (routine and sample) before filters, over-voltage protection devices etc are installed. In this case, for type registration, evidence must be produced that the power supply unit conforms with, for example, IEC 478 Stabilised Power Supplies – (dc) Output.

For circuits operating at voltages of 110 V (ac) or (dc) and above, or where a circuit is energised via an instrument transformer, a dielectric withstand test of 2 kV (ac) and an insulation resistance test of 500 V (dc) shall be performed.

For circuits operated at voltages below 110 V (ac) or (dc) but above 55 V (ac) or (dc), a dielectric withstand test of 1 kV (ac) and an insulation resistance test of 500 V (dc) shall be performed.

For circuits operated at voltages of 55 V (ac) or (dc) and below, the test shall be restricted to an insulation resistance test of 500 V (dc) which shall also act as a dielectric withstand test.

When testing between circuits which have different operating voltages the test level shall be determined by the circuit with the higher operating voltage.

The dielectric withstand test voltage source shall be as described in IEC 60255-5 Clause 6.3 and be applied as detailed in IEC 60255-5 Clause 6.4.

During the dielectric test, no breakdown or flashover shall occur.

The insulation resistance test shall be applied as detailed in IEC 60255-5 Clause 7.2. The resistance values should generally exceed 100 MΩ, (or 20 MΩ where a number of circuits are involved, e.g. equipment handling a number of inputs and outputs).

The complete procedure is as follows:

For all equipment, the following tests shall be applied to the terminals of circuits listed as a-f below.
(i) The insulation resistance shall be measured at a voltage of 500 V (dc) and the insulation resistance shall be noted and shall exceed 100 MΩ, or 20 MΩ where a number of circuits are involved.

If the operating voltage is equal to or less than 55 V (ac) or (dc) the test detailed in (i) also functions as a dielectric test

End of Test

If the operating voltage is equal to or above 110 V(ac) or(dc) or the circuit is energised via an instrument transformer a dielectric withstand test shall be applied:

(ii) A voltage of 2 kV (ac) shall be applied for 1 minute. No breakdown or flashover shall occur.

If the operating voltage is less than 110 V (ac) or (dc) but above 55 V (ac) or (dc) the above voltage shall be reduced to 1 kV.

(iii) Repeat test (i)

The resistance shall be noted and must not be more than 50% lower than the value measured in (i)

End of Test

Tests shall be applied between the following terminals:

a) Each isolated input to exposed conductive parts, including earth.

b) Each isolated input to all other inputs connected together.

c) Each isolated output to exposed conductive parts, including earth.

d) Each isolated output to all other outputs connected together.

e) All isolated inputs connected together to all isolated outputs connected together.

f) The power supply to all isolated inputs, isolated outputs, and exposed conductive parts, including earth.

19.8.19 Electrical Supply Variation and Interruption – Non-maloperate (Site Pre-commissioning Test)

Where variable supply conditions exist on site, the equipment shall be tested over the full range of change, site conditions permitting.

19.8.20 Supply Changeover (Site Pre-commissioning Test)

Where supply interruptions can occur on site due to changeover, the installed equipment shall be tested to demonstrate its compatibility with the changeover requirements.

19.8.21 Electrical Noise (Site Pre-commissioning Test)

Equipment may be required to undergo noise tests on site. The tests may involve the operation of high voltage switchgear and/or a special injection test.

19.9 ATMOSPHERIC ENVIRONMENTAL TESTS

19.9.1 Dry Heat – Non-maloperate (Type Test)

The dry heat test shall be carried out on individual subunits, units and, where applicable, on the complete equipment or assembly, with all doors and covers being in place and closed as in normal operation.

Test conditions shall be in accordance with IEC 68-2-2 (EN 60068-2-2), test Bd at the upper temperature of the Environmental Class (±2ºC, RH ≤ 60%)

For Class 1 or Class 2 equipment which is to be used in a cabinet not included in the EUT, the test shall be carried out at 15 ºC above the Class temperature.

The EUT shall operate continuously during the test.

The duration of the test would normally be 16 hours (excluding acclimatisation time) except for equipment which can directly cause the opening or closing of a circuit breaker which shall be subjected to either 55 ºC for 96 hours or 70 ºC for 16 hours. (The additional 15 °C enclosure factor need not be applied).

Performance checks shall be made at least three times at regular periods while at the test temperature and repeated when the equipment has returned to ambient temperature.

19.9.2 Low Temperature – Non-maloperate (Type Test)

The low temperature test shall be carried out on individual subunits, units and, where applicable, on the complete equipment or assembly, with all doors and covers being in place and closed as in normal operation.

Test conditions shall be in accordance with IEC 68-2-1 (EN 60068-2-2), test Ad at the lower temperature of the Environmental Class (±2ºC, RH ≤ 60%.

The EUT shall operate continuously during the test.

The duration of the test would normally be 16 hours (excluding acclimatisation time) except for equipment which can directly cause the opening or closing of a circuit breaker which shall be subjected to either -10ºC for 96 hours or -25ºC for 16 hours.

Performance checks shall be made at least three times at regular periods while at the test temperature and repeated when the equipment has returned to ambient temperature.

19.9.3 Damp Heat – Non-maloperate (Type Test)

This test is undertaken on complete items of equipment in their normal operational mode. The test is based on IEC 68-2-56 (BS 2011-2.1Cb) Test BC which is designed to avoid the formation of condensation on the EUT. The following conditions shall apply:

a) The test duration shall be 2 days except where noted below and unless a longer period is specified.

b) The test conditions shall be 40 ±2 ºC with 93 ±3% RH; except for equipment which can directly cause the opening or closing of a circuit breaker which shall be subjected to either IEC 68-2-3 at 40 ±2 ºC with 93 ±3% RH for 56 days, or IEC 68-2-30 for 6 times 24 hour cycles of + 25 ºC to +55 ºC with 93 ±3% RH.

c) The initial performance check shall be made with the equipment under ambient conditions in the test chamber. In the case of tests to IEC 68-2-56, the equipment shall be switched off on completion of this check.

d) In the case of tests to IEC 68-2-56 after test conditions have been achieved, the equipment shall be re-energised two hours before test conditions are allowed to alter and a further performance check carried out during the last hour at the elevated temperature and humidity. The equipment shall remain energised for the remainder of the test.

e) Single chamber controlled recovery conditions shall be applied, after which the final performance check shall be made.

19.9.4 Storage Temperature Test – Withstand (Type Test)

Unless otherwise agreed, all electronic equipment shall be subjected to a withstand test to simulate the extreme temperature ranges which can be encountered during storage and transportation.

The equipment shall be subjected to a low temperature test in accordance with IEC 68-2-1 at -25ºC for 96 hours or -40ºC for 16 hours. The EUT shall also be subjected to a high temperature test according to IEC 68-2-2 at 70ºC for 96 hours.

After ambient conditions are re-established a Performance Check shall be performed.

19.9.5 Enclosure (Type Test)

Unless otherwise agreed, tests shall be undertaken to confirm that the degree of protection provided by the enclosure of the equipment is as required. The appropriate enclosure classifications for the degree of protection (IP) are given in IEC 529.

Where the size of the enclosure is such that there is difficulty in carrying out the tests as specified, alternative test procedures may be adopted with the agreement of National Grid.

19.9.6 Salt Corrosion (Type Test)

When required the salt corrosion test shall be carried out in accordance with IEC 68-2-52 Test Kb (BS 2011 2.1Kb), Severity 1. At the end of the test there shall be no undue deterioration of metal parts, finishes, and materials.

The equipment shall be subjected to a performance check at the end of the recovery period.

19.9.7 Humidity Cycling (Type Test)

Where required this test shall be carried out on an agreed number of samples of components, materials or finishes not already registered, or about which the effects of humidity are unknown.

The test shall be carried out in accordance with IEC 68-2-30 Test Db (BS 2011-2.1Db) with the following conditions:

a) The upper temperature shall be 40 ºC.

b) The number of cycles shall be 12.

c) During the temperature-fall period condensation shall occur.

d) Immediately after the end of the test the components or equipment shall be visually examined; there shall be no undue deterioration or corrosion and there shall be no significant change of electrical or mechanical characteristics.

19.9.8 Mould Growth (Type Test)

Informative: The test may be required on samples of components, materials and finishes where their resistance to mould growth is unknown or suspect.

If required, the test shall be carried out in accordance with IEC 68-2-10 Test 2.1J (BS 2011-2.1J).

After 28 days, the sample shall be examined and no mould growth shall be apparent to the naked eye, nor shall there be any significant change of electrical characteristics.

19.9.9 Industrial Atmosphere (Type Test)

Informative: This test may be required on samples of components, materials and finishes where they are not already registered or are of unknown performance.

The test shall be carried out in accordance with IEC 68-2-42 Test Kc. The duration of the test will be 4, 10 or 21 days.

At the conclusion of the test there shall be no evidence of deterioration or corrosion, and tests shall be carried out to establish that there has been no significant change of electrical characteristics.

19.9.10 Soak Test

a) Soak – Non-maloperate (Type Test)

Equipment shall normally be set up to simulate normal operating conditions and allowed to operate continuously for a minimum period of 100 hours. By agreement, this period may be broken down into shorter periods if compatible with the function of the equipment.

During the test, measurements and observations shall be made to demonstrate that the equipment fulfils its functional requirement, has adequate stability, and is capable of operating without frequent attention. The extent of performance monitoring required will depend upon the nature of the EUT.

If any failures occur or adjustments are made, full details shall be recorded for National Grid, who will decide whether the test may be restarted or shall be repeated.

b) Soak – Non-maloperate (Routine & Sample Test)

The equipment shall be powered for a period of at least 100 hours. The input and output conditions and the function performed throughout this period shall, unless otherwise agreed, be determined by the manufacturer.

As one of the main functions of the test is to ‘burn in' the components, the test should if possible exercise all components.

c) Soak – Non-maloperate (Site Pre-commissioning Test)

Informative: Where it is required, the details of this test will be specified.

19.10 MECHANICAL TESTS

19.10.1 Drop and Topple (Type Test)

Informative: This test is for portable equipment, and units and sub-assemblies only. It is not intended that it be carried out on complete racks of equipment. The test is intended to reveal any weakness of assembly and to ensure that the component mountings are of adequate strength. It is not intended to check whether glass items, meters or similar items will break, therefore they may be removed before the test.

Covers which have to be removed for servicing shall be removed after this test to inspect the equipment for damage. The equipment shall not be deemed to have failed the test if externally accessible components such as control knobs or connectors are damaged. Where agreed, some form of guard may be fitted to prevent such damage.

This test shall be carried out in accordance with IEC 68-2-31 Test Ec (BS 2011-2.1Ec). The test will vary depending on the relative dimensions of the equipment.

a) If the height is the smallest dimension, the equipment shall be dropped on the four edges of the base, in accordance with Clause 3.2.1 of IEC 68-2-31, from a distance of 50 mm.

b) If the height is the second largest dimension, the equipment shall be subjected to the topple or pushover test as described in Clause 3.2.3 of IEC 68-2-3, but be toppled about the two longer bottom edges only.

c) If the height is the largest dimension, the test shall be as detailed in b) above, except that the equipment shall be toppled about each bottom edge.

19.10.2 Vibration (Type Test)

Informative: The vibration test is intended to reveal any part or components of the equipment which may be prone to any resonance severe enough to cause possible damage or maloperation. It is not intended to be carried out on complete racks of equipment, but on units and sub-units only.

The test shall be carried out in accordance with IEC 68-2-6. The EUT shall be subjected to the vibration response test at severity class 1 and the vibration withstand test at severity class 1.These test levels are defined in the related standard EN 60255-21-1.

As far as possible, the equipment shall be mounted on its normal fixings and the vibrations shall be applied along each axis in turn. If necessary, to observe otherwise obscured parts, equipment sub-assemblies may also be tested. Equipment may be required to undergo a performance check while being subjected to a sweep frequency test.

When a resonance is detected, a search shall be made on either side of the resonant frequency so that the effects of the resonance may be assessed.

Any resonances liable to affect the performance or reliability of the equipment shall be reduced to an acceptable level by suitable modifications, and the test repeated.

19.10.3 Shock (Type Test)

A shock test shall be carried out in accordance with IEC 68-2-27. The EUT shall be subjected to the shock response test at severity class 1 and the shock withstand test at severity class 1. These test levels are defined in the related standard EN 60255-21-2.

19.10.4 Bump (Type Test)

A bump test shall be carried out in accordance with IEC68-2-29. The EUT shall be subjected to the bump test at severity class 1. These test levels are defined in the related standard EN 60255-21-2.

19.10.5 Seismic (Type Test)

A seismic test at severity class 1 shall be carried out in accordance with EN 60255-21-3.

20 SECTION 17 - GAS INSULATED SWITCHGEAR

20.1 PURPOSE AND SCOPE

This document defines the functional and performance requirements for gas-insulated switchgear (GIS) for use on the GB Transmission System. It supports the more general requirements defined in Part 4, Sections 1,2 and 3.

In addition to busbars and connectors, GIS includes individual components for which separate standards and specifications apply. This document complements the requirements for these components specified in the relevant standards and specifications.

20.2 GENERAL REQUIREMENTS

Gas-insulated switchgear (GIS) shall comply with IEC 62271-203

Pressurised gas-filled enclosures shall comply with the following CENELEC standards:

EN 50-052
EN 50-064
BS EN 50-068
BS EN 50-069

Cast resin partitions shall comply with CENELEC Standard EN 50-089.

20.2.1 Outage Constraints

The design of the equipment shall allow the outage constraint requirements of Part 4, Section 2 to be met. It shall be possible to perform foreseeable activities including maintenance (including replacement of any enclosure and any necessary dismantling of equipment), circuit breaker timing, primary injection tests on CTs and the construction and testing of substation extensions while meeting the above requirements. It shall be possible to perform such activities without the need to work adjacent to a gas compartment partition when pressurised on one side. The supplier shall demonstrate by means of gas zone diagrams or otherwise, how compliance with the outage constraint requirements of Part 4, Section 2 can be achieved.

20.2.2 Earthing Switches

Earthing switches of class E1 as defined in IEC 62271-102 shall be provided on the circuit side of each line disconnector and at one position on each section of busbar.

Earthing switches installed at positions where the only means of dissipating trapped charge is by closing the earthing switch shall be capable of remote operation.

Informative: This is where a de-energised section of GIS cannot be connected to any of the following: Power transformer/shunt reactor winding; electromagnetic VT on all three phases or external air insulated equipment (bushings, etc).

20.2.3 Portable Maintenance Earthing Devices

Provision shall be made for fitting portable maintenance earthing devices (PMEDs) where these are required to permit maintenance/testing as follows:

a) To allow an earthing switch that would normally be the point of earthing to be itself maintained.

b) To earth cable terminations where disconnecting facilities are provided for cable testing.

c) To provide an earth connection where a section of busbar is removed.

d) To provide an earth connection visible from the point of work.

The positions on the GIS at which PMEDs may be fitted shall be clearly identified by painting in a conspicuous colour/pattern or other means of equivalent durability.

The PMEDs shall be clearly visible when applied by painting in a conspicuous colour/pattern or other means of equivalent durability.

20.2.4 SF6 Gas Service Connections

The gas service connection for each gas compartment shall be readily accessible without the use of special access equipment.

A schematic diagram shall be provided showing the gas compartments within a bay and their relationship to the primary plant of that circuit or busbar section.

Filling points shall be fitted with self-sealing valves.

A lockable arrangement to prevent unauthorised operation of the gas service valves shall be provided at each filling point.

20.2.5 Pressure/Density Indication

A permanently installed system for monitoring the gas pressure or density in each compartment shall be provided.

The system shall provide a visual indication of the gas pressure or density in each gas compartment.

The system shall be capable of initiating gas density alarms at user configurable trigger levels.

The system shall be capable of detecting a gas loss equivalent to 0.5 % of the gas compartment volume per annum or shall provide trend analysis facilities.

It shall be possible to replace a pressure or density sensor without taking the GIS out of service.

20.2.6 SF6 Gas Alarm Scheme

Provision shall be made for connection of each gas density alarm to the substation alarm scheme.

Facilities shall be provided to allow temporary blocking of the density alarm signals from an individual gas compartment so that grouped alarms are not initiated.

Informative: The objective is to ensure that, during maintenance of primary equipment, standing common alarms do not mask genuine SF6 density alarms from in-service equipment. This is particularly important where a disconnector gas compartment forming the 'point of isolation' for work would normally initiate the same common SF6 density alarm as the compartment that has been opened for maintenance.

The grouping of 'low' alarms at the normal substation control point shall be such that the section of the substation that requires isolation from the system can be readily identified.

Informative: For example, in the case of a circuit ('circuit 1') connected in a double busbar configuration, there are five possible alarm conditions:

Low gas on the circuit side of the busbar selector disconnectors (Alarm: Circuit 1 SF6 gas low)

Low gas on the MBB side of the busbarr selector disconnectors (Alarm: MBB SF6 gas low)

Low gas on the RBB side of the busbar selector disconnectors (Alarm: RBBG SF6 gas low)

*Low gas in the MBB busbar selector disconnector (Alarm: MBB SF6 gas low **and** Circuit 1 SF6 gas low)*

*Low gas in the RBB busbar selector disconnector (Alarm: RBB SF6 gas low **and** Circuit 1 gas low)*

Suppliers shall identify where leakage of gas from a higher pressure gas compartment to an adjacent lower pressure gas compartment may result in operation of the pressure relief device of the lower pressure compartment. In these cases the lower pressure compartment shall be fitted with a high density alarm.

Provision for checking gas monitoring devices shall be achieved in such a way that operation of as much of the alarm circuit as is reasonably practicable be confirmed. Safe access for performing this check shall be provided.

Informative: For disconnector gas compartments this check must be performed to confirm integrity of a 'point of isolation' during switching to achieve safety from the system.

Informative: It will always be practicable to provide a facility to reduce the SF6 pressure at the primary sensor. Any design proposal that does not allow for testing from this point must therefore be justified on the basis of reduced costs and a low probability of failure of the untested elements.

Informative: Where the primary sensor is a transducer, then a good case can generally be made that testing from the input terminals of the monitoring unit is adequate on the grounds that any credible transducer failure would initiate an alarm condition.

GIS disconnectors shall be provided with lockout facilities to prevent operation at less than the minimum functional pressure or density.

Informative: This is to prevent the equipment from being operated beyond its strength and capability.

20.2.7 Pressure Relief

Pressure relief devices shall be installed so as to eject debris away from normally accessible areas. They shall be set to minimise danger to personnel.

20.2.8 Identification of Pipework

Fixed gas and hydraulic pipework shall be identified in accordance with BS 1710.

20.2.9 Identification of Gas Compartment Partitions

The position of each gas compartment partition shall be clearly identified.

Labels shall be fixed to the enclosure at each gas compartment partition showing the identifier of the gas compartments at each side of that partition.

20.2.10 Primary Injection Testing of CTs

Provision shall be made for carrying out primary injection tests on all current transformers without requiring internal access to any gas compartment.

20.2.11 Partial Discharge Measurement

For GIS equipment for use at 275 kV and above, capacitive couplers for diagnostic monitoring of the GIS equipment and transient voltage measurements shall be provided in all phases at the following positions:

a) The sealing ends of each cable connected circuit.

b) The SF6 side of each transformer bushing.

c) Adjacent to the SF6/air bushings of each circuit connected to AIS equipment.

d) At intervals between these points such that all parts of the GIS shall be between two couplers and that the required sensitivity specified in Clause 20.3.5 shall be achieved.

Informative: Where gas insulated busbar connections are greater than approximately 20 m in length, it is often acceptable to increase the distance between couplers compared with GIS due to the reduced levels of signal attenuation.

To facilitate the use of couplers for in-service monitoring, coupler signal connections shall be cabled so as to be accessible from ground level. Where located outdoors, test boxes conforming to IP65 of BS EN 60529 shall be provided.

The signal cables and the connections shall be identified according to the associated coupler and phase. The signal propagation time of each cable shall also be marked.

Signal connections shall be N series 50 Ohm sockets.

Signal cables between the couplers and test boxes shall be double screened co-axial.

20.3 PERFORMANCE REQUIREMENTS

20.3.1 Rated Insulation Level

For the point of isolation for cable testing and any parts of the switchgear that remain connected to the cable termination during the test, the withstand voltages detailed in Table 33 shall apply.

	145 kV	**300 kV**	**420 kV**
15 minute withstand test voltage to earth and where appropriate between phases, kV D.C.	335	580	780

Table 33 - DC withstand voltages

20.3.2 Performance at 0 Bar Gauge (barg)

GIS circuit breakers and disconnectors shall be able to withstand two fully asynchronous power frequency voltages applied to the opposite terminals of the same pole when in the OPEN position with each voltage equal to the rated phase to earth power frequency voltage when filled with the insulating gas at a pressure of 0 barg.

GIS equipment shall be able to withstand 1.5 times the rated phase to earth power frequency voltage between its conducting parts and earth and, where appropriate, between phases for a duration of 1 minute when filled with the insulating gas at a pressure of 0 barg.

20.3.3 Internal Arcing

Enclosures shall be capable of withstanding an internal arc of rated short-time current for a duration not less than the main protection fault clearance time given in Table 34 such that no external effect other than operation of the pressure relief device on small gas compartments shall result.

Enclosures shall be capable of withstanding an internal arc of rated short-time current for a duration not less than the back-up or circuit breaker fail protection fault clearance time given in Table 34 such that the resulting effect shall be limited to operation of the pressure relief device(s) or the appearance of a hole, provided there is no ejection of fragmented parts.

Rated voltage (kV)	Main protection (ms)	Back-up or breaker fail protection (ms)
420	140	300
300	160	500
145	200	1000

Table 34 Fault Clearance Times for Internal Arcing Design

Informative: In cases where GIS trunking falls within the line protection zone an internal fault would normally result in a trip and DAR operation. If the requirements of this clause cannot be met for the re-application of the fault, consideration should be given to inhibiting the DAR in such cases.

On equipment having three phases in a common enclosure, or gas zone, allowance shall be made for the possibility of faults evolving to include two or more phases.

20.3.4 Partitions

Partitions shall withstand the differential pressures to which they may be subjected during preventative or corrective maintenance.

Informative: Where an adjacent gas compartment contains live high-voltage conductors, a reduction in its gas pressure to limit the differential pressure across the gas compartment partition will not be acceptable.

20.3.5 Couplers for Partial Discharge Measurement

Couplers shall have sufficient sensitivity to allow a defect having an apparent charge of 5 pC to be detected at any point in the GIS.

Partial discharge couplers shall be sensitive to all frequencies in the range 0.1 – 1.5 GHz and shall give an output signal suitable for a spectrum analyser.

Couplers shall have a linear response in the frequency range 50 Hz – 300 MHz and a capability to make D.C. 'trapped charge' measurements.

20.3.6 Portable Maintenance Earthing Devices

PMEDs shall be rated in accordance with the requirements of Part 4, Section 3.

20.4 TYPE TEST REQUIREMENTS

20.4.1 Sensitivity Verification for Couplers for Partial Discharge Monitoring

The sensitivity of the proposed couplers for partial discharge monitoring shall be demonstrated by the method of Electra No 183.

20.5 ROUTINE TESTS AT SITE

20.5.1 Partial Discharge Tests

Partial discharge activity shall be monitored throughout the site power-frequency high voltage tests of GIS equipment.

Suppliers shall state the maximum acceptable partial discharge level during the site test at 1.1 U/√3. This measurement shall be made on reducing voltage following the power frequency withstand test. The partial discharge level at nominal voltage shall also be recorded.

20.6 REFERENCES

IEC 61639	Direct connection between power transformers and gas-insulated metal-enclosed switchgear for rated voltages of 72.5 kV and above
IEC 62271-102	High-voltage switchgear and controlgear – Part 102: High-voltage alternating current disconnectors and earthing switches
IEC 62271-203	Gas-insulated metal enclosed switchgear for rated voltages above 52 kV
EN 50052 (BS 6878)	Specification for high-voltage switchgear and controlgear for industrial use. Cast aluminium alloy enclosures for gas-filled high-voltage switchgear and controlgear.
EN 50064 (BS 7315)	Specification for wrought aluminium and aluminium alloy enclosures for gas-filled high-voltage switchgear and controlgear
BS EN 50068	Specification for wrought steel enclosures for gas-filled high-voltage switchgear and controlgear
BS EN 50069	Specification for welded composite enclosures of cast and wrought aluminium alloys for gas-filled high-voltage switchgear and controlgear
BS EN 50089	Specification for cast resin partitions for metal-enclosed gas-filled high-voltage switchgear and controlgear
BS EN 60529	Degrees of protection for enclosures (IP Code)
BS 1710	Specification for identification of pipelines and services
ELECTRA No 183	Partial discharge detection system for GIS: Sensitivity verification for the UHF method and the acoustic method

PART 5 - GUIDANCE NOTES

21 SECTION 1 - TYPE REGISTRATION

21.1 PURPOSE AND SCOPE

Type Registration is a documented, risk managed process which enables National Grid to verify that plant, equipment and apparatus purchased for use on, or directly connected to, the GB Transmission System complies with National Grid's technical requirements, IEC or other relevant specifications and are therefore deemed suitable for their intended application.

This document gives guidance to National Grid contractors in order to ensure that the requirements of the Type Registration process are met.

The process is applicable to, but not limited to, primary and secondary equipment sub-system solutions only. Individual components, which form part of the sub-system solution, will not be separately registered.

In this context, a sub-system solution is defined as the largest functional assembly that can be connected to the GB Transmission System taking into account design, testing, procurement and lifetime management constraints. A list of sub-system solutions to which this process applies is given below: -

a) Standard bay designs

b) Light current bays

c) Mechanically Switched Capacitor Damping Networks (MSCDN)

d) Power Transformers

e) Cable systems

f) DC systems

g) Static Var Compensators (SVC)

h) Quad Boosters

i) Shunt and Series Reactors

j) Air ring main systems

k) Telecommunication systems

l) OHL conductor and OPGW systems

m) OHL insulator systems

Where individual components are procured directly by National Grid, separate arrangements will apply. In this case the component supplier will be required to submit documentation as defined in Part 3, Section 1 of this document for assessment by National Grid Asset Policy in order to demonstrate suitability for the intended application, fitness for purpose and compliance with the relevant technical requirements.

Subject to satisfactory assessment, National Grid will issue an asset code to the component supplier to indicate that the product may be purchased by National Grid.PART 1 – procedural

21.2 PROCESS

Asset Policy will initiate a consultation process with the solution provider to develop standard sub-system solutions based on the functional requirements specified in the relevant National Grid Technical Requirements.

The solution provider will submit a standard design solution/s to National Grid Asset Policy in the form of a design data pack including general arrangements and layout drawings. The minimum document requirements are specified in 21.8 of this guidance document. Specific document requirements are defined in the relevant National Grid Technical Requirements.

The standard of drawings and manuals submitted with the application shall be in accordance with the general requirements set out 21.9 of this guidance note. Specific drawing requirements relating to products such as Overhead Line and Busbar fittings are defined in the relevant National Grid Technical Requirements.

On receipt of the registration pack, National Grid will assess the solution for compliance with the relevant National Grid Technical Requirements and carry out a risk assessment. Any non-conformances or deviations from the specification will be identified by the solution provider at this stage and recorded using the appropriate electronic form available on National Grid's Extranet site.

On completion of the risk assessment by National Grid and evaluation of any non-conformances impacting on the application, the solution provider is required to electronically submit the following documentation for the final design to National Grid as part of the permanent record:

21.2.1 Sub-System Solution

a) Self Certification Statement (SCS) form (to National Grid format – see note 1 below)

b) Non compliance forms (to National Grid format – see note 1)

c) Schedule of General and technical details (to National Grid format – see note 2 below)

d) Schedule of type tests (to National Grid format – see note 2)

e) Telecomms Interface Specification where applicable (to National Grid format – see note 2)

f) Generic Equipment Models where applicable

g) Layout and or arrangement drawing of complete solution

h) Type test reports where specified in the User Specification section.

i) Installation, operation, maintenance manuals and decommissioning instructions

j) Commissioning schedules

k) Life cycle costs

l) Reference lists

21.2.2 Individual Components

a) SCS sheets (to National Grid format – see note 1)

b) Non compliance forms (to National Grid format – see note 1)

c) Schedule of general and technical details (to National Grid format – see note 2)

d) Schedule of type tests (to National Grid format – see note 2)

e) Calculation sheets where required by relevant National Grid technical specification (to National Grid format – see note 2)

f) General arrangement drawings, key assembly drawings and schematic diagrams

g) Type test reports where specified in the relevant User Specification section.

h) Installation, operation, maintenance manuals and decommissioning instructions

i) Commissioning schedules

Note 1 Templates are available on the Extranet web-site under TGN, forms

Note 2 Templates associated with the relevant National Grid Technical Requirements are available on the Extranet web-site under NGT S schedules. <u>Completed forms must be submitted to National Grid in their original format.</u>

The solution provider is responsible for collating, assessing the component supplier's SCS statements and submitting them to National Grid as required by the type registration process. The relevant National Grid Technical Requirement and issue number shall be stated on the SCS in all cases.

In submitting these statements, the solution provider shall declare that the sub-system and components which comprise the solution are fit for the application for which it is intended and have the strength and capability under the Electricity and Work regulations and relevant UK statutes.

Any non-conformances or deviations from the specification shall be identified at this stage and recorded using the appropriate electronic form available on National Grid's Extranet site.

Test evidence in the form of type test reports and calculations shall be submitted electronically in English language. All tests shall have been performed in accordance with current European, IEC or British standards and specifications.

It is the responsibility of the solution provider to satisfy themselves that test evidence provided has been either verified independently or completed by a person or persons with the appropriate skills, knowledge and experience operating to a recognised quality procedure. National Grid reserves the right to seek independent witnessing/validation when in National Grid's opinion it is appropriate and required.

Calculations will only be accepted in lieu of testing where permitted by the specification or where this cannot practically be verified by direct testing.

21.2.3 Test reports offered in support of the type registration applications shall:

a) Include references to all applied standard(s) including level of conformance

b) Clearly and unambiguously identify the test parameters and pass/fail criteria

c) Explicitly detail all deviations of test procedure and parameters from the referenced standard(s) and associated guidance

d) Clearly state the outcome of the test (pass/fail/unclear) and close out of any failure and details of re-testing

e) Contain sufficient information to fully identify all relevant aspects of the tested component and the tested configuration

f) Contain sufficient information to identify the condition of the component after testing.

Where the test evidence for a component does not meet these criteria, the solution provider should make an assessment as to whether the evidence is acceptable and advise National Grid of any limitations or restrictions on the use of the component.

It is recognised that some sub-system components will have been previously type registered. Where this is the case, the component may be accepted as part of the system registration providing that the solution provider can demonstrate that the component is suitable for the intended application.

Where a component has not been previously registered or is not considered by National Grid to be fully compliant with the technical requirements, the solution provider shall submit a test programme to Asset Policy for achieving compliance and obtaining an asset code from National Grid. National Grid reserves the right to observe and/or review type, routine and sample tests which are specified in the relevant technical requirement and will require a minimum of 10 days notification prior to commencement date of the tests.

National Grid will maintain a database of equipment and solutions, which will be used to record asset data for the sub-system solution and the individual components.

On completion of the registration process, National Grid Asset Policy will issue asset codes for the complete sub-system to the solution provider.

The solution provider is responsible for maintaining a record of the asset codes, which have been allocated by National Grid.

Under the terms and conditions of the type registration process, the solution provider is required to notify National Grid of any changes to design, method, or place of manufacture. National Grid will then determine whether the solution needs to be re-assessed and inform the solution provider of further actions, which are deemed necessary.

Should a component fail in service due to design inadequacy or generic manufacturing defect, National Grid will not procure the solution until such time that a plan of resolution is agreed.

21.3 ROLES AND RESPONSIBILITIES

21.3.1 National Grid Asset Policy

National Grid Asset Policy is responsible for managing the type registration process and the technical assessment of the sub-system solution. In assessing the suitability of the solution, a number of factors are taken into consideration including technical and operational requirements, strength and capability, health and safety, environmental impact and life cycle management issues.

21.3.2 The Solution Provider

The Solution provider is responsible for ensuring that the sub system and the associated equipment components are fully compliant with National Grid's technical requirements. The solution provider is required to document and demonstrate compliance in accordance with the requirements as defined in the relevant National Grid technical requirements.

21.4 TECHNICAL REQUIREMENTS

21.4.1 National Grid Technical Requirements

The functional requirements for complete system solutions are defined in the relevant National Grid Technical Requirements.

The technical requirements for the individual components, which form part of the system solution, are specified in the relevant National Grid Technical Requirement.

Electronic copies of these specifications are available to authorised suppliers from National Grid's extranet web site.

Electronic copies of these documents are available to authorised suppliers from National Grid's Extranet web site.

21.5 FORMS AND RECORDS

SCS Sheet

Generic Technical Data Sheets

Non-Compliance forms

Schedule of Type Tests

21.6 DEFINITIONS

The following are defined terms used in this document:

Component – a product which forms a part of a solution, which may have an impact on strength, capability, or reliability of the GB Transmission System.

Solution – an arrangement of plant, equipment and apparatus that can be procured as a functional unit.

Solution Provider – a main contracting company with project management capability, able to deliver solutions and whose processes and performance are monitored on a continuous basis by National Grid Supplier Development group.

Self Certification Statement – a documented statement provided by solution providers and component suppliers declaring that the solution and the components comprising that solution, satisfies the requirements of the relevant National Grid technical requirements and is suitable for the applications for which it is to be supplied.

Asset Code – a unique identifier assigned by National Grid for a particular solution and/or component.

Authorised Supplier – a contractor who has qualified for inclusion on National Grid's Vendor Qualification System.

Generic Equipment Model (GEM) - a data set expressing National Grid's User requirements for interfacing to a solution (plant, system or equipment). Specifically it defines the I/O interface requirements of a Substation Automation System (Controls, Indications, Alarms, Analogue measurements and Information) for any given type of solution, which can be used for monitoring and control purposes. It also details a rationalised data set to be presented at control centres to enable operational control to be managed.

21.7 NOTES

This guidance document supports the User Policy Statements contained in these Relevant Electrical Standards.

21.8 GUIDANCE NOTE - DESIGN DATA PACK

21.8.1 Document Requirements

a) Technical description of design

b) Layout and or arrangement drawings

c) Calculcations where applicable

d) Site commissioning instructions and test schedules

e) Operation, installation, maintenance, decommissioning and disposal instructions

21.9 GUIDANCE NOTE - STANDARD OF DRAWINGS AND MANUALS

21.9.1 General Requirements

The requirements set out herein relate to drawings and manuals submitted to National Grid by Solution Providers.

Specific drawing requirements for overhead line conductor fittings, insulator fittings, busbar, busbar connectors, and associated fittings for installation on National Grid overhead lines and substations or for direct connection to National Grid's system are defined in the relevant National Grid Technical Requirements.

All drawings and manuals should be in English and must be submitted electronically or on a CD-ROM.

21.9.2 Drawings

Drawings shall be of the General Arrangement type with all individual components identified either alphabetically or numerically.

A4 or A3 sizes are preferred but larger sizes may be used to improve legibility.

The Suppliers name and address hall be included and location of manufacture if different.

The drawing title box shall include the component or assembly description and references as per the relevant BS, IEC and technical requirements.

One unique drawing number only shall be used for each drawing.

All drawings shall be dated, checked and given internal design approval to satisfy normal Quality Assurance requirements before submission to National Grid.

The revision status shall be shown in a separate box from the drawing number. The revision text shall identify changes made since the previous issue of the drawing.

All design critical dimensions shall be shown in millimetres and shall be in conformance with the relevant BS, IEC and / or National Grid drawing. Design critical dimensions are those that are shown on the relevant BS, IEC and / or National Grid drawing and those required as “Technical Data” in the relevant User Specification.. Dimensions which are required to confirm “fit, form or function” shall be supplied together with manufacturing tolerances.

21.9.3 Manuals

The content of manuals shall include all instructions, data and specifications necessary for the installation, operation, commission, maintenance, service, decommissioning and disposal of the complete solution together with each of the individual components comprising that solution.

22 SECTION 2 - WORKING IN PROXIMITY TO LIVE CONDUCTORS -REDUCING THE RISKS

22.1 PURPOSE AND SCOPE

These guidelines have been prepared for information and may be used by designers as an indication of designs that will be considered acceptable by National Grid. Following these guidelines does not, however, absolve the designers of their responsibilities for their design under CDM regulations.

22.2 GENERAL

Designers are obliged to comply with all relevant health and safety legislation, particularly the designers’ duties under the Construction (Design and Management) Regulations 1994 (CDM). In applying the principles of prevention and protection to the reduction of risk, designers’ considerations should include the hazards of working in proximity to exposed live HV conductors (including 'oversailing' conductors) during construction, operation, maintenance, repair, replacement or demolition of electrical/mechanical equipment and civil structures.

If the designer does not eliminate hazards presented by exposed live HV conductors from the design, there is an obligation on the designer to show, by risk assessment, that the design has complied with the principles of prevention and protection, as required by CDM, in some other way. The following hierarchy of risk control shall be considered when selecting alternative control measures.

The preferred hierarchy of risk control principles are:

- Eliminate risk altogether
- Substitute equipment or activities with less hazardous ones
- Combat risk at source by engineering control measures
- Reduce risk by suitable safe systems of work
- Minimise risk by the use of Personal Protective Equipment.

[Reference National Grid National Health & Safety Standard NS-MP1]

22.3 DESIGN PRINCIPLES

It is essential that the Safety Distances (specified in National Grid’s Safety Rules Handbook) to exposed live HV conductors are not infringed either deliberately or accidentally during any work activity. In order to achieve this, designers will need to establish appropriate minimum design clearances. These must take into account not only the immediate requirements of the work activity but also additional factors relating to the means of access and working methods. An indicative, but not exhaustive, list of factors to be considered when considering whether clearances are sufficient include the possibility of a Mobile Elevated Work Platform (MEWP) running out of control, passage of cranes through substations, the use and handling of scaffold poles and setting up enclosures over cable sealing ends.

The clearances recommended in these guidelines may not, in some circumstances, be sufficient to adequately mitigate hazards and designers must be prepared to use risk assessment principles to test their design decisions.

Designers must take account of relevant UK legislation, National Grid Safety Rules and relevant Technical Requirements when considering methods of performing work activities. The procedures defined in National Grid’sSafety Rules must also be considered (although other procedures that meet the legal/Safety Rule requirements may be accepted at the discretion of National Grid).

It is National Grid policy to eliminate from new substation construction:

a) Oversailing conductors (as far as is reasonably practicable).

b) Conductors in proximity.

c) Situations where work activities must be carried out above exposed HV conductors that are live.

In assessing what is reasonably practicable, designers may wish to use the ALARP (As Low As Reasonably Practicable) principle outlined in National Grid National Health & Safety Standard NS-MP1 and 'Tolerability of Risk From Nuclear Power Stations', (HSE Books, 1992).

A higher priority should be placed on eliminating oversailing conductors from routine work activities than from non-routine work activities. Furthermore, a higher priority should be placed on eliminating oversailing conductors where access is intended to be by MEWP (where there is a significant risk of accidentally moving out of the operating area as a result of misjudgement or mechanical failure) than from where access is by temporary fixed-height platform.

Note: The specification by the designer of a temporary fixed-height platform in place of a MEWP will not always be acceptable to National Grid. Refer to 22.8 for application limitations.

Practically, it is impossible to eliminate exposed live HV conductors from a substation during work (with the exception of GIS substations). Part 4, Section 2 of these Relevant Electrical Standards specifies the following maximum outage conditions:

When considering clearances from roadways to exposed live conductors for vehicle access, designers must take into account the largest load that may reasonably foreseeably need to be moved on that roadway. The designer shall also identify the proposed access/egress route for the replacement of the largest single unit of equipment installed on site (e.g. transformer or quadrature booster) taking into account all substation voltages crossing that route.

Where a transformer has failed, this will already have resulted in depletion of one circuit at a substation. It would not, therefore, be an acceptable design solution to require further circuits to be switched out to provide clearance for transporting the failed or replacement units across site.

Guidance for designers can be categorised according to the nature of the work activity and the type of access intended by the designer. This guidance is summarised in the table in 22.8

22.4 DESIGN GUIDANCE FOR ACCESS FROM GROUND LEVEL OR PERMANENT PLATFORM

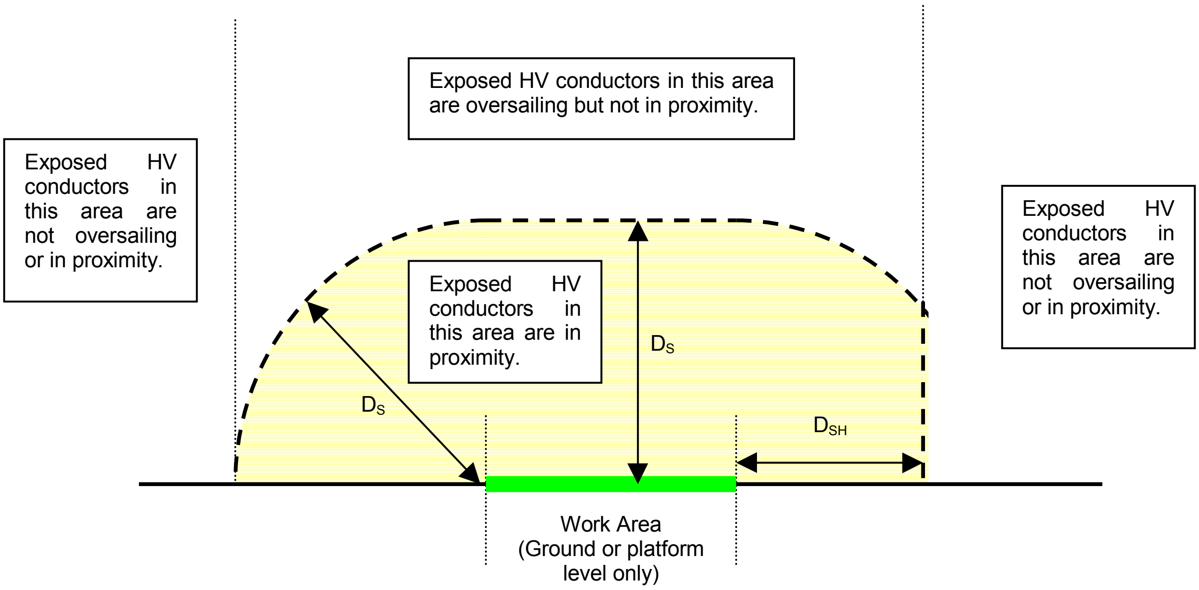
The design objective is to allow personnel to move freely around the substation at ground level and to safely use:

a) any permanently installed access platforms, or

b) mobile steps which have been specifically designed to access specific plant or equipment whilst live.

Conductors in proximity to any reasonably foreseeable work area shall be eliminated by ensuring that the appropriate design clearance for safety D_S (as specified in Table 35) has been achieved from all exposed live conductors.

Conductors that are not in proximity but still oversail the work area shall be accepted by National Grid (since elimination is not considered reasonably practicable) and the designer will not be required to take any measures to avoid them.



D_S is the design clearance for safety (section clearance) specified in Part 4, Section 2.

The reduced horizontal design clearance for safety D_{SH} may be utilised in the substation design where the designer can demonstrate that it would not be reasonably practicable to incorporate the specified vertical clearance.

The above diagram has been simplified for clarity and no means is shown of defining the boundary of the work area. In practice, the work area would need to be bounded by a handrail or fence. A handrail is only acceptable for an elevated platform and designers must consider the possibility of the rail being use as a step – a minimum vertical clearance of D_S must therefore be allowed from the top of the handrail to any exposed live conductor. The required minimum horizontal clearance is D_S (or D_{SH}). Where an earthed fence or barrier meeting the requirements of protection class IP2X as defined in IEC 60529 (and which is not readily climbable) is provided then the minimum horizontal clearance to an exposed live conductor may be reduced to minimum or type tested phase to earth electrical clearance. The required vertical clearance is D_S from floor level of the work area. Where a non-IP2X fence or barrier (which is not readily climbable) is provided then minimum clearances are as shown in the diagram above. Fences that are climbable must be treated as handrails.

Reasonably foreseeable work areas shall be taken to include any part of the substation at ground level or any part of a permanently installed access platform, except where access to the area is specifically restricted (e.g. fenced compounds around capacitor banks).

The designer must consider whether any hazards are present which may not have been adequately controlled by the use of standard design clearances and, where necessary, carry out a specific risk assessment. Any additional prevention and protection measures identified by this specific risk assessment must be implemented.

In areas where conductors in proximity cannot be eliminated then access shall be limited by the use of barriers or fences as defined in Part 4, Section 2. Such a limitation will not be accepted by National Grid where access is required for switching, routine inspections/patrols or fault finding on secondary equipment.

Under circuit outage conditions that permit access to the restricted area, exposed HV conductors of other circuits which may remain energised shall not be in proximity to that area.

The use of mobile steps for operational access in substations is non-preferred. Where the use of such access is agreed by National Grid, then the designer shall ensure that clearances (D_S) as defined in Table 35 are provided from the platform level in any position in which the steps might reasonably foreseeably be located.

Details, including a dimensioned drawing, of the steps on which the design is based shall be recorded in the site Health & Safety file.

22.5 DESIGN GUIDANCE FOR ACCESS BY TEMPORARY FIXED-HEIGHT PLATFORM

The design objective is to allow for safe erection, use and dismantling of the temporary fixed-height platform without exceeding the specified maximum outage criteria.

The presence of oversailing and/or proximity conductors shall be identified as follows:

a) Identify (in plan view) the position (or positions) of the temporary platform required to carry out the work activity.

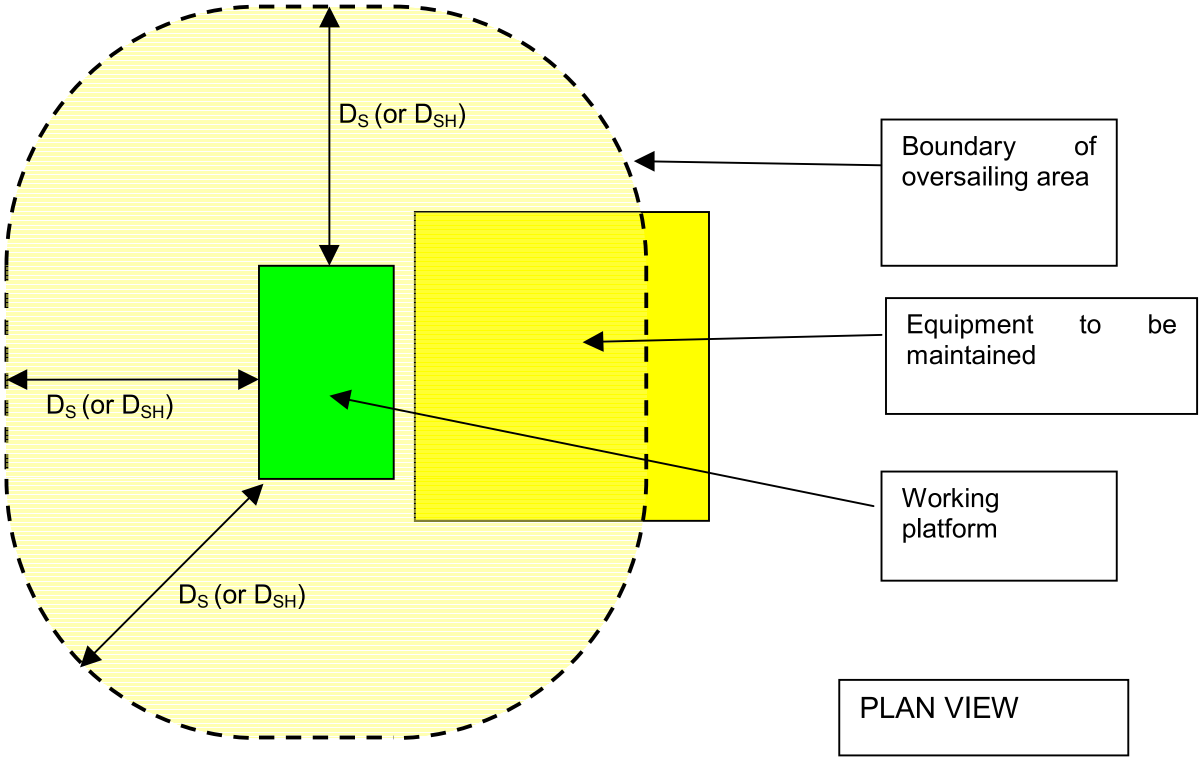
b) Plot an area around the platform with its perimeter measured DS from the edge of the platform (where DS is the design clearance for safety specified in Table 35 and in Part 4, Section 2).

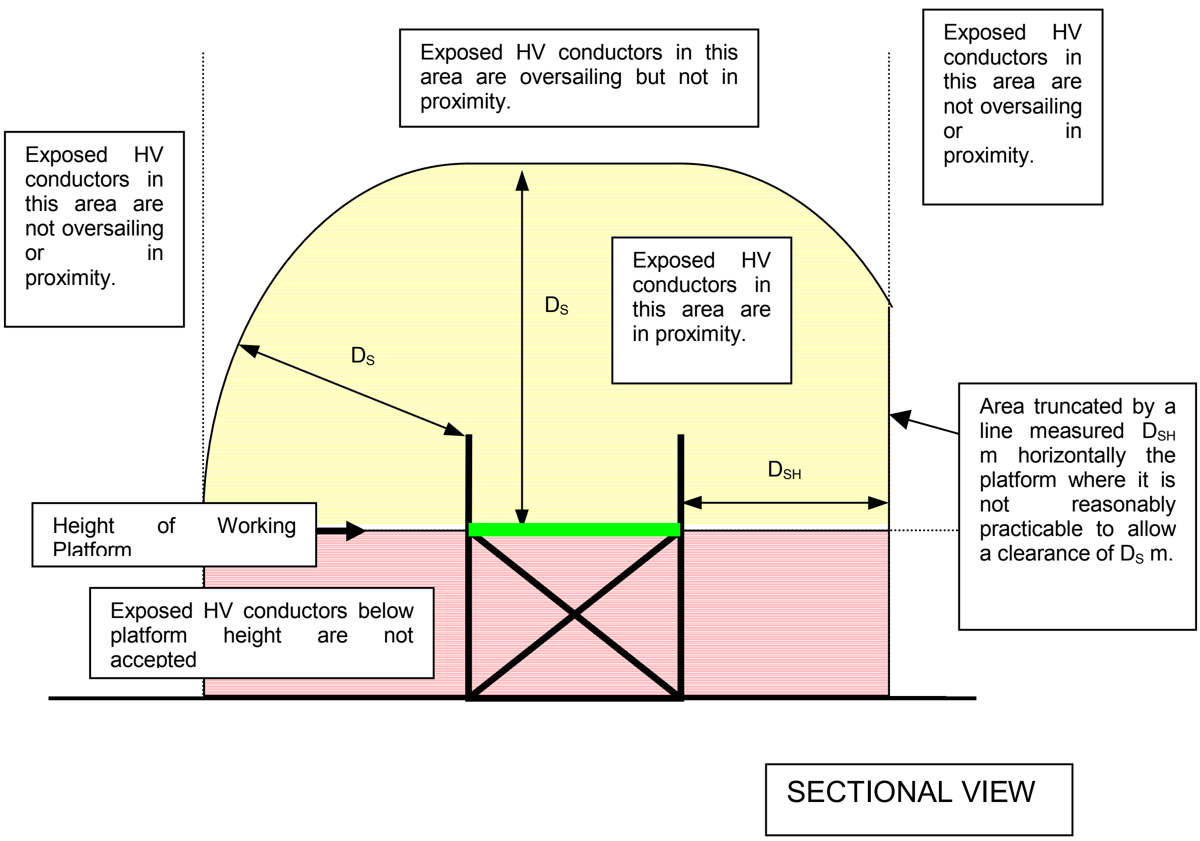
Note: The reduced horizontal design clearance for safety D_{SH} may be utilised in the substation design where the designer can demonstrate that it would not be reasonably practicable to incorporate the specified vertical clearance.

c) Any exposed HV conductor that crosses this area (at any height) will be considered to be oversailing.

Note: Exposed conductors which are not live by virtue of the isolation procedures necessary to carry out the work activity are excluded from this definition.

d) Any exposed HV conductor that crosses this area at a distance $\leq$ DS (measured vertically or at any angle) from any part of the floor of the fixed-height platform will be considered a conductor in proximity.


Ds (or DSH)
Boundary of oversailing area
Equipment to be maintained
Ds (or DSH)
Working platform
Ds (or DSH)
PLAN VIEW


Exposed HV conductors in this area are oversailing but not in proximity.
Exposed HV conductors in this area are not oversailing or in proximity.
Exposed HV conductors in this area are not oversailing or in proximity.
Ds
Exposed HV conductors in this area are in proximity.
Ds
Area truncated by a line measured DSH m horizontally the platform where it is not reasonably practicable to allow a clearance of Ds m.
DSH
Height of Working Platform
Exposed HV conductors below platform height are not accepted
SECTIONAL VIEW

The diagrams above have been simplified for clarity. When preparing designs, designers must consider the possibility of the platform handrail being use as a step. Unless alternative control measures are proposed a minimum vertical clearance of D_S must thus be allowed from the top of the handrail to any exposed live conductor.

The designer must consider whether any hazards are present which may not have been adequately controlled by the use of standard design clearances and, where necessary, carry out a specific risk assessment. Any additional prevention and protection measures identified by this specific risk assessment must be implemented.

Additional risks to be considered might be erection of temporary platforms and, where applicable, handling long objects such as scaffold poles. Possible variations in the location of the temporary platform must also be considered.

Where a design does not eliminate oversailing conductors, this may still be acceptable. In these cases the designer will be required to demonstrate:

a) That the conductors are not in proximity, and

b) That it is not reasonably practicable to eliminate the oversailing condition or to further increase the clearance from the working platform.

c) That a suitable and sufficient risk assessment of the design has been documented and implemented.

Where designers intend temporary fixed-height platforms to be used for fault investigation of secondary equipment or routine maintenance then details shall be included in the site Health & Safety file of the height, size and location of the platform on which the design is based together with any special requirements for erection or dismantling.

The Health & Safety file must also contain details of access arrangements for reasonably foreseeable non-routine work activities (e.g. repair/replacement of major substation components) where the access requirements are critical to the substation design. These details must include requirements for additional circuit outages beyond those that would be assumed from the electrical diagram of the substation.

22.6 DESIGN GUIDANCE FOR ACCESS BY MEWP

The design objective is to allow for safe use of a MEWP without exceeding the specified maximum outage criteria. Because of the risk of misjudgement or mechanical failure, National Grid consider it necessary to provide an additional design margin when allowing clearances for use of a MEWP. As a minimum, designers must ensure that their design does not require any part of the MEWP or of the operator's body to infringe the 'vicinity zone' (as defined in BS EN 50110) surrounding exposed HV conductors which remain energised during the work activity.

Designers should note that the minimum clearances to exposed live conductors suggested in these guidelines provide a margin to allow for misjudgement or mechanical failure.

22.6.1 The presence of oversailing/proximity conductors shall be identified as follows:

a) Identify (in plan view) the area that will be traversed by the platform of the MEWP during the work activity. Also identify the area occupied by the MEWP base unit and that area which will be traversed by any overhanging parts of the MEWP (e.g. booms). Together, these areas form the MEWP operating area.

b) Plot an additional area around the MEWP operating area with its perimeter measured DA from the edge of the area (where DA is the horizontal design clearance for safety specified in User Specification Section + 2 m).

Note: D_A incorporates safety distance + personal reach + 2 m margin and thus exceeds the vicinity zone perimeter clearance D_V suggested in some other documents such as draft IEC 61936.

c) Any exposed HV conductor that crosses this area (at any height) will be considered to be oversailing.

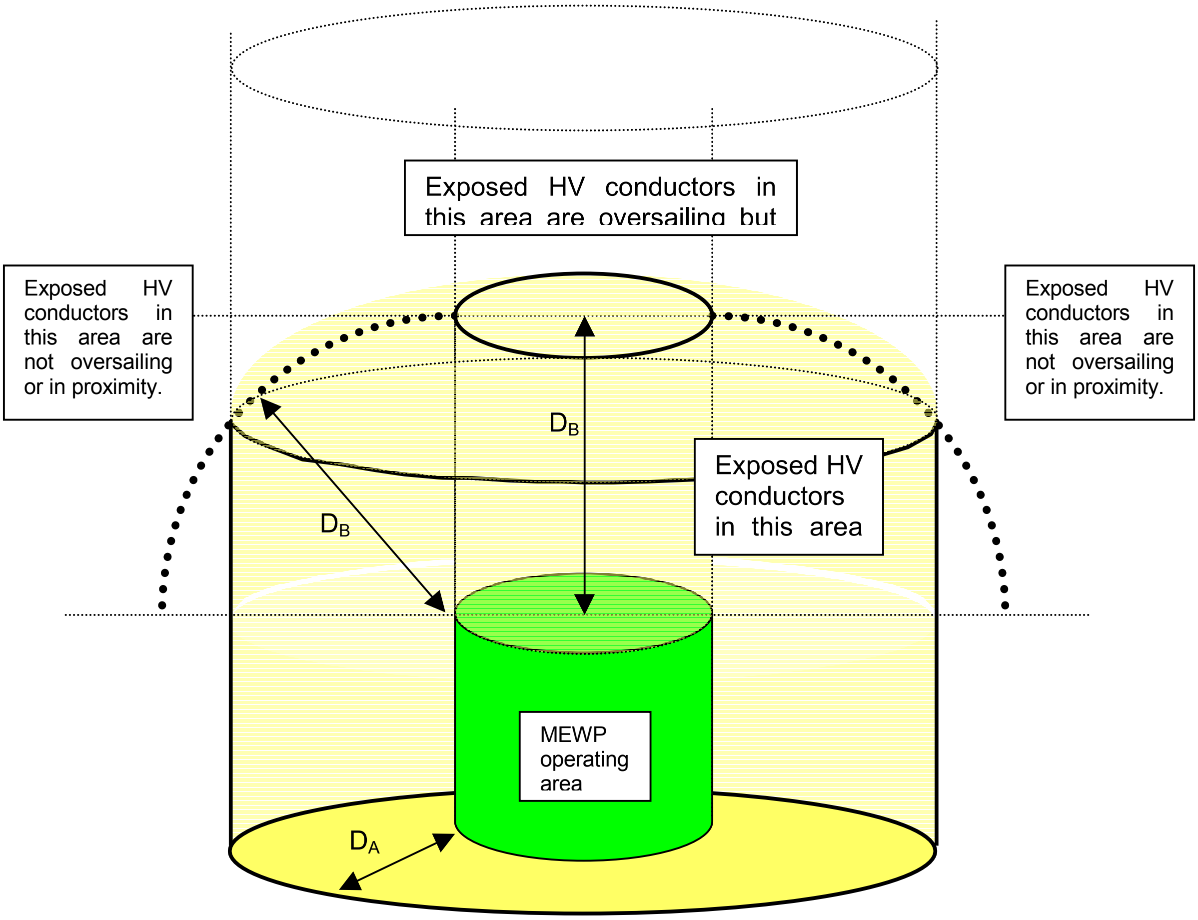
Note: Exposed conductors which are not live by virtue of the isolation procedures necessary to carry out the work activity are excluded from this definition.

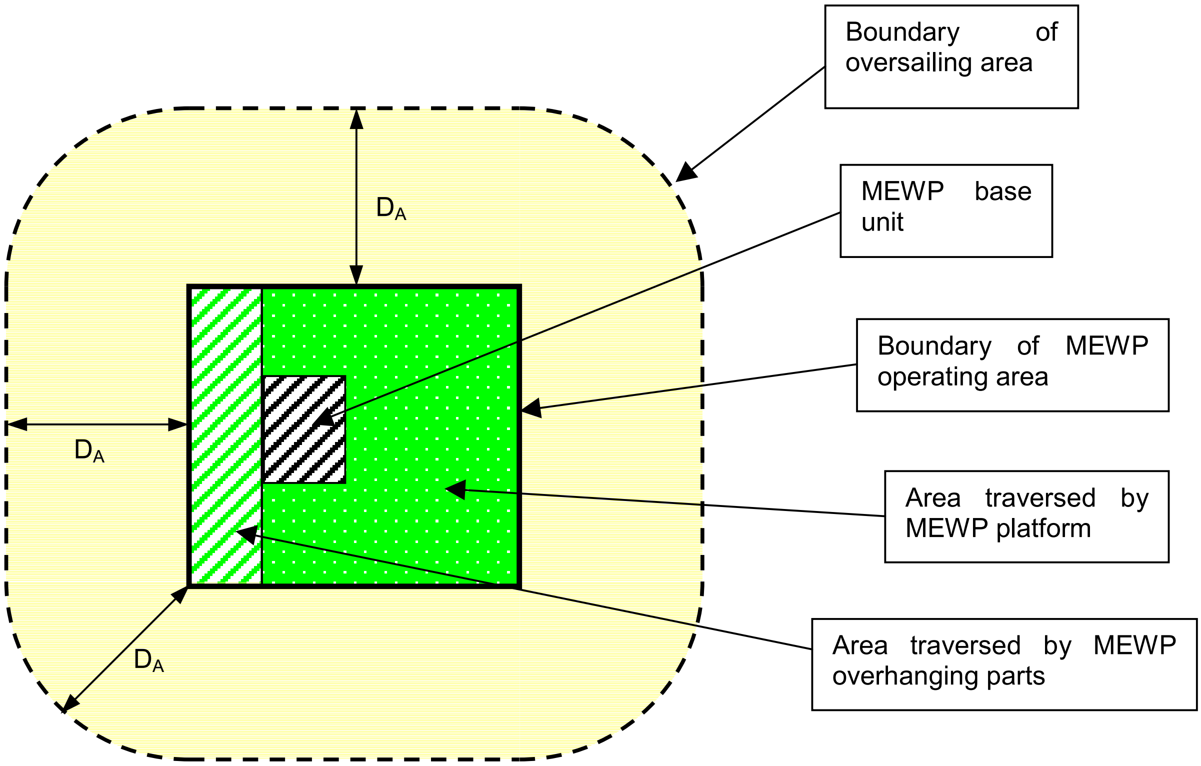
d) The vertical dimension of the MEWP operating area will be determined by the maximum height that the base of the MEWP platform is required to reach to carry out the work activity. Unless otherwise defined, this height will be taken to be the maximum height of the equipment being maintained.

e) Any exposed HV conductor that crosses the zone at a distance ≤ DB (measured vertically or at any angle) from any part of the MEWP operating area will generally be considered a conductor in proximity, (where DB is the vertical design clearance for safety specified in User Specification Section + 2 m).

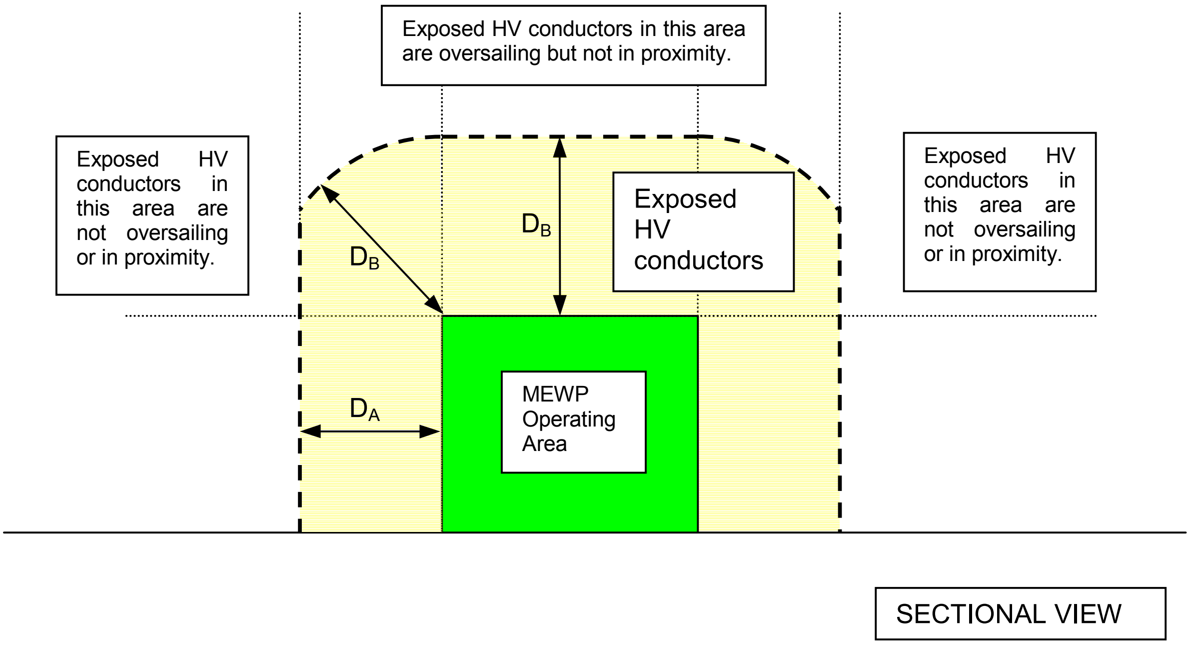
Note: In some cases it may be acceptable to consider different platform operating heights in parts of the MEWP operating area (e.g. the area traversed by overhanging parts of the MEWP). Designers using this approach must, however, demonstrate that it is not reasonably practicable to design on the basis of a uniform worst-case MEWP operating area height.

Note: It is not generally necessary to take account of the possibility of staff climbing on the handrail of the MEWP platform. The 2 m margin is considered adequate to manage this risk since it is considered unlikely that personnel will climb on the handrail whilst the platform is in motion.


Exposed HV conductors in this area are oversailing but
Exposed HV conductors in this area are not oversailing or in proximity.
Exposed HV conductors in this area are not oversailing or in proximity.
Exposed HV conductors in this area
DB
DB
MEWP operating area
DA


Boundary of oversailing area
MEWP base unit
Boundary of MEWP operating area
Area traversed by MEWP platform
Area traversed by MEWP overhanging parts
DA
DA
DA

PLAN VIEW



In determining the MEWP operating area, designers may base their design on a generic MEWP or a specific MEWP. Designs based on a generic MEWP are preferred.

A generic MEWP shall be taken to have the worst-case characteristics of MEWP types normally hired by National Grid, details of which can be obtained from National Grid's procurement section.

It is not intended that the designer should automatically take account of the full operating envelope of a generic or specific MEWP. It is sufficient to identify the required envelope of operation to perform the work activity in determining the MEWP operating area. However, where the operating area of a MEWP is to be limited, it is important to identify the limits of operation in the site Health & Safety file.

The designer must consider whether any hazards are present which may not have been adequately controlled by the use of standard design clearances and, where necessary, carry out a specific risk assessment. Any additional prevention and protection measures identified by this specific risk assessment must be implemented.

Where a design does not eliminate oversailing conductors, this may still be acceptable. In these cases the designer will be required to demonstrate:

a) That the conductors are not in proximity, and

b) That it is not reasonably practicable to eliminate the oversailing condition or to further increase the clearance from the MEWP operating area.

c) That a suitable and sufficient risk assessment of the design has been documented and implemented.

If a designer bases the substation design on the use of a MEWP then full details of the characteristics of this MEWP shall be provided in the site Health & Safety file

The Health & Safety file must also contain details of access arrangements for reasonably foreseeable non-routine work activities (e.g. repair/replacement of major substation components) where the access requirements are critical to the substation design. These details must include requirements for additional circuit outages beyond those that would be assumed from the electrical diagram of the substation.

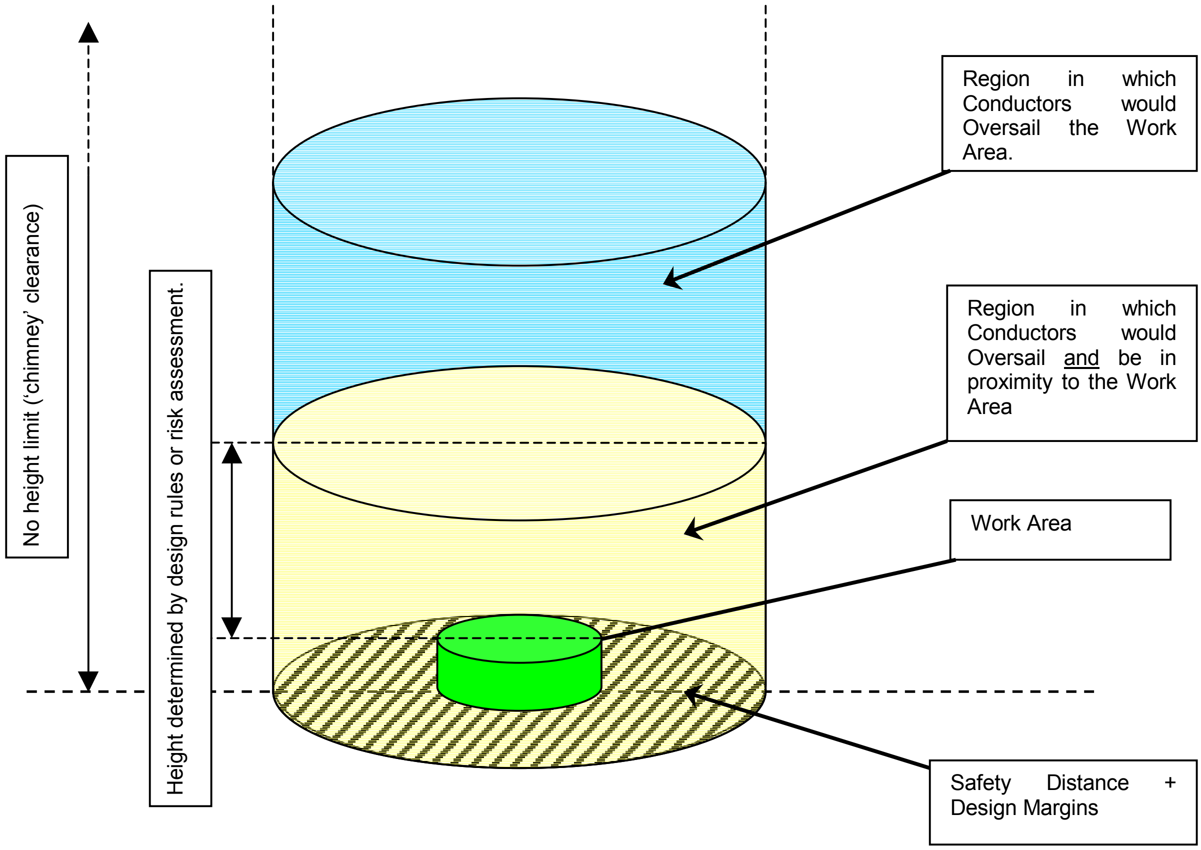
22.7 DEFINITIONS

22.7.1 Oversailing Conductors

Are exposed HV conductors which are above or in proximity to any reasonably foreseeable work area and which would normally remain energised during such work activities.

22.7.2 Conductors in proximity

Are exposed HV conductors with insufficient clearance to a reasonably foreseeable work area to avoid danger and which would normally remain energised during work activities.



22.7.3 Design Clearance for Safety (Vertical) [DS]

The sum of the relevant Safety Distance (from National Grid's Safety Rules) and the maximum vertical reach of a person (taken to be 2.4 m) previously known as Section Clearance.

22.7.4 Design Clearance for Safety (Horizontal) [DSH]

The sum of the relevant Safety Distance (from National Grid's Safety Rules) and the maximum horizontal reach of a person (taken to be 1.5 m).

Note: The horizontal reach dimension adopted in National Grid substation design practice is 100 mm greater than that specified in BS7354.

22.7.5 Design Clearance for MEWP Operation (Horizontal) [DA]

The sum of the relevant Safety Distance (from National Grid's Safety Rules), a margin to allow for operator error or equipment maloperation (2m) and the maximum horizontal reach of a person (taken to be 1.5m).

Note: The Safety Distance + 2 m margin, when measured from an exposed live conductor, defines the boundary of the Vicinity Zone (as specified in BS EN 50110). The design philosophy is that neither the MEWP, any part of the operators body or any object held by the operator should infringe the Vicinity Zone.

22.7.6 Design Clearance for MEWP Operation (Vertical) [DB]

The sum of the relevant Safety Distance (from National Grid's Safety Rules), a margin to allow for operator error or equipment maloperation (2 m) and the maximum vertical reach of a person (taken to be 2.4 m).

Values of D_A, D_B, D_S and D_{SH} for National Grid system voltages are tabulated in Table 35 below.

Nominal System Voltage (kV)	**11/22/33**	**66**	**132**	**275**	**400**
NG Safety Rules, Safety Distance	0.8	1.0	1.4	2.4	3.1
Design Clearance for Safety (Vertical) [D_S]	3.2	3.4	3.8	4.8	5.5
Design Clearance for Safety (Horizontal) [D_{SH}]	2.3	2.5	2.9	3.9	4.6
Design Clearance for MEWP Operation (Vertical [D_B]	5.2	5.4	5.8	6.8	7.5
Design Clearance for MEWP Operation (Horizontal) [D_A]	4.3	4.5	4.9	5.9	6.6
Minimum Height of Conductors Above Roadways **	5.8	6.0	6.7	7.0	7.3

Table 35 - Values of minimum clearances (mtrs) for National Grid system voltages

***Informative: Values given above are based upon the Electricity Safety, Quality & Continuity Regulations 2002. Part 4, Section 2 of these Relevant Electrical Standards also permits a value based upon the maximum vehicle height + 0.5m + safety distance. Actual values to be used shall be the greater of the two values.*

22.7.7 Non-Primary System Work

Any work in a substation which is not directly associated with equipment forming part of National Grid's system.

22.8 GUIDANCE NOTE - GUIDANCE FOR DESIGNERS

	Access from ground level or permanent platform **	**Access by temporary fixed-height platform (e.g. pre-form/pole & clip scaffold).**	**Access by MEWP**
Switching or Routine Inspections/ Patrols	Only method of access accepted by National Grid	Not accepted	Not accepted
	Safe access must be provided without the need for circuit outages.	N/A	N/A
	Oversailing conductors acceptable. For design guidance on avoiding conductors in proximity see 22.4	N/A	N/A
Access to Secondary Equipment (e.g. control/interlocking circuits) for Fault Investigation	Preferred method of access.	Access by small pre-form scaffold platform (≤ 1.8m) may be accepted where access by permanent platform is not reasonably practicable.	Not generally acceptable. Designers must be able to justify this design decision.
	Safe access must be provided without the need for circuit outages.	Safe access must be provided without the need for circuit outages.	Safe access must be provided without the need for circuit outages.
	Oversailing conductors acceptable. For design guidance on eliminating conductors in proximity see 22.4.	Oversailing conductors acceptable. For design guidance on eliminating conductors in proximity see 22.5.	Oversailing conductors are not acceptable except where it is not reasonably practicable to eliminate them. For design guidance on eliminating conductors in proximity see 22.6.

	Access from ground level or permanent platform **	**Access by temporary fixed-height platform (e.g. pre-form/pole & clip scaffold).**	**Access by MEWP**
Routine Preventive Maintenance (any routine work activity specified in the manufacturers operating & maintenance instructions).	Preferred method of low-level access	Acceptable for low-level access (≤ 3.6m) and for high-level access in situations (such as indoor substations) where MEWP access cannot reasonably practicably be provided.	Preferred method of high-level access in all substations.
	The design shall be based on minimum circuit outages (i.e. a requirement for additional 'proximity' outages will generally not be acceptable).	The design shall be based on minimum circuit outages (i.e. a requirement for additional 'proximity' outages will generally not be acceptable).	The design shall be based on minimum circuit outages (i.e. a requirement for additional 'proximity' outages will generally not be acceptable).
	Oversailing conductors acceptable. For design guidance on eliminating conductors in proximity see 22.4.	Oversailing conductors are not acceptable except where it is not reasonably practicable to eliminate them. For design guidance on eliminating conductors in proximity see 22.5.	Oversailing conductors are not acceptable except where it is not reasonably practicable to eliminate them. For design guidance on eliminating conductors in proximity see 22.6.
FaultRepair/ Erection/ Extension/ Replacement /Demolition	Acceptable method of access.	Acceptable for low-level access (≤ 3.6m) and for high-level access in situations where MEWP access cannot reasonably practicably be provided.	Preferred method of high-level access in all substations.
	Required circuit outages must not exceed the maximum conditions as detailed in Part 4, Section 2	Required circuit outages must not exceed the maximum conditions as detailed in Part 4, Section 2.	Required circuit outages must not exceed the maximum conditions as detailed in Part 4, Section 2
	Oversailing conductors acceptable. For design guidance on eliminating conductors in proximity see 22.4.	Oversailing conductors are not acceptable except where it is not reasonably practicable to eliminate them. For design guidance on eliminating conductors in proximity see 22.5.	Oversailing conductors are not acceptable except where it is not reasonably practicable to eliminate them. For design guidance on eliminating conductors in proximity see 22.6.

	Access from ground level or permanent platform **	**Access by temporary fixed-height platform (e.g. pre-form/pole & clip scaffold).**	**Access by MEWP**
Vehicle Access (to defined roadways within the substation)	Safe access should generally be provided without the need for circuit outages.	N/A	N/A
	Oversailing conductors acceptable. Conductors in proximity shall be eliminated by providing a minimum vertical clearance from the roadway to live conductors of either: • Minimum height above ground of overhead lines as defined in the Electricity Safety, Quality & Continuity Regulations 2002. • Max vehicle height + 0.5m margin + Safety Distance Whichever is the greatest.		
Non Primary System Work (i.e. all reasonably foreseeable work in a substation, including repairs, other than work on primary system equipment).	Preferred means of low-level access.	Acceptable	Not generally acceptable for routine work activities. Acceptable for non-routine work activities.
	Safe access should generally be provided without the need for circuit outages.	Safe access should generally be provided without the need for circuit outages.	Safe access should generally be provided without the need for circuit outages.
	Oversailing conductors acceptable. For design guidance on eliminating conductors in proximity see 22.4.	Oversailing conductors are not acceptable except where it is not reasonably practicable to eliminate them. For design guidance on eliminating conductors in proximity see 22.5.	Oversailing conductors are not acceptable except where it is not reasonably practicable to eliminate them. For design guidance on eliminating conductors in proximity see 22.6.

** Includes mobile steps, although they are non-preferred.

23 SECTION 3 - CONDUCTOR JOINTING IN SUBSTATIONS

23.1 PURPOSE AND SCOPE

Within a substation there are many electrical connections ranging from high current busbar and earthing joints down to small assemblies on electronic circuit boards. This appendix deals with the former i.e. connections required to carry either primary load current or fault current or both. The associated maximum permitted temperatures under these conditions are 90°C and 405°C (325°C for aluminium). This appendix does not cover equipment contacts, contractors, and sliding/moving contacts for which specific and detailed installation and maintenance instructions exist.

The integrity of busbar and earthing connections is essential for the security and safety of the high voltage substation. They are heavily loaded and temperatures at the connection interface are high such that degradation of poorly made and maintained joints is likely. Outdoor connections that operate under all weather conditions require protection to avoid corrosion induced long-term degradation.

The aim of this document is to provide guidance on good practice for conductor jointing in substations and it is Informative rather than Normative in nature. It aims to promote a good understanding of how to achieve high quality electrical connection and details typical problems encountered within the jointing process. Particular emphasis is placed on bolted joints for two reasons. Firstly, they can be less secure than joints which rely on fusion of materials e.g. welding and secondly, many bolted joints are disconnected for maintenance or to provide electrical isolation and thereby are at risk of being incorrectly remade.

23.2 JOINTING GUIDELINES

There are a wide range of jointing methods available but, without exception, their effectiveness relies on trained people working to established procedures. Inadequately trained workers or a disregard of the precise instructions is liable to be unsafe and result in an inadequate connection.

Guidance Notes 23.11 and 23.12 provide a summary of different joint types, their application suitability and appropriate standards that may apply. Where particular jointing instructions exist, they should be followed, since they will normally have been developed and tested by the manufacturer or supplier.

23.3 BOLTED JOINTS

23.3.1 Preparation of Unplated/Untinned Bare Surfaces of Bolted Joints

Brushing using a stainless steel wire brush is widely used to remove gross oxide films and contamination and to create the rough sharp peaks needed for good electrical contact. However, the ends of the steel tines become rounded after repeated use and the brush then loses its effectiveness. A more reliable method of abrasion is to use aluminium oxide cloth grade 80. Aluminium surfaces require particularly diligent surface preparation.

The following procedure has been found to give consistent low resistance joints.

a) Use a suitable solvent to clean dirty or greasy surfaces such as Elecsol 41 or Elecsol Super which may be obtained from Forward Chemicals Ltd, Tel 0151 4249441

b) Remove any burrs around bolt-holes or edges. Busbar or strip should be flat and any noticeable bowing or distortion should be removed.

c) Use a fresh strip of aluminium oxide cloth Grade 80 and thoroughly abrade the mating surfaces.

d) Without delay, coat each surface with a thin layer of suitable grease for jointing, e.g. Castrol 'Rustilo 431' or equivalent.

Certain types of joint combinations can develop instability if operating at continuous high temperature. For these types of joint, a suitable transition interface should be used as indicated in 23.11. One of the methods of achieving this is by transition washers, which can be obtained from Sicame Electrical Developments Ltd, Huddersfield, Tel 01484 681115. The assembly instructions provided should be strictly followed.

23.3.2 Preparation of Tinned or Plated Surfaces of Bolted Joints

a) Use a suitable solvent to clean dirty or greasy surfaces such as Elecsol 41 or Elecsol Super, obtained from Forward Chemicals Ltd Tel 0151 4249441

b) Remove any burrs around bolt-holes or edges. Busbar or strip should be flat and any noticeable bowing or distortion should be removed.

c) Do not prepare plated surfaces unless they appear badly tarnished. A toothbrush/nylon nailbrush or similar can be used to remove tarnish without scratching the plating. The exception is nickel plating which has a surface film which can inhibit good contact if the contact pressure is low. It is prudent to abrade this surface lightly and carefully with grade 400 oxide paper.

d) Without delay, coat each surface with a thin layer of approved grease for jointing, e.g. Castrol 'Rustilo 431' or equivalent.

Note The surfaces of bolted joints that are working in transformer oil should be coated with Petroleum Jelly. Other greases may be chemically incompatible.

23.3.3 Assembly of Bolted Joints

a) Ensure that nuts run freely on the bolts or studs.

b) Assemble the joint as soon as possible after the surfaces have been prepared to minimise oxide growth and contamination of the surfaces.

c) Ensure the correct sized washers have been placed under the bolt head and nut before tightening.

d) Tighten using a torque wrench set for the size and grade of bolt material.

e) If the electrical connections allow, measure the resistance of the joint and check the value is less than the resistance of the same length of un-jointed bar.

f) Protect joints used outdoors against corrosion. Smear a liberal amount of grease e.g. Castrol 'Rustilo 431' or equivalent around the joint edges of similar metal joints. If the metals are dissimilar e.g. aluminium bolted to copper, overwrap the whole area of overlap with anticorrosion tape such as Densochrome Tape or preinstall a heat shrink sleeve packed with Castrol 'Rustilo 431'grease or equivalent. Mastic may be more practicable for complex shapes.

Note Do not install copper to aluminium connections with the copper above the aluminium as copper salts can drain down and cause electrolytic action.

23.3.4 Service Performance of Bolted Joints

Bolted joints prepared and assembled in accordance with the above recommendations should give a long and trouble-free life making continuous monitoring unnecessary. However, joints which carry high continuous or cyclic currents or which experience mechanical disturbance, vibration or shock may be susceptible to some degradation and a consequent increase in electrical resistance. Overheating may result.

Measurement of joint temperatures using an infrared camera or measurement of joint resistance can be used to ascertain the condition of current carrying joints. A joint resistance greater than the resistance of the same length of unjointed conductor is a cause for further investigation and, if possible, a comparison should be made with the resistance of similar joints and with commissioned resistance values.

23.4 OTHER METHODS OF JOINTING

This section briefly describes jointing techniques, other than bolting, with an indication of their effectiveness, security and problems.

23.4.1 Gas Shielded Electric Arc Welding (MIG – TIG)

Welding of copper, aluminium and steel produces efficient and compact joints and is useful for jointing tubular conductors and conductors of different cross-sections. Effective jointing relies on correct procedures being followed (see BS 3571-1 and BS 3019-1) and appropriate training (see BS 4872-2 and BS EN 287-2). Particular attention must be paid to the effective tenting of the work area to ensure a relatively draught free environment. Failure to maintain this environment can result in the gas shield being broken resulting in porous or oxidised welds. Measurement of the resistance of completed joints is unnecessary since the electrical contact area is relatively large. Sample testing of completed joints should be undertaken in accordance with BS 3451 and BS EN 1320.

23.4.2 Fusion Electric Arc Welding, Gas Brazing and High Temperature Soldering

These techniques are a common and convenient way of joining copper, aluminium and certain other materials. During fillet or lap jointing of aluminium the fluoride flux used during the jointing process is liable to entrapment between contracting metal surfaces. This material is inherently corrosive and may cause joint deterioration over time despite initial indications of an effective joint. On this basis this technique should be avoided.

Electric arc fusion welding of copper is unsatisfactory due to porosity and brittle inter-metallic formations impairing the mechanical properties of the joint.

Copper/aluminium jointing requires careful control and the provision of a 0.75-1mm layer of silver brazing alloy to the weld area of the copper. This is metallurgically compatible with both copper and aluminium and jointing can be performed by direct fusion welding using conventional aluminium-silicon filler metal.

Jointing of copper to rebar steel or wrought iron can be achieved by ‘bronze welding’. This refernce to welding is misleading since there is no melting of the parent metals. A strong bond is created by the flow of the filler metal and the wetting of the parent metals. The filler wire consists of copper rich alloys and has a lower melting point than the parent metals. Joint preparation and cleanliness are essential to ensure that the molten filler metal flows over the complete joint area. Joint quality is not easy to determine since the electrical resistance will normally be very low. BS EN 1320 recommends the use of a fracture test conducted with dynamic sensible strokes (3 off) applied from a hammer to check whether the joint is sound.

23.4.3 Explosive Jointing / Cold Pressure Welding

These techniques are used mainly for joining aluminium-aluminium and copper-copper. The technique bonds material mating faces by compression from either explosive detonation (explosive jointing) or the hydraulic application of localised compressive forces (cold pressure welding). Cold pressure welding typically employs interconnection by four weld dimples. Joints of this type are particularly difficult to maintain since the resistance of the individual dimples must be measured to ensure the joint integrity.

Experience has shown that aluminium/copper joints of this type suffer from the formation of brittle inter-metallic compounds during the jointing process. Aluminium/aluminium joints suffer similarly if joint face preparation is inadequate. Joints of this type have been know to fail as a result of a hammer blow and, in extreme cases, with no apparent external interference. These methods of jointing are considered unacceptable to National Grid.

23.4.4 Eutectic Welding

This technique employs a carbon crucible and an ignitable eutectic mixture surrounding the area to be joined. Localised heating causes fusion of metal to eutectic. Specialist companies market the components for eutectic welding and the precise jointing instructions must be followed if a successful joint is to be made. Copper – copper, copper – aluminium and copper – steel combinations are possible. Joints involving steel require particular care in their preparation. The eutectic that is formed may have a melting point lower than that of the parent metal. Earthing strip joints, for example, which may rise to very high temperatures during high intensity faults are particularly dependent on the eutectic properties. The supplier must always be consulted in case of doubt.

A mechanical shock is the only way to check the joint has been satisfactorily fused. The finished joint often appears with small blow holes which do not detract from joint efficiency but the porosity could contribute to corrosive degradation in the longer term. A coating of bitumastic paint will provide protection.

23.4.5 Compression Jointing

This method is applicable to joining solid or circular conductors. It is important that the dies, compression tools and the ferrules or lugs from the same manufacturer. Subject to this requirement, the main features are cleaning of the conductor, the correct use of the die (that is the number and order of compression bites) and applying the correct pressure from the hand or hydraulic tool. Greasing of the conductor may be specified to enhance stability and inhibit corrosion.

Compression jointing of flexible aluminium conductor in a substation requires diligent attention to surface preparation. Manufacturers were faced with considerable difficulties in the 1970's in designing compression jointing systems for aluminium conductors that were stable over a thirty year lifespan and many changes to design parameters have been made. Surface preparation and adherence to jointing instructions is equally important today and a measurement of the electrical resistance after assembly is vital. The resistance of the joint should be less than the resistance of the same length of conductor however more specific pass/fail figures are often provided by the supplier.

Greasing of outdoor compression joints is especially important. The large compression joints used on down-droppers from an overhead line entry are particularly susceptible to inadequate greasing of the barrel since water can drain down into the joint and set up a corrosive cell.

23.5 SURFACES IN CONTACT

23.5.1 Background Information

Metal parts welded together by thermal fusion or brazing are kept in intimate contact by molecular attraction forces that are a characteristic of all solid materials. They act as one material with electricity able to flow without hindrance across the interface. In practice there may be occlusions and voids which reduce the mechanical strength of the joint. They also reduce the area for conducting electricity but there is normally so much redundancy in electrical contact area that overheating is not a problem.

Metal parts welded together by the action of pressure alone are also held in intimate contact by molecular attraction forces. However, pressure welded joints have significantly less area in mechanical and electrical contact than heat fused joints. Surface oxide films are only ruptured and they remain within the interface as non-conducting areas which have little or no mechanical bonding strength. Recent experience within National Grid is of pressure welds failing during normal service and also after site checks were conducted by tapping the joints with a 'sensible blow' from a hammer. Principally these failures have been attributed to unsatisfactory surface preparation prior to the jointing process. Since this preparation is difficult to guarantee this method of jointing is presently unacceptable to National Grid.

Finally there are purely mechanical joints of bolted or compression type. Bolted joints are characterised by the drilling of the mating surfaces and clamping by mean of bolts. These joints are readily disconnectable and are commonly used. Compression joints involve the sliding of a ferrule or tubular lug over a circular or shaped conductor. The two parts are then forced into intimate contact using a mechanical tool with indenting dies. The hoop stress created in the distorted ferrule maintains contact. This connection is commonly used for cable & flexible conductor ends and once made can only be removed by cutting off the complete assembly.

23.5.2 Basic Principles

An understanding of the fundamentals of surfaces in contact is important if bolted joints are to be correctly made and maintained.

When two surfaces come together under pressure contact is made where the highest peaks or asperities meet. Even surfaces apparently smooth to the eye are sufficiently rough on a microscopic scale for the contact to be limited to isolated points. These points are under such high pressure that they deform plastically until sufficient contact area exists to support the applied mechanical load. Current flowing across the interface is thus constricted to the small areas in contact – see Figure 20.

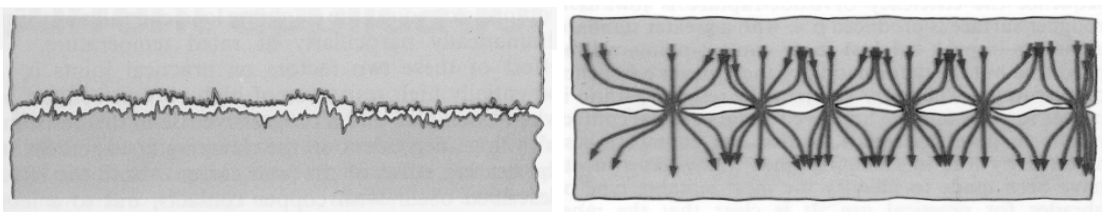


Figure - 20 - Surfaces in Contact and Current Flow

The electrical resistance of the joint is related to the extent that the surfaces are in contact and measurement of the resistance of the joint is a guide to joint efficiency i.e. how much electrical contact has been achieved.

The measurement of resistance (V/I) is normally made using a direct reading instrument with the readout typically in microhms, (μΩ). Determination of joint efficiency is normally by comparison of the electrical resistance of the joint with that of the same length of un-jointed busbar. By reference to Figure 21 it is clear that a perfect joint with an appropriate overlap and contact across the whole surface would have an electrical resistance of about 1/2 that of an unjointed busbar. The "resistance ratio" is 0.5. The aim is for joints made in the substation, and particularly those carrying load current, to have a resistance ratio of less than unity such that the joints will not become hotter than the busbar itself.

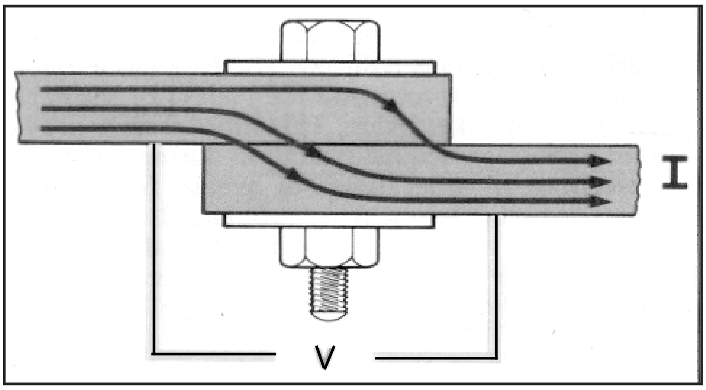


Figure 21 - Joint Resistance

23.5.3 **Application to Bolted Joints**

For both bolted and compression joints the clamping pressure does not result in contact being made over more than about 10 - 20% of the overlap area and many metals also have non-conducting surface oxide films which inhibit the passage of current. Current will only flow through those regions where the oxide has been mutually ruptured to allow metal-to-metal contact and the metallic conducting area is generally less than the mechanical load bearing area. Furthermore, if the clamping pressure reduces during service (e.g. due to relaxation) some of the metal contact spots can be broken reducing further the areas for electricity to pass across the joint. The resultant overheating could lead to further relaxation and thermal runaway could result in joint failure.

Diligent surface preparation and adequate clamping pressure are required to achieve and maintain the maximum number of electrical contacts.

a) Surface Preparation

Rupture of oxide films allowing metal to metal contact is essential if the electrical contact area is to approach the mechanical load bearing area. Surface cleaning by wire brush or oxide cloth removes the gross oxide film growth since manufacture however a thin layer of oxide reforms immediately. Depending on the metal this may act as a more or less effective barrier to current flow.

The two most common busbar materials are copper and aluminium with the latter requiring the more meticulous attention to surface preparation due to the hard, tenacious and insulating nature of its oxide film. Procedures which are effective for aluminium will be more than adequate for copper since copper oxides are fairly soft and easy to remove.

The bringing together of two fairly smooth surfaces, such as that shown in Figure 20, results in many small height peaks coming into contact and the plastic deformation of each peak is relatively small.

Figure 22 shows that for rougher surfaces fewer contact points exist but the area and deformation of individual peaks is much greater resulting in a more effective rupturing of surface oxide films. The conclusion from this is that electrical contact surfaces should be **roughened** before they are bolted together and not polished smooth.

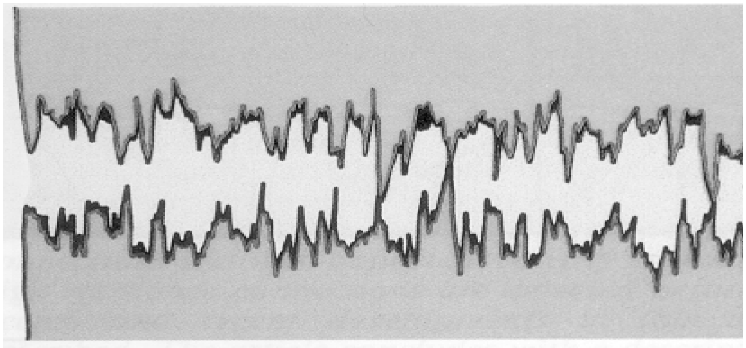


Figure 22 - Surfaces in Contact

Since the peak height and the sharpness of the profile are important it is important that the most appropriate abrasive is chosen. Abrasives differ in their ability to create the rough sharp profiles needed for best electrical contact and aluminium oxide cloth Grade 80 has been found to be particularly effective.

The inside of the ferrule of compression connectors is treated at the factory since it is difficult to abrade it on site. The cable end should, however, be abraded.

A viscous grease, such as petroleum jelly, applied to mating surfaces after they have been abraded helps maintain low resistance contacts since it reduces the rate of oxide growth after abrasion and provides protection during service. Petroleum jelly has low film strength and it is forced into the valleys of the surfaces when assembly takes place however it has a low melting point (below 60 °C) and other greases are available for higher temperatures. The effectiveness of other types of grease for bolted or compression joints will be influenced by their film strength. Lubricating oils and greases used to reduce wear by keeping metal surfaces apart are unsuitable. The other function of the contact grease is to prevent corrosion of the contact interface that may occur outdoors.

b) Clamping Pressure

Clamping pressure can be best achieved and maintained by using:

(i) a larger number of small sized bolts (rather than a few large bolts);

(ii) a bolt material that minimises creep relaxation and relative thermal expansion;

(iii) thick washers under the bolt head and nut;

(iv) a specified torque for tightening the assembly.

For compression joints, the length and thickness of the ferrule, the design of the indenting system and the compressive force applied by the indenting tool are important factors.

An important point to note concerns the tightening of bolted joints using the soft electrical grade of aluminium which is often used for earthing strip. If, as the nut is tightened, the backing washer starts to rotate it can scour the aluminium surface and in extreme cases gouge an ever-deeper hole. This is avoided by using large diameter, thick, flat washers and ensuring they are dry and not lubricated.

23.5.4 Dissimilar Metals in Contact

This is an important topic and one that has created more interface or contact problems with bolted joints than almost anything else. One of the most common scenarios is aluminium earthing tape used above ground but connected to an underground earth mat made of copper. The aluminium and copper must be bonded above ground using an appropriate technique such as brazing or bolting. Since aluminium and copper are distant within the electrochemical scale aluminium is strongly anodic and copper is strongly cathodic. This leads to copper/aluminium joints being very susceptible to progressive erosion of the aluminium and to jacking due to the production of corrosion products. This is particularly the case in the presence of moisture and overwrapping the completed joint with a proprietary tape or using a pre-impregnated heat shrink tube over the joint are good preventive measures. Consideration should also be given to the location of the bolted joint particularly when maintenance procedures may require future examinations.

It is important to note that some metal combinations are inherently unstable.

Experience has shown that copper - copper connections are very secure and they are only likely to degrade at high temperatures. Nevertheless, it is common practice to tin or silver plate the mating surfaces since the contact is superior over a wide temperature range and abrasion of the surfaces prior to assembly is unnecessary. This is because the nature and amount of oxide formation on tin and silver is such that it is broken under modest pressures without the need for high sharp peaks. Excessive tarnishing should still be removed by very light abrasion.

Aluminium - aluminium connections are less secure and much care is needed over surface preparation, greasing and clamping to ensure stable joints. Plating of aluminium with tin, silver or even nickel is possible but difficult and this is normally reserved for special applications.

Copper-aluminium connections used for carrying load current have often suffered from overheating. This is not associated with bimetallic corrosion but is thought to be due partially to differential expansion forces and partially to lack of intermolecular adhesion of the metal-metal contact points.

In summary, the most stable joints are those between like interfaces and the most unstable are those between dissimilar interfaces where the factors mentioned above can be dominant. Aluminium-aluminium and tin-plated aluminium- tin-plated copper would be regarded as stable joints but aluminium - copper and aluminium-tin-plated copper would have a tendency to be unstable particularly at continuous high operating temperatures.

Fitting of a metallic insert is a technique designed to fulfil two roles. First, it overcomes any fundamental incompatibility that may exist between two metals that need to be bolted together. For example, both copper and aluminium form a stable interface with brass and the insertion of a brass disc between copper and aluminium overcomes the inherent incompatibility of these two materials. Second the insert can be profiled to ensure penetration of tenacious oxide films and provide good contact without the need for surface abrasion. The brass metallic insert developed by CEGB engineers and made and marketed by Sicame is an example of such a product.

There are other proprietary ways of combating incompatibility of mating surfaces and providing satisfactory test data is available these may be used. An example is the use of copper clad aluminium (cupal) which combines the lightness and economy of aluminium with the good contact properties of copper. The copper is factory extruded over an aluminium section under a very high pressure. Cut edges and bolt holes made in this clad material are a potential source of corrosion and grease protection of these exposed surfaces is desirable.

23.6 RESISTANCE MEASUREMENT

Resistance measurements are important at the commissioning stage to ensure the jointing procedures have been correctly implemented. Routine measurements of the resistances of critical items of plant throughout their service life are also needed to check there has been no significant deterioration.

The joints covered in this document are all large and their electrical resistance is low. Values can range from as little as 2 μΩ for large busbar connections to a few hundred microhms for small cable connections. Even poorly made joints will still have a relatively low resistance and so it is important to be able to make accurate measurements of resistance to detect joints that are not satisfactory for service.

Accurate field measurements of such low values of resistance can only be achieved by specialist equipment which is widely available. Perhaps the best known in the UK is the Chance Digital Micro Ohmmeter (DMO) which was developed by CEGB engineers in the early 1970's and has been progressively refined since then. The term Ducter was coined for this instrument at the time although this was actually the trade name of an earlier instrument used for low resistance measurements.

The DMO, which can measure resistance from 0.1μΩ to 10Ω, operates using a four-wire measurement technique to obtain the necessary accuracy. Figure 23 shows how the four connections are made between the resistance under test and the DMO.

The connection of the test instrument is either by way of individual voltage and current connection leads using mole clamps or by combined voltage/current hand held probes. Convention is for combined voltage/current probes to be used when resistance measurements are required across short spans on rigid conductors, such as across connectors to equipment palms. Individual current/voltage leads are used for longer spans such as the measurement of complete multiple circuit breaker interrupter heads or where flexible conductors are at the connection points.

A precise current is passed through the joint from a position sufficiently remote to ensure uniformly distribution in the cross-section of the joint. For stranded conductors where there may be significant inter-strand contact resistance this distance should be at least ten diameters. The distance can be shorter for solid conductors. If the current leads are moved further in or out and the reading displayed on the instrument changes, this is evidence that the current leads are too close to the joint being measured.

The voltage measurement leads are positioned such that only the voltage developed across the joint is measured. The instrument passes current through the joint in both directions and the resistance is calculated within the instrument (V/I) using the average of the two measured voltages. This averaging is intended to combat the effect of thermal emfs which can be of a similar magnitude to the voltage developed across the joint due to current flow.

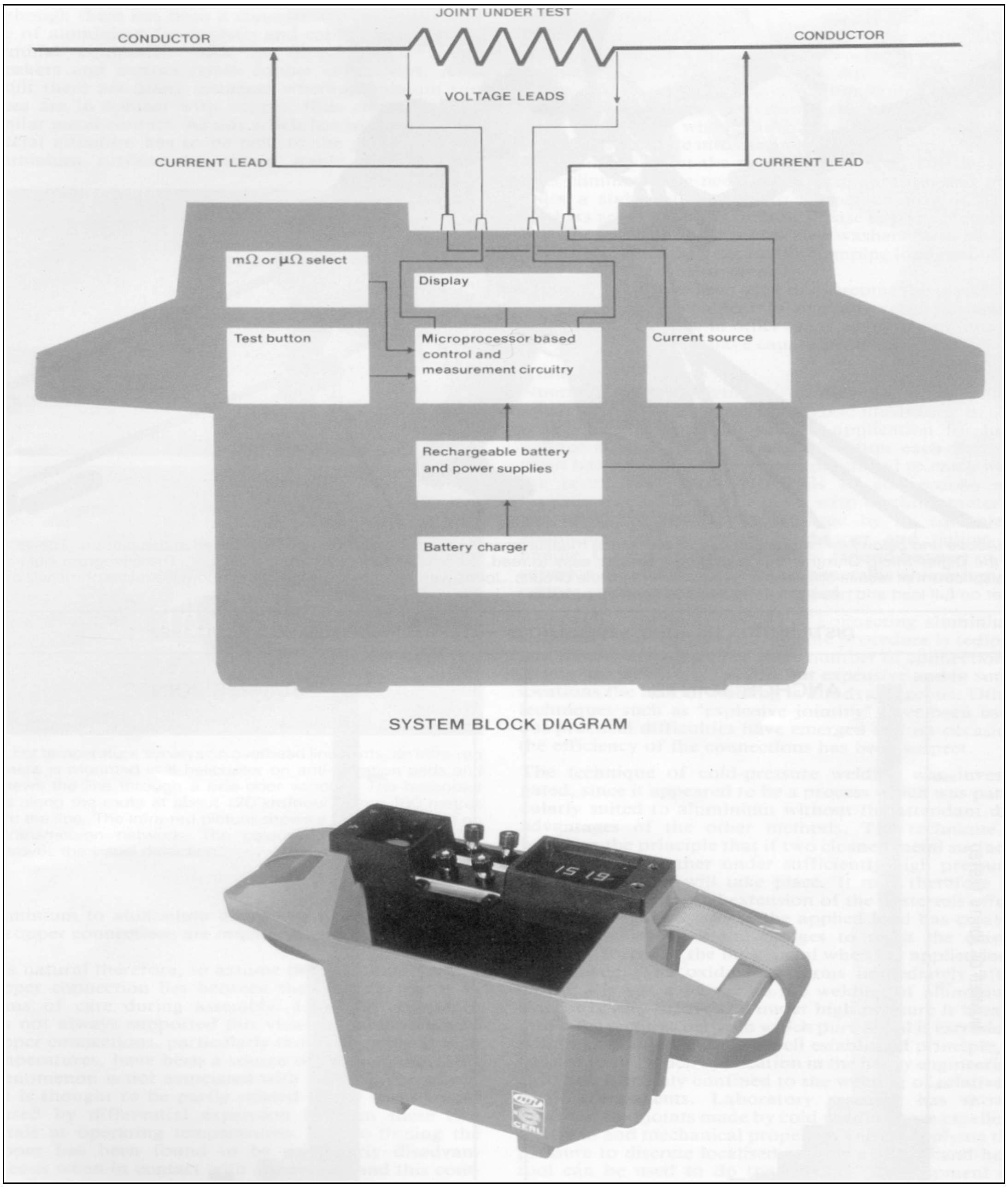


Figure 23 - A typical Digital Micro Ohmmeter (DMO)

23.7 IMPORTANCE OF SURFACE PREPARATION FOR ALUMINIUM

Tests have been made on simple bolted lap joints made between aluminium strips. The surfaces were abraded, left for a specific time (to allow oxide to reform) and then bolted up to a standard torque. The electrical resistance of the joint was then measured and compared with the resistance of the same length of strip (R_{joint} divided by R_{strip} equals Resistance Ratio). Different abrasives were used to test their effectiveness and an example of the results is given in Figure 24.

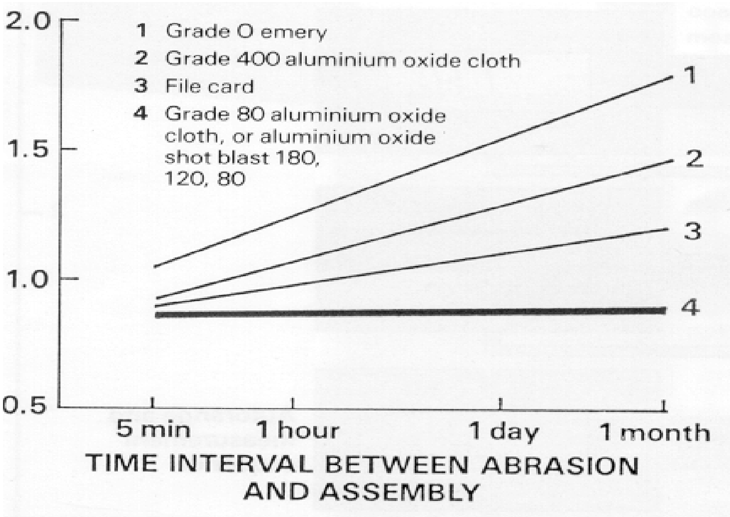


Figure 24 - Initial Resistance of Bolted Aluminium Joints

Figure 14 shows results from current cycling tests on bolted aluminium joints. Current was passed through the joints to raise the temperature to 100 °C over a one-hour heating period. The assemblies were then cooled to ambient and the current switched on again. The electrical resistance of the joints was measured at various stages over a 2000 cycle test. The results are plotted in Figure 25 where the actual resistances are used rather than resistance ratio to further stress how important good surface preparation is to achieving stable performance. The three lowest resistance plots were obtained with Grade 80 cloth abrasion followed by greasing with petroleum jelly and bolting up promptly.

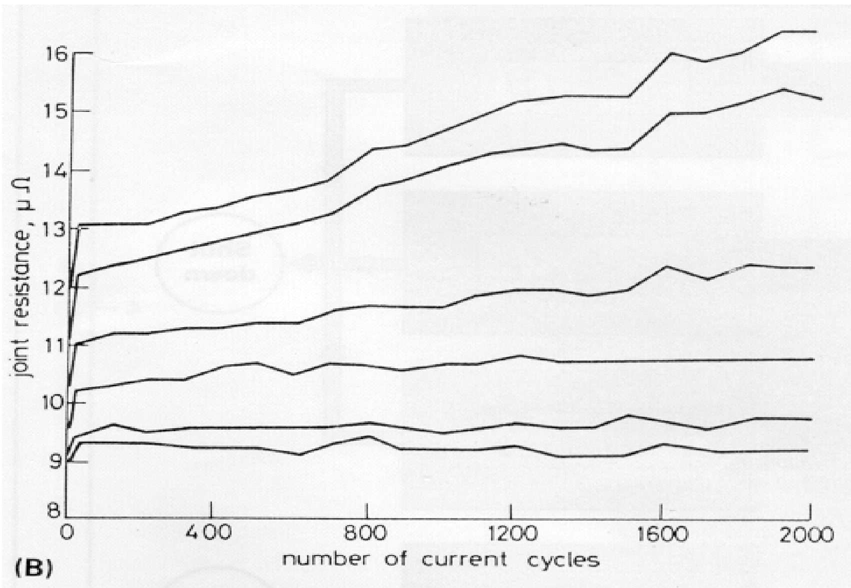


Figure 25 - Load Cycle Performance measurements of Bolted Aluminium Joints with differing initial contact resistances

23.8 FURTHER INFORMATION ON BOLTING

Bolted aluminium joints are more sensitive to variations in clamping load and pressure than copper joints and the guidance given below will be more than adequate for other arrangements. This information is to help in those situations where no other information or instructions are provided. Many items of plant are assembled according to specific information provided by manufacturer or supplier and the instructions should always be followed.

It is preferable to use a larger number of small bolts rather than a few large bolts, (the maximum bolt size should typically be no bigger than M12). The reasons are:

e) The clamping load is more uniformly distributed over the overlap area.

f) There is more strain energy in the clamping assembly which minimises loss in clamping load due to creep in service.

g) Large bolts need a proportionally greater torque for the same bolt load which can be difficult to achieve in practice.

The number and size of bolts for various aluminium busbar arrangements has been determined from tests. Empirical rules have been used to aid design as follows:

h) Total clamping load N (Newton per bolt x number of bolts) divided by current rating (kA) should be not less than 50 i.e. $N/A \geq 50$.

i) The washer clamping pressure (load on bolt divided by washer area) should be around 40 i.e. $N/mm^2 = 40$.

These clamping loads and pressures apply to grade 8.8 steel bolts. From this, the torque values may be calculated for the bolt sizes used. Reference 1 contains useful information on typical bolting arrangements. Alternatives to steel bolts (such as aluminium or brass) can be used but this is outside the scope of this guidance. Some designers offset the loss of clamping load in service with Belleville washers. These should not be necessary if the above empirical rules are followed.

Aluminium used for earthing strip and other applications where flexibility is important (grade 1350) is very soft. If washers under the nut and bolt head are too thin they will dish as the nut is tightened and can be driven into the aluminium making it impossible to achieve the necessary torque on the bolt. The backing washers supplied should always be used and, if none are available, washers that are at least 2 mm thick should be obtained. Table 36 is a guide to bolting torque and washer sizes.

Bolt Size Grade 8.8 steel	Bolt Torque (Nm)	Washer Dimensions – mm		
		Inside diameter	Outside diameter	Thickness
M6	7	6.4	14	2.0
M8	20	8.4	21	2.2
M10	35	10.5	24	2.4
M12	50	12.8	28	3.0
M16	90	16.8	34	3.4

Table 36 - Bolting Guide for Aluminium Joints

23.9 INFRARED TEMPERATURE MEASUREMENTS

This non-contact method is particularly suited to high voltage connections since measurements can be made safely and speedily by scanning the joints in turn and noting the readings obtained. The reading from the instrument, in degrees centigrade, is only an accurate measure of joint temperature if the emissivity of the joint surface is also known precisely. Since the temperature of a joint at any point in time is dependant on the level of current flowing and the degree of cooling (wind speed, air temperature, presence or lack of sun), the actual temperature is less important than the relative temperature of the joint compared to the conductor alongside. Since a joint is larger in surface area than the conductor and thus better cooled, and with a lower initial electrical resistance, it should run cooler than the conductor. Thus, if when making a routine infrared scan, a joint appears to be running hotter than the adjacent conductor, it is suspect. The degree of urgency for investigating the matter further is dependent on how much hotter the joint is running and this itself is a function of load current and weather conditions at the time. Good practice therefore dictates that infrared measurements be undertaken when sizeable load current is flowing and weather conditions are calm. Under these conditions, temperature differences between joint and conductor exceeding 5°C are an indication that the joint is suspect and it should be taken out of service and re-made at the next available outage. Temperature differences in excess of 10°C dictate that more rapid action be taken i.e. urgent joint repair or that frequent surveillance be carried out using a hand held infrared camera to monitor the deterioration rate, so that the potential failure risks can be managed until the repair is done.

23.10 REFERENCES

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23.11 GUIDANCE NOTE - Suitability of Bolted Joints

BOLTED JOINT TYPES	SUITABILITY	SPECIAL REQUIREMENTS	ACCEPTABLE CRITERIA
Aluminium-Aluminium	*	Protect outdoor joints (◊)	Resistance checks required -See 23.6
Copper-Copper	*	Protect outdoor joints (◊)	As above
Tinned Copper-Tinned Copper	*	Excessive tarnish to be removed without scratching surface (toothbrush/nylon nailbrush). Protect outdoor joints (◊)	As above
Plated Copper-Plated Copper	*	Excessive tarnish to be removed without scratching surface (toothbrush/nylon nailbrush). Protect outdoor joints (◊)	As above
Aluminium-Copper	*	Position aluminium above copper to discourage electrolytic action. Protect outdoor joints (◊). Joint not suitable for <u>continuous</u> high temperature operation unless used with a suitable transition interface (#).	As above
Aluminium-Tinned Copper Aluminium – Tin Plated Copper	*	Protect outdoor joints (◊) Joint not suitable for <u>continuous</u> high temperature operation unless used with a suitable transition interface (#). Excessive tarnish to be removed without scratching surface (toothbrush/nylon nailbrush).	As above
Aluminium- Silver Plated Copper	*	Protect outdoor joints (◊). Joint not suitable for <u>continuous</u> high temperature operation unless used with a suitable transition interface (#). Excessive tarnish to be removed without scratching surface (toothbrush/nylon nailbrush)	As above
Aluminium-Nickel Plated Copper	*	Protect outdoor joints (◊). Careful thorough abrading of nickel plated copper with 400 oxide paper is required to remove surface high resistance film.	As above
Aluminium-Steel	*	Protect outdoor joints (◊)	As above
Aluminium-Galvanised Steel	*	Protect outdoor joints (◊) .Not recommended without a transition interface (#), or remove galvanising at interface.	As above
Plated aluminium-Plated Aluminium	*	Only joints with similar platings e.g. tin to tin, nickel to nickel – nickel surfaces require careful preparation with 400 grade oxide paper. Protect outdoor joints (◊)	As above
Plated Aluminium- Copper	*	Excessive tarnish to be removed without scratching surface of plated Aluminium toothbrush/nylon nailbrush). Protect outdoor joints (◊)	Resistance checks required -See 23.6
Plated Aluminium-Plated Copper	*	Only joint similar platings e.g. tin to tin, nickel to nickel – nickel plated surfaces require careful preparation. Excessive tarnish to be removed without scratching plated surface (toothbrush/nylon nailbrush). Nickel plating requires thorough abrading with grade 400 oxide paper. Protect outdoor joints (◊)	As above

BOLTED JOINT TYPES	SUITABILITY	SPECIAL REQUIREMENTS	ACCEPTABLE CRITERIA
Aluminium / Brass	*	Protect outdoor joints (◊)	As above
Copper / Brass	*	Protect outdoor joints (◊)	As above
Copper-Steel	*	Protect outdoor joints (◊)	As above
Copper-Galvanised steel	*	Protect outdoor joints (◊)	As above
Tinned Copper-Steel	*	Excessive tarnish to be removed without scratching tinned surface (toothbrush/nylon nailbrush). Protect outdoor joints (◊)	As above
Tinned Copper-Galvanised Steel	*	Acceptable only if galvanising is fairly clean and uncorroded, otherwise remove tinning. Protect outdoor joints (◊)	As above

Note:
* Not suitable for use below ground
◊ See 23.3.3
Brass interface e.g transition washer – see 23.3.1

23.12 GUIDANCE NOTE - Suitability of other methods of Conductor Jointing

METHOD OF JOINTING	SUITABILITY	SPECIAL REQUIREMENTS	ACCEPTABLE CRITERIA
Gas shielded electric arc welding (MIG,TIG)	Not normally used for dissimilar metal jointing. Copper is suitable for use above and below ground while aluminium and steel jointing is only suitable for use above ground	Normal welding practices required with appropriately trained operators to BS3571, BS3019	Joint resistance measurements unnecessary. Joints should be checked with a sensible blow from a hammer to BS EN 1320. Random sample examined for quality of weld to BS3451.
Fusion / Gas Brazing – High Temperature Soldering.	Not normally used for dissimilar metal jointing although Cu-steel, Cu-iron is possible by a bronze brazing process and copper-aluminium jointing can be undertaken by the silver brazing of the copper section prior to welding. Copper is suitable for use below ground but unsuitable for fusion welding without prior treatment. Aluminium and steel are suitable for use above ground only.	Normal welding practices required with appropriately trained operator to BS 499	Joint resistance measurements unnecessary. Joints should be checked with a sensible blow from a hammer to BS EN 1320
Explosive Jointing / Cold Pressure Welding.	Not acceptable to National Grid	N/A	Not acceptable to National Grid
Eutectic Welding (CAD).	Copper-Copper is suitable for use below ground Aluminium-Aluminium, Steel-Steel and Copper –Steel is possible although they are not suitable for use below ground.	Appropriately trained operators required. Great heat generated therefore care must be taken to protect operators.	Joint resistance measurements unnecessary. Joints should be checked with a sharp blow from a hammer to BS EN 1320
Compression Jointing.	Soft Copper- Soft Copper, Soft Aluminium-Soft Aluminium. Not suitable for use below ground.	Aluminium joints require special joint preparation to ensure interface effectiveness. Correct die sizes required for each conductor size.	Joint resistance measurements required after jointing

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