RATINGS AND GENERAL REQUIREMENTS FOR PLANT, EQUIPMENT AND APPARATUS FOR THE NATIONAL GRID SYSTEM

This document is for Relevant Electrical Standards document only.

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PURPOSE AND SCOPE

The requirements of this document apply to all plant, equipment and apparatus which is directly connected to the National Grid 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 66kV and above. Rating for other nominal voltages will be specified in the contract enquiry document.

Derogation from the requirements of the RES 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 Transmission System in England and Wales.

PART 1 – TECHNICAL REQUIREMENTS

1 ENVIRONMENTAL SERVICE CONDITIONS

1.1 General

Plant, equipment and apparatus shall be suitable for operation under the normal service conditions defined in IEC 61936-1 with the following additions/modifications.

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.

1.2 Normal Service Conditions

1.2.1 Indoor

The temperature class shall be "-5 indoor".

1.2.2 Outdoor

The temperature class shall be "-25 outdoor".

The ice coating classification shall be "class 10" (10mm).

The environmental pollution level shall be "Class III – Heavy" as defined in Table 1 of 60071-2.

1.3 Special service conditions

1.3.1 Indoor

Equipment intended to be sited within a closely controlled environment shall be suitable for operation in the temperature range +18^{0}C to +27^{0}C and within the relative humidity range 20% to 75% (Class A1 of BSEN 60654-1). Critical functionality shall be maintained in the event of failure of the environmental controls i.e. under the Normal Service Conditions defined above.

1.3.2 Outdoor

For particular locations, which may be subject to severe coastal/industrial pollution, the environmental pollution level shall be "Class IV – Very Heavy" as defined in Table 1 of 60071-2.

2 ELECTRICAL REQUIREMENTS

2.1 System Voltage

Plant and Equipment shall satisfy their specified functional and performance requirements over the appropriate range of primary voltages given in Table 1.

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	400 kV	275 kV	132 kV	66kV
Rated voltage of plant	420 kV	300 kV	145 kV	72.5kV
Maximum continuous System voltage	420 kV	303 kV	145 kV	70kV
Minimum continuous System voltage	360 kV	247 kV	119 kV	62kV

Table 1 - System Voltage

2.2 Rated Insulation Level and Protective Gap Settings

Plant shall meet the requirements of Table 3 with regard to its rated insulation level.

Table 4 details protective gap settings commonly used by National Grid which should be taken into account.

2.3 System Frequency

Plant and Equipment shall satisfy their specified functional and performance requirements over the range of frequencies given in Table 2.

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 2 - System Frequency

Nominal voltage (kV)	Rated voltage (kV)	Rated short-duration power frequency withstand voltage (kV)		Rated switching impulse withstand voltage (kV.pk)			Rated lightning impulse switching withstand voltage (kV.pk)	
		Common value*/ Phase to earth & between phases	Across open switching device and/or isolating distance	Phase to earth	Between phases	Across open switching device and/ or isolating distance	Common value*/ Phase to earth & between phases	Across open switching device and/ or isolating distance
400	420	520	610	1050	1575	900 (+345)	1425	1425 (+240)
275	300	380	425	850	1275	700 (+245)	1050	1050 (+170)
132	145	275*	315	N/A	N/A	N/A	650*	750
66	72.5	140*	160	N/A	N/A	N/A	325*	375
13	17.5	38*	45	N/A	N/A	N/A	95*	110

Table 3 - Insulation Level Requirements

Nominal voltage (kV)	Mid-line overhead line arcing gap setting (m)	Substation approach (1.6km) overhead line arcing gap setting (m)	Transformer & reactor screened co-ordinating gaps (m)	Cable sealing end co-ordinating gaps (m)	Unscreened gaps applied to existing transformers/ reactors (m)
400	2.8	2.5	1.5	2.54	1.68
275	2.13	1.9	1.2	1.9	1.22
132	1.1	1	0.66	1	0.66
66	N/A	N/A	N/A	0.54	0.54
13	N/A	N/A	0.1	0.1	N/A

Table 4 - Arcing & Co-ordinating Gap Settings

2.4 Earthing of System Neutral

Plant and Equipment shall satisfy their specified functional and performance requirements under the neutral earthing condition given in Table 5.

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

Table 5 - Neutral earthing

2.5 Fault clearance time

Plant and Equipment shall be suitable for operation under the conditions detailed in Table 6.

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
66	120	N/A	<1500
13	75 (of which 35ms max' protection time)	N/A	N/A

Table 6 - 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 which are capable of supplying a fault infeed within a target fault clearance time not exceeding 300 ms.

2.6 Primary Currents

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

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	3150	40	1	45
132*	2000	40	3	45
		31.5	3	135
66	2000	31.5	3	135
13	4000	50	1	96

Table 7 - Short-circuit and load current requirements

*132kV equipment is required to meet **both** short-circuit current ratings detailed in Table 7.

3 DESIGN REQUIREMENTS

4 OPERATIONAL, MAINTENANCE AND MONITORING REQUIREMENTS

4.1 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.

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5 SAFETY, HEALTH, ENVIRONMENT AND SECURITY REQUIREMENTS

Products supplied for installation on the National Grid 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.

The National Grid system, in its entirety, complies with the Electromagnetic Compatibility (EMC) Directive (Statutory Instrument No. 2372 ‘The Electromagnetic Compatibility Regulations 1992’) i.e. it is designed and constructed such that it does not introduce intolerable electromagnetic disturbances to its environment and is immune to electromagnetic disturbances in its environment. Equipment introduced into the system shall not detrimentally effect this compliance.

5.1 Date Proofing

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

Provision shall be made for all products to be clearly marked with their operational identity in accordance with TP109.

6 FORMS AND RECORDS

None.

PART 2 - DEFINITIONS AND DOCUMENT HISTORY

7 DEFINITIONS

7.1 Directly (Connected)

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

7.2 Plant

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

7.3 Equipment

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

7.4 Apparatus

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

8 AMENDMENTS RECORD

Issue	Date	Summary of Changes / Reasons	Author(s)	Approved By (Inc. Job Title)
1	February 2014	New document		

9 IMPLEMENTATION

9.1 Audience Awareness

Audience	Purpose Compliance (C) / Awareness (A)	Notification Method Memo / letter / fax / email / team brief / other (specify)

9.2 Training Requirements

Training Needs N/A / Informal / Workshop / Formal Course	**Training Target Date**	**Implementation Manager**

9.3 Compliance

Text here.

9.4 Procedure Review Date

5 years from publication date.

PART 3 - GUIDANCE NOTES AND APPENDICES

10 REFERENCES

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
IEC 61936-1	Power installations exceeding 1kV : Common rules
Engineering Recommendation (ER) G5/4	Levels of harmonic distortion
National Grid Safety Rules	

SUBSTATIONS - PART 1 - PROCEDURAL

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1 Scope

This Specification covers all NGET substations with equipment installed for use on 66, 132, 275 and 400kV, 50 Hz systems. Substations operating at other voltages are expected to comply with the general provisions of this specification. It is applicable to both open-terminal air-insulated (AIS) and metal-enclosed gas-insulated (GIS) substation constructions (including hybrids thereof) and covers equipment operated at lower voltages on the same substation site. It is applicable to new construction and extensions to existing installations.

All NGET plant and apparatus wholly within the substation and not covered more specifically by other NGET Technical Specifications (TS) is within the scope of this document.

This document follows closely the format and content of IEC 61936-1*, Power installations exceeding 1kV – common rules*, and should be read in conjunction with BS 7354*, Design of high-voltage open terminal stations*. Regarding the hierarchy of requirements given in these documents, specific requirements detailed in NGET Technical Specifications shall take precedence over guidance of BS 7354 which in turn shall take precedence over the general provisions of IEC 61936-1.

2 Normative references

In addition to the references detailed in IEC 61936-1, the following are referred to in this document.

IEC 61936-1	Power installations exceeding 1kV – common rules
IEC 60815	Guide for the selection of insulators in respect of polluted conditions
BS EN 60529	Specification for degrees of protection provided by enclosures (IP code)
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 1710	Specification for Identification of Pipelines and Services.
BS 5395	Stairs, ladders & walkways.
BS 7354	Design of high-voltage open terminal stations
BS 7671	Requirements for electrical installations. IEE Wiring Regulations.
ENA (ER) G74	The calculation of short circuit currents in three-phase AC power systems
ENA (ER) G5	Planning levels for harmonic voltage distortion and the connection of non-linear equipment to transmission systems and distribution networks in the UK.
TS 1 (RES)	Ratings and General Requirements for Plant, equipment and apparatus for the NGET System
TS 2.12 (RES)	Substation auxiliary supplies

TS 2.19 (RES)	Ancillary light current equipment
TS 3.1.1 (RES)	Substation Interlocking Schemes
TS 3.1.2 (RES)	Substation Earthing
TS 3.2.1 (RES)	Circuit-breakers
TS 3.2.2 (RES)	Disconnectors and Earthing Switches
TS 3.2.4 (RES)	Current transformers for protection and general use
TS 3.2.9 (RES)	Solid core post insulators for substations
TS 3.2.14 (RES)	Gas Insulated Switchgear
TS 3.24.15 (RES)	Environmental and test requirements for electronic equipment
TGN(E)187 (RES)	Guidance for conductor jointing in substations
HS(G)38	Lighting at Work
NGET Safety Rules	
The Horlock Rules	NGET substations and the environment :Guidelines on siting and design

3 Definitions

The definitions of IEC 61936-1 apply without modification.

4 Fundamental requirements

Clause 4 and the associated sub-clauses of IEC 61936-1 are applicable with the following modifications.

Substations shall meet the system requirements detailed in TS 1.0 (RES) and shall be designed & constructed in accordance with BS7354.

4.1 General

No additional requirements specified.

4.2 Electrical requirements

4.2.1 Methods of neutral earthing

Neutral earthing of the NGET system at various voltages is defined in TS 1.0 (RES).

4.2.2 Voltage classification

Rated voltages (highest voltages for equipment) and the associated dielectric withstand requirements are defined in TS 1.0 (RES).

4.2.3 Current in normal operation

Rated normal currents are defined in TS 1.0 (RES).

In additions to these requirements, substation plant shall also be capable of withstanding the overload conditions detailed in Table 1 where rated normal current = 1.0.

4.2.4 Short-circuit current

Rated short-circuit currents and rated durations of short-circuit are defined in TS 1.0(RES).

Calculation of short-circuit currents shall take into account Energy Networks Association, Engineering Recommendation (ENA, ER) G74.

4.2.5 Rated frequency

The rated frequency is defined in TS 1.0 (RES).

4.2.6 Corona

No specific requirements.

4.3 Mechanical requirements

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

4.4 Climatic and environmental conditions

Climatic and environmental conditions are defined in TS 1.0 (RES)..

4.4.101 Pollution performance requirements for ceramic insulation

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

4.4.102 Pollution performance requirements for composite (non-ceramic) insulation

As mentioned in IEC 61462, the pollution test procedures defined in IEC 60507 are not applicable for non-ceramic insulation and standard test procedures remain under consideration.

4.4.103 Environmental protection of outdoor plant and equipment

Equipment shall be adequately protected from the corrosive effects of its intended operating environment taking into account the anticipated operating life.

Material construction and/or applied protective coatings shall, as far as reasonably practicable, keep the equipment in operational condition for the anticipated operating life without preventive maintenance.

4.5 Special requirements

4.5.1 Effects of small animals and micro-organisms

No additional requirements are specified.

4.5.2 Noise level

Impulse and steady state noise shall not exceed the relevant action levels specified in the UK noise at work regulations.

5 Insulation

Clause 5 and the associated sub-clauses of IEC 61936-1 are applicable with the following modifications.

5.1 Selection of insulation level

Insulation level requirements are detailed in TS 1.0 (RES).

5.2 Verification of withstand values

No additional requirements are specified.

5.3 Minimum clearances of live parts

The layout of AIS equipment shall ensure the integrity of the air space between live parts and other conductors (including earthed conductors) for the rated voltage conditions for which the substations is designed.

Equipment configurations which have not been dielectrically tested shall meet the minimum operational clearances defined in Table 4.

Table 4: Minimum electrical clearances

Nominal voltage (kV)	**Phase-to-earth clearance (m)** Note 2	**Phase-to-phase clearance (m)**
	(IEC values in brackets)	
33	0.5 *(0.32)* Note 1	0.43 *(0.32)*
66	0.7 *(0.63)*	0.78 *(0.63)*
132	1.1 *(1.3)*	1.4 *(1.3)*
275	2.1 *(2.4 rod-structure, 1.9 conductor structure)*	2.4 *(3.1 rod-conductor, 2.6 conductor-conductor)*
400	2.8 *(3.4 rod structure, 2.6 conductor structure)*	3.6 *(4.2 rod-conductor, 3.6 conductor-conductor)*

Note 1: A minimum clearance of 500 mm is specified to cover vermin and bird interference.

Note 2: Under some circumstances temporary infringement of phase to earth clearances during earthing switch operation may be permitted. Refer to TS 3.2.2 (RES)

Note 3: Table 1 lists MINIMUM clearances and an appropriate additional allowance should be made for constructional tolerances, effects of short-circuit, wind effects etc.

Note 4: The minimum clearances which are in widespread use in the UK differ from those recommended in IEC 61936-1. On the basis of long term satisfactory service experience and familiarity of operational staff these clearances are maintained in preference to the IEC values.

5.4 Minimum clearances between parts under special conditions

No additional requirements are specified.

5.5 Tested connection zones

No additional requirements are specified.

5.101 Electrical safety clearances

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

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

The safety clearances to be maintained in AIS installations are listed in Table 5.

Table 5: Substation Safety Clearances/Distances

Nominal System Voltage	Safety Distance (From NGET 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

It should be noted that Table 5 lists MINIMUM clearances and an appropriate additional allowance should be made for constructional tolerances.

Where the design of the substation requires the use of mobile equipment working platforms the design clearances for safety D_S and D_{SH} shall be increased by 2m.

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.

Note 2: This is 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 up-stretched hand), which is taken to be 2.4 m, to the appropriate Safety Distance.

Note 3: Where practicable the vertical design clearance should be applied in all directions.

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

All structures installed in substations shall be designed such that they deter climbing.

Note 5: The use of anti-climbing guards in substations is not normally acceptable unless they can be shown to pose no significant risk during planned activities requiring access to equipment.

5.102 Oversailing conductors and conductor in proximity

Designers are obliged to comply with all relevant health and safety legislation, however particular attention is drawn to the designers' duties under the Construction (Design and Management) Regulations (CDM). In applying the principles of prevention and protection in the reduction of risk, 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.

Note 1: 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.

Note 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.

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

6 Equipment

Clause 6 and the associated sub-clauses of IEC 61936-1 are applicable with the following modifications.

6.1 General requirements

Requirements for ancillary light current equipment are detailed in TS 2.19 (RES).

6.1.1 Selection

Existing plant, civil structures and foundations may be re-used providing that adequate strength and capability is demonstrated and that the residual anticipated asset life is appropriate for NGET's plans for the installation.

6.1.2 Compliance

Equipment shall comply with all relevant NGET Technical Specifications.

6.1.3 Personnel safety

No additional requirements are specified.

6.1.4 Maintenance regimes

No additional requirements specified.

6.1.5 Mid-life refurbishment

No additional requirements specified.

6.2 Specific requirements

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

6.2.1 Switching devices

Specific requirements for circuit-breakers are detailed in TS 3.2.1 (RES)

Specific requirements for disconnectors and earthing switches are detailed in TS 3.2.2 (RES),

Substations shall have sufficient earthing provision to enable the safe maintenance of any item of primary equipment including fixed earthing switches. Sufficient earthing switches shall be provided to enable the application of a primary earth between all foreseeable points of work and all potential infeeds.

As a minimum, earthing switches in accordance with TS 3.2.2 (RES) shall be provided at circuit entries ('line' earth switches) and at one position on each section of busbar. Further earthing provision may be by means of other types of interlocked motorised earthing device which meet the specified rating.

Note: For GIS installations the number of busbar earthing devices may be reduced by reference to the “30m rule” detailed in NGET Safety Rules For all but the largest GIS installations a single earth switch on each section of busbar will meet this requirement.

Where high level earthing switches are employed, e.g. on high level busbars, specific procedures for maintenance of these devices must be agreed with NGET.

6.2.2 Gas insulated metal enclosed switchgear (GIS), metal-enclosed switchgear, insulation-enclosed switchgear and other prefabricated type-tested switchgear assemblies

Specific requirements for gas insulated switchgear are detailed TS 3.2.14

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 and shall fail safe i.e. shall not fail in such a way that correct alarms are suppressed.

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

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

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

SF_6 detection and alarms should be installed in substations where a slow leak may result in a build up of gas e.g. in basement areas.

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.

6.2.3 Instrument transformers

6.2.3.1 Current transformers

Specific requirements for current transformers are detailed in TS 3.2.4 (RES)

The accommodation of current transformers shall be as specified in 0.

The location of current transformers shall be as specified in 0.

6.2.3.2 Voltage transformers

No additional requirements specified.

6.2.3.3 Current Transformers, Voltage Transformers and Combined Instrument Transformers for Settlement Metering

No additional requirements specified.

6.2.4 Surge arresters

No additional requirements specified.

6.2.5 Capacitors

No additional requirements specified.

6.2.6 Line traps

No additional requirements specified.

6.2.7 Insulators

Specific requirements for insulators are detailed in TS 3.2.9 (RES)

6.2.8 Insulated cables

No additional requirements specified.

6.2.9 Conductors and accessories (busbar systems)

Guidance regarding jointing of current carrying conductors is given in TGN(E)187.

6.2.10 Rotating electrical machines

No additional requirements are specified.

6.2.11 Static converters

No additional requirements are specified.

6.2.12 Fuses

No additional requirements are specified.

6.2.101 Portable earthing equipment

The need to use portable primary earthing equipment shall be minimised as far as reasonably practicable. 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.

Where the use of portable earthing is foreseen, e.g. to permit maintenance of fixed earthing, provision shall be made to employ NGET's standard portable earthing equipment.

The substation design shall cater for a maximum earthing clamp size of 90mm. The application of portable primary earths to larger diameter busbars and flexible conductors shall be by means of earthing stubs or equivalent primary attachment points. Primary attachment points shall be adequately dimensioned for the attachment of sufficient earth leads to match the substation short-circuit rating. Consideration should be given to safe application positions and compliance with the Manual Handling Regulations

Points for attachment of the earth end of portable earthing leads shall be provided at each switchgear structure and shall be adequately dimensioned for the attachment of sufficient earth leads to match the substation short-circuit rating. .

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

The application of portable earthing at heights exceeding 4.8m is unacceptable.

7 Installations

Clause 7 and the associated sub-clauses of IEC 61936-1 are applicable with the following modifications.

7.1 General 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.

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

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.

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

Roads shall be provided to access substation main buildings, relay rooms and heavy items of plant (e.g. transformers).

Substations shall be provided with a full interlocking scheme as specified in TS 3.1.1 (RES)

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

The extent to which this Clause shall apply to extensions to existing installations shall be specified by NGET in the Project Enquiry.

- Adequate toilet and washing facilities for operation and maintenance staff taking into account NGET's equal opportunities policies.

- Adequate lighting in accordance with HS(G)38

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

- At indoor GIS substations access to the control room shall not be through the switchgear hall and the room shall prevent ingress of SF_6 decomposition products in the event of a switchgear fault.

- At sites where SF_6 gas-filled equipment is installed a standing area and suitable water and drainage connections for a mobile changing/shower facility shall be provided. Where large volumes of SF6 are installed, e.g. GIS Substations, a fixed installation is required.

  SF_6 gas waste shall not be discharged into a sewage treatment plant or septic tank. Where a dedicated cesspool is used the drainage system shall be sealed against rainwater ingress.

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

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

- Vehicle parking.

7.1.1 Circuit arrangement

NGET Substation bays shall be in accordance with the functional (single line) diagrams presented in Annex C. These diagrams represent the standard construction of commonly used bay types and deviation from these arrangements shall be agreed with NGET. Less common or non-standard circuit designs are not covered and separate agreement shall be reached regarding the most appropriate arrangement.

The design of a substation shall permit installation, extension, operation and maintenance (preventive and corrective) with a maximum of one circuit (including any circuit requiring intervention) and one section of busbar out of service simultaneously.

Note: A section of busbar is taken to be a part of either the main or reserve busbars or a mesh corner. Associated busbar section and busbar coupler circuits may be considered to be part of the busbar section.

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 6.

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

Table 6: Maximum Equipment Heights in Substations

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

The substation shall be designed to minimise the land area required.

7.1.2 Documentation

Documentation requirements are defined in TS 1.0 (RES).

7.1.3 Transport rules

No additional requirements specified.

7.1.4 Aisles & access areas

No additional requirements specified.

7.1.5 Lighting

Adequate lighting shall be provided in accordance with HS(G)38.

7.1.6 Operational safety

No additional requirements specified.

7.1.7 Labelling

No additional requirements specified.

7.2 Outdoor installations of open design

7.2.1 Protective barrier clearances

No additional requirements specified.

7.2.2 Protective obstacle clearances

No additional requirements specified.

7.2.3 Boundary clearances

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 (including all subsequent amendments).

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

Subject to agreement with NGET a reduced horizontal clearance may be acceptable provided clearances of D_S and D_{SH} (as appropriate) are maintained from the top of the perimeter fence (but excluding any electrified wires). See Figure 1 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.

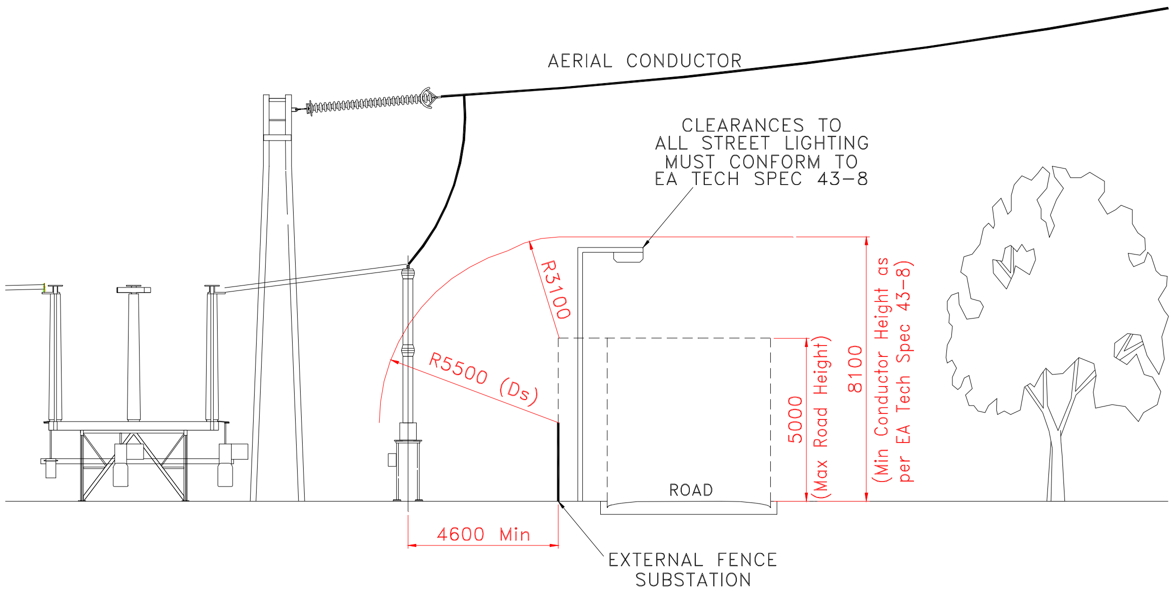

Figure 1: Reduced Clearance to Substation Perimeter Fence (400kV Clearances Shown)

7.2.4 Minimum height over access areas

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:

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

or

Maximum agreed 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.

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

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

and

D_{SH} (Ref' Table 5) is maintained from the driving and/or riding position of any vehicle.

Note: 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.

7.2.5 Clearance to buildings

7.2.6 External fences or walls and access doors

No additional requirements specified.

7.3 Indoor installations of open design

No additional requirements specified.

7.4 Installation of factory built, type-tested enclosures

7.4.1 General

No additional requirements specified.

7.4.2 Additional requirements for gas-insulated metal-enclosed switchgear

7.4.2.1 Design

Specific requirements for GIS are detailed in TS 3.2.14 (RES)

7.4.2.2 Erection on site

No additional requirements specified.

7.4.2.3 Protection against overvoltages

No additional requirements.

7.4.2.4 Earthing

No additional requirements specified.

7.5 Requirements for 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.

7.6 High voltage/low voltage prefabricated substations

No additional requirements are specified.

7.7 Electrical installations on pole, mast & tower

No additional requirements are specified.

7.101 Maintenance access

For general access around the substation, a safe means of access and egress shall be provided, or be identified in the design, for all foreseeable activities.

Provision of access to plant, equipment and apparatus for maintenance, repair and operation shall take into account the intended activity, the expected frequency that access will be required and the anthropometric data of the human body. For the purposes of this document the anthropometric data detailed in BS EN 547-3 shall be used. For parameters where percentile values are given, assessments should be undertaken using the 5th and 95th percentile as boundary conditions.

Note: Example clearances meeting these requirements are as follows:

Minimum vertical clearance for walking/standing access :	2100mm
Minimum passageway width for walking/standing access:	750mm
Minimum passageway width for work in a kneeling position:	1100mm
Height range for work in standing position:	900-1500mm
Height range for work in kneeling position:	600-1200mm
Height range for work in sitting position:	300-900mm

Access for operation, routine periodic inspection shall be from ground level or a fixed platform.

Access for routine preventive maintenance, repair, erection, extension, replacement and demolition may be from:

- ground level or a fixed platform (preferred)
- temporary fixed height access equipment (<= 3.6m)
- mobile elevated working platform (MEWP) (>3.6m)

The choice of fixed access means shall be in accordance with BS EN ISO 14122-1.

The need to work at height, particularly for routine activities, should be eliminated where it is reasonably practicable to do so.

It shall be possible for an unaccompanied individual to undertake routine operational & frequent maintenance activities such as isolation, earthing and routine inspection.

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.

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

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.

Fixed access facilities shall comply with BS EN ISO 14122-2, 14122-3 or 14122-4 as appropriate and their arrangement shall be agreed with NGET to suit site requirements.

Fixed ladders should not be provided in circumstances where it would be practical to install a staircase.

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

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

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.

8 Safety measures

Clause 8 and the associated sub-clauses of IEC 61936-1 are applicable with the following modifications.

It is intended that NGET 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 NGET and our 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.

Substations shall be designed and installed with due regard to the NGET safety rules.

8.1 Protection against direct contact

No additional requirements specified.

8.2 Means to protect persons in case of indirect contact

No additional requirements specified.

8.3 Means to protect persons working on electrical installations

No additional requirements specified.

8.4 Protection from danger resulting from arc fault

No additional requirements specified.

8.5 Protection against direct lightning strokes

No additional requirements specified.

8.6 Protection against fire

8.6.1 General

Fire protection shall be in installed on the User bays(s) to a standard consistent with that of NGET's substation site.

8.6.2 Transformers & reactors

No additional requirements specified.

8.6.3 Cables

No additional requirements specified.

8.6.4 Other equipment with flammable liquids

No additional requirements specified.

8.7 Protection against leakage of insulating liquid and SF_6

No additional requirements specified.

8.7.1 Insulating liquid leakage and subsoil water protection

8.7.1.1 General

No additional requirements specified.

8.7.1.2 Containment for indoor equipment

No additional requirements specified.

8.7.1.3 Containment for outdoor equipment

No additional requirements specified.

8.7.2 SF_6 leakage

Specific details regarding the use of SF_6 gas are detailed in TS 1.0 (RES).

8.7.3 Failure with loss of SF6 and its decomposition products

No additional requirements specified.

8.8 Identification and marking

8.8.1 General

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 SF_6 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.

Note: Experience indicates that this requirement can be met by the use of UV resistant engraved labels with mechanical fixings. NGET 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.

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

8.8.2 Information plates & warning plates

No additional requirements specified.

8.8.3 Electrical hazard warning

No additional requirements specified.

8.8.4 Installations with incorporated capacitors

No additional requirements specified.

8.8.5 Emergency signs for emergency exits

No additional requirements specified.

8.9 Safety from pressurised systems

Pressurised systems, such as hydraulic and/or pneumatic pipework, shall be adequately protected to prevent danger arising from external damage. If such pipework is installed in shared ducts/trenchs with other equipment (e.g. cabling), mechanical segregation/protection shall be provided.

8.10 Safety from moving mechanical parts

Parts of equipment which move during normal operation and which are accessible from fixed or temporary access facilities e.g. drive linkages, shall be guarded to prevent inadvertent contact and injury. The principles outlined in the following documents shall be adopted in the design.

- ISO 12100-1 Safety of machinery- Basic concepts, general principles for design Part 1 and part 2.
- BS EN 811 Safety of machinery – Safety distances to prevent danger zone being reached by the lower limbs
- BS EN 294 Safety of Machinery - Safety distances to prevent danger zones being reached by upper limbs
- L22 - Safe use of work equipment – Provision and use of work equipment regulations 1998.

9 Protection, control and auxiliary systems

Clause 9 and the associated sub-clauses of IEC 61936-1 are applicable with the following modifications.

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.

Electronic equipment shall be located in accommodation commensurate with its environmental performance which is classified in TS 3.24.15 (RES) as appropriate.

Fixed heating shall be thermostatically controlled.

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

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.

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 TS 2.12 (RES).

Protection relays and circuits associated with equipment owned by Users (e.g. generating companies, distribution companies or directly connected consumers) shall be accommodated in separate panels from those associated with equipment owned by NGET. This requirement shall also apply to multi-core cable terminations, marshalling facilities and jumper fields.

Ideally all NGET 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 NGET owned plant shall be segregated from that of User owned plant. Separate individually lockable local/remote control selector switches shall be provided for NGET and User equipment such that staff with authority to operate only User equipment are unable to access control of NGET ational Grid owned equipment.

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

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

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

9.1 Monitoring and control systems

No additional requirements specified.

9.2 DC and AC supplies

9.2.1 General

Specific requirements for dc and ac supplies are detailed in TS 2.12 (RES). The use of dangerous voltages (>50V ac or >120V dc) shall be avoided as far as reasonably practicable. Where dangerous voltages are utilised appropriate warning labels and guarding shall be employed to ensure personnel safety.

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 NGET owned equipment. LCC's and common panels should be sited in areas to which access will be permitted to non-NGET staff.

9.2.2 AC supply

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

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.

9.2.3 DC supply

The rated supply voltage of the DC system at NGET substations is 125 V. Closing and opening releases and operating devices shall operate over the voltage ranges, measured at their terminals during operation, given in Table 7.

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.

Table 7: Rated Supply and Operating Voltage Range for D.C. Systems and Operating Devices

		D.C. 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

9.3 SF_6 gas handling plants

No additional requirements specified.

9.4 Basic rules for electromagnetic compatibility of control systems

No additional requirements specified.

10 Earthing systems

10.1 General

Substation earthing systems shall be designed and installed in accordance with TS 3.1.2. (RES)

Particular attention should be paid to requirements for high frequency earthing.

10.2 Fundamental requirements

No additional requirements specified.

10.3 Design of earthing systems

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

10.4 Construction of earthing systems

No additional requirements specified.

10.5 Measurements

No additional requirements specified.

10.6 Commissioning

No additional requirements specified.

10.7 Maintenance

No additional requirements specified.

11 Inspection and testing

No additional requirements specified.

ANNEX A - CURRENT TRANSFORMER (CT) ACCOMMODATION

This guidance note does not form part of the RES document.

A1 INTEGRATED DIGITAL PROTECTION/CONTROL

The requirements specified in sections B2 to B8 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:

- 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.

- 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.

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).

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.

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

1. Automatic changeover on failure of primary data channel.

2. Manual changeover by unskilled staff on failure of primary data channel.

3. Manual changeover by skilled staff on failure of primary data channel.

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

A2 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:

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.

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.

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.

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 A3 to A8 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.

A3 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 a minimum of four current transformer cores using one of the arrangements listed below.

The following 'standard' configurations of CT cores are commonly used by NGET. Alternative configurations may be accepted or specified on a project basis:

A3.1 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.

A3.2 Four-Core Arrangement

A complement of four secondary windings as follows:

Core 1 Protection Type A

Core 2	Protection Type A
Core 3	Protection Type B
Core 4	Protection Type B

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

A4 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 A2.1 or A2.2, as required by the application. For busbar coupler and section applications CT accommodation shall be provided on each side of the circuit-breaker.

A5 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 A3.1 or A3.2.

A6 TRANSFORMER AND SHUNT REACTOR BUSHING TURRETS

The accommodation available in the turrets of bushings shall allow for a maximum of four current transformer windings, excluding those which may be required for winding temperature indicators, as follows:

Core 1	Protection Type B
Core 2	Measurement/Protection
Core 3	Protection Type A
Core 4	Protection Type A

The allocation of current transformer cores to particular transformers will depend upon the protection requirements of the local primary systems to which the transformer is connected.

A7 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.

A8 THE NEUTRAL AND NEUTRAL END CONNECTIONS OF TRANSFORMER AND SHUNT REACTORS

For neutral current transformers associated with double-wound grid transformers and supergrid auto-transformers, and neutral end current transformers associated with supergrid auto-transformers, accommodation shall be provided as follows:

i) Neutral current transformer housings shall provide accommodation for at least three current transformer windings as follows:

Core 1	Protection Type B
Core 2	Measurement/Protection
Core 3	Measurement/Protection

ii) Neutral end current transformer housings shall provide accommodation for one Protection Type B current transformer winding per phase.

iii) Combined neutral and neutral-end current transformer housings shall provide accommodation for at least two neutral current transformer windings as follows:

Core 1	Protection Type B (one current transformer per phase)
Core 2	Measurement/Protection (one only - on neutral conductor)
Core 3	Measurement/Protection (one only - on neutral conductor)

For neutral and neutral end current transformers associated with supergrid shunt reactors, accommodation shall be provided as follows:

1. Neutral end current transformer housings shall provide accommodation for one Protection Type B current transformer per phase.

2. Neutral current transformer housings shall provide accommodation for one Measurement/Protection current transformer.

ANNEX B - LOCATION OF CURRENT TRANSFORMERS ASSOCIATED WITH 420, 300 AND 145 kV CIRCUIT BREAKERS

B.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.

B.2 BUSBAR STATIONS

B2.1 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.

B2.2 Bus Section and Bus Coupler Circuits

Current transformers for busbar protection shall be installed on both sides of the circuit-breaker with the current transformer for a particular zone of protection being located on the side of the circuit-breaker remote from the zone.

Current transformers for commissioning overcurrent and back up earth fault protection shall be installed on the reserve busbar side of the bus coupler circuit-breaker and on the lower numbered main or reserve busbar side (as appropriate) of the bus section circuit-breaker.

Current transformers for system back-up protection shall be installed in the bushings or housings on the reserve busbar side of the bus-coupler circuit-breaker and on the lower numbered main or reserve busbar side (as appropriate) of the bus-section circuit-breaker. The current transformers shall preferably be of the Measurement/Protection type but, where there is only one set of such current transformers in the correct location, Type A current transformers shall be used instead; this will normally only apply where post-type current transformers are employed.

Current transformers for instrumentation purposes and circuit-breaker fail protection shall be installed on the main busbar side of the bus-coupler circuit-breaker and on the higher numbered main or reserve busbar side (as appropriate) of the bus-section circuit-breaker.

B.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.

B.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.

ANNEX C - STANDARD SUBSTATION BAY FUNCTIONAL (SINGLE LINE) DIAGRAMS

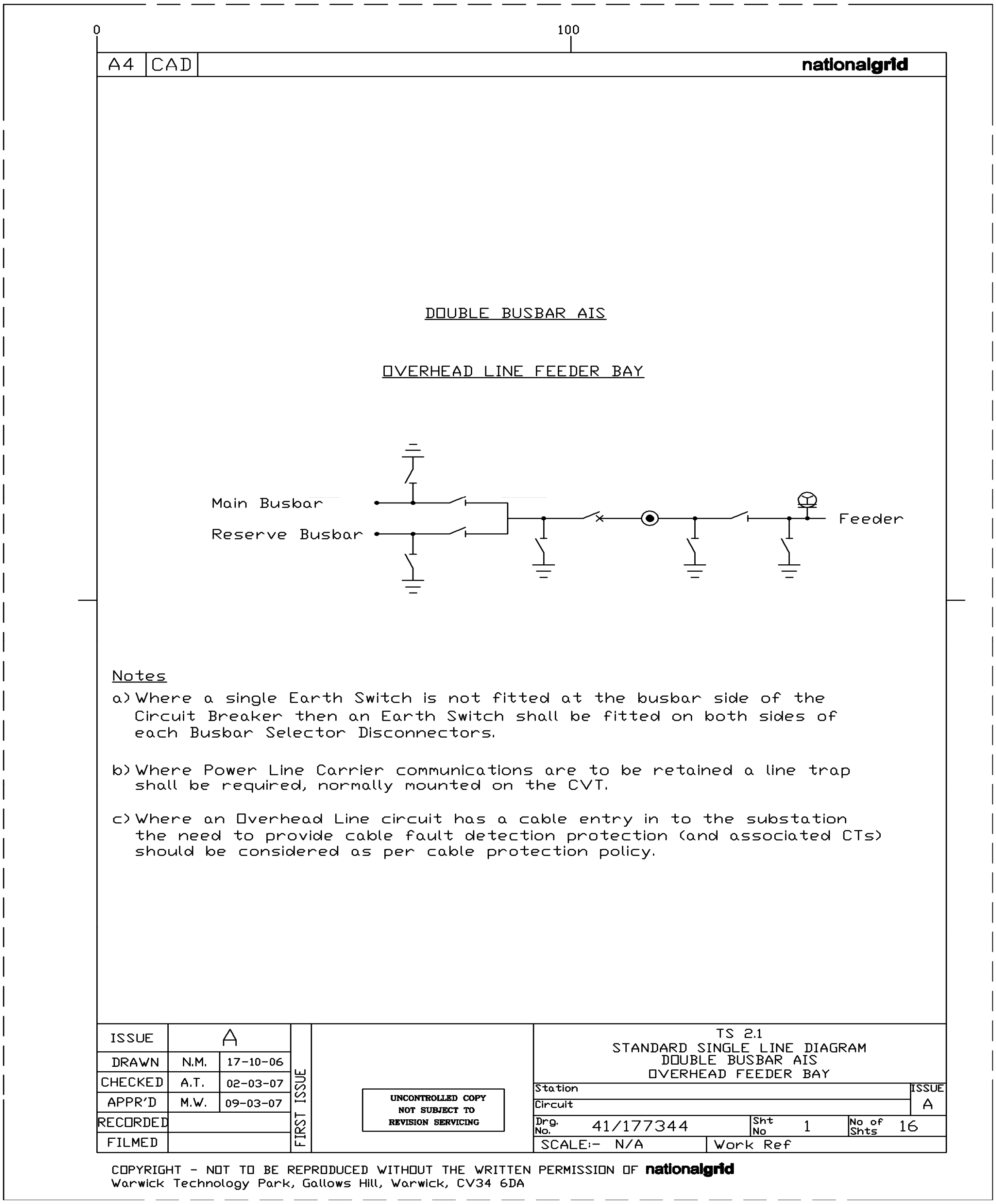

Figure 11:1

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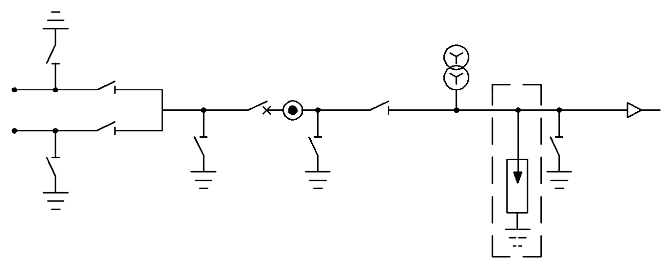
DOUBLE BUSBAR AIS

CABLE FEEDER BAY



Notes

a) Where a single Earth Switch is not fitted at the busbar side of the Circuit Breaker then an Earth Switch shall be fitted on both sides of each Busbar Selector Disconnectors.

b) The Wound VT is for cable discharge duty and is only required at one end of the Cable Circuit.
The VT arrangement at the remote end shall be shall be in accordance with protection policy.

c) The use of Slip-over CT's at the cable termination is non-preferred unless DAR lockout facilities are required.

d) A Surge Arrester may be required but should be determined on a circuit basis.
See TGN(E)27 for further guidance.

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STANDARD SINGLE LINE DIAGRAM
DOUBLE BUSBAR AIS
CABLE FEEDER BAY

Station
Circuit
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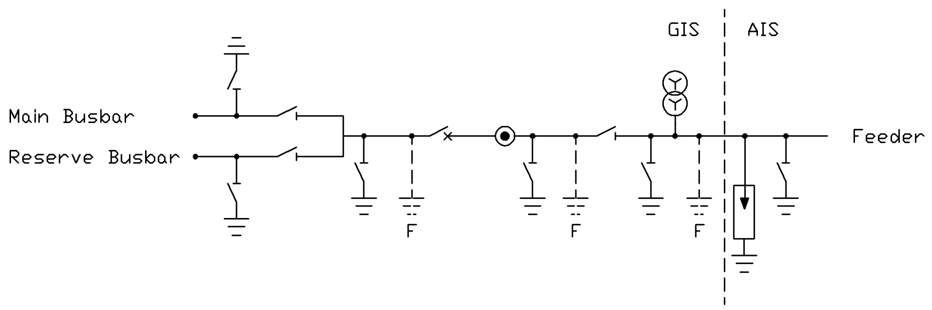
DOUBLE BUSBAR GIS

OVERHEAD LINE FEEDER BAY



Notes

a) The Surge Arrester is shown in the preferred location but may be within the GIS boundary.

b) Where the requirements of NSI 2 can be met by the use of Busbar Earth Switches located at the end of each section of busbar and by the use of Portable Earthing Devices, then Busbar Earth Switches in every bay are not required.

c) Preferred location of Portable Earthing devices shown by the dotted Earth Symbol and designated 'F'.

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TS 2.1
STANDARD SINGLE LINE DIAGRAM
DOUBLE BUSBAR GIS
OVERHEAD LINE FEEDER BAY

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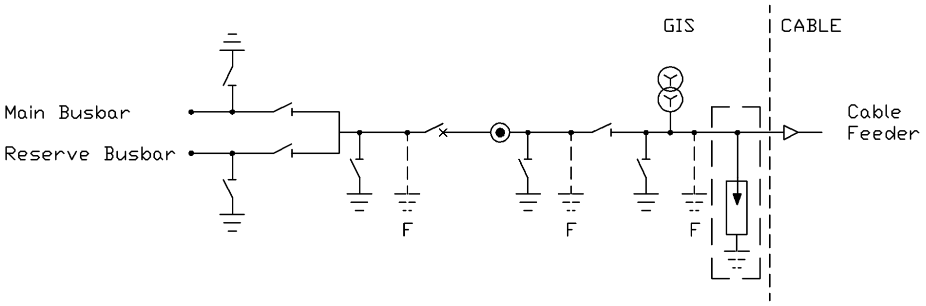
DOUBLE BUSBAR GIS

CABLE FEEDER BAY



Notes

a) Preferred location of Portable Earthing Devices shown by the dotted Earth Symbol and designated 'F'.

b) A Surge Arrester may be required but should be determined on a circuit basis. See TGN(E)27 for further guidance.

c) Where the requirements of NSI 2 can be met by the use of Busbar Earth Switches located at the end of each section of busbar and by the use of Portable Earthing Devices, then Busbar Earth Switches in every bay are not required.

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TS 2.1
STANDARD SINGLE LINE DIAGRAM
DOUBLE BUSBAR GIS
CABLE FEEDER BAY

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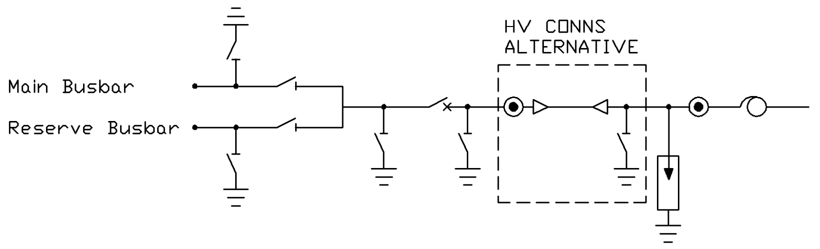
DOUBLE BUSBAR AIS
TRANSFORMER BAY (HV SIDE) / SVC BAY/ REACTOR



Notes

a) Where a single Earth Switch is not fitted at the busbar side of the Circuit Breaker then an Earth Switch shall be fitted on both sides of each Busbar Selector Disconnectors.

b) Turret CT's within the transformer bushing have been assumed in this arrangement.

c) HV Conns shown in this drawing are representative of the situation when the connected equipment is remote from the busbars.

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TS 2.1
STANDARD SINGLE LINE DIAGRAM
DOUBLE BUSBAR AIS
TRANSFORMER BAY (HV SIDE) / SVC BAY/REACTOR

Station | ISSUE A
Circuit

Drg. No. 41/177344 | Sht No 5 | No of Shts 16

SCALE:- N/A | Work Ref

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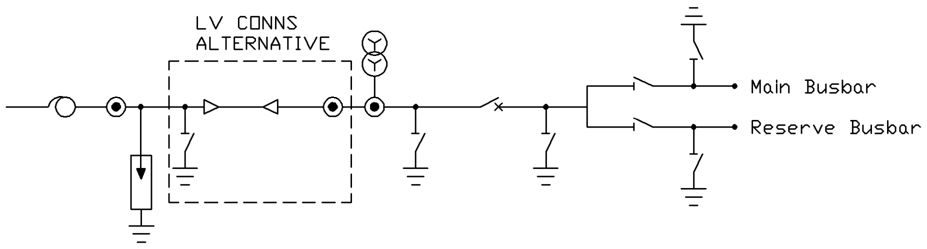
DOUBLE BUSBAR AIS
TRANSFORMER BAY (LV SIDE)



NOTES

a) Tariff metering to be fitted as per Metering practice and the agreed commercial boundary.

b) For interbus (400kV to 275kV) transformers the Tariff metering is not required.

c) LV Conns shown in this drawing are representative of the situation when the connected equipment is remote from the busbars.

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TS 2.1
STANDARD SINGLE LINE DIAGRAM
DOUBLE BUSBAR AIS
TRANSFORMER BAY (LV Side)

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SCALE:- N/A | Work Ref

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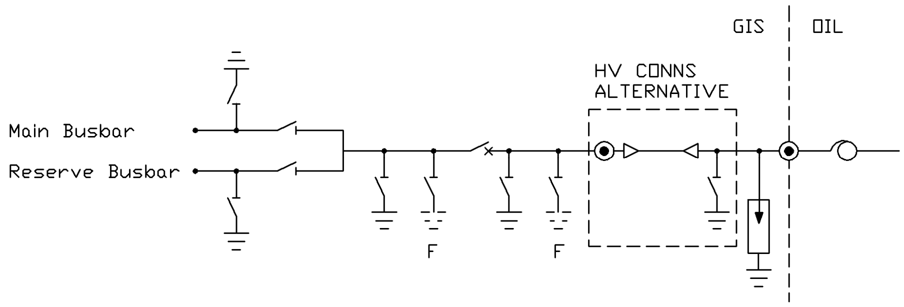
DOUBLE BUSBAR GIS

TRANSFORMER BAY (HV SIDE) / SVC BAY / REACTOR BAY



NOTES

a) Turret CT's within the transformer bushing have been assumed in this arrangement.

b) HV Conns shown in this drawing are representative of the situation when the connected equipment is remote from the busbars. The use of cable is indicative and alternatives (e.g. GIB) maybe appropriate.

c) Where the requirements of NSI 2 can be met by the use of Busbar Earth Switches located at the end of each section of busbar and by the use of Portable Earthing devices, then Busbar Earth Switches in every bay are not required.

d) Preferred location of Portable Earthing Devices shown by the dotted Earth Symbol and designated 'F'.

ISSUE	A		FIRST ISSUE	UNCONTROLLED COPY NOT SUBJECT TO REVISION SERVICING	TS 2.1 STANDARD SINGLE LINE DIAGRAM DOUBLE BUSBAR GIS TRANSFORMER BAY (HV Side)/SVC BAY/REACTOR
DRAWN	N.M.	11-10-06			Station — ISSUE A
CHECKED	A.T.	02-03-07			Circuit
APPR'D	M.W.	09-03-07			Drg. No. 41/177344 — Sht No 7 — No of Shts 16
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FILMED					

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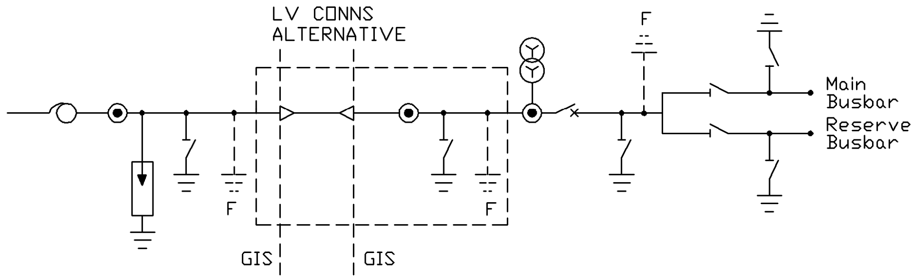
DOUBLE BUSBAR GIS
TRANSFORMER BAY (LV SIDE)



NOTES

a) Tariff metering to be fitted as per Metering practice and the agreed commercial boundary.

b) For interbus (400kV to 275kV) transformers the Tariff metering is not required.

c) LV Conns shown in this drawing are representative of the situation when the connected equipment is remote from the busbars. The use of cable is indicative and alternatives (e.g. GIB) maybe appropriate.

d) Where the requirements of NSI 2 can be met by the use of Busbar Earth Switches located at the end of each section of busbar and by the use of Portable Earthing devices, then Busbar Earth Switches in every bay are not required.

e) Preferred location of Portable Earthing Devices shown by the dotted Earth Symbol and designated 'F'.

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TS 2.1
STANDARD SINGLE LINE DIAGRAM
DOUBLE BUSBAR GIS
TRANSFORMER BAY (LV Side)

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SCALE:- N/A		Work Ref			

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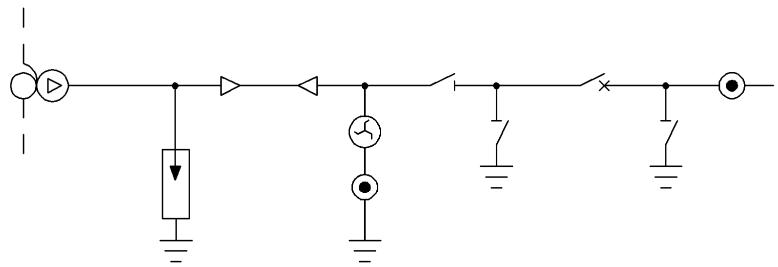
DOUBLE BUSBAR 400kV AND 275kV
TRANSFORMER BAY / SVC BAY

TV SIDE - 13kV



NOTES

a) RSVC layout defined in TS2.18.

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TS 2.1
STANDARD SINGLE LINE DIAGRAM
DOUBLE BUSBAR
TRANSFORMER BAY/SVC BAY

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SCALE:- N/A	Work Ref		

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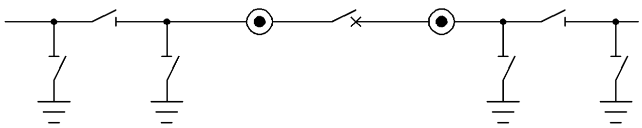
DOUBLE BUSBAR AIS & GIS
COUPLER / SECTION BAY

MAIN BUSBAR



NOTES

a) The outer Earth Switches may be installed at the ends of the busbars for a GIS substation.

b) Earth Switches are not required for bus couplers in GIS substations.

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TS 2.1
STANDARD SINGLE LINE DIAGRAM
DOUBLE BUSBAR AIS & GIS
COUPLER/SECTION BAY

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SCALE:- N/A Work Ref

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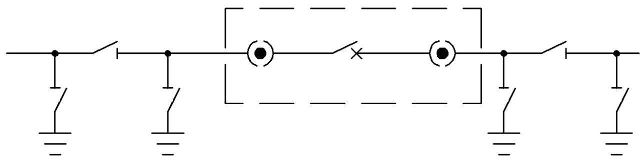
DOUBLE BUSBAR AIS & GIS
SECTION BAY

RESERVE BUSBAR



NOTES

a) The circuit breaker and current transformers may be omitted by agreement with National Grid.

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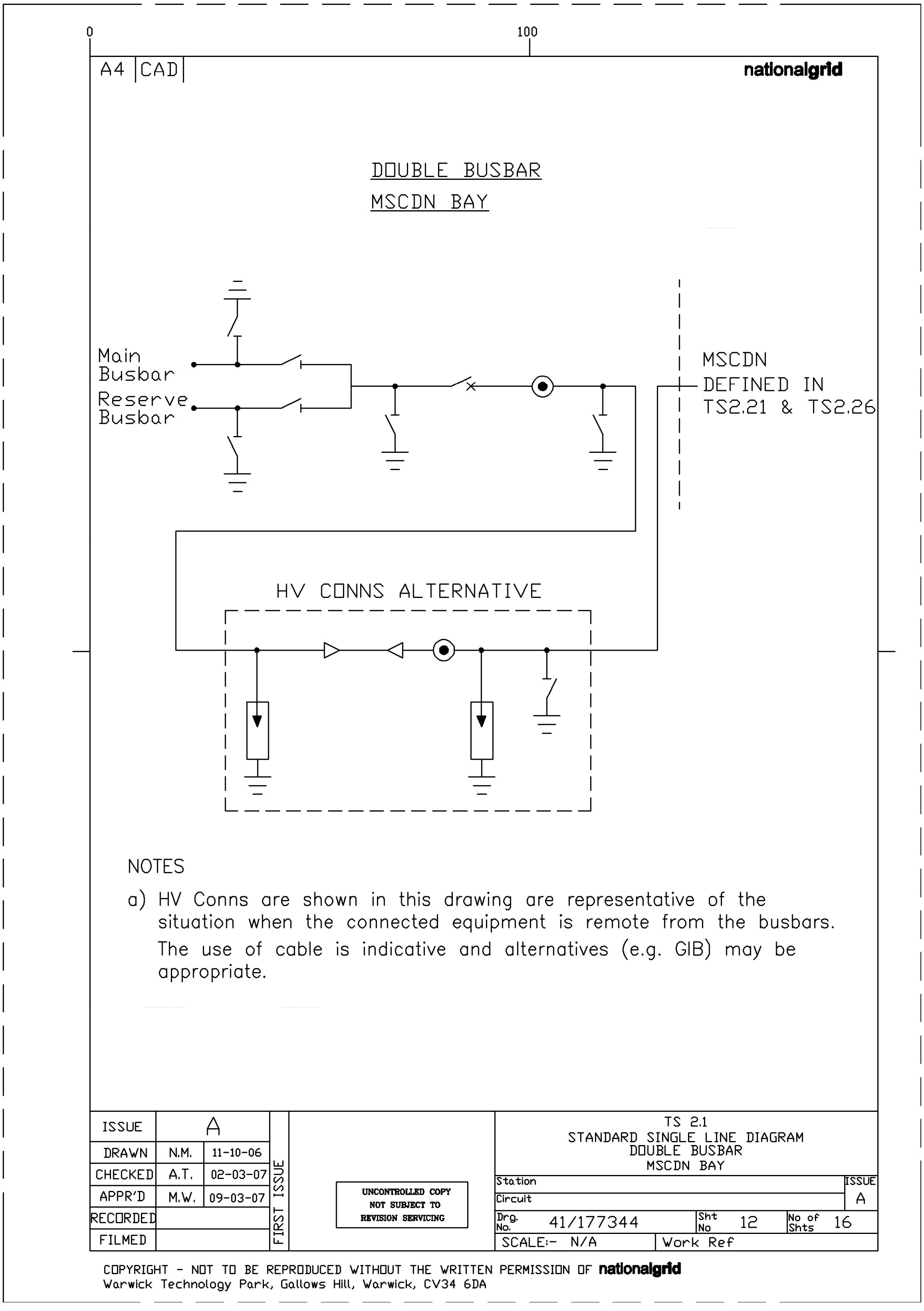
TS 2.1
STANDARD SINGLE LINE DIAGRAM
DOUBLE BUSBAR AIS & GIS
SECTION BAY

Station
Circuit
ISSUE A

Drg. No. 41/177344 Sht No 11 No of Shts 16

SCALE:- N/A Work Ref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DOUBLE BUSBAR
MSCDN BAY
Main Busbar
Reserve Busbar
MSCDN DEFINED IN TS2.21 & TS2.26
HV CONNS ALTERNATIVE
NOTES
a) HV Conns are shown in this drawing are representative of the situation when the connected equipment is remote from the busbars. The use of cable is indicative and alternatives (e.g. GIB) may be appropriate.
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STANDARD SINGLE LINE DIAGRAM
DOUBLE BUSBAR
MSCDN BAY
Station
Circuit
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No of Shts 16
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Work Ref
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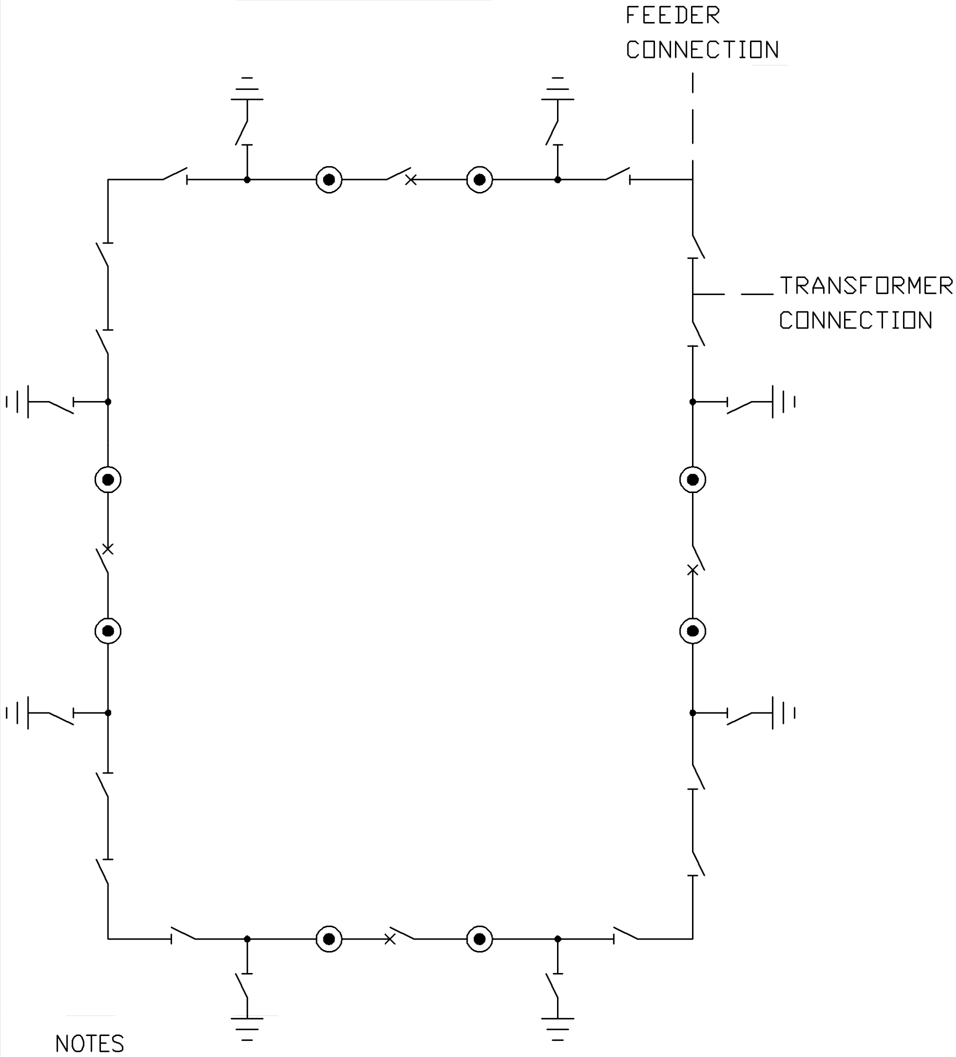
MESH BUSBAR
FOUR SWITCH MESH



NOTES

a) GIS meshes may require additional earthing facilities.
eg. PMED.

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TS 2.1
STANDARD SINGLE LINE DIAGRAM
MESH BUSBAR
FOUR SWITCH MESH

Station
Circuit
ISSUE A

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SCALE:- N/A Work Ref

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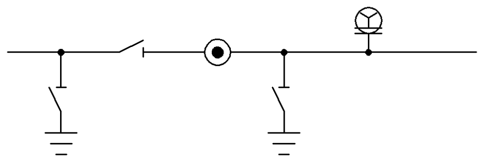
MESH BUSBAR

OHL FEEDER CONNECTION



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TS 2.1
STANDARD SINGLE LINE DIAGRAM
MESH BUSBAR
OHL FEEDER CONNECTION

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Circuit
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SCALE:- N/A Work Ref

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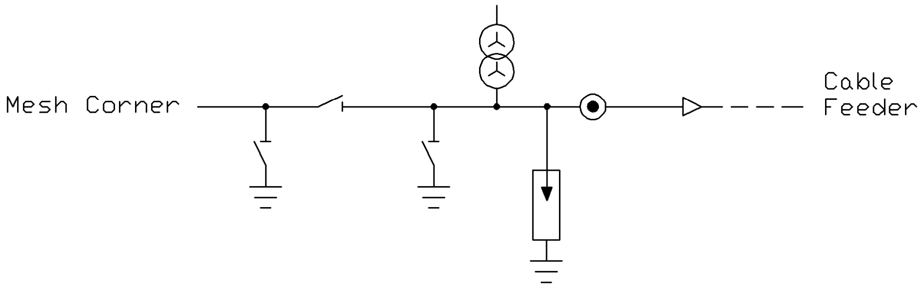
MESH BUSBAR
CABLE FEEDER CONNECTION



Notes

a) The Wound VT is for cable discharge duty and not generally required for protection purposes.
A Wound VT is only required at one end of the Cable circuit.
The remote end may be a single phase VT.

b) CT location may be as a conventional feeder bay if practicable.
Slip-over CT's have been assumed in this drawing.

c) A Surge Arrestor may be required but should be determined on a circuit basis.
See TGN(E)27 for further guidance.

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TS 2.1
STANDARD SINGLE LINE DIAGRAM
MESH BUSBAR
CABLE FEEDER CONNECTION

Station					ISSUE
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SCALE:- N/A		Work Ref			

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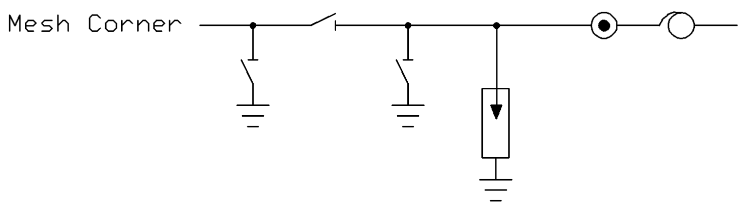
MESH BUSBAR

TRANSFORMER CONNECTION



NOTES

a) Ferro–resonance quenching earth switch may be required.

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TS 2.1
STANDARD SINGLE LINE DIAGRAM
MESH BUSBAR
TRANSFORMER CONNECTION

Station
Circuit
ISSUE A
Drg. No. 41/177344 Sht No 16 No of Shts 16
SCALE:- N/A Work Ref

SWITCHGEAR

This document is for Relevant Electrical Standards document only.

TABLE OF CONTENTS

PURPOSE AND SCOPE

This document defines the technical requirements for switchgear connected to the National Grid Electricity Transmission System at 400kV, 275kV, 132kV. The principles of this document also apply to equipment connected at other voltages.

This Specification applies to all switchgear for connection to, the National Grid 66kV, 132kV, 275kV, 400 kV and 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. These aspects are covered in companion Technical Specifications.

PART 1 – PROCEDURAL

1 GENERAL REQUIREMENTS

1.1 General

1.1.1 All mandatory requirements of IEC 62271-1 shall be met.

1.2 Compressed Gas

1.2.1 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.

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

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

1.3 Operating Mechanisms, Ancillary Equipment and their Enclosures

1.3.1 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.

1.3.2 Three phase switching devices with separate phase mechanisms shall be controllable from a single point,

1.3.3 Auxiliary switches shall be positively driven in both directions.

2 PERFORMANCE REQUIREMENTS

2.1 Gaseous Insulation

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

2.2 Rated Voltage of Closing and Opening Releases and Operating Devices

2.2.1 The rated supply voltage of the D.C. 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 during operation, given in Table 1.

2.2.2 The characteristics of the current required by the closing and opening releases and operating devices when operating at the minimum operating voltage shall be declared.

		D.C. 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 1: Rated Supply and Operating Voltage Range for D.C. Systems and Operating Devices

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

3 TEST REQUIREMENTS

3.1 Dielectric Tests

3.1.1 Dielectric tests on Gas Insulated Switchgear shall be to the requirements of IEC 62271-203. Where doubt exists regarding the path of any breakdown during testing it shall be assumed that the breakdown involved non-self restoring insulation.

3.1.2 Dielectric tests on Air Insulated Switchgear shall be to the requirements of IEC 62271-1. Where doubt exists regarding the path of any breakdown during testing it shall be assumed that the breakdown involved non-self restoring insulation.

3.2 Mechanical Strength of Pressurised Hollow Ceramic Insulation

3.2.1 Pressurised hollow ceramic insulation shall be designed and tested according to IEC 62155.

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.

3.3 Mechanical Strength of Hollow Composite Insulation

3.3.1 Hollow composite insulation for unpressurised and pressurised applications shall be designed and tested in accordance with IEC 61462.

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.

4 FORMS AND RECORDS

Not applicable.

PART 2 - DEFINITIONS AND DOCUMENT HISTORY

5 DEFINITIONS

Not Applicable.

6 AMENDMENTS RECORD

Issue	Date	Summary of Changes / Reasons	Author(s)	Approved By (Inc. Job Title)
1	February 2014	New document		

7 IMPLEMENTATION

7.1 Audience Awareness

Audience	Purpose Compliance (C) / Awareness (A)	Notification Method Memo / letter / fax / email / team brief / other (specify)

7.2 Training Requirements

Training Needs N/A / Informal / Workshop / Formal Course	Training Target Date	Implementation Manager

7.3 Procedure Review Date

5 years from publication date.

PART 3 - GUIDANCE NOTES AND APPENDICES

8 REFERENCES

8.1 BS 1710 Specification for Identification of pipelines and services

8.2 IEC 60376 Specification of technical grade sulfur hexafluoride (SF_6) for use in electrical equipment

8.3 IEC 60480 Guidelines for the checking and treatment of sulfur hexafluoride (SF_6) taken from electrical equipment and specification for its re-use

8.4 IEC 61462 Composite hollow insulators — Pressurized and unpressurized insulators for use in electrical equipment with rated voltage greater than 1 000 V — Definitions, test methods, acceptance criteria and design recommendations

8.5 IEC 62155 Hollow pressurized and unpressurised ceramic & glass insulators for use in electrical equipment with rated voltages greater than 1000V

8.6 IEC 62271-1 High-voltage Switchgear & Controlgear – Part1: Common Specifications

8.7 IEC 62271-203 High-voltage Switchgear & Controlgear – Part 203: Gas-insulated metal-enclosed switchgear for rated voltages above 52kV

SUBSTATION AUXILIARY SUPPLIES

This document is for Relevant Electrical Standards document only.

PURPOSE AND SCOPE

This document defines National Grid's technical requirements for the application of substation auxiliary equipment and describes the functional and performance requirements for both A.C. and D.C. auxiliary power supplies and equipment in the Transmission System in England and Wales.

PART 1 – PROCEDURAL

1 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.

1.1 Manufacture

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

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

1.2 Equipment

1.2.1 All equipment shall meet statutory requirements for safety as specified in TS 1 (RES).

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

Informative: The preferred choice of supply for light current equipment is 110 V D.C.

1.2.3 A.C. 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 A.C. supply such as for a computer and monitor then it shall be fed from a D.C. supplied inverter or a stand-alone uninterruptible power supply (UPS).

Informative: The use of a 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 D.C. supply.

1.2.4 For safety reasons, the use of 230 V A.C. supplies for control systems should be avoided where reasonably practicable. If A.C. 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.

1.3 A.C. Supplies

1.3.1 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%.

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

1.4 D.C. Supplies

1.4.1 Both the 48 V and 110 V D.C. supply systems at 400 kV and 275 kV substations shall be provided by two independent D.C supply systems.

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

1.4.3 Cross connections of D.C. 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.

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

2 PERFORMANCE REQUIREMENTS

2.1 A.C. Supplies

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

2.1.2 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.

2.1.3 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.

2.2 D.C. Supplies

2.2.1 D.C. systems shall provide no-break supplies at all times up to the end of the specified standby period.

2.2.2 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.

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

2.2.4 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.

2.2.5 The battery/charger system shall maintain the voltage on the distribution boards at all times and at the extremes of the A.C. supply voltage to the charger within the following levels:

	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 6V or 12 V monoblocs are provided eg 100 Ah or less normal and nominal voltages are 122.6 V and 108 V respectively.

3 TEST REQUIREMENTS

N/A.

4 FORMS AND RECORDS

None.

PART 2 - DEFINITIONS AND DOCUMENT HISTORY

5 DEFINITIONS

The definitions used in TS 1 (RES) and TS 2.2 (RES) apply.

6 AMENDMENTS RECORD

Issue	Date	Summary of Changes / Reasons	Author(s)	Approved By (Inc. Job Title)
1	February 2014	New document		

7 IMPLEMENTATION

7.1 Audience Awareness

Audience	Purpose Compliance (C) / Awareness (A)	Notification Method Memo / letter / fax / email / team brief / other (specify)

7.2 Training Requirements

Training Needs N/A / Informal / Workshop / Formal Course	Training Target Date	Implementation Manager

7.3 Procedure Review Date

5 years from publication date.

PART 3 - GUIDANCE NOTES AND APPENDICES

8 REFERENCES

8.1 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 50160 Voltage Characteristics of Electricity Supplied by Public Distribution Systems.

8.2 National Grid Technical Specifications

The following TS documentation is relevant to substation auxiliary supplies and should be read in conjunction with this document.

TS 1 (RES) Ratings and General Requirements for Plant, Equipment, Apparatus and Services for the National Grid System and Connection Points to it.

ANCILLARY LIGHT CURRENT EQUIPMENT

This document is for Relevant Electrical Standards document only.

TABLE OF CONTENTS

PURPOSE AND SCOPE

This specification describes the overall functional and performance requirements for all ancillary light current equipment for use in substations, including equipment used in conjunction with protection, control, monitoring and metering systems and ancillary equipment associated with primary plant. It covers the requirements for:

- Light current equipment, auxiliary switches and indicators
- Cubicles, boxes and kiosks
- Marshalling
- Earthing of light current equipment
- Marking and labelling
- Components and accessories
- Interposing relays
- Testing facilities

Additional requirements may also apply depending on the light current system application and reference should be made to the appropriate Level 2 or Level 3 Technical Specification.

PART 1 – PROCEDURAL

1 GENERAL REQUIREMENTS

Ancillary light current equipment in substations shall conform to the relevant International or British Standards for its application, 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.

Informative:

The use of auxiliary energising voltages above 110 V (ac) shall be avoided, the preferred voltage for such ac 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). The labels shall be in accordance with BS 5499-5.

In the event that NGET are required to operate and/or maintain Users equipment, the following requirements will apply.

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

Equipment that consists of elements that can be withdrawn shall have marking on all the fixed and removable portions, to assist in 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.

Where plug in links are employed the installation shall be such that it is impossible to insert the link incorrectly. For example, it may be necessary to use different horizontal and vertical link spacing to avoid a possible cross connection.

All materials shall be non-ignitable or resistant to flame propagation (tested in accordance with BS EN 60695-2-13 or BS EN 60695-9-1).

All materials shall be dimensionally stable i.e. they 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 shall be protected from dust.

Equipment shall be designed such that all maintenance operations may be carried out safely, in an unencumbered manner and in compliance with the statutory requirements quoted in TS 1(RES)

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

1.1 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 meet the requirements of IEC 60947-2 and shall either be removable or facilities shall be provided such that they can be locked in the open position. MCBs shall have an auxiliary contact such that their operation may be alarmed.

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

1.2 Switchgear Auxiliary Switches

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

Indicators of plant state must be clearly visible from all points of operation.

1.3 Indoor Equipment Cubicles

Cubicles shall normally be manufactured, equipped, wired and tested in the manufacturers or contractors works before delivery to site. All equipment, terminals and wiring shall be readily accessible. All trunking provided within the cubicle(s) shall be capable of accommodating all cables and wiring for the complete site installation. On the completed installation all cable identification, ferruling and labelling shall be clearly visible and legible to personnel requiring access to the cubicle for maintenance or testing/commissioning purposes.

Cabling from external plant and equipment shall be terminated on one side of the terminal blocks within the cubicle only. Inter cubicle or bus wiring shall also be located on separate terminal rails within the cubicle.

Where a cubicle is to house differing systems within the same panel the following conditions apply:

a) Equipment within the cubicle must be segregated and clearly labelled on both the front and rear of the cubicle.

b) All equipment within a system must be grouped together. For the avoidance of doubt, system in this context includes fuses, links and MCBs.

c) Different systems shall where practicable use separate terminal rails.

d) All terminal blocks shall be clearly labelled.

e) All tripping racks shall be mounted as separate systems and shall not be incorporated into other protection systems, excepting a trip relay that is part of a function based system. The tripping racks shall include all necessary trip relays, trip circuit supervision relays, fuses, links and MCBs.

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.

Cubicles shall be provided with internal illumination such that all internal labelling, ferruling and wiring can be readily read/identified. Cubicle lighting shall be supplied from a 230 V (ac) single-phase supply that incorporates earth leakage protection.

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 such as relays have an IP rating less than that specified in the appropriate NGET Technical requirements, consideration shall be given to increasing the cubicle IP rating to meet the NGET Technical requirements. Facilities shall be provided to maintain the air temperature and humidity within the ranges specified in TS 1 (RES) – Environmental Service Conditions. All cubicles shall be provided with locking facilities.

Equipment on panel fronts shall be flush mounted.

All equipment requiring access for test or adjustment and or equipment that has a readable display shall not be mounted either less than 1 m or greater that 1.7 m above permanent access ways.

1.4 Outdoor Kiosks

Outdoor kiosks shall be of rigid construction and suitable, without any maintenance, for the life of the associated plant. Kiosks shall meet Environmental Class 4 conditions, (see TS 1(RES)), 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.

1.5 Termination Boxes

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

All terminations and connections shall be readily accessible.

Cable entries (e.g. 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 site conditions covered by TS 1(RES) – Environmental Service Conditions may be provided with sliding covers. Other types of covers shall be secured with captive fasteners.

Termination boxes for use outdoors shall be compliant with the ambient requirements of TS1(RES) - Environmental Service Conditions and shall be mounted so as to prevent pockets or spaces that could collect water. Termination boxes 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.

1.6 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. All cores shall be terminated on the same side of the terminal block and the side used shall be consistent with the rest of the site/installation. Inter-panel connections shall be terminated on terminal blocks in number order and on the same side of the terminal blocks in each panel, where practicable. 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.

Systems employing fibre optics shall be installed such that the fibre optic cable and its terminations are not subjected to bend radii in excess of those stipulated in the cable manufacturer's recommendations. This requirement applies equally to installations where the equipment is mounted on movable panels (e.g. swing-frame racks). The cable and terminations shall not be put under tension or be bent beyond the manufacturer's guidelines throughout the complete range of motion of the cubicle panel/door.

1.7 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 bar or aluminium 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 galvanised steel.

All equipment within a cubicle and the cubicle metalwork shall be electrically bonded to earth. A single earth connection shall be provided between the cubicle and the substation earth mat. This connection shall meet the requirements of TS 3.1.2(RES). As a minimum a cubicle shall be fitted with an earth terminal or stud as specified below, for kiosks and termination boxes. The disconnection of any one piece of equipment from earth shall not disconnect any other equipment.

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 and unambiguously labelled.

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 shall interconnect the equipments. The cross-sectional area of the wire shall be not less than 2.5 mm^2 if protection against mechanical damage is provided, and 4 mm^2 if mechanical protection is not provided. Doors, covers, subracks etc shall be similarly interconnected to ensure electrical continuity to earth.

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 via a secure sliding link and shall be labelled as an earth link. The link shall be of a captive type and mounted such that the moving element shall, if inadvertently left loose, fall under gravity to the earthed position. All circuit earth connections and links shall be readily accessible in the relay cubicle or associated terminal box. A notice warning of dangerous voltage shall be provided adjacent to the CT secondary circuit link.

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

1.8 Marking and Labelling of Equipment

Labels shall be provided for the clear and unambiguous identification of all equipment requiring operation and maintenance. Equipment with the same system function (e.g. First Main Protection) shall be clearly identified and separate from other equipment in the same panel but providing another protection function (e.g. System Back-up Protection). Such equipment shall be clearly and unambiguously labelled front and back. For the avoidance of doubt equipment in this context includes links, MCBS and, where possible, terminal rails.

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. It shall be possible, through the use of wire-end marking ("ferruling"), to identify individual wire-end terminations along with their function. All wire-end marking shall be in accordance with the requirements of Energy Network Association Technical Specification 50-19 – Standard Numbering for Small Wiring. All numerals shall be in strong contrast to the colour of the insulation. The identification shall be given in arabic numerals. In order to avoid confusion, unattached numerals 6 and 9 shall be underlined.

For telecommunications equipment 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).

Where an installation is either the refurbishment/ replacement of or an extension to equipment on an existing site the wire-end termination identification methodology used at that site shall be maintained on the new installation. Within a panel or an item of equipment a supplier shall use its proprietary wire-end identification. At the point of interface with existing equipment, where differing wire-end identification methods have been used, both methods shall be employed so that the change is clear and unambiguous.

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 and sequentially numbered. The labels shall be mounted such that they are not disassociated from the mouldings when access to terminals is required.

1.9 Terminal Blocks

For the avoidance of doubt the requirements contained in this section apply to all substation equipment including, but not limited to, circuit breakers, disconnectors, current and voltage transformers.

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

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

The design of terminal blocks shall be such that the integrity of the connection may be confirmed by visual inspection.

Terminal blocks of the insulation displacement type are acceptable only for telecommunications applications.

Terminal blocks using push-on connections are acceptable where the connection is secured, e.g. by means of a spring clip.

Where terminals of the screw or stud types are used, the correct torque shall be applied in accordance with the manufacturer's instructions. The torque setting shall be confirmed during commissioning.

Terminal blocks shall be suitable for accommodating the required number of terminations in accordance with the terminal block manufacturer's instructions.

Terminal blocks and their installation shall allow unencumbered access to all terminations. For the avoidance of doubt termination arrangements that provide more than two cable entries on the same vertical plane (double stacked terminal blocks) are not acceptable.

Terminal blocks provided for alarm connections to substation control system equipment shall incorporate isolating facilities.

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 1.9.

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 and VT and dc circuit wiring that serves circuit protection systems 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.

Current Transformer terminal blocks housed at the marshalling point closest to the Current Transformer shall facilitate the application of temporary shorting links that are secured using a nut and washer locking arrangement. Facilities for isolating the short circuited CT shall also be provided at this point. The design shall be such that the integrity of the short and open circuits may be readily confirmed by visual inspection. The terminal block shall be located at an easily accessible position.

On high impedance busbar protection schemes only - termination blocks that facilitate the in service shorting and disconnection of circuit current transformers (i.e. isolation and earthing links) shall be provided at the point of connection to the common bus-wiring.

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.

Where a protection system incorporates a selection facility for the direct or qualified tripping of the remote end of a circuit from the local busbar protection system(s) this shall be provided by clearly and unambiguously labelled bolted or hard wired links mounted in the back of the appropriate relay cubicle panel.

All connections shall be made in accordance with the terminal manufacturer's instructions. Connections shall be made only by appropriately trained and supervised staff. The correct tools shall be used and where applicable these shall be calibrated (e.g. torque screwdrivers). Each connection shall be inspected, including checking of torque settings where applicable, and the inspection recorded.

1.10 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. The type of termination shall be compatible with the terminal with which it is to be used as specified by the terminal manufacturer.

The termination shall be made such that there is no undue tension in the wire or force exerted on the terminal after connection.

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.

1.10.1 Crimps

Crimps shall meet the requirements of BS EN 60352-2.

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

An extended sleeve over the crimp barrel shall be used to provide additional conductor insulation support on flexible stranded conductor below 0.5 mm^2 and on single strand conductor of 1 mm^2 and below.

Each crimped termination shall be fitted with one conductor only.

Where crimps are used for CT secondary terminations, the manufacturer shall demonstrate that the connection cannot become loose through vibration or other environmental factors.

Crimping shall be carried out in accordance with the crimp manufacturer's instructions.

1.10.2 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.

1.11 Small Wiring

The colouring of small wiring shall comply with Table 1 except where as specified below.

Function	Colour
Protective conductors Functional earthing conductors	Green-and-yellow Cream
a.c. power circuit (motor/fan drives, power socket outlets, lighting, etc) single-phase three-phase	 Brown (L), Blue (N) Brown (L1), Black (L2), Grey (L3), Blue (N)
a.c. control circuits and other applications (including VT/CT secondaries)	White*
d.c. control circuit	White

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

Table 1 - Small Wiring Colours

Where a minor addition or modification to an existing wiring scheme is undertaken, the existing wiring convention should be adopted. For the purposes of the above, minor shall be considered as being an addition or deletion of single protection or control functions. Full protection or control replacements shall require the adoption of Table 1.

Factory produced equipment wiring panels, i.e. those associated with and included within a Type Registration submission, are not affected by the requirements of this clause. Examples of the above are:

a) A current transformer (CT) secondary winding loom from the CT winding to the equipment terminals connection point.

b) Wiring from a HV disconnector motor winding and/or its auxiliary contact assemblies to the equipment terminals connect point.

Current transformer small wiring shall have a cross sectional area of not less than 2.5 mm^2 unless 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. The conductor shall meet the requirements of IEC 60228.

PVC insulated small wiring shall be in accordance with BS 6231, BS 6004 (or IEC 60227 parts 1 to 4) and BS 7211 as appropriate to the particular application being considered. The contract shall specify the general ambient conditions for small wiring and where, if appropriate, low smoke zero halogen insulation is required.

1.12 Interposing Relays

1.12.1 General

The environmental and performance test requirements for interposing relays are as specified in TS 3.24.15(RES)

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 EN 60529 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 IEC 61810-1 where relevant. However a lower rating may be used where it can be shown that the contacts are suitable for the particular application.

The relay will be required to operate either from a 48 V or 110 V nominal dc supply as specified in TS 2.12(RES)

1.12.2 In/Out Switching Relays for Protection and Auto-Reclose Equipments

The relay shall be of the latched type with independent operate and reset coils. 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.

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.

The relay shall be sized according to the application. Consideration shall be given to the provision of a sufficient number of spare contacts to allow for future requirements.

1.12.3 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 2 or shall be double-pole switched.

1.12.4 Forced Tripping Relays

Relays that provide a forced tripping function on 110 V (dc) systems shall be Class 1 or Class 2 as specified in Table 2. Class 2 may be required where extensive dc wiring is associated with the relay and operation due to capacitive discharge is more likely.

Forced tripping relays for use on 48 V (dc) systems, shall be double pole switched.

1.13 Testing Facilities

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

Test Blocks must be provided on the Protection Equipment panels to enable access into the CT, VT and DC circuits of the protection relays for commissioning and periodic testing of the relay equipment without disturbing any wiring connections associated with the protection scheme. Test Plugs for use with the Test Blocks, must have all circuits (14 circuits) brought out to twenty eight 4mm sockets on the front of the plug, with no shorting devices between the sockets or plugs, allowing full access to the CT, VT and Protection relay circuits for injection or measurement purposes. The Test Plugs must be compatible with Test Blocks (MMLG 01 or equivalent) used on pre NICAP Protection panels.

The Test Blocks must be 19'' rack compatible, and shall comply with the following IEC specifications:-

High Voltage withstand.

Insulation.

BS EN 60255-5:2001. – 5kVrms for 1 minute between all case terminals connected together and the case earth terminal

5kV rms for 1 minute between any contact pair and either adjacent alternate contact pair provided the intermediate contact pair is not used.

2kV rms for 1 minute between any contact pair and either adjacent contact pair.

Current Withstand.

– All contact circuits rated at 20A continuously or 400A for 1s, ac or dc.

Atmospheric environment.

Temperature.

BS EN 60255-1: 2010 – Storage and transit -25°C to +70°C.

Operatin**g** -25°C to +70°C.

BS EN 60068-2-1:2007. – Cold.

BS EN 60068-2-2:2007. – Dry Heat.

Humidity.

BS EN60068-2-78:2002. – 56 days at 93% RH and +40°C.

Enclosure Protection.

BS EN 60529:1992. – IP50 (dust protected).

Mechanical environment.

BS EN 60255-21-1: 1996. – Response Class 2

Where Test Blocks are fitted they should be mounted in such a way that when the Test Plug is inserted it will not foul any other equipment when the relay panel door that they are mounted on, is not in the normal closed position.

For the avoidance of doubt this includes a requirement to provide a 'Simulated Trip Test' facility for each circuit bay tripping system. The simulated trip test system shall provide a means of testing the tripping system up to but not including the bay circuit breaker. A 'dummy circuit breaker' shall be provided in the form of a portable plug in test box that simulates the operation of the bay circuit breaker. As a guide the 'Simulated Trip Test' facility shall provide an equivalent interface and have the same functionality as the Areva Simulated Trio Test Socket and Dummy Circuit Breaker Test Box.

2 PERFORMANCE REQUIREMENTS

2.1 Enclosures and Equipment

Enclosures, equipment and ancillary components etc, shall be designed to operate under the appropriate general ambient conditions specified in TS 1 (RES) - Environmental Service Conditions.

2.2 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.

Terminal blocks for use with pilot cables shall be rated to withstand the potential rise induced during switching of the associated primary circuits.

2.3 Plug and Socket Type Connectors

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

2.4 In/Out Switching Relays for Protection and Auto-Reclose Equipments

For operation at 48 V (dc) the following requirements apply:

a) The burden of the coil shall not exceed 15 W at 48 V (dc)

b) For general application the relay shall function correctly with 200 Ω in series with each coil and with a battery voltage of 46 V. For applications associated with a coordinated control system, where the control is via a local bay computer the relay shall function correctly with 15 Ω in series with each coil.

c) The relay shall function correctly when 56 V (dc) is applied and maintained at the appropriate terminals.

d) Minimum operating and resetting current shall be 25 mA.

e) Operation or resetting should not occur when 110 V (dc) 50 Hz is applied to the external case terminals of the respective relay coil circuit for 5 seconds).

For operation at 110 V (dc) the following requirements apply:

f) The relay shall function correctly with 30 Ω (or 15 Ω where the supply originates at the relay panel) in series with each coil and a battery voltage of 100 V.

g) The relay shall have a rated voltage of 125 V (dc).

2.5 Control Interposing Relays

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

Class	**1**		**2**
D.C. 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 °C ambient (V)	137.5	60	137.5

Table 2 - Control Interposing Relays

* For details of the capacitive discharge test refer to Section 3.1.

The requirements for capacitor discharge immunity shall not apply to auxiliary energising circuits of a relay.

2.5.1 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.

2.5.2 110 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.

3 TEST REQUIREMENTS

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

3.1 Control interposing relays

3.1.1 Capacitance discharge test

The trip relay shall be tested to ensure that it does not operate when a charged capacitor is discharged across the dc energising circuit(s). The value of the capacitor and charging voltage is as specified in Table 2.

4 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.

5 FORMS AND RECORDS

Not applicable.

PART 2 - DEFINITIONS AND DOCUMENT HISTORY

6 DEFINITIONS

The definitions given in TS 1(RES) and TS 2.2(RES) apply to this document.

7 AMENDMENTS RECORD

Issue	Date	Summary of Changes / Reasons	Author(s)	Approved By (Inc. Job Title)
1	February 2014	New document		

PART 3 - GUIDANCE NOTES AND APPENDICES

8 REFERENCES

This Specification makes reference to, or should be read in conjunction with, the following documents.

International and British 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 60352-2	Solder-less connections. Solderless crimped connections. General requirements, test methods and practical guidance
BS EN 60439-1	Specification for Low-Voltage Switchgear and Controlgear Assemblies - Type Tested and Partially Type Tested Assemblies
BS EN 60529	Degrees of Protection Provided by Enclosures (IP code)
BS EN 60694	Common Specifications for High-Voltage Switchgear and Controlgear Standards
BS EN 60695-2-13	Fire Hazard Testing . Test methods. Glowing/hot-wire based test methods. Glow wire ignitability test method for materials
BS EN 60695-9-1	Fire hazard testing. Surface spread of flame. General guidance
BS EN 60947-2	Specification for low-voltage switchgear and controlgear. Circuit-breakers
BS EN 60947-7-1	Specification for low-voltage switchgear and controlgear. Ancillary equipment. Terminal Blocks for Copper Conductors
IEC 60227 (1-4)	Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V
IEC 60228	Conductors of insulated cables
IEC 60255-5	Electrical Relays – Part 5: Insulation coordination for measuring relays and protection equipment – Requirements and tests
IEC 60297-2	Dimensions of Mechanical Structures of the 482.6 mm (19 in) Series. Part 2: Cabinets and pitches of rack structures

BS 5499 Part 5	Graphical symbols and signs. Safety signs, including fire safety signs. Signs with specific safety meanings
BS 6004	Electric cables. PVC insulated, non-armoured cables for voltages up to and including 450/750 V for electric power, lighting and internal wiring
BS 6231	Specification for PVC-Insulated Cables for Switchgear and Controlgear Wiring
BS 7211	Electric cables. Thermosetting insulated, non-armoured cables for voltages up to and including 450/750 V, for electric power, lighting and internal wiring, and having low emission of smoke and corrosive gases when affected by fire
BS 7671	Requirements for Electrical Installations
ENA – TS 50-19	Standard Numbering for Small Wiring

National Grid Documents

TS 1(RES)	Ratings and General Requirements for Plant, equipment and Apparatus for the National Grid System and Connection Points to it
TS 2.2(RES)	Switchgear
TS 3.1.2(RES)	Earthing
TS 2.12(RES)	Substation Auxiliary Supplies
TS 3.24.15(RES)	Environmental and Test Requirements for Electronic Equipment

SUBSTATION INTERLOCKING SCHEMES

This document is for Relevant Electrical Standards document only.

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PURPOSE AND SCOPE

This document defines the technical requirements of interlocking schemes for NGET equipment and for Users equipment directly connected to the Transmission System in England and Wales.

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

PART 1 – TECHNICAL REQUIREMENTS

1 GENERAL REQUIREMENTS

1.1 Common Requirements

1.1.1 So that operators do not compromise the integrity of the Transmission System in England and Wales 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.

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

1.1.3 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 are both open or both closed.

(f) For equipment at sites where NGET 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.

1.1.4 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.

1.1.5 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.

1.1.6 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.

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

1.1.8 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'.

1.1.9 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).

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

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

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

1.1.13 Interlocking may, in certain circumstances, have to be by-passed by auto-reclose schemes.

1.2 Mechanical Interlocking

1.2.1 Mechanical interlocking systems shall be designed to provide a level of security and reliability comparable with equipment specified in Clauses 1.2.2 to 1.2.6 below.

1.2.2 Mechanical interlocking shall be by key operated systems.

1.2.3 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 which prevents it being interchangeable with another.

1.2.4 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.

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

1.2.6 Where mechanical key interlocking is fitted to disconnector and earthing switch mechanisms the requirements specified in TS 3.2.2 (RES) shall apply.

1.3 Electrical Interlocking

1.3.1 Electrical interlocking systems shall be designed to provide a level of security and reliability comparable with equipment specified in Clauses 1.1. 3 and 1.3.3 below.

1.3.2 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 1.1.3 above.

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

1.3.3 Disconnector and earthing switch mechanisms which form part of electrical interlocking schemes shall meet the requirements of TS 3.2.2 (RES).

2 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.

3 FORMS AND RECORDS

None.

PART 2 - DEFINITIONS AND DOCUMENT HISTORY

4 DEFINITIONS

4.1 Directly (Connected)

Connected in such a way that performance of the connected equipment directly affects the performance of the Transmission System in England and Wales. Typically this is limited to equipment within the coverage of National Grid busbar protection.

4.2 Plant

Primary (high voltage) elements of the Transmission System in England and Wales-such as the circuit-breakers, transformers, overhead lines and cables.

4.3 Equipment

Secondary (low voltage) elements of the Transmission System in England and Wales such as those for control, measurements, protection and auxiliary supplies.

4.4 Apparatus

Physical components of, or associated with, the Transmission System in England and Wales which are required in support of the plant and equipment. Examples are substation structures, auxiliary plant and portable test equipment.

5 AMENDMENTS RECORD

Issue	Date	Summary of Changes / Reasons	Author(s)	Approved By (Inc. Job Title)
1	February 2014	New document		

PART 3 - GUIDANCE NOTES AND APPENDICES

6 REFERENCES

The following NGTS documents are relevant to Substation Interlocking and should be read in conjunction with this document as appropriate.

TS 1 (RES) Ratings and general requirements for plant, equipment, apparatus and services for the National Grid System and connection points to it.

TS 2.1 (RES) Substations.

TS 3.2.2 (RES) Disconnectors and Earthing Switches

EARTHING

This document is for Relevant Electrical Standards document only.

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PURPOSE AND SCOPE

This document defines the functional performance and test requirements for earthing systems forming part of the NGET System and protected by fast acting protection systems*. It supports the more general conditions defined in the companion documents TS 1 (RES) and TS 2.1 (RES).

The requirements of this document 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, NGET will state if it is necessary to control the earth potential rise (EPR) in accordance with section 1.2. If not stated, this requirement does not need to be applied.

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

PART 1 – PROCEDURAL

1 GENERAL REQUIREMENTS

The earthing system shall comply with BS EN 50522, EA TS 41-24 and BS 7430, unless otherwise stated.

1.1 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 1989 and Management of Health and Safety at Work Regulations 1999.

1.2 Earth Potential Rise (EPR)

1.2.1 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 1.

Table 1 Touch and Step Potential Limits

	Maximum Voltage for Touch	Maximum Voltage for Step
Chippings surface (150mm)	2.06kV	Limit could not foreseeably be exceeded
Chippings surface (75mm)	1.78kV	Limit could not foreseeably be exceeded
Soil surface	1.57kV	Limit could not foreseeably be exceeded

The limits in Table 1 assume a 200ms clearance time, a 1m step distance, a footwear resistance of 4kΩ per shoe, and effective earth foot resistance values respectively. They are based upon the approach agreed within BS EN 50522 UK national annex 'A'.

Informative: Current design practices show that touch voltage has always been the more critical design criteria, comparing to step voltage. As a key change to its 1994 version, IEC 60479-1 (2005) has since introduced the remarkable heart factor of 0.04 for step voltage scenarios, which directly resulted in the values 'Maximum Voltage for Step' to be in excess of 130kV. As the step voltage limit values are not foreseeable to be exceeded in reality, following the convention of BS EN 50522 (2012), they are not listed in Table 1 above.

1.2.2 From earthing perspectives, cable sealing ends shall be treated as substations unless otherwise agreed by NGET.

1.2.3 Critical third party EPR impact voltage thresholds via proximity effects are given in **Table 2**.

Table 2 Third Party Impact Threshold Voltages via Proximity Effect **

Third Party Infrastructure	Threshold Limit Voltage
Domestic residence or commercial property	1700V
Large hazardous process plant e.g. refinery	650V
Railways	645V

**: Proximity effect refers to EPR conduction via the ground

1.2.4 Where a NGET substation provides a HV connection to a third party, the applicable threshold limit values via conduction are given below.

Table 3 Third Party Impact Threshold Voltages via Conduction ***

Third Party Infrastructure	Threshold Limit Voltage
Domestic residence or commercial property	Not Applicable
Large hazardous process plant e.g. refinery	650V
Railways	645V

***: Conduction refers to electrical conduction via metallic conductors.

1.2.5 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 **Table 2** and **Table 3**.

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

1.2.6 Calculations to design the main earth system shall be carried out using the MALZ module of CDEGS software package (***C***urrent ***D***istribution, ***E***lectromagnetic Fields, ***G***rounding and ***S***oil Structure Analysis). The design models produced shall be made available once completed and shall become the property of NGET as part of the contract.

1.2.7 Communication cables connecting to all NGET substations must be fitted with appropriate electrical isolation.

1.3 Earth Electrodes

1.3.1 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 BS 7430. The fault duration times to be used for rating the electrodes are 1 second for 275kV and 400kV and 3 seconds for all other voltages.

1.3.2 Buried bare copper horizontal earth electrodes shall be installed at around 500mm depth. If the indigenous soil is hostile to copper, see section 3.1.1 (b), the electrode shall be surrounded by 150mm min of non-corrosive soil of fine texture, firmly rammed. Conductors installed in ploughed farmland shall be buried at least 1m deep, at all points, measured from undisturbed ground level.

1.3.3 Earthing electrodes should not be directly buried in high resistivity materials such as are commonly encountered as back-fills. These could include for example MOT Type 1 crushed concrete aggregate. Sand is also not suitable. In these cases, the electrodes shall be surrounded by 150mm min of non-corrosive soil of fine texture, as per clause 1.3.2. Alternatively, the properties of any backfill materials may be established through laboratory testing and shall be deemed acceptable if commensurate with the indigenous ground properties.

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

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

1.3.5 Driven rod electrodes in accordance with EA TS 43-94 shall be used to exploit lower resistivity ground strata where present to reduce the EPR in accordance with clause 1.2. 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.

1.3.6 Special types of earth rods, e.g. Chem-Rod, may be employed, provided conventional techniques could not meet the design requirements. Due to the use of chemicals, such cases should be considered thoroughly, taking into account the environment concerns and special maintenance needs. Appropriate agreement must be obtained with NGET prior to use.

1.3.7 Where beneficial, reinforcing steelwork incorporated within piling may be connected to the MES for the purpose of equipotential bonding and/or to form part of a common bonding network (CBN). However, care must be taken to ensure that the current carrying capacity of the steelwork is not exceeded.

Although it is acknowledged that buried concrete encased steel reinforcement can, depending on certain conditions, constitute an effective earth electrode, it should not normally be relied upon to provide an earth electrode as part of the earthing system design.

Where reinforcement steelwork in piles is connected to the MES, connections shall be made to the vertical steel bars 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 TS 2.1. Fortuitous connections must not be relied upon. Welded connections are preferred.

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

1.4 Earth Electrode Arrangement

1.4.1 Unless otherwise agreed by NGET, 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.

1.4.2 For indoor substations the earthing grid shall be installed with spur connections to the steel reinforcing mat of the concrete floor, every 20m. Additionally, a second peripheral main earthing conductor shall be buried at 1m distance from the building, which shall be bonded to the first main conductor, and to the building if it is metalclad, both at 20m intervals. Earth rod groups shall be connected to the second peripheral conductor as described in clause 1.4.1.

1.5 Test Facilities

1.5.1 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 50mm diameter circular clamp meter jaws (min length 75mm). An example of how this can be achieved is shown in Figure 1. This section of conductor shall be a part of a spur connection to the rod group, i.e. so that all the test current flows into the rod group and is not diverted into the main earth system. All testing points shall be identified both on the design earthing drawings and within the test pit at site.

1.5.2 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.

Figure 1 An example of earthing connection box with test facility*

*Note – The image shown above is without a lid and is meant to simply depict a surface accessible earth test box. This box example is suitably dimensioned to allow the testing of earth rod groups without disconnection in accordance with sections 1.5/1.6.

1.6 More Than One HV Substation

1.6.1 Where there is more than one NGET 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 50mm diameter circular clamp meter jaws (min length of conductor 75mm). An example of how this can be achieved is shown in Figure 1. All testing points shall be identified both on the design earthing drawing and within the test pit at site.

1.6.2 Where a NGET substation is located on the same site as another user's substation, the earthing systems shall be interconnected as defined by NGET. All testing points shall be identified both on the design earthing drawing and within the test pit at site.

1.6.3 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, NGET shall be informed by the supplier at the time of production of the earthing design.

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

1.7 Equipment Connected to the Main earth system

1.7.1 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 66kV 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.

1.7.2 All metalwork, e.g. panels, cubicles, kiosks etc., including the steelwork of buildings, shall be bonded to the main earth system, preferably by a conductor of no less than 70mm^2 cross section or a strip conductor no less than 3mm thick. The minimum conductor can be reduced to 16mm^2 where it is not reasonably practicable to install 70mm^2 conductors, provided the connection is secure.

1.7.3 For all substation fully rated flexible insulator strings, shunt conductors should be used between the arcing ring adjacent to the structure and the earth bars on the structure, so as to by-pass the major proportion of fault current under flashover conditions from the end fittings.

1.7.4 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 in clause 1.7.2 above.

1.8 Installation

1.8.1 Earthing conductors laid in trenches in outdoor substation compounds should be avoided where possible due to the vulnerability of the copper to theft. Where this is unavoidable, the earthing conductor should be protected from theft using the techniques detailed within section 1.8.7.

Where a trench contains power cables and/or multicore cables, the earthing conductor shall be fixed to the walls of the trench approximately 100mm from the top to maintain separation from the cables.

1.8.2 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 500mm to civil works, such as drainage pits, shall be maintained. Conductor runs above ground shall be designed to minimise the possibility of mechanical damage.

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

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

1.8.5 Where earthing conductors terminate above ground, the connections shall as far as is reasonably practical be made onto equipment surfaces in the vertical plane to avoid standing water. Connections to metal cladding of buildings shall be made on the inside of the building. Moreover, all bolted joints shall be situated at least 150mm above ground level. Bolts and nuts with security features, e.g. as listed in 1.8.8.3, shall be used, particularly to make the joints where earth tapes are connected to equipment tank/base or structures.

1.8.6 Aluminium conductor used for earthing systems shall only be installed above 250mm from ground level. All joint interfaces between the below ground copper earth conductors and the above ground aluminium earth conductors shall be jointed to manage any potential galvanic corrosion issue, to clause 1.8.5.

1.8.7 All vulnerable shallow buried earth tapes (tapes installed with less than 400mm of covering), shall be protected from theft at 2m intervals with either concrete anchors or driven earth rods.

1.8.8 Due to their vulnerability to theft, all above ground earthing conductors shall be fixed firmly and tidily to structures at a spacing of no more than 200mm between fixings. The fixings shall not promote galvanic corrosion. Where earthing conductor fixing systems require the earth conductor to be drilled, checks shall be undertaken to ensure that the loss of cross sectional area of the earthing conductor does not de-rate its operational performance requirements.

Due to the lack of security fixing techniques for stranded conductors, where reasonably practicable, flat copper tapes should be used for all above ground earthing conductors.

1.9 Portable Earthing

1.9.1 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 NGET standard portable earthing equipment, and shall be made of copper. The loops shall be not less than 230mm long and shall be 75mm clear of the earthing conductor. Loops for portable earths shall be installed at a convenient height and shall be directly connected to the MES by copper conductors, i.e. not via steel structures. Above ground earthing tapes should be securely fixed to deter theft in accordance with section 1.8.

The loops for portable earths shall employ designs which minimise the provision of climbing aids. For instance, the loops with tops inclined at degrees ≥45°, shall be adopted for vertical installations. Wherever this is not implementable, they should be positioned following consultation with NGET in a way to deter them being used as climbing aids.

The rating of multiple portable earth leads shall be as listed in **Table 4**.

Table 4 Ratings for multiple portable earth leads

Number of leads (150mm^2 aluminium)	132/66kV	400/275/13kV
1	17.5kA	23.4kA
2	31.5kA	42.12kA
3	47.25kA	63.18kA
4	63kA	-

1.10 Steel Support Structures

1.10.1 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.

1.10.2 Where a steel structure is relied upon to provide an earth connection for supported equipment, current carrying joints across the earth path within 2.4m of ground level shall be bridged across with fully rated earth tapes. Above 2.4m, the normal structural joints are considered adequate for electrical integrity during fault conditions.

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

1.10.4 Where post insulators, other than those forming part of shunt connected equipment (e.g. voltage transformers and surge arresters) are supported by a steel structure, the insulator base does not require a bridging connection to the structure.

1.11 Fences

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

1.11.2 Perimeter fences may be independently earthed using 4.8m long rod electrodes in accordance with EA TS 41-24. Alternatively, perimeter fences may be connected to the main earth system in accordance with EA TS 41-24 with permission from NGET.

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

1.11.4 Unless otherwise agreed by NGET, where a perimeter fence is connected to the main earth system, then an additional buried bare conductor shall be installed 1m outside the fence buried at a depth of 0.5m to control touch potentials. This conductor shall be connected to the main earth system and fence at 50m min intervals and adequately protected from theft using the techniques identified within section 1.8.

1.11.5 Metallic internal fences within the curtilage of the main earth system shall be connected to the earthing system at 50m min intervals and at changes of direction and where power lines cross overhead. Earth tapes should be protected from theft using the techniques identified within section 1.8.

1.11.6 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 5cm (approx) creepage at each end of a 2m section which is not connected electrically to either of the fences. A suggested method of installation using insulating bushes is shown in Figure 5.

An alternative to insulating bushes is to have a separate section of fence supported on its own posts at either end and separated by a 5cm gap as illustrated in Figure 6. Note that this is not suitable for security fences.

1.11.7 Most NGET perimeter fences are electrified, i.e. they are fitted with a secondary security system of electrified conductors on the inside of the fence. These 'power fence' systems are supplied via step-up transformers which provide inherent isolation between their LV supplies (and hence the main earthing system) and their HV conductors. One pole of the HV conductors must be connected to the perimeter fence earth to comply with current standards and this is normally done by installing bonds between one pole of the HV conductors and the fence at the fence corners. It is important that this power fence HV earth does not compromise any fence insulating sections. This could inadvertently be done by connecting the earthed HV pole to both an independently earthed fence and an MES earthed fence. This should therefore be avoided by ensuring the power fence is earthed to only either the independently earthed fence or the MES earthed fence, or by having additional power fence zones fed by separate step up transformers.

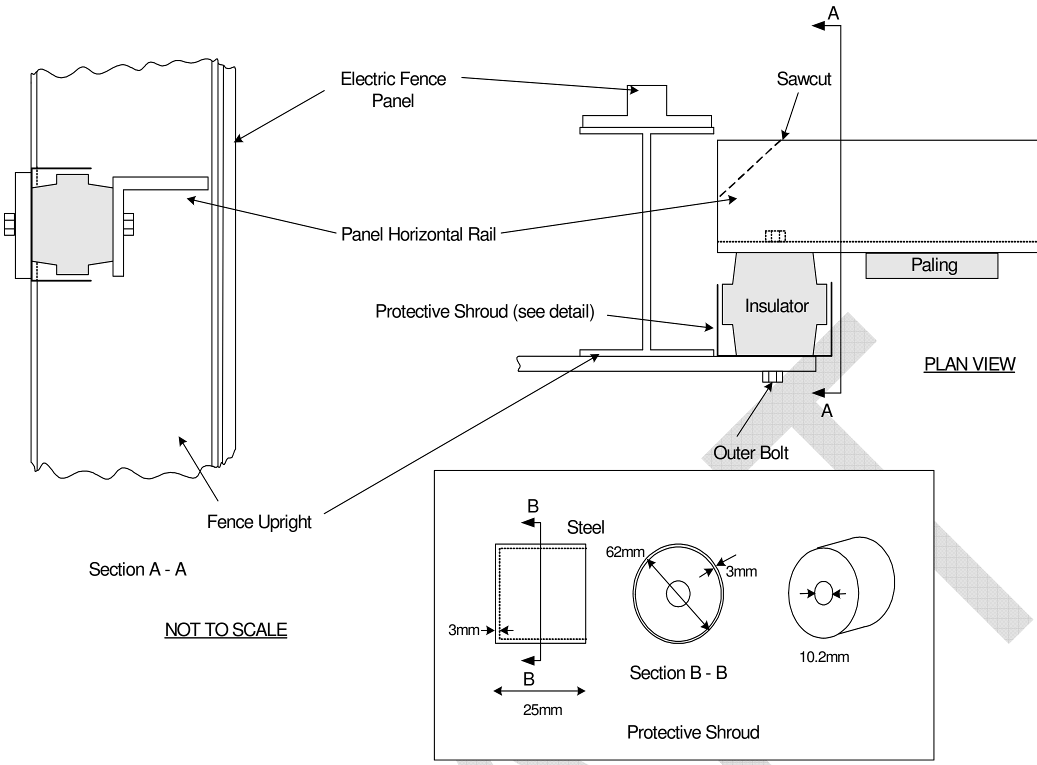


Figure 5 An example installation of insulating bushes on palisade fence

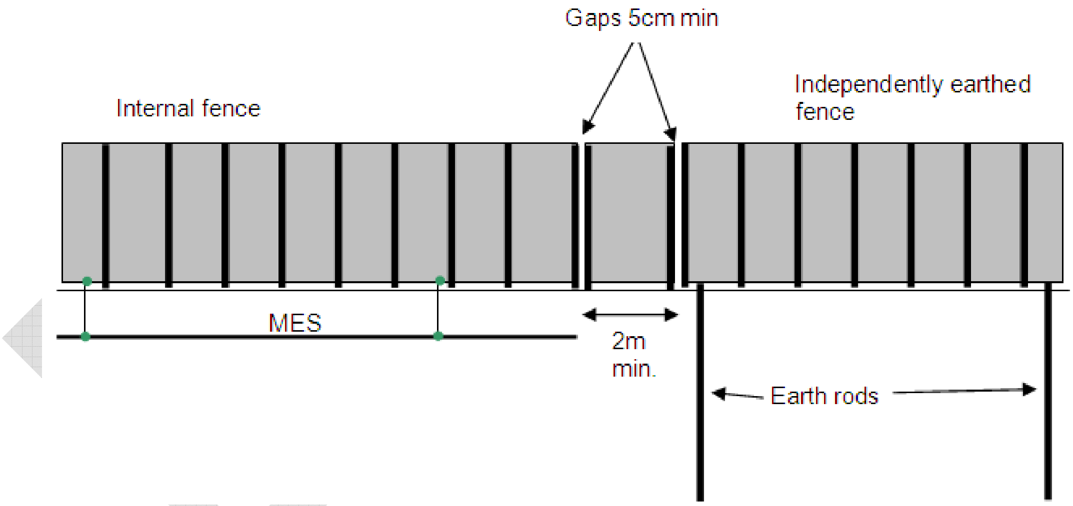
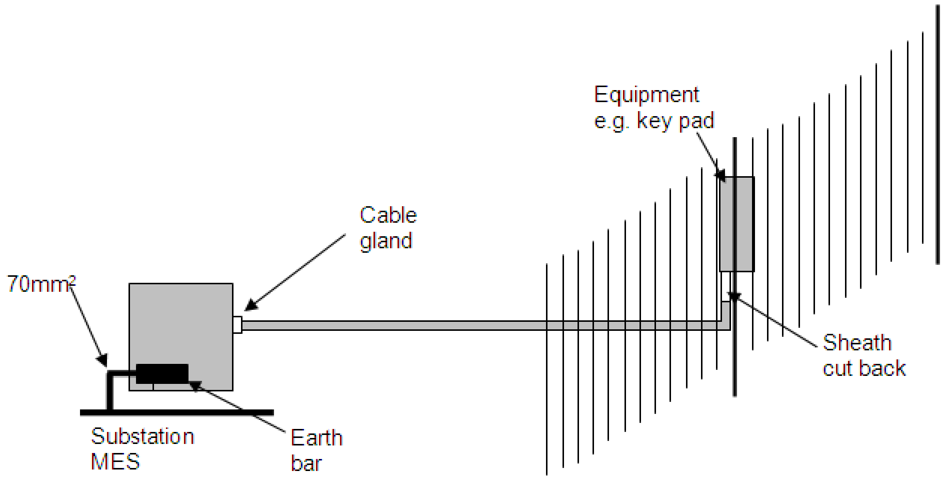


Figure 6 An example arrangement of separately earthed fences

1.11.8 When it is necessary to fit ancillary equipment, e.g. security key pads, to independently earthed perimeter fences, the equipment shall be effectively bonded to the fence. It is important that the connections to the equipment do not inadvertently serve to connect the equipment (and hence the fence) to the MES. Therefore the armouring of any Steel Wire Armoured (SWA) cables should be insulated from the equipment, i.e. they should be cut back at least 50mm from the cable gland and insulated. As an alternative, an insulating cable gland plate may be used. The armour of the cable should remain earthed at the remote end of the cable. No conductors (say from a multi-core conductor feeding the equipment) should be allowed to provide a connection to the MES. A warning notice, as shown in Figure 7 a), should be affixed to the equipment, to alert anyone carrying out maintenance on it, that a transferred potential hazard exists. **Note that it is preferred that where practicable a non-metallic junction box is used to reduce the risks from a transferred potential hazard.** The arrangements are illustrated in Figure 7.

DANGER TRANSFERRED POTENTIAL
Electric Shock Hazard
Do Not Proceed Without Authorisation

a) Notice on equipment installed on independently earthed perimeter fences



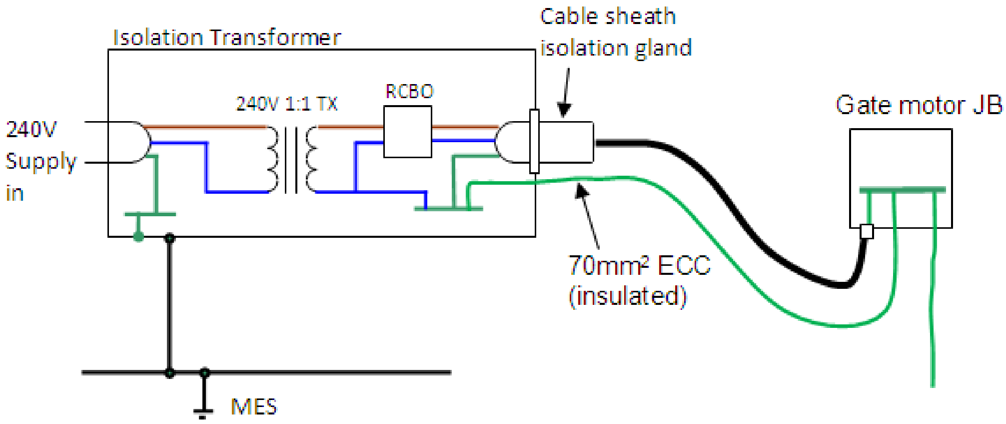
b) Earthing arrangement

Figure 7 Typical earthing arrangement for equipment (e.g. key pad) installed on independently earthed perimeter fences

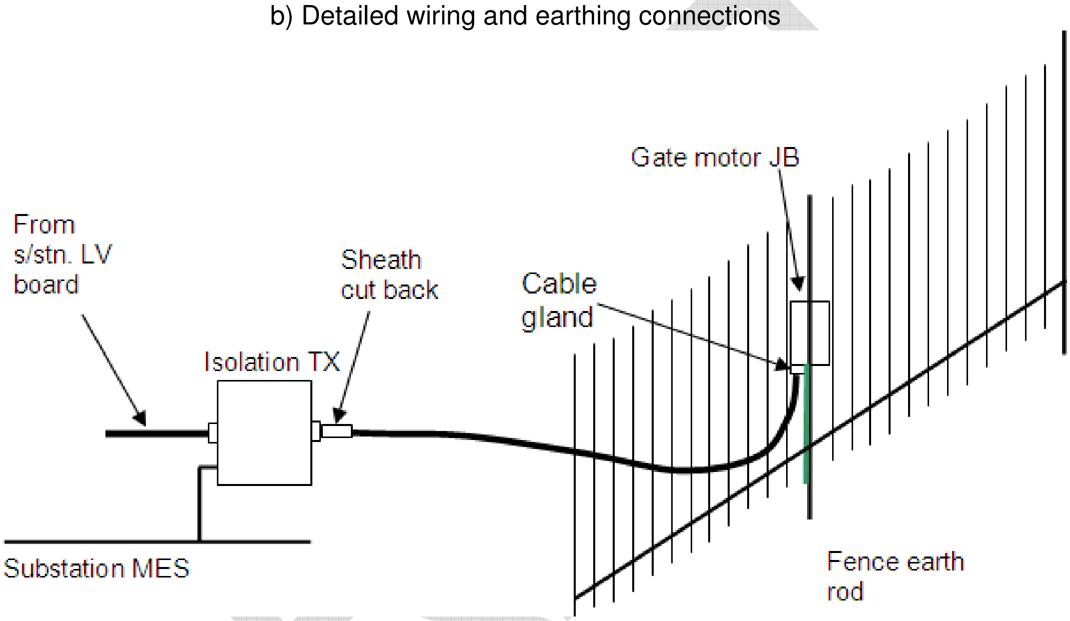
1.11.9 When it is necessary to fit LVAC supplied equipment, e.g. gate motors, to independently earthed perimeter fences, the LVAC supply to the gate shall not inadvertently serve to connect the gate (and hence the fence) to the MES. Therefore LVAC supply should be routed via an isolation transformer, ideally located where the supply is derived within the substation. The arrangements are illustrated in Figure 8. The isolation transformer enclosure should be connected to the MES via a 70mm^2 min conductor. A warning notice, as shown in Figure 8 a), should be affixed to the isolation transformer enclosure to alert anyone carrying out maintenance on equipment within the enclosure that a transferred potential hazard exists between the enclosure and its internals.

DANGER TRANSFERRED POTENTIAL
Electric Shock Hazard
Do Not Proceed Without Authorisation

a) Notice on isolation transformer enclosure



b) Detailed wiring and earthing connections



c) Overall view of LVAC supply and earthing arrangement

Figure 8 Typical earthing arrangement for LVAC supplies to gate motors

The armour of the SWA cable should be insulated from the isolation transformer enclosure, i.e. it should be cut back at least 50mm from the cable gland and insulated. Alternatively an insulating gland plate may be used. The armouring should be earthed at the motor junction box on the gate via a cable gland. The neutral from the LVAC supply should be connected via a 70mm^2 earth continuity conductor (ECC) to the fence earth via the gate motor junction box. A fence earth rod should be installed at this location and connected directly to the motor junction box earth bar.

No conductors (say from a multi-core conductor to the gate) should be allowed to provide a connection from the gate to the MES.

1.11.10 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 2m on either side of the fence. For example this may be achieved by running the conductor in an alkethene pipe 2m either side of the fence.

1.11.11 Where galvanised steel chain link internal fencing is used, a separate earth conductor (70mm^2 min) shall be installed along the fence and shall be connected to each section of fence every 10m or less and to the main earth system at 50m intervals.

1.11.12 Where plastic coated steel chain link internal fencing is used, connection (70mm^2 min) to the main earthing system shall be made at all fence guide wire anchor points.

1.11.13 Earthing connections to the perimeter fence shall be via a conductor which shall be accessible and shall have dimensions which would fit inside 50mm diameter circular clamp meter jaws. Where bolted joints are used to connect to the fence, these shall be protected from the environment.

1.12 Access/Egress Gates and Hinged Height Barriers

1.12.1 Access/egress gates and hinged height barriers are not required to be bonded to their supporting posts. Note that this should not be confused with the requirement to cross bond between gate and barrier supporting posts, and that this requirement should still be met.

1.13 Temporary Fences

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

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

1.13.3 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 EA TS 41-24.

1.13.4 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.

1.14 Terminal Towers and Gantries Supporting HV Conductors

1.14.1 Where the earth wire of an incoming Overhead Line (OHL) terminates on a tower it shall be connected to the top of the tower.

1.14.2 The terminal tower/gantry shall be directly connected to the adjacent substation main earth system.

1.14.3 Where a terminal tower leg is within 2m 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.

1.15 LV Distribution Transformers

This section should be read in conjunction with TS 3.12.3 (RES) in respect of the earthing connection arrangements for LV supplies.

1.15.1 The earthing and isolation of DNO derived LV distribution transformers associated with NGET substations shall be designed assuming that the substation EPR is greater than 650V rms. Appropriate mitigation measures shall be agreed with the local DNO to manage the hazards associated with step/touch/transferred potentials seen under fault conditions on the NGET network.

1.15.2 The incoming HV supply earth shall be electrically isolated from the substation MES at a minimum level of 10kV rms. This may be achieved (for cable fed HV supplies) through the use of HV cable sheath insulating gland or a HV cable sheath barrier joint. Where an insulating gland is used this shall be clearly labelled to indicate a transferred potential hazard. For pole mounted transformers, the transformer earthing shall be configured so as to prevent the export of EPR directly from the substation into the DNO HV network. The DNO would normally achieve this by segregating the HV and LV earthing.

1.15.3 An LV distribution transformer, which supplies a NGET substation, must not be used to provide LV supplies external to the substation, other than to an adjacent DNO or Generator Operator, which effectively share a common earthing system with that of the NGET substation.

1.16 Gas Insulated Substations (GIS)

The earthing requirements for gas insulated substations are substantially dependent on the particular type of equipment and its configuration. For this reason, the earthing arrangements should principally be determined by the supplier in conjunction with the manufacturer. However, the following minimum requirements shall apply, unless it can be demonstrated by the supplier/manufacturer that they are not required:

1.16.1 The main earth system shall be well integrated in the regions close to equipment with short spur connections taken to specific points. The GIS floor rebar system shall be connected to the MES at frequent intervals throughout the installation to provide an overall conductive mesh and this should not be relied upon to carry fault current. Connections to the MES, together with direct connections between phases shall be made at all line, cable and transformer terminations, at busbar terminations and at approximately 20m min 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. As a guide, the resistance of the bonded flanges should not exceed 5μΩ.

1.16.2 The earthing arrangements shall, in so far as is reasonably practicable, minimise the possibility of external arcing due to high frequency transients during switching operations.

1.16.3 The earthing arrangements shall ensure that circulating currents in supporting steelwork etc. are below levels which could result in hazards to persons or electrical interference with electronic equipment.

1.17 Substation Lightning Protection Systems

1.17.1 Where required, lightning protection systems shall be in accordance with BS EN 62305. All lightning protection system conductors shall be connected to the substation main earthing system.

1.18 Design Life of the 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.

2 PERFORMANCE REQUIREMENTS

2.1 Conductors

2.1.1 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 in Table 5a. Corresponding maximum current densities for a 30℃ ambient are given in Table 5b. Duplex or loop connections shall be de-rated by a minimum of 40% to allow for unequal current sharing. Preferred conductor sizes for copper and aluminium conductors are given in Table 5c.

Table 5a Highest Temperatures for Non- Mechanically Stressed Conductors

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

Table 5b Maximum Conductor Current Densities

Type of conductor	Current density for 1sec duration (A/mm^2)	Current density for 3secs duration (A/mm^2)
Copper	212	123
Aluminium	130	75
Galvanised Steel	80	45

Table 5c Preferred Conductor Sizes

Short-circuit current requirement	63kA/1sec		40kA/1sec		40kA/3secs	
Type of conductor	Spur	Duplex	Spur	Duplex	Spur	Duplex
Copper	50x6mm	50x4mm	50x4mm	40x3mm	50x7mm	50x4mm
Aluminium	75x6.5mm	50x6mm	50x7mm	50x4mm	75x8mm	50x7mm

3 DESIGN INFORMATION

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

a) The site soil resistivity profile and suitability for driving earth rods (see Appendix A 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, etc.) 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

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

4 TEST REQUIREMENTS

4.1.1 Validation by electrical measurement of any design is required for all installed systems to confirm the satisfactory installation and design of the system. All measurements shall be recorded. NGET reserves the right to witness all tests. The measurement methods are outlined in Appendix A.

4.1.2 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.

4.1.3 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, the layout of the main earth system, and any interactions between earthing systems owned by others.

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

4.1.5 Tests of all electrical joints shall be made. Wherever specific acceptable criteria are not available, as a principle guide, the measured resistance across a joint should not be more than that of a plain conductor of similar length. For instance, half a meter of 50mm×6mm copper tape would typically present a resistance value of ~25µΩ.

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

5 ACCEPTANCE PROCEDURE

5.1.1 The supplier shall provide evidence that the tests described in this document have been carried out satisfactorily. The test results shall be recorded.

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

5.1.3 The supplier shall provide documentation to demonstrate that the earthing installation complies with this document and includes with it EPR contour plots showing 430V, 650V, 1150V and 1700V contours overlaid onto an OS map (see also section 1.2.8).

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

5.1.4 The supplier shall provide a drawing detailing the new below ground earthing layout. Where an earthing system has been modified or extended, the existing drawing should be updated to reflect the changes. Where reasonably practicable, existing drawings should be consolidated onto a minimum number of new CAD drawings to depict the whole site earthing system. This may require the recreation of some legacy drawings which are presently in out of date formats.

5.1.5 All results shall be submitted, preferably within an earthing report, and become the property of NGET as part of the contract.

6 REFERENCES

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

The Health and Safety at Work Act, 1974

The Electricity at Work Regulations, 1989, Statutory Instrument No 635

The Electricity Safety, Quality and Continuity Regulations 2002, Statutory Instrument No 2665

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, Statutory Instrument No 3242

DD IEC/TS 60479-1 International Electrotechnical Commission, Effects of Current on Human Beings and Livestock - Part 1: General Aspects

BS EN 50341 Overhead lines exceeding AC 45kV

BS EN 50522 Earthing of power installations exceeding 1kV a.c.

BS EN 60228 Conductors of insulates cables

BS EN 62305 Protection against lightning

BS 638:Part4 Arc welding power sources equipment and accessories, Part 4. Specification for welding cables

BS 6004 Electric cables — PVC insulated, non-armoured cables for voltages up to and including 450/750 V, for electric power, lighting and internal wiring

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

BS 7430 Code of practice for Earthing 2011 (Formerly CP 1013: 1965)

Department for Transport (DfT): The Manual of Contract Documents for Highway Works (MCHW), Volume 1 - Specification for Highway Works, Series 0800 - Road Pavements - Unbound, Cement and Other Hydraulically Bound Mixtures (http://www.dft.gov.uk/ha/standards/mchw/vol1/pdfs/series_0800.pdf)

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

EA TS 34 A Guide for Assessing the Rise of Earth Potential at Substation Sites, May 1986

EA TS 36-1, Procedure to Identify and Record hot Substations, 2007

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

PART 2 - DEFINITIONS AND DOCUMENT HISTORY

7 DEFINITIONS

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

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

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 EPR is greater than 650V rms (based on a 200ms clearance time).

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

Other Earth System Earth conductors which are part of the System (as defined in NGET 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.

Earth Potential Rise (EPR) 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. EPR was previously known, in many national and industrial documents, as RoEP (Rise of Earth Potential).

Step Potential/Voltage 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 1m.

Touch Potential/Voltage The electrical voltage between two points, for instance predominantly bridgeable by a person's hand(s) and feet, due to a ground voltage profile. The touch distance is assumed to be 1m. For occasions, hand-to-hand touch voltage may need considerations.

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 object.

8 AMENDMENTS RECORD

Issue	Date	Summary of Changes / Reasons	Author(s)	Approved By (Inc. Job Title)
1	Feb 2014	New document	Dongsheng Guo - Asset Policy	

9 IMPLEMENTATION

9.1 Audience Awareness

Audience	Purpose Compliance (C) / Awareness (A)	Notification Method Memo / letter / fax / email / team brief / other (specify)

9.2 Training Requirements

Training Needs N/A / Informal / Workshop / Formal Course	Training Target Date	Implementation Manager

9.3 Compliance

Design Assurance/Policy Design Review

9.4 Procedure Review Date

5 years from publication date.

PART 3 - APPENDICES

APPENDIX A: MEASUREMENT METHODS

MEASUREMENT OF EARTH ROD AND EARTH ROD GROUP RESISTANCE

Unless otherwise agreed by NGET, 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.

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.

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.

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 BS 7430. The method described is also known as the Wenner Method. Resistivity shall be measured up to a depth of 60m 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).

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

CIRCUIT-BREAKERS

This document is for Relevant Electrical Standards document only.

TABLE OF CONTENTS

PURPOSE AND SCOPE

This document defines the technical requirements for circuit-breakers connected to the National Grid Electricity Transmission System at 400kV, 275kV, 132kV, 66kV. The principles of this document also apply to equipment connected at other voltages.

PART 1 – PROCEDURAL

1 GENERAL REQUIREMENTS

1.1 General Requirements for Circuit-breakers

1.1.1 All mandatory requirements of IEC 62271-100 and IEC 62271-1 shall be met for the specified rating in an effectively earthed neutral system.

1.1.2 The circuit-breakers shall satisfactorily complete all initiated close and open operations.

1.1.3 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.

1.1.4 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.

1.1.5 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.

1.1.6 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.

1.1.7 Provision shall be made for low density, close lockout and open lockout levels, as appropriate, to be remotely alarmed.

1.1.8 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.

1.1.9 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.

1.2 General Requirements for Mechanisms and Stored Energy Systems

1.2.1 Circuit-breakers shall be arranged for three pole operation by powered mechanism or mechanisms.

1.2.2 The rated operating sequence in accordance with IEC 62271-100 shall be O - 0.3s - CO - 3 min - CO.

1.2.3 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.

1.2.4 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.

1.2.5 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.

1.2.6 In satisfying clause 1.2.6 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.

1.2.7 Where a hydraulic system utilizes a compressed gas for energy storage, the pre-charge pressure of this gas related to the ambient temperature at the time of pre-charging 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 TS 1(RES). Where such systems initiate lockouts following loss of the pre-charge they shall also initiate appropriate alarms indicating the conditions.

1.2.8 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.

1.2.9 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.

1.2.10 Loss of stored energy from the mechanism shall not cause the primary contacts to part.

1.2.11 Stored energy systems shall not be released due to vibration caused by normal operation or other normal service phenomena.

1.2.12 Mechanisms incorporating springs for energy storage shall be provided with an unambiguous indication of spring state (charged or discharged).

1.3 General Requirements for Control Schemes and Circuitry

1.3.1 Where individual poles have separate operating releases the control scheme shall be such that the requirements of clause 1.3.8 are met.

1.3.2 If the opening circuit is initiated the closing circuit shall be rendered inoperative.

1.3.3 Operating mechanisms shall be provided with facilities for closing and opening and for selection of local/remote control

1.3.4 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.

1.3.5 300 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 C illustrate the requirements.

1.3.6 If the d.c. power supply is removed from either opening circuit of a circuit-breaker control scheme, the closing circuit or mechanism shall be rendered inoperative.

1.3.7 Circuit-breaker opening coils and their associated opening circuits shall be suitable for continuous supervision which is functional regardless of the state of the circuit-breaker (open or closed). .

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. 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.

1.3.8 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.

2 PERFORMANCE REQUIREMENTS

2.1.1 Electronic equipment shall comply with the relevant requirements of NGTS 3.24.15(RES).

2.1.2 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.

2.1.3 The short-circuit ratings specified apply to both three phase and single phase fault conditions including the relevant arc duration considerations.

2.1.4 The maximum short-circuit break time required to comply with TS 1(RES) 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 TS 2.2 (RES).

2.1.5 The circuit-breaker opening and closing times at the maximum, rated and minimum operating voltage of the opening and closing releases shall be declared.

2.1.6 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.

2.1.7 The minimum Make-Break time at rated conditions shall be declared and it shall be demonstrated that the circuit-breaker can perform all switching and fault interrupting duties under these conditions.

2.1.8 Operating tolerances, including those for simultaneity of poles, shall be as specified in IEC 62271-100

2.1.9 Circuit-breakers for intentionally non-simultaneous pole operation shall be designed and tested in accordance with IEC 62271-302.

3 TEST REQUIREMENTS

3.1 Control System Test Requirements

3.1.1 Control system testing shall be in accordance with the requirements of TS 3.24.15 (RES).

3.2 Type Test Requirements for Circuit-Breakers

3.2.1 For general application, asymmetrical current short-circuit interruption tests shall be undertaken with a time constant of 45 ms or greater.

3.2.2 145kV circuit-breaker 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.

3.2.3 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 durations related to single phase fault conditions.

3.2.4 Short-circuit testing shall be demonstrated at the minimum (lockout) conditions of arc extinguishing and insulating media

3.2.5 Demonstration of ability against the non-mandatory and Out of Phase requirements of IEC 62271-100 is required.

3.2.6 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.

3.3 6.6 Routine Tests

3.3.1 Routine testing shall comply with IEC 62271-100.

3.4 6.7 Site Commissioning Tests

3.4.1 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.

4 FORMS AND RECORDS

None

PART 2 - DEFINITIONS AND DOCUMENT HISTORY

5 DEFINITIONS

General purpose circuit-breaker	A circuit-breaker for application or connection to NGET's 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.
Special purpose circuit-breaker	A circuit-breaker for application to a particular part of NGET's network requiring special consideration and testing in excess of that for general application. Typically this refers to shunt capacitor banks, shunt reactors and series reactors.
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.
Controlled switching system	The combination of a circuit-breaker, controller (relay) and control scheme which, in combination, achieves controlled switching.

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6 AMENDMENTS RECORD

Issue	Date	Summary of Changes / Reasons	Author(s)	Approved By (Inc. Job Title)
1	February 2014	New document		

7 IMPLEMENTATION

7.1 Audience Awareness

Audience	Purpose Compliance (C) / Awareness (A)	Notification Method Memo / letter / fax / email / team brief / other (specify)

7.2 Training Requirements

Training Needs N/A / Informal / Workshop / Formal Course	Training Target Date	Implementation Manager

7.3 Procedure Review Date

5 years from publication date.

PART 3 - GUIDANCE NOTES & APPENDICES

8 REFERENCES

8.1 Noise at Work Regulations 1989

8.2 IEC 62271-1 High-voltage Switchgear & Controlgear – Part 1: Common Specifications

8.3 IEC 62271-100 High-voltage Switchgear & Controlgear – Part 100: Alternating Current Circuit-breakers

8.4 IEC 62271-110 High-voltage Switchgear & Controlgear – Part 110: Inductive Current Switching.

8.5 IEC 62271-302 High Voltage Switchgear & Controlgear – Part 302: Alternating Current circuit-breakers with intentionally non-simultaneous pole operation

8.6 BS 381C Specification for Colours for Identification, Coding and Special Purposes.

8.7 TS 1(RES) Ratings and General Requirements for Plant, Equipment & Apparatus for the National Grid system

8.8 TS 2.2(RES) Switchgear

8.9 TS 3.24.15(RES) Environmental and Test Requirements for Electronic Equipment

APPENDIX A - OPENING AND CLOSING RELEASE LOGIC DIAGRAMS

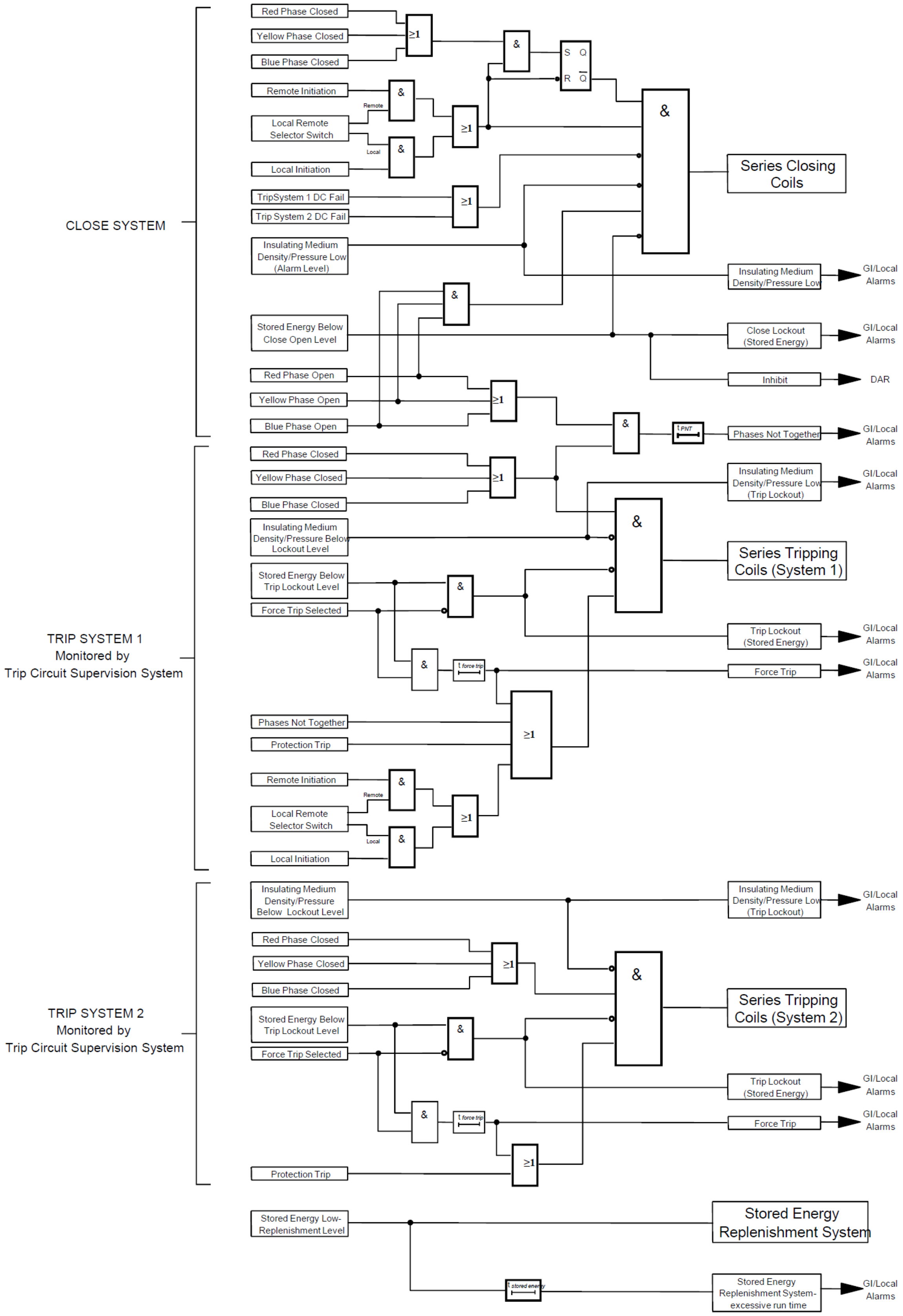
The attached logic diagrams detail the circuit segregation requirements applicable for the double opening release and series closing control schemes for circuit-breakers and switches.

Attachment 1 - Segregated phases with forced open facility

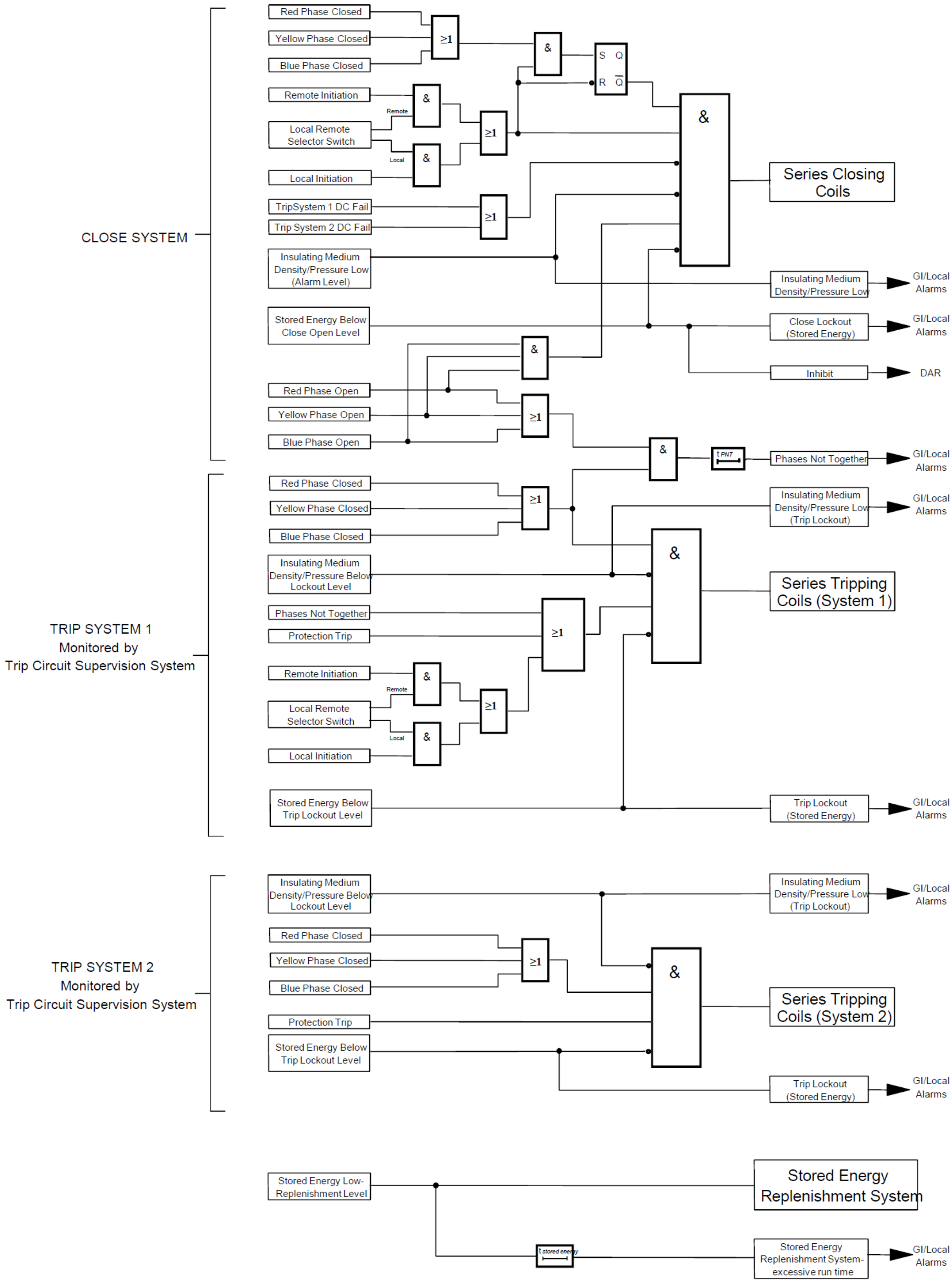
Attachment 2 - Segregated phases with open lockout

Attachment 3 - Three phase mechanism with forced open facility

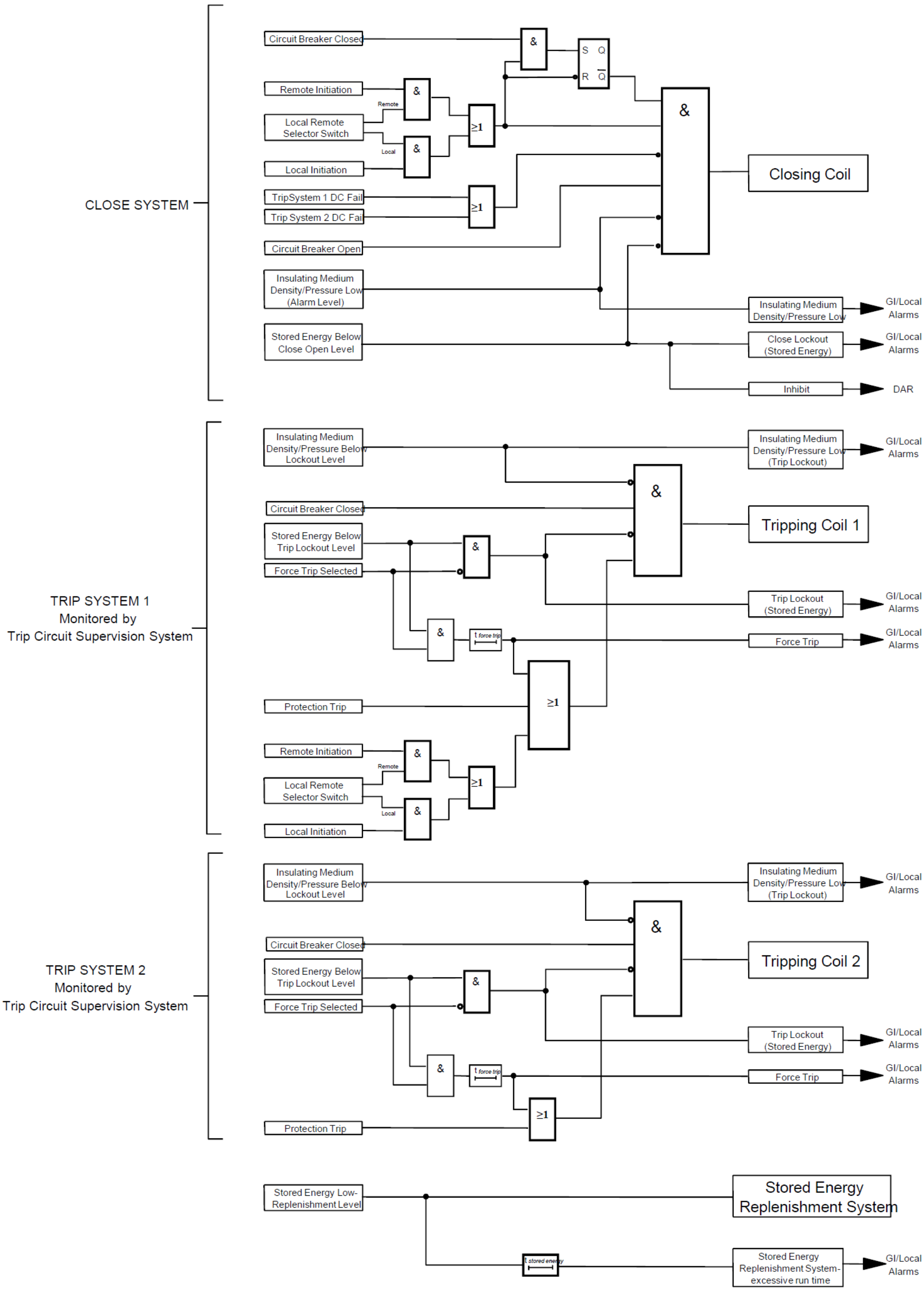
Attachment 4 - Three phase mechanism with open lockout



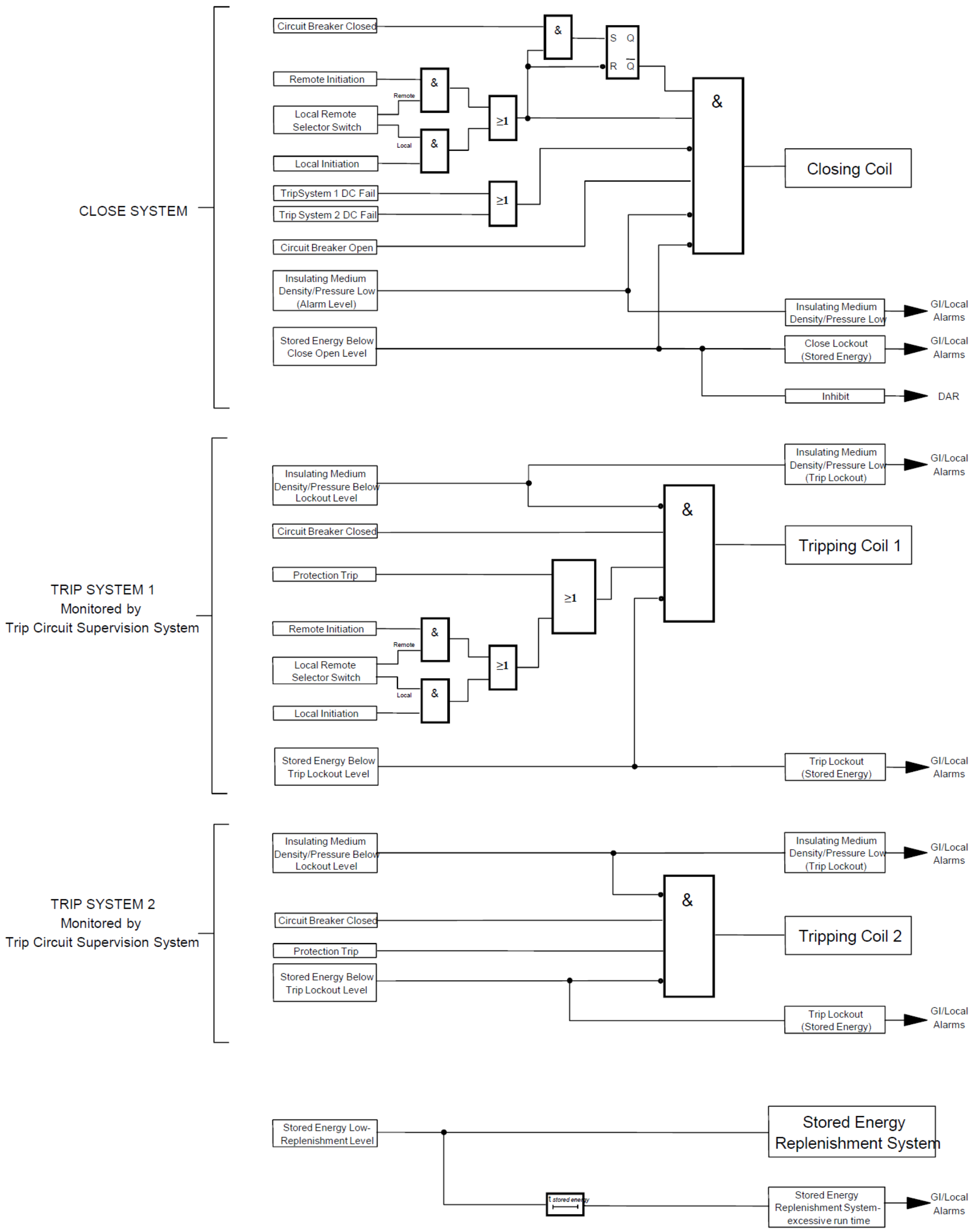
Attachment 1 - Segregated Phases with Force Trip Facility



Attachment 2 - Segregated Phases with Trip Lockout



Attachment 3 - Three Phase Mechanism with Force Trip Facility



Attachment 4 - Three Phase Mechanism with Trip Lockout

DISCONNECTORS AND EARTHING SWITCHES

This document is for Relevant Electrical Standards document only.

TABLE OF CONTENTS

PURPOSE AND SCOPE

This specification for disconnectors and earth switches is by reference to BS EN 62271-102, BS EN 62271-1, BS EN 62271- 203 and associated documents. This specification defines the required enabling parameters and additional technical requirements for disconnectors and earth switches for use on, and directly connected to, the Transmission System in England and Wales, rated from 72.5 kV to 420 kV.

This document defines the functional performance requirements for disconnectors and earth switches connected to the Transmission System in England and Wales. It supports the more general conditions defined in the companion documents TS 1 (RES), TS 2.1 (RES) and TS 2.2. (RES)

PART 1 – PROCEDURAL

1 RATINGS AND PERFORMANCE REQUIREMENTS

1.1 In addition to the general ratings and performance requirements defined in TS 1 (RES), TS 2.1 (RES) and TS 2.2 (RES), the following ratings apply to disconnectors and earth switches.

1.2 Disconnectors and Earth Switches shall satisfy the requirements of BS EN 62271-102.

Disconnectors rated at 420 kV and 300 kV shall be motor/power operated.

1.3 Rated Short-Time Withstand Currrent

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.

Divided Support Disconnectors and Earthing Switches

1.3.1 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 BS EN IEC 62271-102.

1.4 Bus-transfer Duty

1.4.1 Disconnectors intended for bus-transfer or mesh-corner switching shall comply with the bus transfer requirements of BS EN IEC 62271-102 Annex B.

1.4.2 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.

1.4.3 The design of the disconnector shall ensure that the operator is not endangered by arc debris during bus-transfer switching.

1.5.4 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 3.6

1.5 Rated Values of Mechanical Endurance for Disconnectors

1.5.1 Disconnectors shall be rated to Class M1 as specified in BS EN IEC 62271-102.

1.6 Rated Values of Electrical Endurance for Earth Switches

1.6.1 Air Insulated Earth Switches shall be rated to Class E0 as specified in BS EN IEC 62271-102.

2 GENERAL REQUIREMENTS FOR DISCONNECTORS AND EARTH SWITCHES

2.1 Clearance Distances

2.1.1 Phase-to-phase and phase-to-earth clearance distances shall be as specified in TS 2.1 (RES) 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 TS 1 (RES) and TS 2.1 (RES). 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.

2.2 Simultaneous Operation of Poles

2.2.1 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).

2.3 Flexibility of Design and Setting Adjustment Tolerances

2.3.1 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.

2.3.2 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.

2.4 Position Indication

2.4.1 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.

2.4.2 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 part of the disconnector or earth switch which enables a signal to be given, generally at a location remote from the disconnector or earth switch, indicating that the contacts of the main circuit are in the closed or open position and 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.

2.4.3 For GIS disconnectors and earthing switches, a reliable position indicating device (designed in accordance with BS EN 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.

2.5 Mechanical Key Interlocking

2.5.1 Where mechanical key interlocking is fitted to disconnector and earth switch mechanisms the following requirements shall apply.

2.5.2 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.

2.5.3 On power operated mechanisms with facilities for in-service manual operation the interlocking shall be effective for both power and manual operations.

2.5.4 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.

2.6 GIS Combined Disconnectors and Earthing Switches

2.6.1 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 NGET Safety Rules. .

2.7 Drive System Mechanical Interference Device

2.7.1 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 NGET 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.

2.7.2 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.

2.8 'Lockout' Interlock Keys

2.8.1 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.

2.8.2 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.

2.8.3 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.

2.9 Earthing Switch Magnetic Bolt Device

2.9.1 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.

2.10 Condition Monitoring for Disconnectors

2.10.1 Provision shall be made on disconnectors for the installation of condition/performance monitoring equipment. The provision should enable recording of the stiffness of the driven system and the displacement and velocity of the drive system throughout an operation. It should also enable the recording of the condition of the relevant insulation and energy systems whether as values of pressure, density or displacement. The requirement to attach the monitoring equipment will be separately specified in the Contract Enquiry Document.

3 OPERATING MECHANISMS, ANCILLARY EQUIPMENT AND THEIR ENCLOSURES

3.1 General

3.1.1 The requirements of TS 2.19 (RES) shall apply to disconnector and earth switch operating mechanisms, ancillary equipment and their enclosures.

3.2 'Sealing In' of Control Circuits

3.2.1 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.

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.

3.3 Drive Limit Switch

3.3.1 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.

3.4 Control Switches

3.4.1 Local/Hand/Remote Close control switch shall be provided with a facility for locking in each position.

1.1.1 The Open/Neutral/Close control switch shall be provided with a facility for locking in the Neutral position.

3.5 Auxiliary Switches

3.5.1 Auxiliary switches shall comply with TS 2.2 (RES) and BS EN 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.

3.5.2 The number of each type (i) to (vii) in Figure 1 will be specified on a site specific basis.

3.6 Auxiliary Switch requirements for disconnectors with bus transfer duty

3.6.1 The auxiliary switch variant (vii) in Figure 1 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.

3.6.2 The disconnector positions marked ** in Figure 1 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.

4 TEST REQUIREMENTS

4.1 The test requirements of TS 1 (RES), TS 2.2 (RES) and BS EN IEC 62271-102 for disconnectors and earth switches are appropriate.

5 FORMS AND RECORDS

PART 2 - DEFINITIONS AND DOCUMENT HISTORY

6 DEFINITIONS

Not applicable.

7 AMENDMENTS RECORD

Issue	Date	Summary of Changes / Reasons	Author(s)	Approved By (Inc. Job Title)
1	February 2014	New document		

8 IMPLEMENTATION

8.1 Audience Awareness

Audience	**Purpose** Compliance (C) / Awareness (A)	**Notification Method** Memo / letter / fax / email / team brief / other (specify)

8.2 Training Requirements

Training Needs N/A / Informal / Workshop / Formal Course	Training Target Date	Implementation Manager
N/A	N/A	N/A

8.3 Procedure Review Date

5 years from publication date.

PART 3 - GUIDANCE NOTES & APPENDICES

9 REFERENCES

9.1 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 NGTS.

IEC 62271-102	High Voltage Switchgear and Controlgear. Part 102: High Voltage Alternating Current Disconnectors and Earth switches.
IEC 62271- 203	Gas Insulated Metal Enclosed Switchgear for rated voltages above 52kV
BS EN 62271-1	High–voltage switchgear and controlgear – Part1: Common Specifications

9.2 NGET Technical Specifications

The following NGTS documents are relevant to Disconnectors and Earth Switches and should be read in conjunction with this document as appropriate.

TS 1 (RES)	Ratings and general requirements for plant, equipment, apparatus and services for the National Grid System and connection points to it.
TS 2.1 (RES)	Substations.
TS 2.2 (RES)	Switchgear for use on, and at Connection Points to, The National Grid System.
TS 2.19 (RES)	Ancillary Light Current Equipment.

APPENDIX A - OPENING AND CLOSING RELEASE LOGIC DIAGRAMS

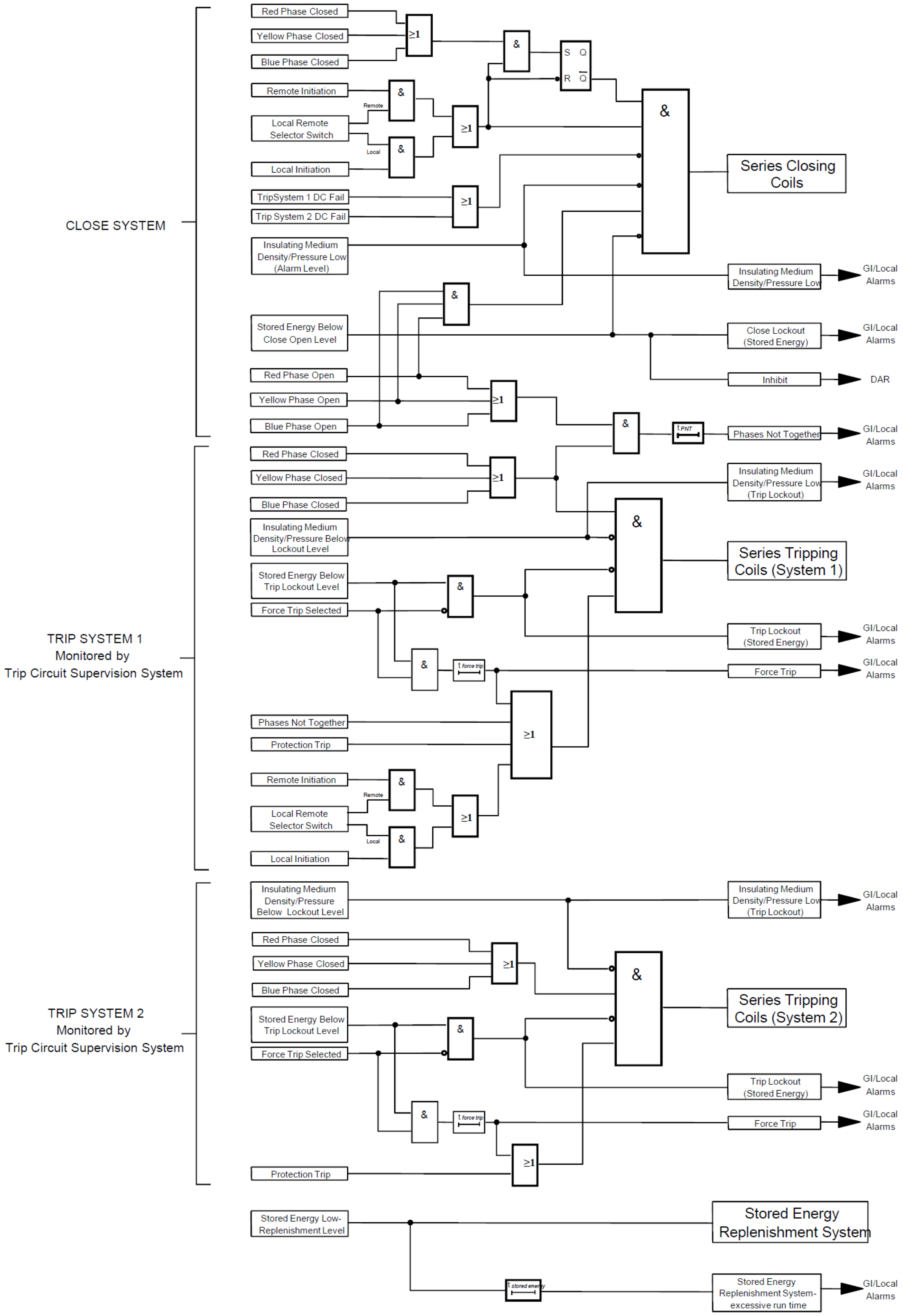
The attached logic diagrams detail the circuit segregation requirements applicable for the double opening release and series closing control schemes for circuit-breakers and switches.

Attachment 1 - Segregated phases with forced open facility

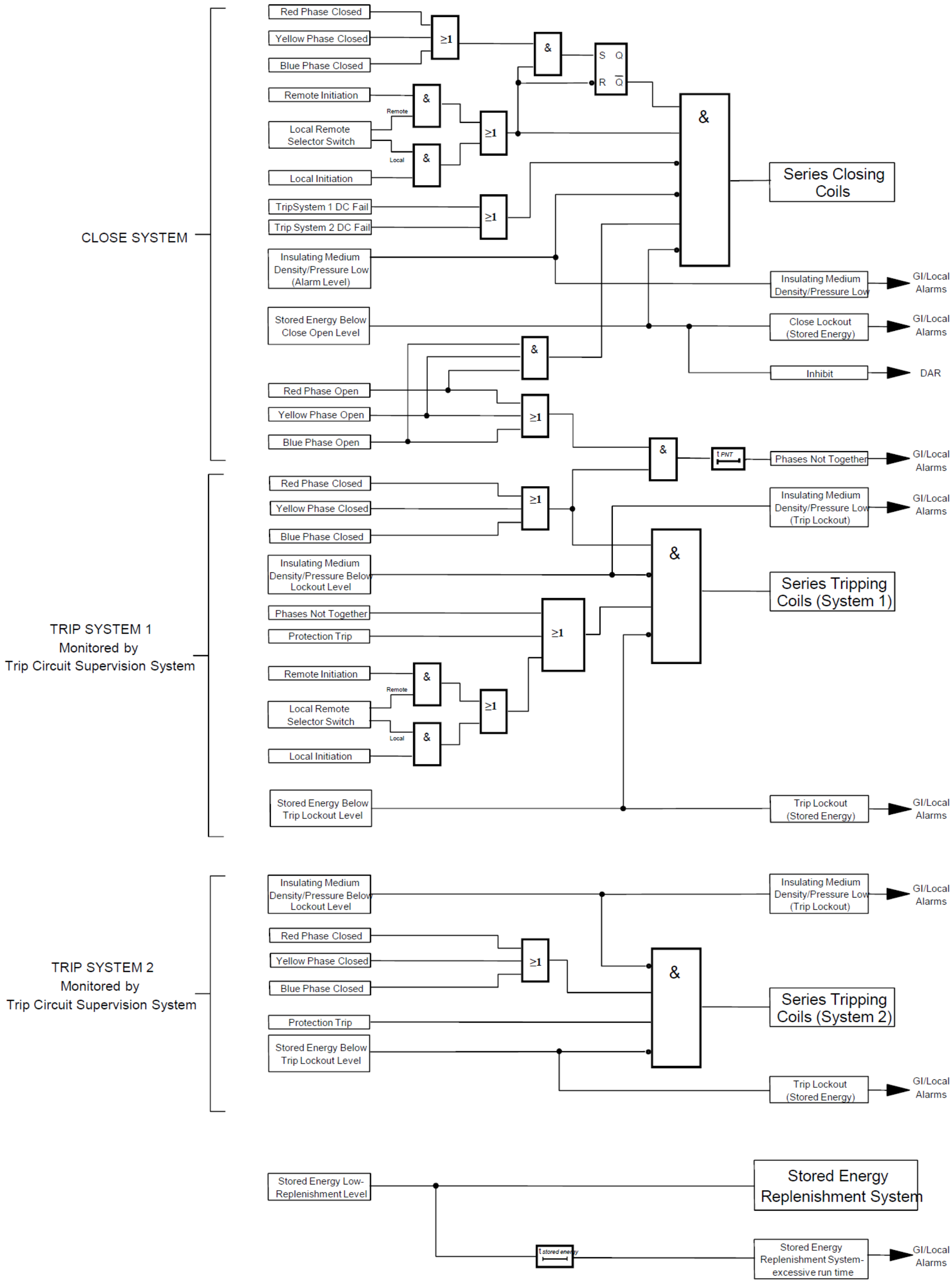
Attachment 2 - Segregated phases with open lockout

Attachment 3 - Three phase mechanism with forced open facility

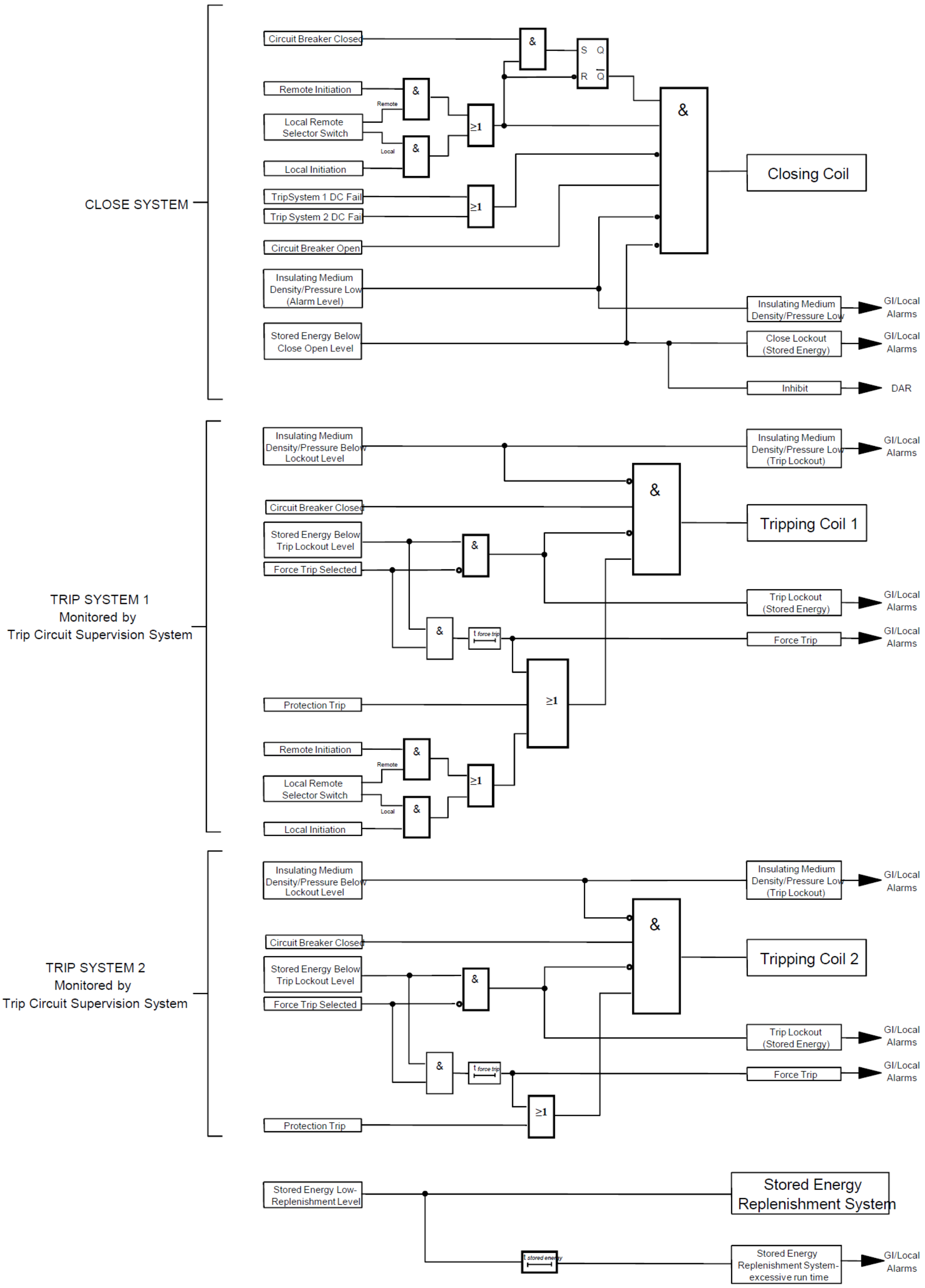
Attachment 4 - Three phase mechanism with open lockout



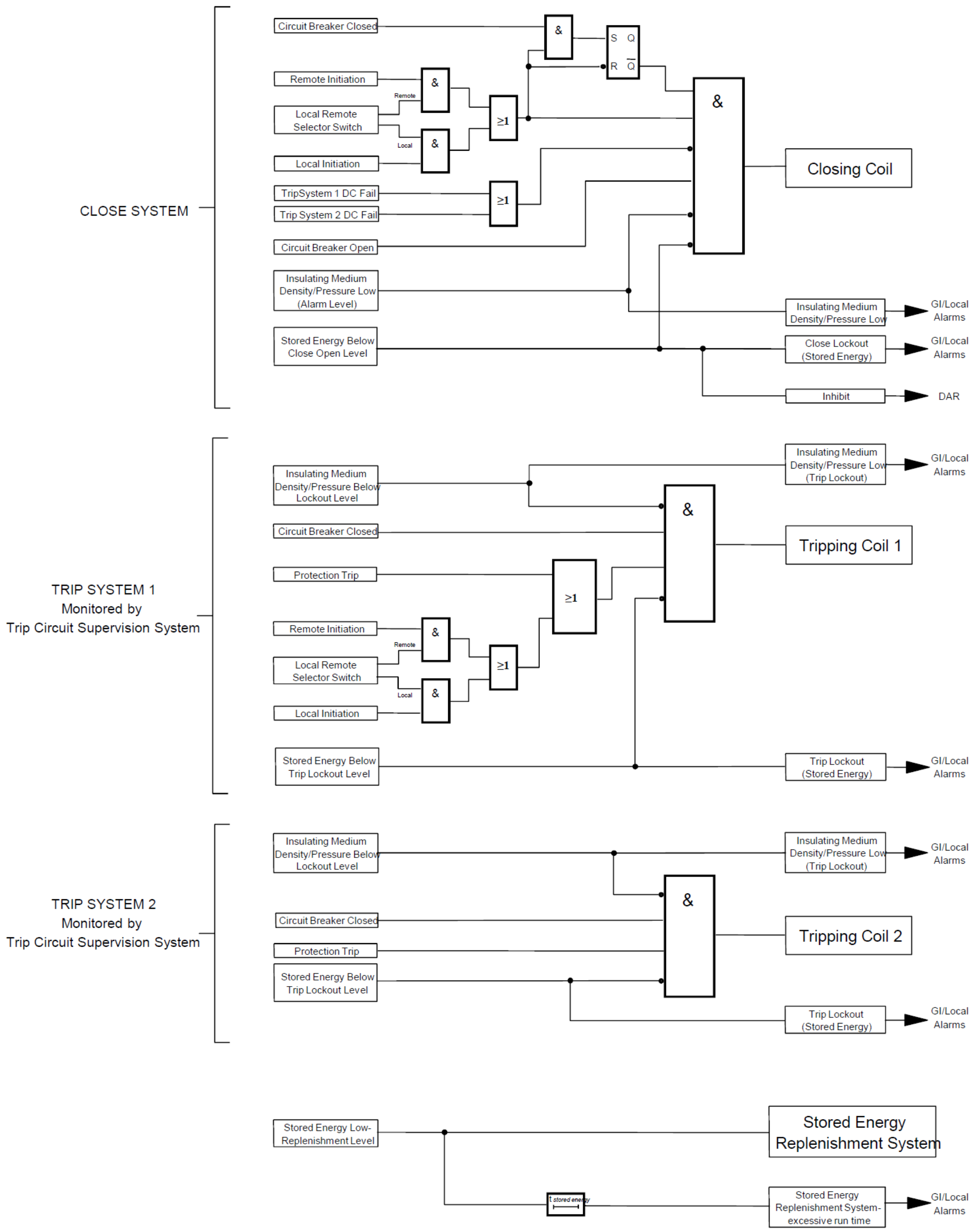
Attachment 1 - Segregated Phases with Force Trip Facility



Attachment 2 - Segregated Phases with Trip Lockout



Attachment 3 - Three Phase Mechanism with Force Trip Facility



Attachment 4 - Three Phase Mechanism with Trip Lockout

CURRENT TRANSFORMERS FOR PROTECTION AND GENERAL USE

This document is for Relevant Electrical Standards document only.

TABLE OF CONTENTS

PURPOSE AND SCOPE

This Specification defines the functional and performance requirements for current transformers (CTs) for protection and general use on The Transmission System in England and Wales. It supports the more general requirements defined in the companion documents TS 1 (RES), and TS 2.2 (RES).

This is a functional and performance specification for CTs used for protection and measurement application.

PART 1 – PROCEDURAL

1 GENERAL REQUIREMENTS

All CTs shall comply with TS 1 (RES), TS 2.2 (RES), IEC 61869-1 & IEC 61869-2. In addition, the following clauses apply:

1.1 General Requirements for all Current Transformers

1.1.1 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

1.1.2 Secondary terminals and connections shall be suitable for their required purpose regarding rating, reliability and the effects of environmental conditions and corrosion.

1.1.3 Primary and secondary terminal markings, and rating plate markings shall be in accordance with IEC 61869-2

1.1.4 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 61869-2

1.1.5 A thermal short-time current rating (Ith) shall be assigned to all current transformers in accordance with IEC 61869-2. The value of Ith shall not be less than the corresponding value for the associated switchgear or transformer primary plant.

1.1.6 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.

1.1.7 Both ends of the CT secondary windings shall be earth free.

1.2 Additional Requirements for Current Transformers for GIS Application

1.2.1 Current transformers may be mounted internally or externally to the GIS enclosure.

1.2.2 Adequate protection against adverse environmental conditions shall be provided for externally mounted CTs as required in TS 2.2 (RES).

1.3 Additional Requirements for Ring-Type Current Transformers

1.3.1 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 Clause 3.3.3.

1.3.2 Current transformers supplied with throughwall 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 by TS 2.2 (RES).

1.3.3 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 by TS 2.2 (RES).

1.4 Additional Requirements for Measurement/Protection and Class PX Protective Current Transformers

1.4.1 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 61869-2). 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.

1.4.2 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 61869-2

2 PERFORMANCE REQUIREMENTS

2.1 General

All current transformers shall comply with the performance requirements of IEC 61869-2 for the primary ratings detailed in TS 1 (RES) and TS 2.2 (RES). The following requirements shall also apply as appropriate:

2.2 Protection Type PX-A Current Transformers

2.2.1 Protection type PX-A current transformers shall meet the requirements given in IEC 61869-2 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

2.2.2 Type PX-A current transformers shall also meet the performance requirements of Schedule 10 of this Specification.

2.3 Protection Type PX-B Current Transformers

2.3.1 Protection type PX-B current transformers shall meet the requirements given in IEC 61869-2 providing accurate steady-state transformation up to the maximum fault current rating of the associated main plant.

2.3.2 Type PX-B current transformers shall also meet the performance requirements of Schedule 10 of this Specification.

2.4 Dual Purpose Measurement/Protection Current Transformers

2.4.1 Current transformers intended for the dual purpose of measurement and protection shall meet the performance requirements of IEC 61869-2, Clause 4.2.1 and Schedule 10 of this Specification.

3 TESTING REQUIREMENTS

3.1 Type Tests

3.1.1 All current transformers shall be type tested in accordance with IEC 61869-2 (type tests) and IEC 61869-2 (special tests). The additional requirements for protection class PX cores given in Appendix B. Current transformers using a gas insulation system, a leakage test on the gas system shall be performed by the supplier to demonstrate compliance with TS 2.2 (RES).

3.1.2 Radio interference voltage tests to IEC 60694 are to be performed on open-terminal current transformers.

3.1.3 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 Appendix A.

3.1.4 Temperature Rise - The thermal time constant of all equipment shall be determined on both rising and falling temperature.

3.1.5 For oil filled equipment oil samples for DGA shall be taken before and after the dielectric type tests and shall comply with Appendix A3.

3.1.6 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.

3.1.7 Routine tests shall be performed before and after all type tests.

3.2 Routine tests

3.2.1 All current transformers shall be routine tested in accordance with:

IEC 61869-2 (routine tests)

IEC 61869-2 (special tests)

3.3 Additional Routine Tests

3.3.1 Accuracy Tests

a) These shall be performed in a laboratory having traceability to National/International standards.

b) 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.

c) Full accuracy routine tests to IEC 61869-2.

3.3.2 Capacitance and dielectric loss angle (tan δ) measurements of the primary insulation over the voltage range 10 kV to rated voltage shall be performed.

3.3.3 Leads for loose current transformers as detailed in Clause 1.4.2 of this Specification shall withstand a power frequency test voltage of 5 kV

4 LIST OF SCHEDULES

Schedule 6	Bus Sections and Couplers and other users Directly Connected via NGC bus bar protection
Schedule 10	Table of Particulars for 420 kV, 300 kV and 145 kV Current Transformers

SCHEDULE 6 BUS SECTIONS AND BUS COUPLERS

ALSO OTHER USER CT's AT CONNECTION POINTS AND ASSOCIATED WITH NGC BUSBAR PROTECTION

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

SCHEDULE 10 TABLE OF PARTICULARS FOR 420 kV, 300 kV AND 145 kV CURRENT TRANSFORMERS

Reference Clauses	CT Designation	Ratio		Knee-Point Voltage (V_k) or IEC Rating and Class	Magnetising Current (mA)	Max Sec Res (ohms)
		Turns	Current			
4.2 to 4.4	**420 KV, 4000 A**					
	(I) PROT A	1/1000/2000		300 (R_{ct} + 7.5)		
	(ii) Prot B	1/2000		60 (R_{ct} + 5)	40 at $\frac{Vk}{2}$	5.0 at 75°C
	(III)PROT B SPECIAL RATIO	1/600/1200		82 (R_{ct} +3)	60 at $\frac{Vk}{2}$	2.4 at 75°C
	(IV)...................	1/1000/2000	2000/1	30 VA Class 1 5P20		
			1000/1	30 VA Class 1 5P10		
4.2 to 4.4	300 kV, 2000 or 2500 A					
	(I) PROT A	1/600/1200		160 (R_{ct} + 7.5)		
	(ii) Prot B	1/600/1200		82 (R_{ct} + 3)	60 at $\frac{Vk}{2}$	2.4 at 75°C
	(III)PROT B SPECIAL RATIO	1/600/1200	1200/1	30 VA Class 1 5P20		
			600/1	30 VA Class 1 5P10		
4.2 to 4.4	145 kV, 2000A					
	(I) PROT A	1/600/1200		50 (R_{ct} + 17)		
		1/500/1000		60 (R_{ct} + 12)		
	(ii) Prot B	1/500/1000		95 (R_{ct} + 2.5)	60 at $\frac{Vk}{2}$	2.4 at 75°C
	(III)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.

5 FORMS AND RECORDS

PART 2 - DEFINITIONS AND DOCUMENT HISTORY

6 DEFINITIONS

The definitions used in TS1 (RES) and TS2.2 (RES) apply to this document.

7 AMENDMENTS RECORD

Issue	Date	Summary of Changes / Reasons	Author(s)	Approved By (Inc. Job Title)
1	February 2014	New document		

8 IMPLEMENTATION

8.1 Audience Awareness

Audience	Purpose Compliance (C) / Awareness (A)	Notification Method Memo / letter / fax / email / team brief / other (specify)

8.2 Training Requirements

Training Needs N/A / Informal / Workshop / Formal Course	Training Target Date	Implementation Manager
N/A	N/A	N/A

8.3 Procedure Review Date

5 years from publication date.

PART 3 - GUIDANCE NOTES & APPENDICES

9 REFERENCES

9.1 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 61869-1 Instrument transformers- Part 1: General requirements

IEC 61869-2 Instrument transformers- Part 2: Additional requirements for current transformers

BS EN 60567 Oil-filled electrical equipment - Sampling of gases and of oil for analysis of free and dissolved gases - Guidance

BS EN 62271 High Voltage switchgear and control gear.

9.2 National Grid Technical Specifications

The following TS documentation is relevant to current transformers and should be read in conjunction with this document.

TS 1 (RES) Ratings and General Requirements for Plant, Equipment, Apparatus and Services for use on and Direct Connections to the National Grid Transmission System

TS 2.2 (RES) Switchgear for use on, and at Connection Points to, the National Grid System

APPENDIX A - 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 the user details of how the test will be conducted.

The three criteria which must all be satisfied for the CT to pass the test are:

A1 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.

A2 No evidence of degradation is found when the CT is dismantled and examined after the test.

A3 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 the user and the supplier.

BUSHINGS FOR HIGH VOLTAGE ALTERNATING CURRENT SYSTEMS

This document is for Relevant Electrical Standards document only.

PURPOSE AND SCOPE

This Specification defines the functional and performance requirements for bushings for connection to the Transmission System in England and Wales. It supports the more general requirements defined in the companion documents TS 1 (RES) and TS 2.2 (RES).

This specification is applicable to bushings intended for use on alternating current systems only. Bushings which are intended for use in high voltage direct current systems are covered by a separate specification.

PART 1 – PROCEDURAL

1 GENERAL REQUIREMENTS

Bushings shall comply with TS 1 (RES), and TS 2.2 (RES).

Bushings shall comply with BS EN 60137.

2 PERFORMANCE REQUIREMENTS

Bushings shall comply with the performance requirements of BS EN 60137 according to the relevant rating requirements detailed in TS 1 (RES), and TS 2.2 (RES).

3 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 the user and the bushing supplier. There shall be no change in the dissolved gas levels before and after type tests.

4 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 SF6 and located adjacent to the SF6 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.

5 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.

6 FORMS AND RECORDS

None

PART 2 - DEFINITIONS AND DOCUMENT HISTORY

7 DEFINITIONS

The definitions used in TS 1 (RES) and TS 2.2 (RES) are applicable to this specification.

8 AMENDMENTS RECORD

Issue	Date	Summary of Changes / Reasons	Author(s)	Approved By (Inc. Job Title)
1	February 2014	New document		

9 IMPLEMENTATION

9.1 Audience Awareness

Audience	Purpose Compliance (C) / Awareness (A)	Notification Method Memo / letter / fax / email / team brief / other (specify)

9.2 Training Requirements

Training Needs N/A / Informal / Workshop / Formal Course	**Training Target Date**	**Implementation Manager**

9.3 Procedure Review Date

4 years from publication date.

PART 3 - GUIDANCE NOTES AND APPENDICES

10 REFERENCES

10.1 International, European and British National Standards

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 62271	High Voltage switchgear and control gear.
IEC TS 60815-1	Selection and dimensioning of high-voltage insulators intended for use in polluted conditions – Part 1: Definitions, information and general principles - Edition 1.0
IEC TS 60815-2	Selection and dimensioning of high-voltage insulators intended for use in polluted conditions – Part 2: Ceramic and glass insulators for a.c. systems - Edition 1.0
IEC TS 60815-3	Selection and dimensioning of high-voltage insulators intended for use in polluted conditions – Part 3: Polymer insulators for a.c. systems - Edition 1.0
BS EN 60567	Oil-filled electrical equipment - Sampling of gases and of oil for analysis of free and dissolved gases - Guidance

10.2 National Grid Technical Specifications

The following NGTS documentation is relevant to bushings and should be read in conjunction with this document.

TS 1 (RES) Ratings and General Requirements for Plant, Equipment, Apparatus and Services for use on and Direct Connections to the National Grid Transmission System

TS 2.1 (RES) Substations

TS 2.2 (RES) Switchgear for use on, and at connection points to, the National Grid System

SOLID CORE POST INSULATORS FOR SUBSTATIONS

This document is for Relevant Electrical Standards document only.

PURPOSE AND SCOPE

This specification defines the functional and performance requirements, enabling parameters and additional technical requirements for solid core post insulators rated from 1 kV to 420 kV connected to the Transmission System in England and Wales.

The specific requirements for solid core post insulators detailed in this document are by reference to IEC 60273, BS EN 60168 and associated documents and support the more general conditions defined in the companion documents TS 1 (RES) and TS 2.2 (RES).

PART 1 – PROCEDURAL

1 RATINGS AND PERFORMANCE REQUIREMENTS

In addition to the general ratings and performance requirements defined in TS 1 (RES) and TS 2.2 (RES), post insulators shall satisfy the requirements in IEC 60273.

2 TEST REQUIREMENTS

2.1 Type Tests

Type tests shall be as required in TS 1 (RES) and TS 2.2 (RES), together with the requirements of BS EN 60168. Where the purchaser is presented with test options within BS EN 60168, the following shall apply: -

2.1.1 Dry Lightning Impulse Withstand Test

Either test method described in BS EN 60168 is acceptable.

2.1.2 Dry or Wet Switching-Impulse Withstand Voltage Test

The test shall be performed in wet conditions.

Either test method described in BS EN 60168 is acceptable.

2.1.3 Mechanical Failing Load Tests

In addition to the bending test, the tensile and torsion tests shall be performed during type testing as described in BS EN 60168.

2.1.4 Test for Deflection Under Load

This test shall be performed during type tests to determine the top flange deflection obtained as a result of applying 70% of the specified mechanical failing load.

2.1.5 Radio Interference Test

This special test shall be performed as described in BS EN 60168 and BS EN 60437.

2.1.6 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 BS EN 60168, with any site specific requirements being detailed in the Contract Enquiry Document or Supplemental Agreement.

2.2 Routine Testing

Routine tests shall be as required in TS 1 (RES), TS 2.2 (RES) and the requirements of BS EN 60168. Where the purchaser is presented with test options within BS EN 60168, the following shall apply: -

2.2.1 Routine Mechanical Test on Complete Post

This test shall be performed with a load applied of 70% of the specified mechanical failing load.

3 FORMS AND RECORDS

Not applicable.

PART 2 - DEFINITIONS AND DOCUMENT HISTORY

4 DEFINITIONS

The definitions given in TS 1 (RES) and TS 2.2 (RES) apply to this document.

5 AMENDMENTS RECORDS

Issue	Date	Summary of Changes / Reasons	Author(s)	Approved By (Inc. Job Title)
1	February 2014	New document		

6 IMPLEMENTATION

6.1 Audience Awareness

Audience	Purpose Compliance (C) / Awareness (A)	Notification Method Memo / letter / fax / email / team brief / other (specify)

6.2 Training Requirements

Training Needs N/A / Informal / Workshop / Formal Course	**Training Target Date**	**Implementation Manager**
N/A	N/A	N/A

6.3 Procedure Review Date

5 years from publication date.

PART 3 - GUIDANCE NOTES AND APPENDICES

7 REFERENCES

7.1 International, European and British Standard Documents

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. The issue date of these documents shall be that current at the time of the issue of this TS.

IEC 60273	Characteristics of indoor and outdoor post insulators and post insulator units for systems with nominal voltages greater than 1000 V.
BS EN 60168	Tests on indoor and outdoor post insulators of ceramic material or glass for systems with nominal voltages greater than 1000 V.
BS EN 60437	Radio interference tests on high voltage insulators.
BS EN 62271	High Voltage switchgear and control gear.
IECTS 60815	Selection and dimensioning of high voltage insulators intended for use in polluted conditions.

7.2 National Grid Technical Specifications

TS1 (RES)	Ratings and general requirements for plant, equipment, apparatus and services for National Grid System and connection points to it.

GAS INSULATED SWITCHGEAR

This document is for Relevant Electrical Standards document only.

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PURPOSE AND SCOPE

This document defines the functional and performance requirements for gas-insulated switchgear (GIS) for use on the National Grid Transmission System. It supports the more general requirements defined in TS 1(RES), TS 2.1(RES) and TS 2.2 (RES).

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.

PART 1 – PROCEDURAL

1 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.

1.1 Outage Constraints

Faults occurring in gas zones containing circuit breakers, disconnectors and earth switches shall not force an outage greater than a single bar section to effect repair of the device. Additionally, where the adjacent bay is owned by another utility, sufficient gas zone segregation shall exist between the bays to allow a gas zone at reduced (atmospheric) pressure to sit between the faulted gas zone, where it contains either a circuit breaker, disconnector or earth switch, and the gas zone containing the Point of Isolation for the adjacent bay.

Informative: To comply with this requirement it may be necessary to introduce additional gas zones between the switching devices and the points of isolation.

Where a fault would result in the need to switch out parts of a bus coupler or bus section, there is no requirement to have the bus coupler or bus section bay gas zones put back into service provided the fault doesn't necessitate an outage of more than 1 busbar section.

The supplier shall demonstrate by means of gas zone diagrams or otherwise, how compliance with the outage constraint requirements above can be achieved.

1.2 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.

All SF6 gas 'low' alarms shall be enunciated individually such that the section of the substation that requires isolation from the system can be readily identified.

Informative: Gas zone identification shall use the actual zone name: e.g. X103G1

Gas alarm systems shall be sufficiently robust so that any single point of failure will not necessitate an outage greater than the outage constraint requirements defined in TS 2.1. RES

2 PERFORMANCE REQUIREMENTS

2.1 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.

2.2 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 2 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 2 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.

Table 2 Fault clearance times for internal arcing design

Rated voltage (kV)	Main protection (ms)	Back-up or breaker fail protection (ms)
420	140	300
300	160	500
145	200	1000

Informative: In cases where GIS trunking falls within the line protection zone an internal fault would normally result in a trip and DAR operation. The need to inhibit the DAR completely or install equipment to detect and inhibit DAR for faults inside the GIS trunking shall be determined by site-specific risk assessment.

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.

2.3 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.

3 ROUTINE TESTS AT SITE

3.1 Partial Discharge Tests

Partial discharge activity shall be monitored throughout the site power-frequency high voltage tests of GIS equipment at all voltages in accordance with Dielectric Test Procedure B for tests after installation on site. Where capacitive couplers have not been installed on 132kV equipment and below as standard, alternative arrangements shall be made to monitor partial discharge during power-frequency high voltage testing and at rated voltage.

Prior to site testing, suppliers shall declare the maximum acceptable partial discharge level for a site test at $1.1U/\sqrt{3}$. 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.

4 FORMS AND RECORDS

Not applicable

PART 2 - DEFINITIONS AND DOCUMENT HISTORY

5 DEFINITIONS

NSI – National Safety Instructions.

PMED – Portable Maintenance Earthing Device.

HVSCC – High Voltage System Changes Certificate

6 AMENDMENTS RECORD

Issue	Date	Summary of Changes / Reasons	Author(s)	Approved By (Inc. Job Title)
1	February 2014	New Document		

7 IMPLEMENTATION

7.1 Audience Awareness

Audience	Purpose Compliance (C) / Awareness (A)	Notification Method Memo / letter / fax / email / team brief / other (specify)

7.2 Training Requirements

Training Needs N/A / Informal / Workshop / Formal Course	Training Target Date	Implementation Manager

7.3 Compliance

Compliance with this specification will be verified by Policy as part of the Type Registration process.

7.4 Procedure Review Date

5 years from publication date.

PART 3 - GUIDANCE NOTES

8 REFERENCES

IEC 61639	Direct connection between power transformers and gas-insulated metal-enclosed switchgear for rated voltages of 72.5 kV and above
IEC 62271-1	High-voltage switchgear and controlgear – Part 1: Common Specifications
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
TS 1 RES	Ratings and General Requirements for Plant, Equipment, Apparatus and Services for the National Grid System and Connection Points to it
TS 2.1 RES	Substations
TS 2.2 RES	Switchgear for the National Grid System
TS 3.2.2 RES	Disconnectors and Earthing Switches

ENVIRONMENTAL AND TEST REQUIREMENTS FOR ELECTRONIC EQUIPMENT

This document is for Relevant Electrical Standards document only.

Disclaimer
NGG and NGET or their agents, servants or contractors do not accept any liability for any losses arising under or in connection with this information. This limit on liability applies to all and any claims in contract, tort (including negligence), misrepresentation (excluding fraudulent misrepresentation), breach of statutory duty or otherwise. This limit on liability does not exclude or restrict liability where prohibited by the law nor does it supersede the express terms of any related agreements."

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PURPOSE AND SCOPE

This specification is an equipment policy specification within the Substation Information, Control and Protection suite of technical specifications. It defines the environmental and test requirements for electronic equipment at the user owned operational locations.

This specification defines the user's Environmental and Test Requirements for Electronic Equipment

This Specification contains general requirements; the specific requirements are in the individual function specifications.

All electronic equipment supplied to the user for operational use in transmission locations must meet its specified functionality and performance as set out in individual Technical Specifications and under the relevant environmental conditions stated in this Specification.

PART 1 – PROCEDURAL

1 INTRODUCTION

Relationship with European Standards

Informative: This Specification 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.

1.1 CENELEC document Electronic Equipment for Use in Power Installations (BS EN 50178) gives minimum design and manufacture requirements with which control equipment within the scope of this specification must comply.

1.2 This document specifies those performance requirements that must be met by electronic equipment to be used on and connected to NGET transmission system.

Informative: This document is a generic specification and therefore when used to specify requirements for equipment to be purchased, the TS shall 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.

2 GENERAL REQUIREMENTS

Informative: Electronic equipment for operational use within the user is required to comply with specific environmental performance criteria. This document sets out the essence of these criteria, with particular emphasis on the testing required. Section 2 General Requirements states these criteria. Sections 3, 4, 5 and 6 Test Requirements, define the tests required to prove that these requirements have been met under various ranges of environmental conditions.

Environment

2.1 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.

2.2 The following clauses define the conditions that the equipment shall meet with the performance being degraded

Temperature and Humidity

2.3 Equipment shall operate within its functional specification over the range of the specified atmospheric environmental classes, as defined in the TS 1(RES) table 10, Temperature and Humidity Environmental Classes.

2.4 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.

2.5 The temperature rise above ambient within an enclosure, when the equipment is operating normally, shall not exceed 10°C.

2.6 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 TS 1 (RES) Table 10, Temperature and Humidity Environmental Classes. The additional 15°C enclosure factor need not apply.

Mechanical

Shock and Vibration

2.7 Performance life shall not be affected by the Drop and Topple Test, where specified.

2.8 Where specified, equipment shall conform to the requirements of the Vibration Test.

2.9 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.

Self-generated Vibration

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

Electrical

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

Supply Parameters

Informative: Equipment may operate from a variety of supplies. The supply parameters are defined in TS 1(RES), TS 2.12 (RES),

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 s based on this definition.

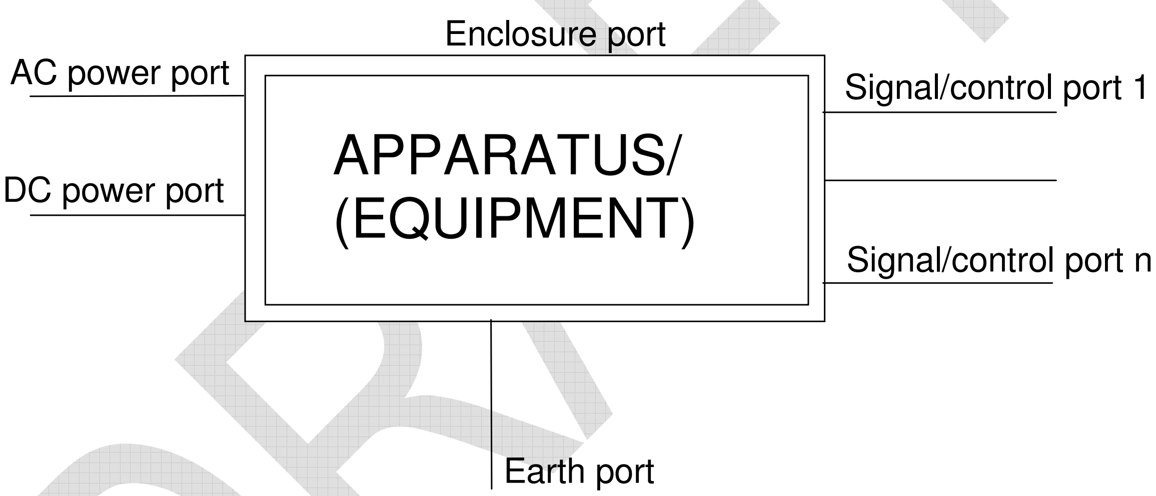

Figure 1 Definition of Ports

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 3.

Informative: Table 4 and Table 5, which refer to substation equipment and grid control centre equipment respectively.

Special Installation Measures

2.12 Equipment shall operate in the presence of interference generated by portable radios/telephones without maloperation or significant error.

2.13 Where it is agreed that equipment may be supplied which does not meet the user'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.

Conducted and Radiated Emissions

2.14 The level of conducted and radiated emissions produced by the equipment shall be quoted in its specification.

2.15 The earthing and cabling arrangements shall not exacerbate any interference caused by the equipment. **Supply Interruptions**

2.16 Equipment shall be capable of accepting supply interruptions of up to and including 10 ms or otherwise specified without the performance being affected.

2.17 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.

3 GENERAL TEST REQUIREMENTS

Informative: The tests specified in this section are intended to show that the equipment meets the general user's requirements for electronic equipment.

Table 1 Test Classifications, shows the basic testing classifications for equipment supplied to the user. These tests shall be applied to electronic equipment in the manner defined in this document.

Table 1 Test Classifications

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 the user.
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 the user.
Site Pre-commissioning	These tests take place after the equipment has been fully installed.
Energisation	These tests are only applicable to turnkey projects.

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.

Test Methods and Equipment

3.1 The test equipment and methods shall comply with ISO 10012-1.

Type Testing

Informative: Type tests are intended to show that electronic equipment meets the requirement of its specification.

3.2 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, the user may require the repetition of any or all of the tests.

Reference Conditions

3.3 Unless otherwise specified in the appropriate source standard all type tests shall be carried out under the reference conditions quoted in Table 2 Test Reference Conditions.

Table 2 Test Reference Conditions

Variable	**Limits**
Ambient temperature	20°C ±2°C
Ambient relative humidity	≤70%
Supply voltage	Normal † ±1%
Supply frequency (for A.C. equipment)	50 Hz ±0.5% (no significant voltage waveform distortion)

† Normal may not be the same as nominal. Where normal voltage is not quoted, nominal may be assumed.

Measurement of Equipment Characteristics

3.4 Details of the equipment characteristics to be measured during the course of the test shall be given.

Description of the Tests Required

Informative: The following clauses give general details of the tests discussed in Clauses for Type Testing

Informative: Particulars of the performance requirements and pass/fail criteria will be included in the individual equipment specification.

Non Maloperation Tests

3.5 For Non Maloperation tests the Equipment Under Test (EUT) is required to be performed 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.

Protection Equipment

Informative: The BS EN 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 3 are compatible with the IEC 60255 tests. For each test in this specification the appropriate BS EN 60255 standard, where it exists, will be indicated.

3.6 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 BS EN 60255 standard is definitive and shall take precedence.

3.7 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 3 and Table 4.

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 3 relates the test levels called up by TS 3.24.15 (RES) with those required by BS EN 60870.

Performance Tests (Type Test)

3.8 Performance tests shall demonstrate that the equipment functions correctly in all performance aspects of its functional specification as defined in the appropriate functional TS(s).

3.9 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.

3.10 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.

3.11 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.

4 ELECTRICAL ENVIRONMENTAL TESTS

The tests to be applied are summarised in Table 3 and Table 4, Substation Equipment and Table 5, 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

Informative: Table 6. Not all the tests will be appropriate to every item of equipment.

4.1 The tests in Table 3 are mandatory while those in Table 4 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).

4.2 Unless otherwise stated in the appropriate TS 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.

4.3 Except where otherwise stated, the method of application for each test shall be as specified in the appropriate source standard as quoted in Table 3, Table 4 and Table 5.

4.4 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 the user for assessment.

Table 3 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 BS EN 60870-2-1*	Enclosure	Local Connections **See** Table 6	Cross-site Connections **See** Table 6	HV Equipment Connections **See** Table 6	Telecomms Connections Across Site	Telecomms Connections Up to 20 metres	A.C. Power Supply i/p	D.C. Power Supply i/p
MANDATORY TESTS											
Electrical Fast Transient/ Burst N = coupling/decoupling network C = capacitive clamp	*BS EN 61000-4-4*	*BS EN 60255-22-4 Class A*	*BS EN 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	*BS EN 61000-4-12*	*BS EN 60255-22-1*	*BS EN 61000-4-1 sic* *3-4 2.5 kV*	N/A	N/A	1 MHz 2.5 kV C 1 MHz 1 kV D 0.1 MHz 1 kV C 0.1 MHz 0.5 kV D	1 MHz 2.5 kV C 1 MHz 1 kV D 0.1 MHz 2.5 kV C 0.1 MHz 1 kV D	1 MHz 2.5 kV C 1 MHz 1 kV D 0.1 MHz 2.5 kV C 0.1 MHz 1 kV D See Note 2	N/A	1 MHz 2.5 kV C 1 MHz 1 kV D 0.1 MHz 2.5 kV C 0.1 MHz 1 kV D	1 MHz 2.5 kV C 1 MHz 1 kV D 0.1 MHz 2.5 kV C 0.1 MHz 1 kV D
Electrostatic Discharge Relay Rooms	*BS EN 61000-4-2*	*BS EN 60255-22-2*	*BS EN 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	*BS EN 61000-4-2*		*BS EN 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	*BS EN 61000-4-3*	*BS EN 60255-22-3*	*BS EN 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 4.29	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Conducted Disturbances Induced by RF Fields	*BS EN 61000-4-6*		*Refers to BS EN 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.	*BS EN 61000-4-5*		*BS EN 61000-4-5* *1.2/50 Φs 8/20 Φs* *3 2 kV* *4 4 kV*	N/A	1.2/50 Φs 1 kV L to E; 0.5 kV L to L Inst Class 2[1]	1.2/50 Φs 2 kV L to E; 1 kV L to L Inst Class 3[1]	1.2/50 Φs 4 kV L to E; 2 kV L to L Inst Class 4[1]	10/700 Φs 4 kV L to E; 2 kV L to L Inst Class 5[1]	N/A	1.2/50 Φs 2 kV L to E; 1 kV L to L Inst Class 4[1]	1.2/50 Φs 2 kV L to E; 1 kV L to L Inst Class 4[1]
Mains Frequency Voltage	*BS EN 60255-22-7 Pending release – see below*	*BS 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)	*BS EN 61000-4-16*			N/A	10 V continuous 100 V for 1 sec	30 V continuous 300 V for 1 sec	30 V continuous 300 V for 1 sec	30 V continuous 300 V for 1 sec	N/A	N/A	30 V continuous 300 V for 1 sec
Voltage Dips, Interruptions and Slow Variations	*BS EN 61000-4-11 (A.C. supplies only)*		*BS EN 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, 20, 100, 200, 500, 1000 ms	Interruption: 10, 20, 100, 200, 500, 1000 ms
Supply Variation	*Not yet available*		*No method but classes:* *D.C. x (+25-10%)* *A.C. x (±15%)*	N/A	N/A	N/A	N/A	N/A	N/A	EUT to operate over range specified in TS 3.24.4	EUT to operate over range specified in TS 3.24.4
Dielectric and Insulation Resistance Test – Withstand	*IEC 60255-5* *EN not available*		*Ref A.6.1 but no test or level*		See Sections 4.59 to **Error! Reference source not found.**		2 kV for 1 minute	See Sections 4.59 to **Error! Reference source not found.**		2 kV for 1 minute	500 V/2 kV for 1 minute
Conducted and Radiated Emissions	*BS EN 55022*			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 4 Substation Equipment – Port Test Levels – Additional Tests

Test	Reference		When should test be called up?	Test Levels							
	Source Standard	*Test and Relevant Levels Called up in BS EN 60870-2-1*		Enclosure	Local Connections **See** Table 6	Cross-site Connections **See** Table 6	HV Equipment Connections **See** Table 6	Telecomms Connections Across Site	Telecomms Connections Up to 20 metres	A.C. Power Supply i/p	D.C. 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 Section 4.20 & Section Informative:	N/A	N/A	10 MHz 2.5 kV C 10 MHz 1 kV D 10 kHz 1 kV C 10 kHz 0.5 kV D	10 MHz 2.5 kV C 10 MHz 1 kV D 10 kHz 1 kV C 10 kHz 0.5 kV D	10 MHz 2.5 kV C 10 MHz 1 kV D 10 kHz 1 kV C 10 kHz 0.5 kV D	N/A	10 MHz 2.5 kV C 10 MHz 1 kV D 10 kHz 1 kV C 10 kHz 0.5 kV D	10 MHz 2.5 kV C 10 MHz 1 kV D 10 kHz 1 kV C 10 kHz 0.5 kV D
Power Frequency Magnetic Field	*BS EN 61000-4-8*	*BS EN 61000-4-8 continuous/ short duration* *3 30/300 A/m* *4 100/1k A/m* *(no specific require-ment for CRT)*	See Section 4.55 & Section **Error! Reference source not found.**	30 A/m continuous 300 A/m for 1 sec 12.8 A/m for display equipment	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Pulsed Magnetic Field	*BS EN 61000-4-9*	*N/A*	See Section 4.57	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	*BS EN 61000-4-10*	*BS EN 61000-4-10* *3 30 A/m* *4 100 A/m*	See Section 4.58	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 Section 4.35	0.9 & 1.89 GHz 10 V/m	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Voltage Dips, Interruptions and Slow Variations	*BS EN 61000-4-11*	*BS EN 61000-4-11* *1 30% 0.5 s* *& 100% 10ms* *2 60% 0.5 s* *& 100% 0.5 s*	See Section 4.13	N/A	N/A	N/A	N/A	N/A	N/A	Dips: 30%: 10 & 20 ms 60%: 10, 50, 100, 250, 500 & 1000 ms	N/A
Voltage Dips, Interruptions and Slow Variations	*BS EN 61000-4-11*	*BS EN 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	*BS EN 61000-4-16*	*Not included*	See Section 4.46	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 5 Grid Control Centre Equipment – Port Test Levels

Test	*Standard Reference*	Test Levels – Reference BS EN 50082-2			
		Enclosure	Signal Lines and Control Lines	A.C. Power Supply i/p	D.C. Power Supply i/p
Electrical Fast Transient/ Burst N = coupling/decoupling network, C = capacitive clamp	BS EN 61000-4-4	N/A	0.5 kV, 5 kHz C	1 kV 5 kHz N	0.5 kV, 5 kHz N
Electrostatic Discharge	BS EN 61000-4-2	4 kV contact 8 kV Air 4 kV HCP & VCP	N/A	N/A	N/A
Radiated Electromagnetic Field	BS EN 61000-4-3	3 V/m 80% modulated 80 MHz -1 GHz	N/A	N/A	N/A
Conducted Disturbances	BS EN 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	BS EN 61000-4-5	N/A	1.2/50 µs 2 kV common 1 kV difference	1.2/50 µs 4 kV common 2 kV difference	1.2/50 µs 500 V common and different modes
Power Frequency Magnetic Field	BS EN 61000-4-8	3 A/m CRT display interference allowed	N/A	N/A	N/A

Table 6 Port Environment Definition

Name	**Environment/Source of Cable Connected to Port**
Remote:	Equipment and connections to it, located in a benign electromagnetic environment eg Grid Control Centre – See Table 5
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 Equipment	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	
A.C. Power Supply i/p	Supplied from normal site 230 V A.C. mains
D.C. Power Supply i/p	Supplied from site D.C. supply (normally 48 or 110 V)

Surge – Non-maloperate (Type Test)

Informative: This test simulates overvoltages caused by switching and lightning transients. The test shall be applied in accordance with BS EN 61000-4-5 including increasing test levels, application at various points on the voltage waveform etc.

Informative: The impulse waveform is an aperiodic transient voltage without appreciable oscillations. There are two versions, the first, having a 1.2 μs rise time 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.

4.5 The source impedance of the test equipment shall be selected in accordance with the standard.

4.6 The test shall be applied to be applied both line to line and line to earth at levels as defined in Table 3, Table 4 and Table 5.

Informative: Where a large number of identical interface circuits are used, this test may be restricted to a representative sample, as agreed by the user's test observer.

Supply Variation – Non-maloperate (Type Test)

4.7 The performance of the equipment shall be checked over the full range of the supply voltage as specified. See Section 2.11.

4.8 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.

4.9 In the case of equipment which has two alternative sources of supply, the procedure in Section 4.8 shall be followed with the other supply at each of its extreme values in turn.

4.10 A record shall be made of the maximum wattage and VA of the equipment when operating at normal voltage and frequency.

Voltage Dips, Interruptions and Slow Variations – Non-maloperate (Type Test)

A.C. Mains Powered Equipment

4.11 For A.C. mains powered equipment the following tests shall be carried out at the periods given and in accordance with BS EN 61000-4-11.

4.12 The voltage dips and short interruption test shall be carried out in accordance with Table 1 of the standard at the 0% (i.e. 100% dip) test level for the durations listed in Table 3.

4.13 For equipment containing electro-mechanical devices such as disc drives, the 40% and 70% level tests (i.e. 60% and 30% dips) shall also be applied as in Table 1 of the standard for the periods listed in Table 4.

4.14 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 (i.e. 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 5, Table 4 and Table 5, 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.

4.15 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.

4.16 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.

D.C. Powered Equipment

4.17 For D.C. powered equipment the following shall be carried out:

(a) 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.

(b) The minimum interval between interruptions shall be three times the period of the interruption.

(c) For interruptions of 100 ms and above at least one minimum interval shall occur in the sequence.

(d) The tests shall cover all modes of equipment operation.

(e) The pass/fail criteria requirements as stated above shall apply.

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).

4.18 The test shall be carried out in accordance with BS EN 61000-4-4and the levels to be applied to the various ports are defined in Table 3, Table 4 and Table 5.

Informative: Where the EUT has a large number of identical interface circuits, the test may be restricted to an agreed sample.

Damped Oscillatory Wave – Non-maloperate (Type Test)

Informative: This test is intended to simulate the effects of switching with restrike of the arc (e.g. disconnector operation).

4.19 The tests are to be applied in accordance with BS EN 61000-4-

Informative: Where the EUT has a large number of identical interface circuits, the test may be restricted to an agreed sample.

4.20 The 100 kHz and 1 MHz damped oscillatory wave test shall be applied at levels and to ports as defined in Table 3 and Table 4.

Informative: he damped oscillatory wave test shall be extended to include the 10 kHz and 10 MHz versions of these tests as per IEC 61000-4-18.

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.*

4.21 The test is based on BS EN 61000-4-2. The level to be applied is dependent upon the environment in which the equipment is intended to be installed (see Table 3) and is to be applied while the EUT is energised.

4.22 The test shall be undertaken on fully installed items of equipment, within their enclosures.

4.23 The test is to be applied to all points which are accessible during normal use.

4.24 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.

4.25 Testing is to be carried out in accordance with the standard including the use of horizontal and vertical coupling planes where applicable.

4.26 The test voltage shall be increased from the minimum to the selected test level.

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.

4.27 The performance of the EUT shall be monitored throughout the test.

4.28 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.

4.29 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.

4.30 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.

4.31 The testing shall be with the normal supply, input and output leads intended for the equipment.

4.32 The test method shall be the radiating antenna method detailed in BS EN 61000-4-3 but with test limits as defined in Table 3, Table 4 and Table 5.

4.33 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.

4.34 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.

4.35 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"

4.36 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.

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.

4.37 The test is to be applied in accordance with BS EN 61000-4-6.

4.38 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 3, Table 4 and Table 5.

4.39 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.

4.40 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.

4.41 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.

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. This standard is based on IEC 61000-4-16 but includes a differential mode test, a current mode test for communication lines and uses different coupling capacitors and test voltages.

4.42 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 A.C. powered equipment) is applied via a capacitor.

4.43 The method as specified in BS EN 60255-22-7 shall be used using test levels as specified in Table 3 and Table 4.

4.44 The method of application shall be one of those illustrated in Figures 2 to 5 of BS EN 60255-22-7, selected to suit the type of port being tested.

Informative: 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.

Informative: 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.

4.45 In the interim period, before IEC 60255-22-7 is formally issued, the method as specified in BS EN 61000-4-16 shall be used unless otherwise agreed with the user. The required test levels are defined in Table 3.

Conducted Disturbance 15Hz to 150 kHz

Informative: This test simulates the effect of conducted disturbances which may be generated by power electronic equipment.

4.46 The test shall be carried out in accordance with BS EN 61000-4-16 using the test profile as defined in **Error! Reference source not found.** of that standard.

Informative: Application of the test should be considered for equipment to be installed on sites incorporating power electronics e.g. SVCs.

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.

4.47 A conducted and radiated emissions test shall be carried out to check that the equipment meets the requirements of BS EN 55022 (BS 6527). Normally the acceptable limits shall be taken as those applicable to Class A equipment.

4.48 In the specific case where equipment is to be powered from a 48 V D.C. 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

Inrush Current (Type Test)

Informative: This test shall be carried out in order to ensure that the requirements for inrush current as stated in TS 3.24.4 (Hardware Platform) are satisfied.

4.49 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.

4.50 The tests shall be performed with the equipment operating under conditions of maximum power consumption.

4.51 An interval of several minutes shall be allowed to elapse between each test.

4.52 Every effort shall be made to ensure that the supply source impedance does not significantly limit the inrush current.

4.53 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 A.C. supplies, not less than ten measurements shall be recorded.

Power Frequency Magnetic Field Immunity – Non-maloperate (Type Test)

Informative: This test would normally only be applied to equipment which utilises an electron beam (e.g. Cathode Ray Tube Monitors, Electron Microscopes etc) or to certain measuring instruments. However the test is also called up in BS EN 60870-2-1 and is therefore available as an additional test for other equipment at levels as specified in Table 4.

4.54 The test shall be carried out in accordance with BS EN 61000-4-8 in all three planes of the EUT.

4.55 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 4.

Pulsed Magnetic Field – Non-maloperate (Type Test)

Informative: This test simulates the magnetic field generated by a) lightning strikes, b) initial fault transients and c) the switching of HV busbars and lines by circuit breakers. Research carried out for the user has concluded that the test is of most relevance in the case of a) above.

4.56 The test shall be carried out in accordance with BS EN 61000-4-9 at test levels as specified in Table 4.

4.57 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.

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 BS EN 61000-4-10 requires oscillatory waves of 0.1 and 1.0 MHz. The user 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.

4.58 The Damped Oscillatory Magnetic Field test shall be performed 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 4.

Dielectric and Insulation Resistance – Withstand (Type Test)

Informative: The objective of these tests which are based on BS EN 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.

4.59 The type test is only to be applied to isolation and safety barriers.

4.60 Other items (e.g. 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 – D.C. Output.

4.61 For circuits operating at voltages of 110 V A.C. or D.C. and above, or where a circuit is energised via an instrument transformer, a dielectric withstand test of 2 kV A.C. and an insulation resistance test of 500 V D.C. shall be performed.

4.62 For circuits operated at voltages below 110 V A.C. or D.C. but above 55 V A.C. or D.C., a dielectric withstand test of 1 kV A.C. and an insulation resistance test of 500 V D.C. shall be performed.

4.63 For circuits operated at voltages of 55 V A.C. or D.C. and below, the test shall be restricted to an insulation resistance test of 500 V D.C. which shall also act as a dielectric withstand test.

4.64 When testing between circuits which have different operating voltages the test level shall be determined by the circuit with the higher operating voltage.

4.65 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.

4.66 During the dielectric test, no breakdown or flashover shall occur.

4.67 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).

5 ATMOSPHERIC ENVIRONMENTAL TESTS

Dry Heat – Non-maloperate (Type Test)

5.1 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.

5.2 Test conditions shall be in accordance with BS EN 60068-2-2, test Bd at the upper temperature of the Environmental Class (±2ºC, RH ≤ 60%; see TS 1 Table 10) specified in the corresponding functional TS or the contract documentation.

5.3 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 15ºC above the Class temperature.

5.4 The EUT shall operate continuously during the test.

5.5 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 55ºC for 96 hours or 70ºC for 16 hours. (The additional 15ºC enclosure factor need not be applied).

5.6 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.

Low Temperature – Non-maloperate (Type Test)

5.7 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.

5.8 Test conditions shall be in accordance with BS EN 60068-2-1, test Ad at the lower temperature of the Environmental Class (±2ºC, RH ≤ 60%; see TS 1 Table 10) specified in the corresponding functional TS or the contract documentation.

5.9 The EUT shall operate continuously during the test.

5.10 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.

5.11 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.

Damp Heat – Non-maloperate (Type Test)

5.12 This test is undertaken on complete items of equipment in their normal operational mode. The test is based on BS EN 60068-2-78 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 ±2ºC 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 EN 60068-2-78 at 40 ±2ºC with 93 ±3% RH for 56 days, or IEC 68-2-30 for 6 times 24 hour cycles of + 25ºC to +55ºC 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 BS EN 60068-2-78, the equipment shall be switched off on completion of this check.

(d) In the case of tests to BS EN 60068-2-78after 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.

Storage Temperature Test – Withstand (Type Test)

5.13 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.

5.14 The equipment shall be subjected to a low temperature test in accordance with EN 60068-2-1 at -25ºC for 96 hours or -40ºC for 16 hours. The EUT shall also be subjected to a high temperature test according to BS EN 60068-2-2 at 70ºC for 96 hours.

5.15 After ambient conditions are re-established a Performance Check shall be performed.

Enclosure (Type Test)

5.16 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 BS EN 60529.

5.17 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 the user.

Salt Corrosion (Type Test)

5.18 When required the salt corrosion test shall be carried out in accordance with BS EN 60068-2-52. At the end of the test there shall be no undue deterioration of metal parts, finishes, and materials.

5.19 The equipment shall be subjected to a performance check at the end of the recovery period.

Humidity Cycling (Type Test)

5.20 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.

5.21 The test shall be carried out in accordance with BS EN 60068-2-30 with the following conditions:

(a) The upper temperature shall be 40ºC.

(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.

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.

5.22 If required, the test shall be carried out in accordance with BS EN 60068-10.

5.23 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.

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.

5.24 The test shall be carried out in accordance with BS EN 60068-2-42. The duration of the test will be 4, 10 or 21 days.

5.25 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.

Soak Test

Soak – Non-maloperate (Type Test)

5.26 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.

5.27 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.

5.28 If any failures occur or adjustments are made, full details shall be recorded for the user, who will decide whether the test may be restarted or shall be repeated.

6 MECHANICAL TESTS

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.

6.1 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.

6.2 This test shall be carried out in accordance with IEC 68-2-31 Test Ec (BS 2011-2.1 Ec). 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.

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.

6.3 The test shall be carried out in accordance with BS EN 60068-2-6 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 BS EN 60255-21-1.

6.4 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.

6.5 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.

6.6 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.

Shock (Type Test)

6.7 A shock test shall be carried out in accordance with BS EN 60068-2-27. 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 BS EN 60255-21-2.

Bump (Type Test)

6.8 A bump test shall be carried out in accordance with BS EN 60068-2-29. The EUT shall be subjected to the bump test at severity class 1. These test levels are defined in the related standard BS EN 60255-21-2.

Seismic (Type Test)

6.9 A seismic test at severity class 1 shall be carried out in accordance with BS EN 60255-21-3.

7 FORMS AND RECORDS

Not applicable.

PART 2 - DEFINITIONS AND DOCUMENT HISTORY

8 DEFINITIONS

EUT Equipment under test.

Port A particular interface of the specified equipment with the external electromagnetic environment (see Figure 2). 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.

9 AMENDMENTS RECORDS

Issue	Date	Summary of Changes / Reasons	Author(s)	Approved By (Inc. Job Title)
1	February 2014	New document	Dechao Kong and Ray Zhang	

10 IMPLEMENTATION

10.1 Audience Awareness

Audience	Purpose Compliance (C) / Awareness (A)	Notification Method Memo / letter / fax / email / team brief / other (specify)

10.2 Training Requirements

Training Needs N/A / Informal / Workshop / Formal Course	Training Target Date	Implementation Manager
N/A	N/A	N/A

10.3 Compliance

10.4 Procedure Review Date

5 years from publication date.

PART 3 - GUIDANCE NOTES AND APPENDICES

11 REFERENCES

This Specification makes reference to the following related specifications:

ISO 10012-1 Quality Assurance Requirements for Measuring Equipment – Part 1: Metrological Confirmation System for Measuring Equipment (BS EN 30012-1)

IEC Standards

IEC 61000-4 series	Electromagnetic Compatibility (EMC) – Part 4: Testing and Measuring Techniques (BS EN 61000-4 series)
IEC 60255 series	Electrical Relays (BS EN 60255 series)
IEC 61000 series	Electromagnetic Compatibility (EMC)
IEC 68-2 series	Basic Environmental Testing Procedures - Part 2 series

European Standards

BS EN 61000-6-1	Electromagnetic Compatibility (EMC) - Part 6-1: Generic Standards - Immunity for Residential, Commercial and Light-industry Environments
BS EN 50178	Electronic Equipment for Use in Power Installations
BS EN 55022	Information Technology Equipment - Radio Disturbance Characteristics - Limits and Methods of Measurement
BS EN 60068 series	Environmental Testing Procedures
BS EN 60068-2-1	Part 2-1: Tests - Test A: Cold
BS EN 60068-2-2	Part 2-2: Tests - Test B: Dry heat
BS EN 60068-2-6	Test 2-6: Tests - Test Fc: Vibration (Sinusoidal)
BS EN 60068-2-10	Part 2-10: Test - Test J and Guidance: Mould Growth
BS EN 60068-2-27	Part 2-27: Tests - Test Ea and Guidance: Shock
BS EN 60068-2-29	Part 2-29: Tests - Test Eb and guidance: Bump
BS EN 60068-2-30	Part 2-30: Tests - Test Db: Damp Heat, Cyclic (12 hour+12 hour cycle)
BS EN 60068-2-31	Part 2-31: Tests - Test Ec: Rough Handing Shocks, Primary for Equipment-type Specimens
BS 2011-2.1 Ec	Basic environmental testing procedures Part 2.1 Tests – Test Ec: Drop and topple, primarily for equipment-type specimens
BS EN 60068-2-42	Part 2-42: Tests - Test Kc: Sulphur Dioxide Test for Contacts and Connections
BS EN 60068-2-52	Part 2-52: Tests - Test Kb: Salt Mist, Cyclic (Sodium Chloride Solution)
BS EN 60068-2-78	Part 2-78: Tests - Test Cab: Damp Heat, Steady State
BS EN 60255-21-1	Electrical Relays - Part 21: Vibration, Shock, Bump and Seismic Tests on Measuring Relays and Protection Equipment - Section 1: Vibration Tests (Sinusoidal)
BS EN 60255-21-2	Electrical Relays - Part 21: Vibration, Shock, Bump and Seismic Tests on Measuring Relays and Protection Equipment - Section 2: Shock and Bump Tests

BS EN 60255-21-3	Electrical Relays - Part 21: Vibration, Shock, Bump and Seismic Tests on Measuring Relays and Protection Equipment - Section 3: Seismic Tests
BS EN 60870-2-1	Telecontrol Equipment and Systems Part 2: Operating Conditions Section 1: Power Supply and Electromagnetic Compatibility
BS EN 60870-2-2	Telecontrol Equipment and Systems Part 2: Operating Conditions Section 2: Environmental Conditions (Climatic, Mechanical and Other Non-electrical Influences)
BS EN 61000-4-1	Part 4-1: Testing and Measurement Techniques - Overview of IEC 61000-4 series
BS EN 61000-4-2	Part 4-2: Testing and Measurement Techniques - Electrostatic Discharge Immunity Test
BS EN 61000-4-3	Part 4-3: Testing and Measurement Techniques - Radiated, Radio-frequency, Electromagnetic Field Immunity Test
BS EN 61000-4-4	Part 4-4: Testing and Measurement Techniques - Electrical Fast Transient/Burst Immunity Test
BS EN 61000-4-5	Part 4-5: Testing and Measurement Techniques - Surge Immunity Test
BS EN 61000-4-6	Part 4-6: Testing and Measurement Techniques - Immunity to Conducted Disturbances, Induced by Radio-frequency
BS EN 61000-4-8	Part 4-8: Testing and Measurement Techniques - Power Frequency Magnetic Field Immunity Test
BS EN 61000-4-9	Part 4-9: Testing and Measurement Techniques - Pulse Magnetic Field Immunity Test
BS EN61000-4-10	Part 4-10: Testing and Measurement Techniques - Damped Oscillatory Magnetic Field Immunity Test
BS EN 61000-4-11	Part 4-11: Testing and Measurement Techniques – Votlage Dips, Short Interruptions and Voltage Variations Immunity Tests
BS EN 61000-4-12	Part 4-12: Testing and Measurement Techniques - Oscillatory Waves Immunity Test
BS EN 61000-4-16	Part 4-16: Testing and Measurement Techniques – Test for Immunity to Conducted, Common Mode Disturbances in the Frequency Range 0 Hz to 150 kHz
BS EN 61000-4-18	Part 4-18: Testing and Measurement Techniques – Damped Oscillatory Wave Immunity Test
BS EN 60529	Degrees of Protection Provided by Enclosures (IP Code)
BS 6527	Limits and Methods of Measurement of Radio Interference Characteristics of Information Technology Equipment
ETSI ETS 300 132-2	European Telecommunications Standards Institute (ESTI): Equipment Engineering (EE); Power Supply Interface at the input to Telecommunications Equipment; Part 2: Operated by Direct Current (dc)
ETSI ETS 300 386-1	European Telecommunications Standards Institute (ESTI): Equipment Engineering; Public Telecommunications Network Equipment

	Electromagnetic Compatibility (EMC) Requirements; Part 1: Product Family Overview, Compliance Criteria and Test Levels

National Grid Technical Specifications

TS 1 (RES)	Ratings and Requirements for Plant, Equipment and Apparatus for the National Grid System
TS 2.12 (RES)	Substation Auxiliary Supplies
TS 3.24.15 (RES)	Environmental and Test Requirements for Electronic Equipment

BUSBAR PROTECTION

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PURPOSE AND SCOPE

This Specification 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. It defines the interfaces to the appropriate bay level specifications.

PART 1 – GENERAL REQUIREMENTS

1 FUNCTIONAL REQUIREMENTS

1.1 Busbar Protection System

1.1.1 Busbar protection shall provide fully discriminative protection for phase-to-phase and phase-to-earth faults occurring within the substation.

1.1.2 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 busbar protection shall provide fully discriminative protection for phase-to-phase and phase-to-earth faults occurring within each section.

1.1.3 The busbar protection shall discriminate between faults in the protected busbar section and faults elsewhere in the substation or the primary system.

1.1.4 Where numerical busbar protection is used, this shall employ a minimum of two different fault detection algorithms which must both be satisfied for tripping to occur.

1.1.5 If a biased differential principle is used, the protection shall comply with the requirements of IEC 60255-13.

1.1.6 The minimum operating current of the busbar protection shall be settable in the range 10 – 200% of nominal current.

1.1.7 When a busbar fault occurs, all circuit breakers connected to the faulted busbar shall be tripped simultaneously.

1.1.8 The busbar protection shall be able to correctly detect a fault condition occurring during an on-load busbar changeover and issue trip commands to the connected bays.

1.1.9 Where necessary and applicable, end fault protection shall be provided.

Informative – End fault protection is provided to cover for faults where a busbar protection trip will not clear the fault, and/or will trip beyond open switchgear, and/or may not be sensitive enough to trip; for example a fault between the circuit breaker and line side CTs when the circuit breaker is open.

1.2 Switchgear Positional Information

1.2.1 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.

1.2.2 Switchgear positional information shall be used to determine the primary arrangement of each busbar section using busbar disconnectors and/or circuit breaker auxillary contacts, and to determine the selection of end fault protection.

Informative: The selected disconnector auxiliary switches must ensure correct zone selection for all fault conditions including 1.9. In the closing cycle the correct zone must be selected prior to the primary contacts being able to carry current.

1.2.3 Where circuit breaker positional information affects the selection of CT's to the algorithm a means of ensuring advance selection prior to circuit breaker closure shall be provided.

Informative – Pre-close repeat relay contacts can be used to give advance information of circuit breaker closing to cover for slow circuit breaker auxiliary switches.

1.2.4 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. Unaffected zones shall remain in operation

1.2.5 Where the supply for switchgear positional information is interrupted the bay unit shall retain correct status during the power down cycle.

Informative – a single MCB operation on a bay unit shall not affect the ability of the central unit to determine last known state of any switchgear connected to that bay unit.

1.3 Differential Current Supervision

1.3.1 Where necessary and applicable, differential current supervision shall be provided on each zone.

1.3.2 The differential current supervision shall be settable in the range 2 to 20% of nominal current.

1.3.3 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.

1.3.4 Operation of the differential current supervision shall generate an alarm after a time delay settable in the range 0 - 10 s.

1.4 Circuit Breaker Fail

1.4.1 Where integral circuit breaker fail is provided this shall comply with TS 3.24.39 (RES).

1.5 Physical Arrangement

1.5.1 If and where numerical protection is used, the system shall consist of a distributed set of bay units and a single central unit. A duplicate standby central unit shall be provided if applicable., Both central units shall be identical and interchangeable but only one shall be in operational service at any time. Facilities shall be provided to allow physical transfer of either to service within 4 hours.

1.5.2 Where numerical busbar protection is used, individual bay units shall be provided on a per circuit basis and shall only be used for input/output on that circuit.

Informative – a main busbar section shall have a separate bay unit to a reserve busbar section.

Informative: A typical arrangement of bay units and duplicate central units is shown in Figure 1. The System 2 central unit is provided to allow fast return to service of the system for a failed system 1 central unit and vice versa.

1.5.3 Where numerical busbar protection is used, the following shall apply:

a) The protection shall collect current and switchgear positional information at the bay units

b) Bay units shall preferably be mounted with the bay secondary equipment.

c) The central unit shall perform the busbar protection algorithm using the current and positional information transmitted from the bay units.

d) The central unit shall transmit tripping commands to the required bay units to operate the required outputs.

e) The System 2 central unit where provided shall be provided in a separate cubicle to the System 1 central unit.

f) Communications between bay units and central unit shall be immune to electrical noise.

1.5.4 Separate multicore cables shall be employed and the wiring and terminals shall, as far as reasonably practicable, be segregated from other circuits.

1.5.5 Where applicable, the auxiliary supply to each bay unit shall be provided from the 110 V D.C first tripping supply for the bay for distributed relay room applications. For common relay room applications, duplicate supplies with automatic changeover shall be provided to the bay units. The changeover shall be such that the busbar protection remains in service throughout.

1.5.6 Where applicable, the auxiliary supply used for switchgear positional information shall be provided with a separate MCB to allow isolation of such circuits without affecting the auxiliary supply.

1.5.7 Where numerical busbar protection is applied, the auxiliary supply to the System 1 central unit shall be taken from duplicate 110 V D.C supplies with an automatic changeover. The System 2 central unit shall use the same supplies but with discrete MCBs. The changeover shall be such that the busbar protection remains in service throughout.

Informative: It is preferred that the central unit and bay units in a common relay room shall have duplicated energising supplies with automatic changeover facility.

1.5.8 The equipment for busbar protection shall be electrically and physically independent from other equipment as far as practivable

1.5.9 Where numerical busbar protection is applied, the following bay unit failure modes shall only block busbar protection for the affected zone:-

a) Failure of a Bay Unit

b) Loss of DC supply to a Bay Unit causing the Bay Unit to power down.

c) Loss of communication between the Central Unit and the Bay Unit

1.6 System 1 and System 2 Central Units

1.6.1 The System 2 Central Unit shall have permanent fibre connections run to each bay unit, disconnected at the bay unit end parked in a position to allow easy transfer.

Informative - For star topology spare fibres in the same cable as the main fibres can be used for the system 2 central unit to bay unit connections. For a redundant ring topology a connection of the existing fibres at the central units is accepted.

1.6.2 Fibres and connectors shall be sufficiently durable to allow multiple disconnection and re-connection to/from the IEDs.

Informative: This would likely use ruggedised patch cords with standard ST connections.

2 INTERFACE REQUIREMENTS

Informative: Figure 2 shows the interfaces to a typical bay unit.

2.1 Current transformer Inputs

2.1.1 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.

2.1.2 The busbar protection system shall be capable of operating from Measurement/Protection current transformers as defined in TS 3.2.4 (RES).

2.1.3 The busbar protection system shall be capable of accepting inputs from current transformers having different ratios in different bays.

2.2 In/Out Switching, Test and Maintenance Facilities

2.3 Switchgear Positional Information

2.3.1 Switchgear positional information shall be determined by double point inputs as specified in TS 3.24.04 (RES)

Informative: Double point inputs have an association with two physical inputs and are used when there is a need to detect an on / off condition, and any intermediate state.

2.3.2 Double point inputs shall be used for receiving:

a) Plant and status inputs

b) Control and Protection inputs

2.3.3 States 1 and 2 shall be used to represent normal conditions.

2.3.4 States 0 and 3 shall be classified as “DBI” (Don’t believe it).

2.3.5 Full isolation shall be provided between double pole inputs and all other circuits.

2.3.6 Where required by the application or contract, full isolation shall be provided between double point inputs, or groups of double point inputs.

2.3.7 Discrepancies in switchgear positional information shall generate an alarm after a time delay settable in the range 0 - 10 s.

2.4 Outputs

2.4.1 Where numerical busbar protection is applied, each bay unit shall provide a minimum of three single point outputs, for tripping, two operating from the busbar protection and one from the circuit breaker fail protection. Where the busbar protection uses multiple input/output cards, these tripping contacts shall be from different input/output cards.

2.4.2 The following alarm outputs shall be provided :-

a) Disconnector auxiliary switch discrepancy alarm.

b) Equipment inoperative, for the loss of D.C. auxiliary energising supply and internal relay failures. These alarms must be circuit specific

c) Bay unit maintenance mode in/out of service (numerical schemes only).

d) Bay unit in test

e) Bay unit alarms shall allow correct identification of equipment which is either out of service, in test mode or faulty.

2.4.3 Where de-centralised numerical busbar protection is applied, the central unit shall provide the following alarm outputs:-

a) Busbar protection zone operation and faulty alarms. These must be zone specific.

b) Differential current supervision.

c) Disconnector Auxiliary Switch discrepancy alarm.

d) Equipment inoperative, for the loss of D.C. auxiliary energising supply and internal relay failures. For system 1 and 2 central units these alarms must be continuously provided regardless of which central unit is in service.

e) System 1 and system 2 central unit in/out of service.

f) For system 1 and 2 central units, alarms (a), (b), (c) above are only required for the central unit in service. A means of transfer and isolation shall be provided.

2.5 Inputs

2.5.1 Where required, pre-close inputs shall be provided to give the protection advance circuit breaker closing as per section 1.2.3. This shall allow double pole connection or shall use an interposing relay to class EB2.

2.5.2 An input shall be provided on each bay unit to allow backtripping initiation from an external source. This shall allow double pole connection or shall use an interposing relay to class EB2.

2.6 Informative Interface

2.6.1 Where applicable, for numerical busbar protection ,the following information shall be provided:

a) Faulted zone.

b) Fault type, e.g. R – E or Y – B.

c) Current substation configuration.

Informative: To minimise future database changes where only the circuit name has changed; references to bay names should revert to plant nomenclature not circuit name - e.g. "X105 Bay"

a) Differential currents for each zone.

b) Records of recent faults shall be stored and be available for downloading either locally or remotely. This shall include oscillographic records of each phase, differential and bias currents and status of trip outputs and CB status.

3 PERFORMANCE REQUIREMENTS

3.1.1 The protection system shall perform correctly in accordance with the requirements of this Specification for the range of power system conditions specified in TS 1(RES) and the range of environmental conditions specified in TS 3.24.15 (RES).

3.1.2 The protection system shall perform correctly under the conditions of current transformer saturation and magnetising inrush.

3.2 Accuracy

3.2.1 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.

3.2.2 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 TS 1 (RES).

3.3 Reliability

3.3.1 Upon recovery of the input energising supply from a failure condition, the full discriminative protection system shall come into operation within 10 s.

3.4 Operating Time

3.4.1 The operating time of the busbar protection shall be not greater than 30 ms.

3.4.2 The resetting time of the busbar protection shall be not greater than 50 ms.

3.4.3 Where a change of setting, a configuration change or other software change requires the busbar protection to be temporarily out of service, the period of non-availability shall not exceed 30 minutes.

4 TEST REQUIREMENTS

4.1 Power System Conditions

4.1.1 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 TS 1 (RES).

4.1.2 The busbar protection shall be demonstrated to operate correctly under the conditions of current transformer saturation and inrush.

4.2 Protection System Characteristics

4.2.1 The characteristics of the busbar protection and its accuracy and repeatability shall be demonstrated.

4.2.2 The presentation of these characteristics shall make it possible to verify that the performance meets the requirements as specified in Section 3.

4.3 Operating Time

4.3.1 The requirements of clauses 3.7 and 3.8 shall be demonstrated for the range of influencing quantities as specified and over a reasonable range of settings.

5 FORMS AND RECORDS

Not Applicable.

PART 2 - DEFINITIONS AND DOCUMENT HISTORY

6 DEFINITIONS

BC	Bus Coupler
BS	BUS SECTION
CB	Circuit Breaker
CBF	Circuit Breaker Fail
CT	Current Transformer
CTS	CT Supervision
DTT	Direct Transfer Trip
ENCC	Energy Network Control Centre
HV	High Voltage
MB	Main Bar

RB Reserve Bar

RS Reserve Section

LV Low Voltage

OC Over Current

TS Technical Specification

7 AMENDMENTS RECORD

Issue	Date	Summary of Changes / Reasons	Author(s)	Approved By (Inc. Job Title)
1	February 2014	New Document		

8 IMPLEMENTATION

8.1 Audience Awareness

Audience	**Purpose** Compliance (C) / Awareness (A)	**Notification Method** Memo / letter / fax / email / team brief / other (specify)

8.2 Training Requirements

Training Needs N/A / Informal / Workshop / Formal Course	**Training Target Date**	**Implementation Manager**

8.3 Compliance

Compliance with this specification will be verified by Policy as part of the Type Registration process.

8.4 Procedure Review Date

5 years from publication date.

PART 3 - GUIDANCE NOTES AND APPENDICES

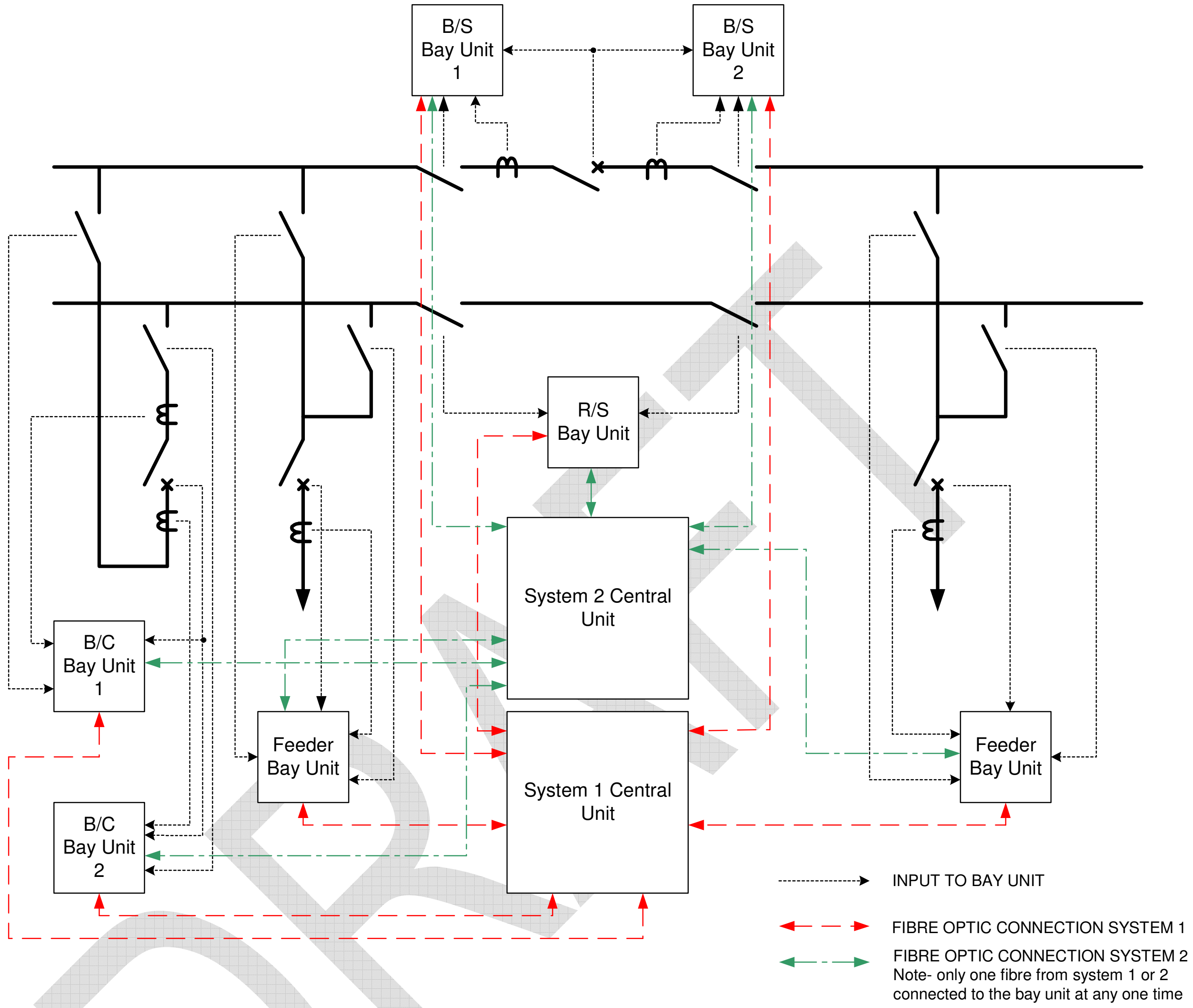


Figure 1 - Typical Block Diagram of Connections for Numerical Busbar Protection Star Topology with Duplicate Central Units

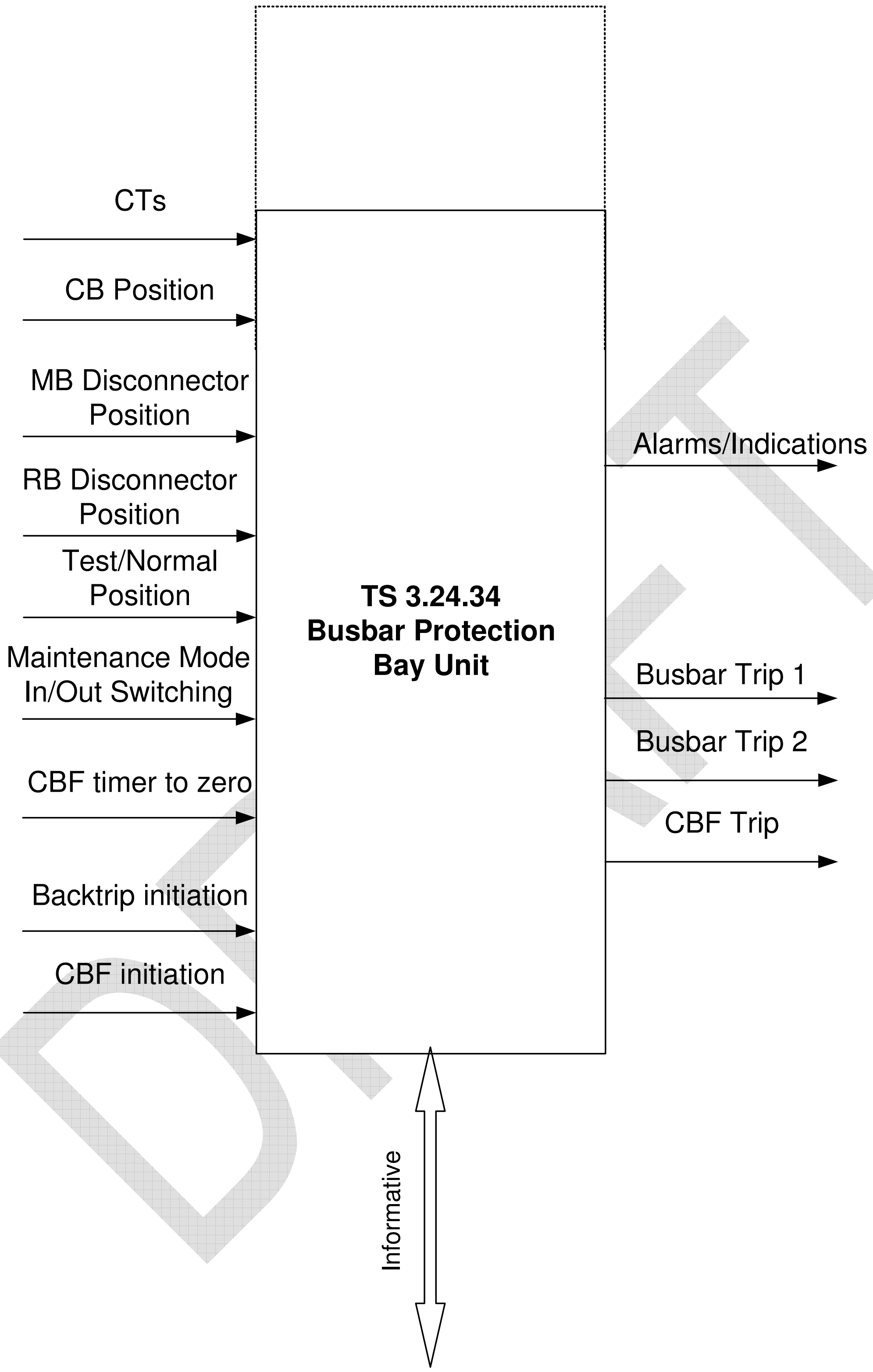


Figure 2 - Interface Diagram - Typical Bay Unit

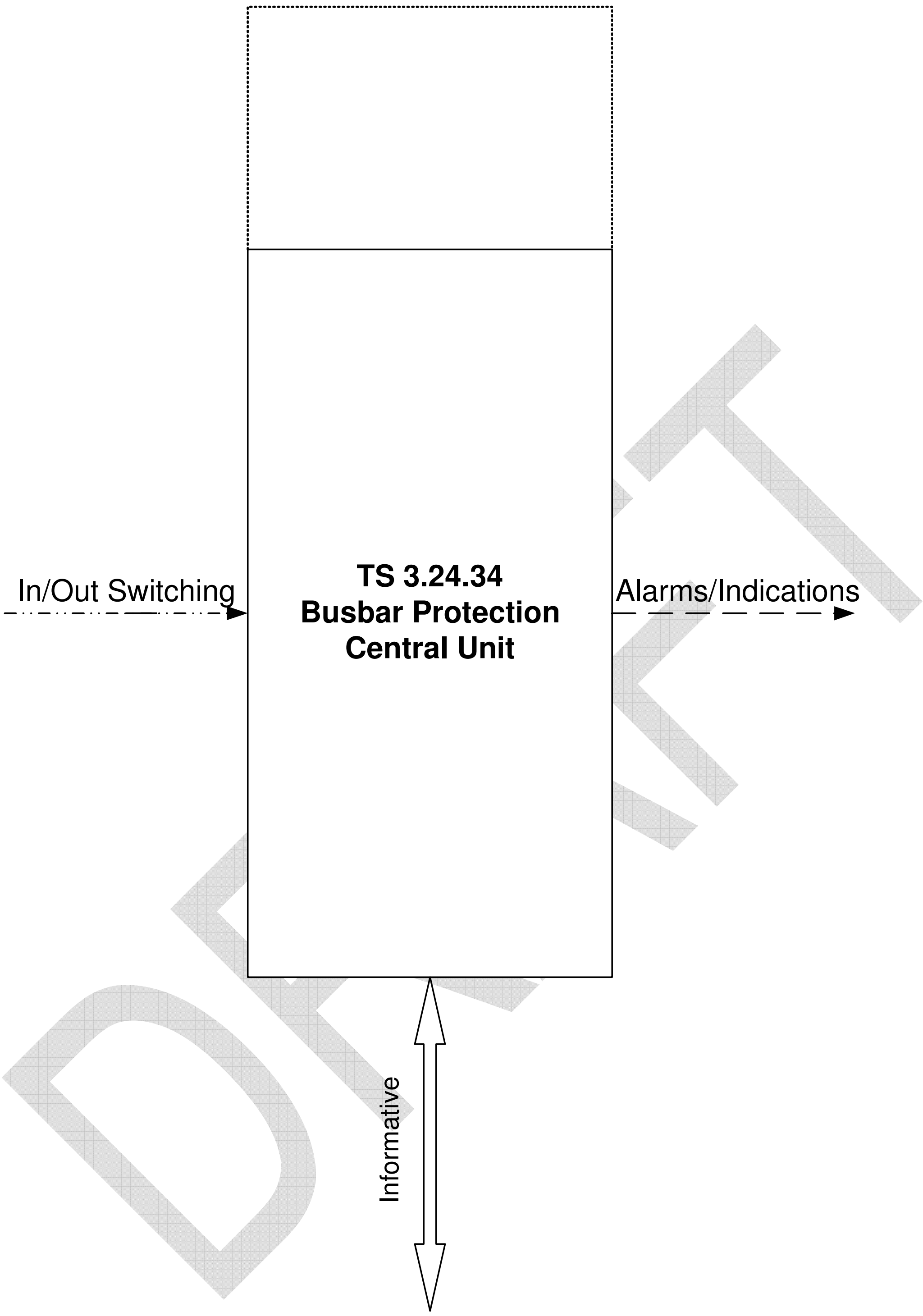


Figure 3 - Interface Diagram - Central Unit

9 REFERENCES

TS 1 (RES) Ratings and General Requirements for Plant, Equipment and Apparatus for the NGT System and Connection Points To It

TS 2.19 (RES) Ancillary Light Current Equipment

TS 3.2.4 (RES) Current Transformers for Protection and General Use

TS 3.24.15 (RES) Environmental and Test Requirements for Electronic Equipment

TS 3.24.39 (RES) Circuit Breaker Fail

IEC 61810-1 - Electromechanical elementary relays – Part 1: General requirements - Edition 3.0.

IEC 60255-1 - Measuring Relays and Protection Equipment – Part 1: Common requirements – Edition 1..

IEC 60255-13 - Biased Differential Relays.

CIRCUIT BREAKER FAIL PROTECTION

This document is for Relevant Electrical Standards document only.

TABLE OF CONTENTS

PURPOSE AND SCOPE

This Specification defines User technical requirements for Circuit Breaker Fail Protection.

PART 1 – TECHNICAL REQUIREMENTS

1 FUNCTIONAL REQUIREMENTS

General

1.1 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.

Circuit Breaker Fail Detectors

1.2 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.

1.3 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.

1.4 A detector shall comprise the following:

(a) A current check element to check if current is still flowing in any phase of the circuit breaker following circuit breaker trip initiation.

(b) A timing element to delay tripping until the circuit breaker has had adequate time for normal extinction of fault current.

Informative: Acceptable arrangements of the current check element and timing element to form a detector are shown in Figures 3 and 4.

1.5 For Option A (see Fig. 3):

(a) The current check element shall be enabled by the circuit breaker fail initiating inputs to monitor the current flowing through the circuit breaker.

(b) Detection of current in any phase of the circuit breaker above setting shall start and maintain the timing element.

(c) A trip output from the detector shall be initiated if the current is still above setting at the end of the timing period.

1.6 For Option B (see Fig. 4):

(a) The timing element shall be started directly from the circuit breaker fail initiating inputs.

(b) 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.

(c) If the current in any phase of the circuit breaker is above setting, then a trip output from the detector shall be initiated.

(d) 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.

Informative: One such measure would be to block circuit breaker closing for the duration of trip relay operation.

1.7 The method of preventing unwanted back tripping shall be declared by the supplier.

Current Check Function

1.8 The function shall comply with IEC 60255-151.

1.9 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. However, a current rating of 5A and different CT ratios could equally apply.

Timing Function

1.10 The timing function shall comply with IEC 61810-1

1.11 The timing function shall have, as a minimum requirement, a time setting range of 50 ms to 250 ms in steps of 2 ms.

Circuit Breaker Fail System

1.12 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.

1.13 Where the circuit breaker fail detector is affected by discrete conventional relays, two detectors operating in a two-out-of-two mode shall initiate tripping of contiguous circuit breakers.

Interfaces

1.14 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.

1.15 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.

1.16 Inputs to the Circuit Breaker Fail Protection shall be immune from maloperation due to wiring earth faults.

Informative: Double pole switching is one accepted way of ensuring immunity from maloperation.

Outputs – Busbar Stations

1.17 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.

1.18 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.

1.19 The back tripping initiations shall be immune from maloperation due to wiring earth faults.

Informative: Double pole switching is one accepted way of ensuring immunity from maloperation.

1.20 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.

Informative: A typical logic diagram for a feeder circuit breaker fail protection system at a busbar substation is shown in Figure 5.

Outputs – Mesh Stations

1.21 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 logic diagram for circuit breaker fail protection systems at a mesh substation is shown in figure 6.

Alarm Outputs

1.22 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.

2 PERFORMANCE REQUIREMENTS

Current Check Function

2.1 The operating time shall be not greater than 10 ms.

2.2 The drop off/pick up ratio shall be not less than 70%.

2.3 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.

2.4 For 'Option B' the resetting time shall be not greater than 30 ms.

2.5 The error of the function shall be not greater than 5%.

Timing Function

2.6 The reset or disengage time of the function shall be not greater than 30 ms.

2.7 For 'Option A', only the overshoot of the function shall be not greater than 10 ms.

3 TEST REQUIREMENTS

3.1 The current check function shall be tested in accordance with the requirements of IEC 60255-151 to demonstrate that it meets the requirements of Clauses 4.1 to 4.5.

3.2 The timing function shall be tested in accordance with the requirements of IEC 61810-1 to demonstrate that it meets the requirements of Clauses 4.6 and 4.7.

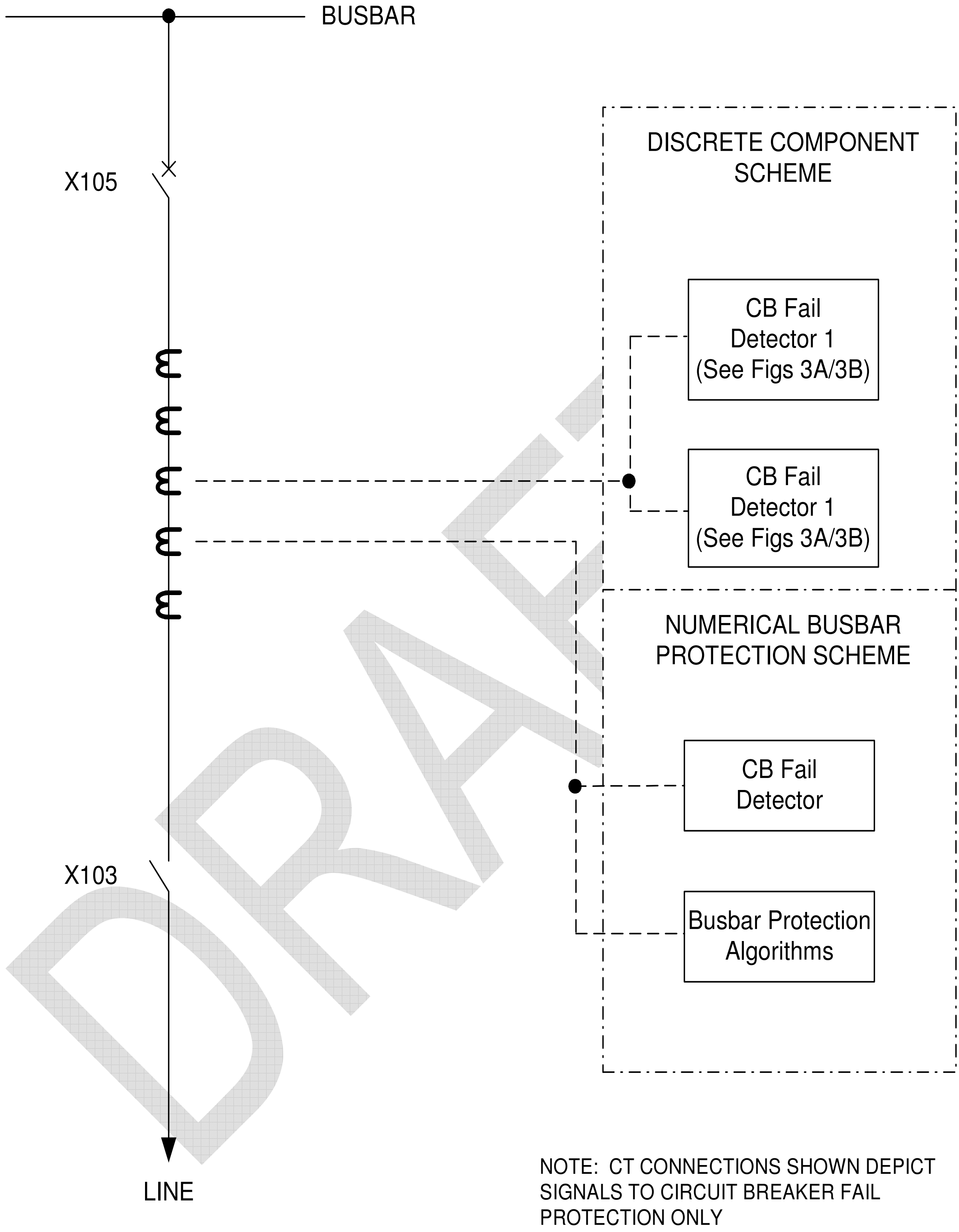


Figure 1: Typical CT Arrangement for Circuit Breaker Fail Protection for Busbar Stations - Feeder Circuit

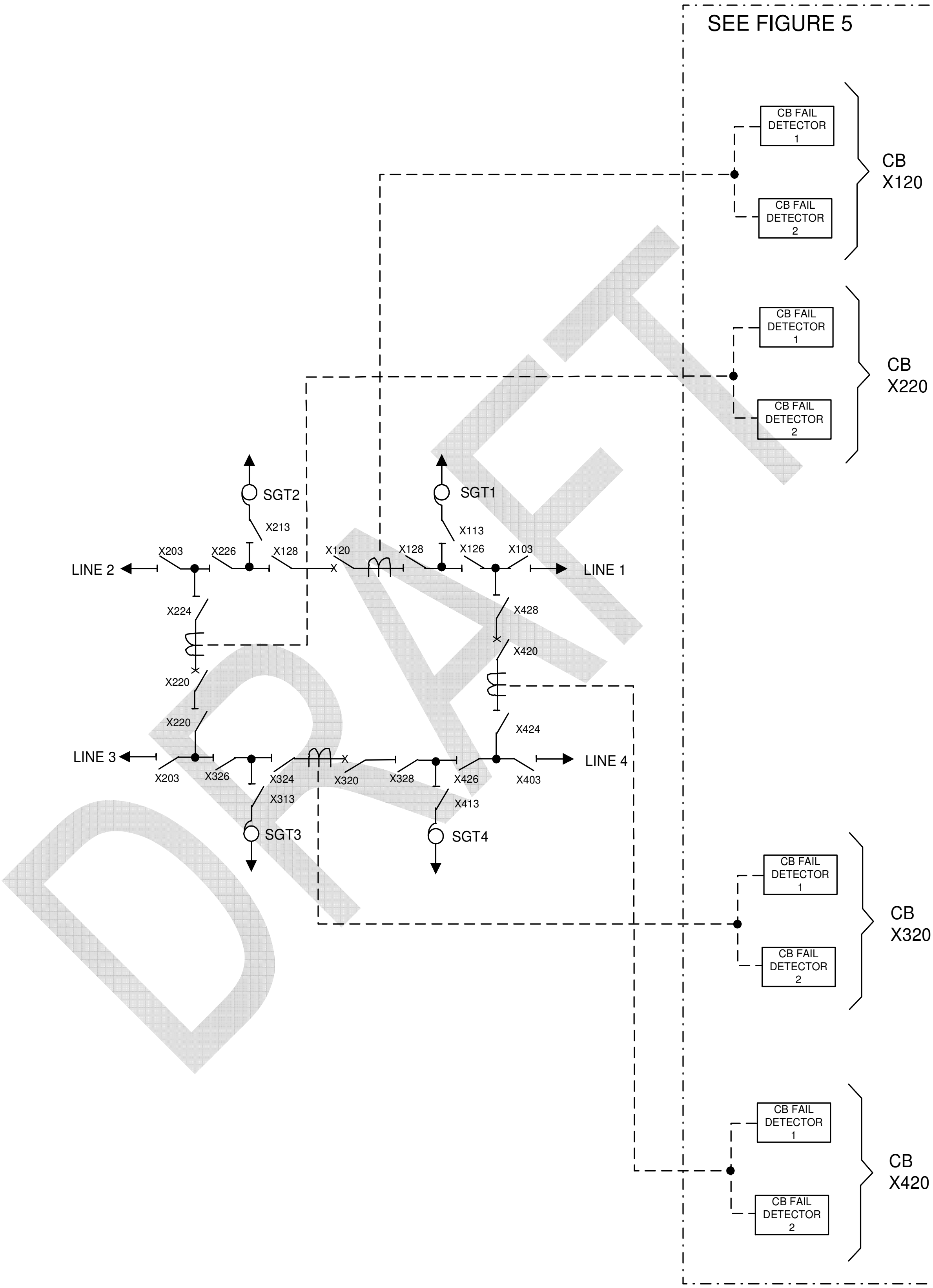


Figure 2: Typical CT Arrangement for Circuit Breaker fail Protection for Mesh Stations

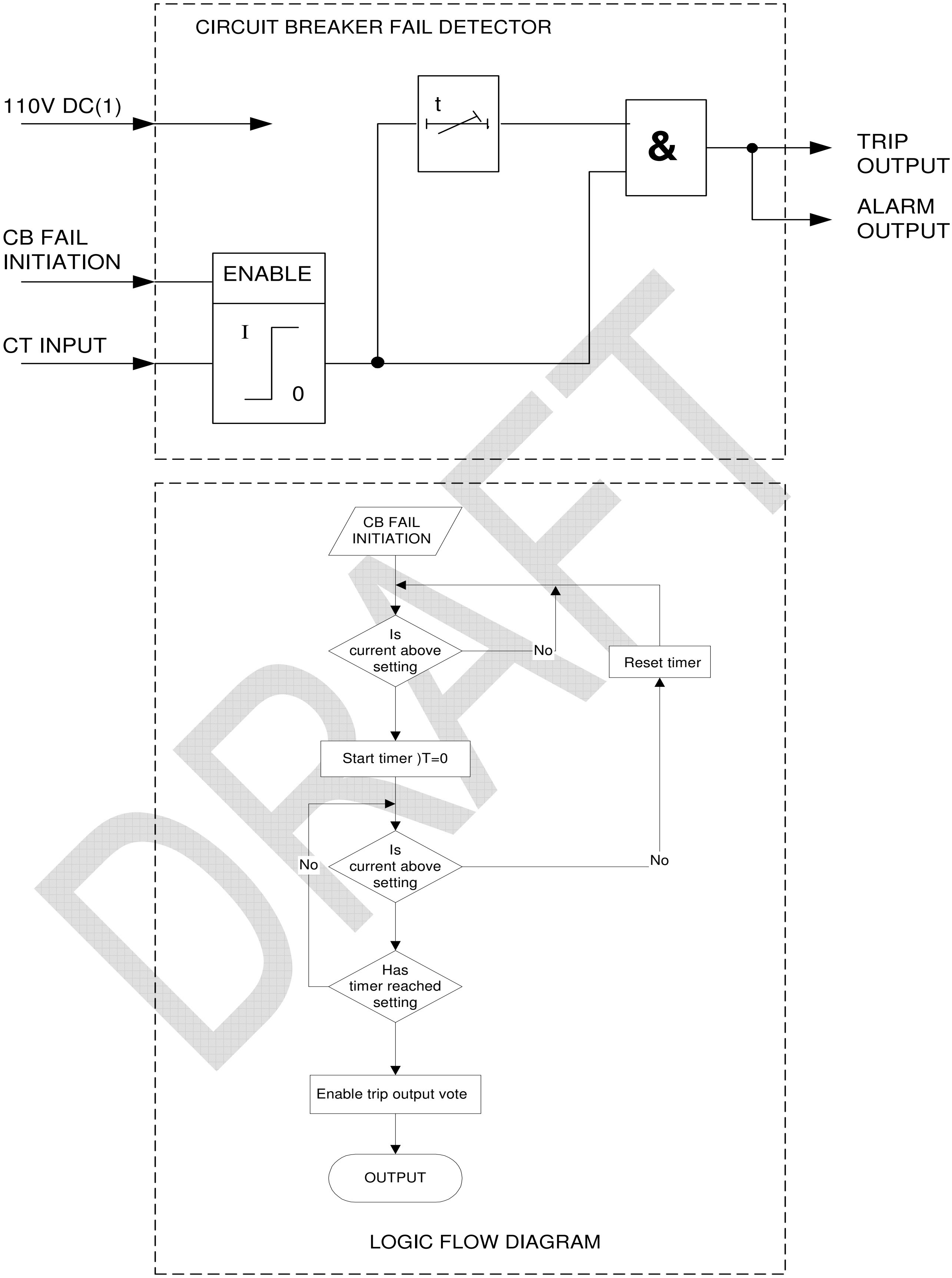


Figure 3: Circuit Breaker Fail Detector - Option A

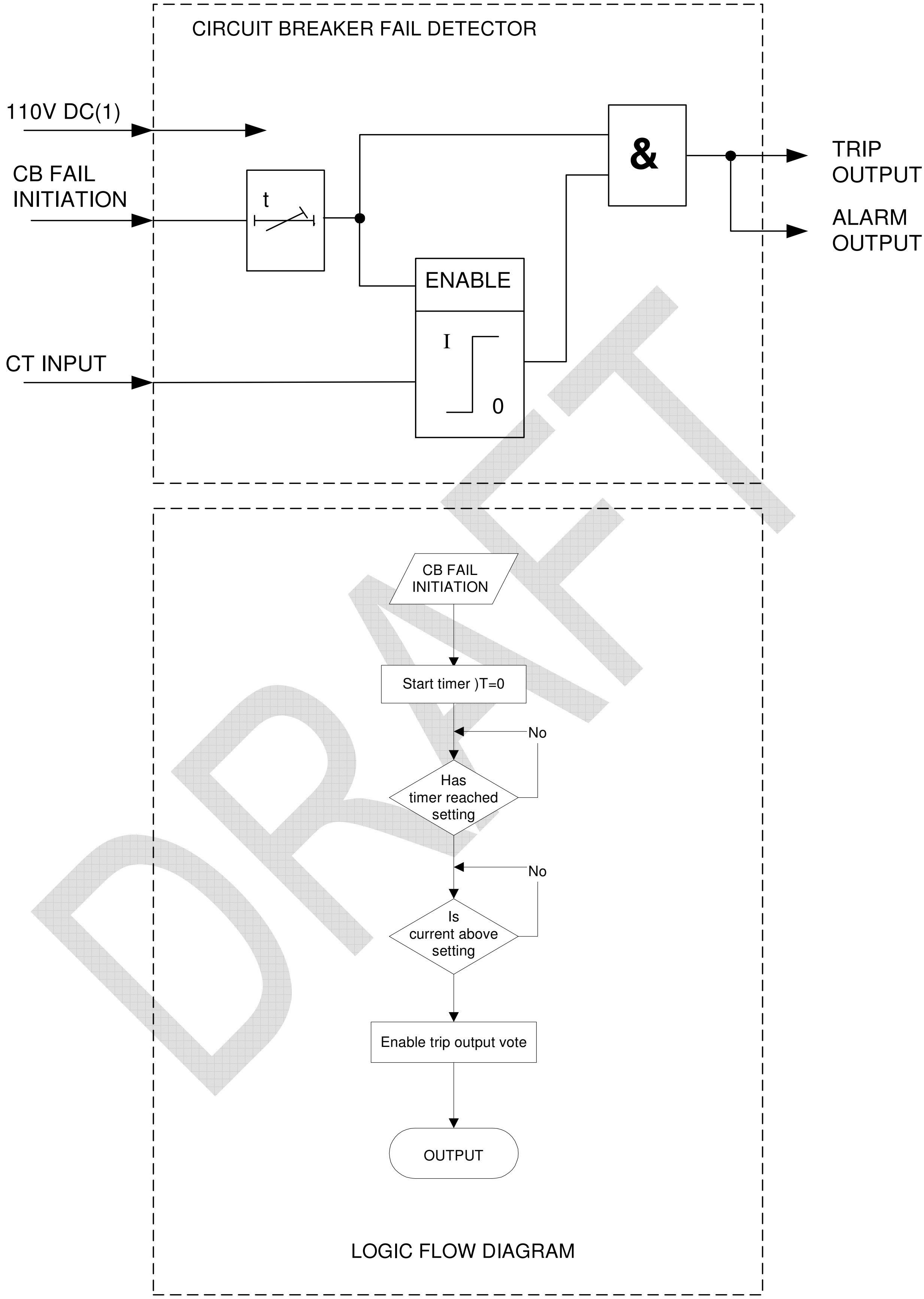


Figure 4: Circuit Breaker Fail Detector - Option B

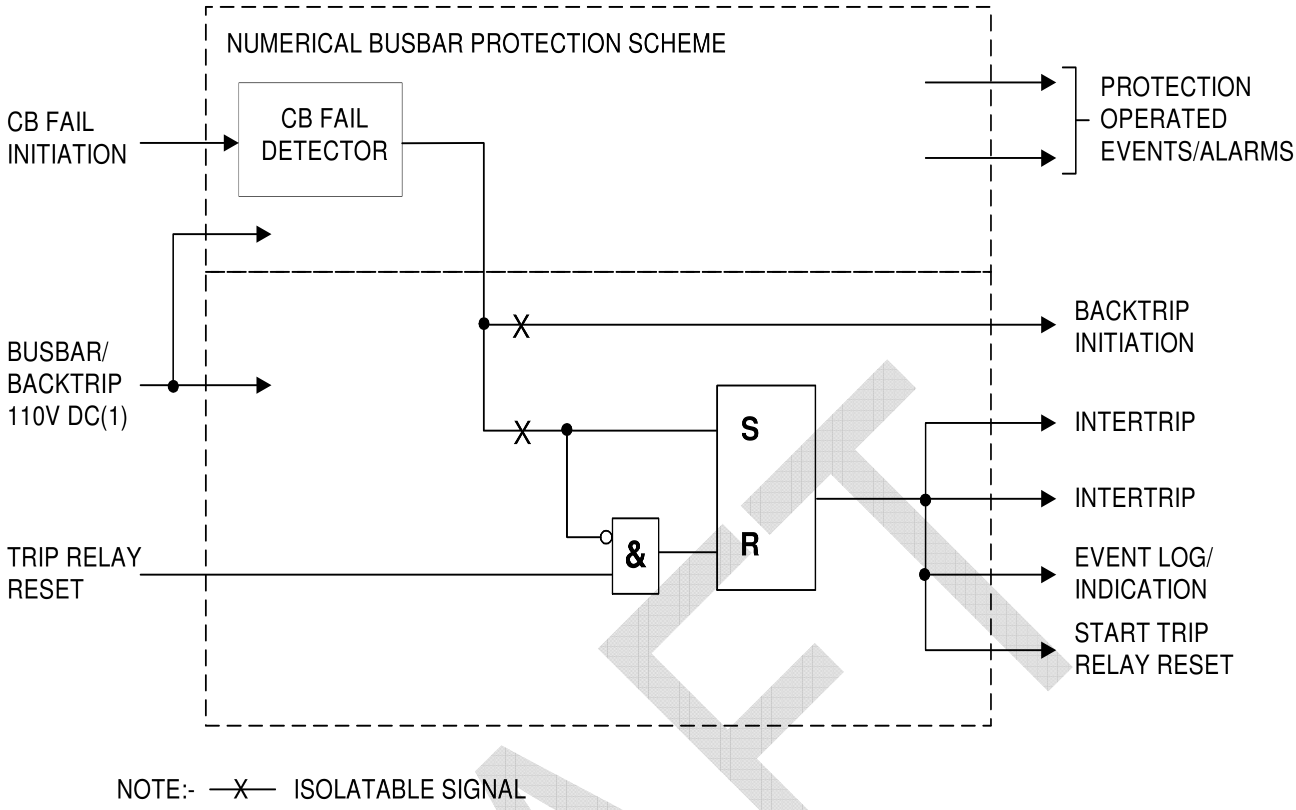


Figure 5: Typical Tripping Logic Diagram for Circuit Breaker Fail Protection System for Busbar Substations - Feeder Circuit

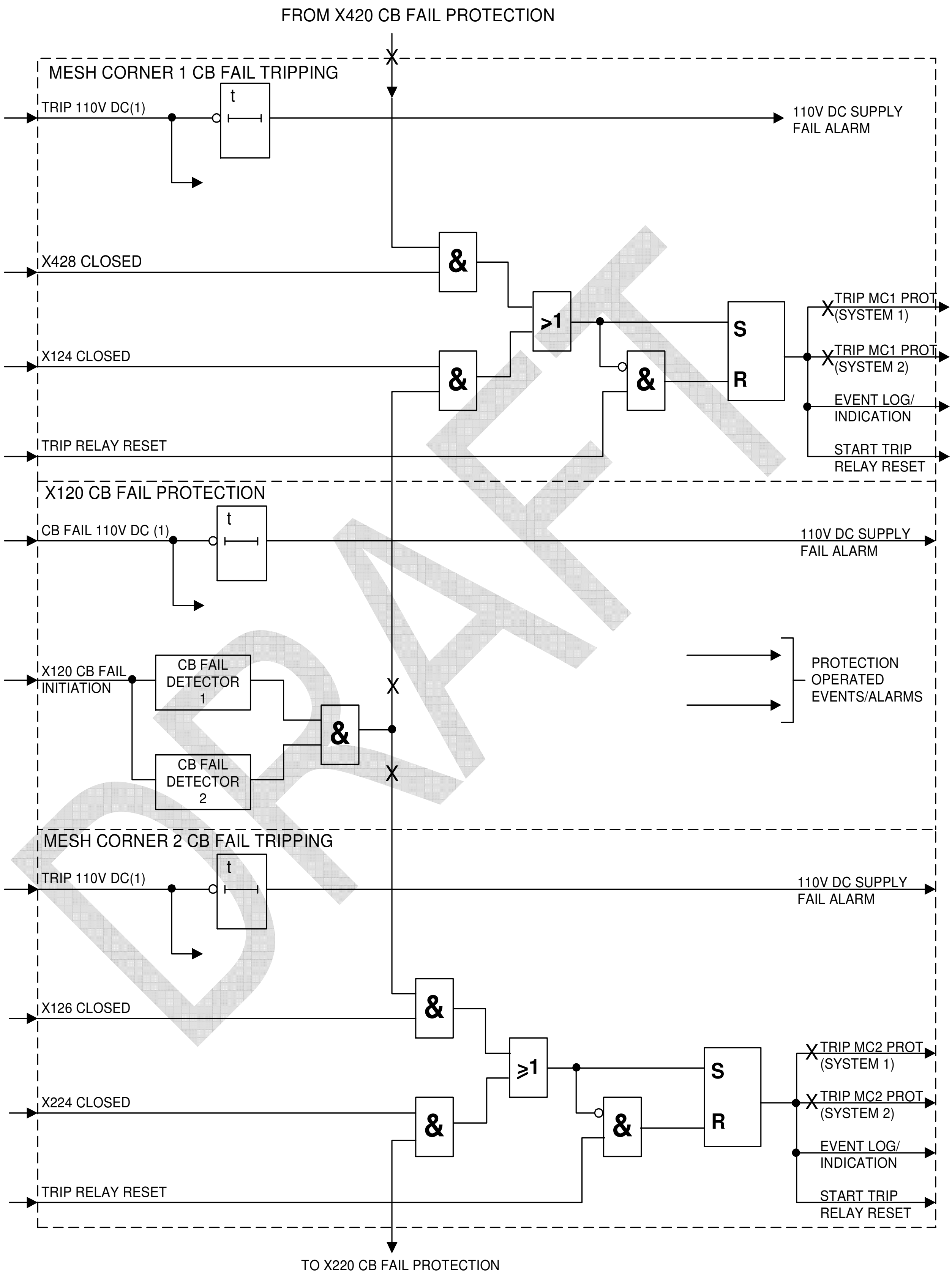


Figure 6: Part of Typical Tripping Logic Diagram for Circuit Breaker Fail Protection System for Mesh Substations

4 FORMS AND RECORDS

None.

PART 2 - DEFINITIONS AND DOCUMENT HISTORY

5 DEFINITIONS

Not applicable.

6 AMENDMENTS RECORD

Issue	Date	Summary of Changes / Reasons	Author(s)	Approved By (Inc. Job Title)
1	February 2014	New document		

7 IMPLEMENTATION

7.1 Audience Awareness

Audience	Purpose Compliance (C) / Awareness (A)	Notification Method Memo / letter / fax / email / team brief / other (specify)

7.2 Training Requirements

Training Needs N/A / Informal / Workshop / Formal Course	Training Target Date	Implementation Manager

7.3 Compliance

Text here.

7.4 Procedure Review Date

5 years from publication date.

PART 3 - GUIDANCE NOTES AND APPENDICES

8 REFERENCES

IEC 61810-1 - Electromechanical elementary relays- Part 1: General requirements – Edition 3.0

IEC 60255-151 - Measuring relays and protection equipment – Part 151: Functional requirements for over/under current protection – Edition 1.0

IEC 60255-1 - Measuring relays and protection equipment – Part 1: Common requirements – Edition 1.0

BS EN 255-22-3 - Electrical Relays – Electrical Disturbance Tests for Measuring Relays and Protection Equipment – Radiated Electromagnetic Field Disturbance Tests

TS 1(RES) - Overview – National Grid System

SYNCHRONISING

This document is for Relevant Electrical Standards document only.

PURPOSE AND SCOPE

This specification details the functional, performance and interface requirements for synchronising associated with the qualification of circuit breaker closure on the Transmission System in England and Wales. It is also applicable to those associated circuit breakers not owned by NGET 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 Specification is applicable to the interfacing to all synchronising facilities for control actions undertaken from either the Remote or Substation control points.

PART 1 – PROCEDURAL

1 GENERAL REQUIREMENTS

1.1 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.

Synchronising Scheme and Voltage Selection Facilities

1.2 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 primary voltage by means of single phase VT's.

1.3 The synchronising scheme shall be able to cater for substation extensions

1.4 Two basic schemes of synchronising cover the substation layouts used by NGET:

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

Informative: Where busbar VT's 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.

(ii) 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.

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

Voltage Parameters and Burdens

1.6 a.c. measuring systems shall be capable of being earthed and use interposing voltage transformers (IVT) supplied from the secondary side of voltage transformers connected to the primary plant.

Interposing Voltage Transformers

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

1.8 The synchronising facilities shall incorporate suitable means to interface the voltage outputs from main VT's, providing adequate isolation.

Synchronising Function

1.9 Functionality is required to operate circuit breakers 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.

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

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

1.12 Upon receipt of a close command and subsequent initiation of the synchronising function, an indication 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.

1.13 A facility shall be provided to inhibit the operation of the synchronising function for the failure of either incoming or running VT supplies. Typically, this may be achieved by the use of the following ;.

(a) Appropriate auxiliary switch contacts from each VT MCB

(b) A suitable algorithm within the equipment

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

1.14 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 2.

1.15 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.

1.16 Upon receipt of the close command and subsequent circuit breaker close indication the synchronising sequence shall be reset and cleared down.

1.17 Circuit Breaker closure outputs shall be initiated without any appreciable delay and any delay shall be constant and quantified.

1.18 If the d.c. 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.

Energising Check

1.19 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)

1.20 The voltage levels, which define both live and dead conditions, shall be configurable separately and within the ranges shown in table 2.

Check Synchronising

1.21 Pre-set selectable values of phase angle shall be provided in the range shown in table 2.

1.22 Whilst in check synchronising mode the functionality shall prevent closure in the event of slip being in excess of a pre selected value in the range defined in Table 2. This shall be irrespective of the phase angle setting.

1.23 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.

System Synchronising

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

1.25 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. This output shall remain active until either; the Circuit Breaker has closed, asynchronous conditions are no longer detected or the synchronising sequence has timed out.

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

(a) 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 2.

(b) The slip frequency is within the range defined in table 2.

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

1.27 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.

1.28 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 by configuration settings.

2 FUNCTIONAL INTERFACES

Informative: The functional interfaces for the Synchronising function are depicted in Figure 1.

2.1 The Synchronising function shall provide the functional interfaces as detailed in Figure 1. The User bay(s) synchronising facility shall meet the same design and functional requirement as NGET's site synchronising scheme that it interfaces with Figure 2.

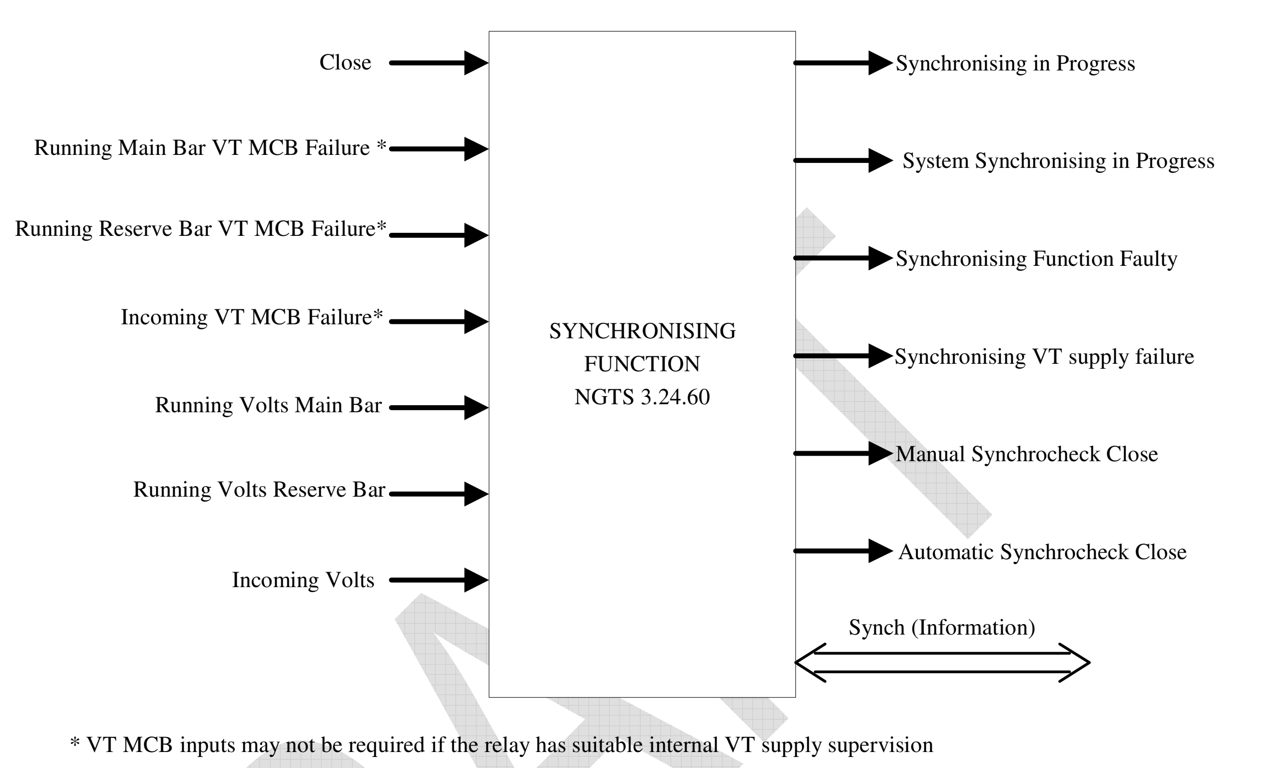


Figure 1: Synchronising Functional Interfaces

Table 1: Details each interface's ID, function and type.

Table 1: Synchronising Functional Interfaces		
Interface	Interface Function	Type of Interface
2.2		÷
2.3 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
2.4 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
2.5 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 section 4.12 are met.	Single Point Digital Output

Table 1: Synchronising Functional Interfaces

Interface		Interface Function	Type of Interface
2.6	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 section 4.25(c) are met.	Single Point Digital Output
2.7	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
2.8	Synchronising Function Faulty	This alarm shall be active for any detectable fault within the synchronising function.	Single Point Digital Output
2.9		.	

3 SETTING RANGES

3.1 The Synchronising facility function settings as detailed in Table 2 shall be provided as a set of settings that the user can change.

Table 2: Synchronising Setting Ranges

Setting		Minimum Setting Range	Maximum Setting Resolution
3.2	VT Ratio Error Correction	1:1 - 5000:1	10
3.3	Under-voltage Check Facility	80% – 90% of Rated Voltage	2.5%
3.4	Voltage Difference	10% – 50% of Rated Voltage	5%
3.5	Check Synchronising Phase Angle	20º - 90º	5º
3.6	Check Synchronising Slip Speed	0.01 – 0.1Hz	0.01Hz
3.7	System Synchronising Phase Angle	10º - 20º (or less)	5º
3.8	System Synchronising Slip Speed	0.02Hz - 0.3Hz	0.01Hz
3.9	Energising Check dead volts	10% – 50% of Rated Voltage	5%
3.10	Energising Check live volts	60% – 100% of Rated Voltage	5%

Table 2: Synchronising Setting Ranges		
Setting	Minimum Setting Range	Maximum Setting Resolution
3.11 Synchronising Sequence Timer	0 – 15 minutes	1 minute

4 PERFORMANCE REQUIREMENTS

Voltage Transformers and Burdens

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

4.2 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%.

4.3 The IVT shall withstand 2 kV a.c. r.m.s. between windings and between windings and frame and earth screen for 1 minute.

Accuracy

4.4 The synchronising function shall maintain the accuracy given below over the frequency range given in TS 1_RES

4.5 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.

4.6 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.

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

4.8 If abnormal power supply conditions are encountered then, either accuracy shall be maintained by the synchronising function, or circuit breaker closure shall be inhibited.

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

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

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

4.12 The slip measurement accuracy shall be 0.01 Hz or better.

5 IMPLEMENTATION

5.1

6 FORMS AND RECORDS

None

PART 2 - DEFINITIONS AND DOCUMENT HISTORY

7 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.

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.

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.

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.

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.

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 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.

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

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).

8 AMENDMENTS RECORD

Issue	Date	Summary of Changes / Reasons	Author(s)	Approved By (Inc. Job Title)
1	February 2014	New document		

9 IMPLEMENTATION

9.1 Audience Awareness

Audience	Purpose Compliance (C) / Awareness (A)	Notification Method Memo / letter / fax / email / team brief / other (specify)

9.2 Training Requirements

Training Needs N/A / Informal / Workshop / Formal Course	Training Target Date	Implementation Manager
N/A	N/A	N/A

9.3 Compliance

Compliance with this specification will be verified by Asset Policy through the Type Registration process.

9.4 Procedure Review Date

4 years from publication date.

PART 3 - GUIDANCE NOTES AND APPENDICES

10 REFERENCES

TS 1_(RES) Ratings and General Requirements for Plant, Equipment, Apparatus and Services for the National Grid System and Connection Points to it.

DYNAMIC SYSTEM MONITORING (DSM)

This document is for Relevant Electrical Standards only.

TABLE OF CONTENTS

PURPOSE AND SCOPE

This document details the functional and performance requirements for Dynamic System Monitoring (DSM).

Equipment topologies other than those proposed in this specification are acceptable where such solutions can be demonstrated by the supplier to meet the overall functional and performance requirement specified herein.

PART 1 – PROCEDURAL

1 FUNCTIONAL AND PERFORMANCE REQUIREMENTS

1.1 General

1.1.1 DSM is required to provide data on a substation and system wide basis of System Dynamic behaviour on a continuous time series basis.

1.1.2 Access to system data, parameter settings and the configuration of equipment shall be via a secure network connection.

1.1.3 DSM system shall comprise:

a) A data acquisition unit providing both local and remote access capability.

b) A master server at substation level and software to interrogate and collect data from all bay level data acquisition units.

c) All appropriate user software to access and analyse data stored on the substation master servers.

1.1.4 All DSM equipment shall be dual rated for use on both 110 / 48V DC supplies

1.1.5 The Data Acquisition Units shall have at least 2 x Ethernet ports and 1 x USB port

Each Ethernet port shall be capable of accepting individual TCP/IP address's and manage the data traffic independent of the other.

All cross site communications shall be conducted using fibre connections.

The USB port or a third Ethernet port shall be utilised to update the firmware locally and provide access to system configuration locally.

1.2 Time Keeping

1.2.1 Sampling of inputs and all derived data shall be time-tagged.

1.2.2 Inputs shall be sampled such that a 1 µs timing accuracy is achieved.

1.2.3 Storage of data shall maintain the timing accuracy specified in 1.2.3.

1.3 Continuous Time Series Data

1.3.1 All data acquired by the Data Acquisition Unit shall be continuously stored.

1.3.2 The storage rate shall be user selectable but capable of at least 256 samples per cycle.

1.3.3 Non-volatile static memory shall be provided for storage of a minimum of 28 days data, prior to overwriting on a first in first out basis.

1.3.4 In the event of a deviation from the minimum or maximum set thresholds, the Data Acquisition Unit will trigger a flag, attach it to the event and raise a notification to the substation master server. Each user shall be able to customise their individual profile to state which system parameter flags they will be notified of. Users shall be notified of event flags immediately via user defined means (email, sms).

1.3.5 The following flag types shall be provided as a minimum for the parameters given in Table 1.

a) Rate of change (±).

b) Level (over and/or under).

c) Oscillatory condition of active power values. Setting shall enable the detection of small oscillations to be made on the basis of the oscillation period, amplitude, and the number of oscillations within a given time window. The frequency of the oscillations will be in the range 0.01 to 5 Hz. Settings shall enable the detection of small oscillations to be made by configurable frequency bands.

d) Status inputs (change of state: open to closed, closed to open, or both).

1.4 Parameters to Measure for the Activation Flags

1.4.1 Parameters comprising derived values from CT and VT inputs and plant status inputs shall be determined on a real time basis as required below for the purpose of activation of flags:

a) For each 3-phase voltage and current vector group: 3-phase active and reactive PPS power values.

b) For each 3-phase voltage and current vector group the PPS and NPS sequence components (rms magnitude).

c) For each vector group having single-phase voltage input: the active and reactive power values, scaled as total 3-phase power (Based on PPS current).

d) For each voltage vector group having a single-phase input: rms magnitude.

e) For each voltage vector group the system frequency, derived from one of the 3 phase VT inputs.

f) Plant status inputs

1.5 Accuracy, Resolution and Measurement Range for Time Series Data

1.5.1 Accuracy requirements shall be met over the power system frequency range of 45 – 55 Hz. The supplier shall provide data regarding the performance over the range 40 to 60 Hz.

Parameter	**Measurement Range**	**Accuracy (±)% of nominal input**	**Resolution (±)% of nominal input**	**Notes**
r.m.s voltage	0 – 1.5 Vn	0.1	0.01	Crest Factor ≤ 1.5
Phase sequence components (voltage)	0.8 – 1.5 Vn	0.1	0.01	Crest Factor ≤ 1.5
Phase sequence components (current)	0 – 5 In	0.1	0.02	Crest Factor ≤ 3.0
Active Power	0 – 5 Pn	0.5	0.01	Pn = nominal active power = Vn.In. Cos ǀ. Accuracy to be maintained over the power system phase angle range unity to 60° Lag/Lead
Reactive Power	0 – 5 RPn	0.5	0.01	RPn = nominal reactive power = Vn.In. Sin ǀ. Accuracy to be maintained over the power system phase angle range zero to 30 ° Lag/Lead
Frequency	45 – 55Hz	0.005	0.001	20 to 150% Vn.

Table 1: Accuracy, Resolution and Measurement Range.

2 DATA & USER REQUIREMENTS

2.1 Software and Firmware

2.1.1 DSM firmware shall be available to National Grid free of charge and on an as required basis to enable upgrade activities.

2.1.2 The User Software shall allow up to 12 analogue and 12 status channels to be selectable for simultaneous display.

2.1.3 The channels required for display shall be selectable from any Data Acquisition Unit on the system.

2.1.4 All data selected for display shall be clearly identified by its source.

2.1.5 The display of time shall be selectable to relative, or real time.

2.1.6 The units of time shall be appropriate to the period selected for display.

2.1.7 Export of data should be in a range of common formats such as .CSV, .XLS, .MDB COMTRADE.

2.2 Communication Architecture

Each Data Acquisition shall have the capability to independently sense, acquire and store data and then to transfer the data via a LAN to the master substation server

2.2.1 The master substation server shall collect all the data from the remote Data Acquisition Units on a pre-determined regular interval, with the option to access the data on request.

2.2.2 The data should then be accessible to National Grid by web browser.

3 HARDWARE PLATFORMS

The following apply to all hardware items supplied, as appropriate to the equipment item.

3.1.1 A Real Time Multi-tasking Operating System should be used to maximise reliability

3.1.2 Hardware platforms used within a National Grid substation environment shall comply with the requirements of TS 3.24.15 (RES).

3.2 Single Point Status Inputs

3.2.1 Single point status inputs shall be provided for the indication of main plant status.

3.3 Single Point Status Outputs

3.3.1 The following Status Outputs shall be provided

a) Equipment healthy.

b) Out of service mode selected.

3.4 CT and VT Inputs

3.4.1 Three VT and three CT inputs shall be provided.

3.4.2 The nominal value of CT inputs (In) shall be 1 amp.

3.4.3 The nominal value of VT inputs (Vn) shall be 110 V / $\sqrt{3}$.

3.4.4 CT and VT inputs shall be sampled at a frequency of 256 samples per cycle. Higher whole integer sampling frequency multiples may also be considered.

Anti-aliasing filters shall be incorporated, having a rollover characteristic of $\geq$ 3 dB per octave and a Nyquist frequency of $\geq$ 0.5 and $\leq$ 0.7 of that of the sampling frequency.

4 CONTRACT SPECIFIED OPTIONS

None

5 OTHER REQUIREMENTS

5.1.1 The calibration period over which performance requirements are met shall be defined. The equipment and software shall be supportable for a period not less than 15 years.

6 TEST REQUIREMENTS

6.1 General

6.1.1 The equipment shall be tested in accordance with the requirements of TS 3.24.15 (RES) - Environmental and Test Requirements for Electronic Equipment.

For the purposes of electrical environmental tests all equipment shall be classified as “substation equipment”.

During and after all environmental tests, all equipment shall meet with the requirements of this specification. No additional derogation is given for influence quantities.

Performance requirements are inclusive of the effects of all external accessories e.g. current shunts and current transformers.

6.1.2 The manufacturer of the electrical equipment shall declare conformance with the essential requirements (safety objectives) of the European Union Low Voltage Directive 2006/95/EC. A CE mark shall be affixed to all equipment to confirm that the equipment has been manufactured in accordance with the applicable technical standards and essential requirements as defined in the Directive.

7 FORMS AND RECORDS

Not applicable

PART 2 - DEFINITIONS AND DOCUMENT HISTORY

8 DEFINITIONS

CT	Current Transformer
DAU	Data Acquisition Unit
DSM	Dynamic System Monitor
GPS	Global Positioning System
In	Nominal input current
LAN	Local Area Network
NPS	Negative Phase Sequence
PPS	Positive Phase Sequence
QoS	Quality of Supply
Vn	Nominal input voltage
VT	Voltage Transformer

WAN	Wide Area Network
PMU	Phasor Measurement Unit
MTBF	Mean Time between Failure

9 AMENDMENTS RECORD

Issue	Date	Summary of Changes / Reasons	Author(s)	Approved By (Inc. Job Title)
1	Feb 2014	First Issue		

10 IMPLEMENTATION

10.1 Audience Awareness

Audience	Purpose Compliance (C) / Awareness (A)	Notification Method Memo / letter / fax / email / team brief / other (specify)

10.2 Training Requirements

Training Needs N/A / Informal / Workshop / Formal Course	Training Target Date	Implementation Manager

10.3 Compliance

Text here.

10.4 Procedure Review Date

5 years from publication date.

PART 3 - GUIDANCE NOTES AND APPENDICES

11 REFERENCES

11.1 National/International Standards

IEEE C37.118-2005	Reporting synchronized phasor measurements in power systems.
IEC 61000-4-30	Electromagnetic Compatibility – Testing and Measurement Techniques – Power Quality Measurement Techniques
IEC 61850	Communication networks and systems in substations

11.2 National Grid Documents

TS 3.24.15 (RES)	Environmental and test requirements for the hardware units
TS 2.19 (RES)	Ancillary Light Current Equipment

PROTECTION & CONTROL FOR HVDC SYSTEMS

TABLE OF CONTENTS

PURPOSE AND SCOPE

This specification defines the functional and performance requirements for the protection and control of HVDC systems. It is applicable for point to point HVDC links with both Current Sourced Converters (CSC) and Voltage Sourced Converters (VSC). An example of an HVDC system arrangement is shown in the Appendix B. It includes AC busbar(s), Harmonic filter(s), Converter Transformer(s), Pole(s), Converter(s), DC busbar(s)/link(s), DC filter(s) as well as DC Neutral.

PART 1 - FUNCTIONAL AND PERFORMANCE REQUIREMENTS

1 GENERAL REQUIREMENTS

Informative: This is a generic specification based on a bipole HVDC application. Each of the protection and control functions specified in this document may be called up and applied separately as appropriate and necessary to achieve the overall desired system for other application scenarios.

1.1 General

Each HVDC converter station shall be equipped with a control and protection system designed to operate satisfactorily under normal as well as abnormal conditions.

The control system shall be designed to permit transmission of power in both directions. The design shall assure that there are no harmful interactions between the HVDC transmission system and the AC network which may adversely affect either the HVDC converter protection system or the AC network protection system. The HVDC transmission system shall be stable in all situations and the system shall be self-protecting with and without the inter-station telecommunication in service. The control and protection system for the two converter stations shall be identical as far as possible. The Contractor is responsible for finding an optimised control strategy to ensure a robust system.

Where a bipolar system is used for an HVDC system, each of the two poles shall be able to operate independent of the other pole in monopolar operation configuration for the case of an outage of one converter or scheduled maintenance and repair work on one of the converters. The same control functions as available for the whole bipolar system shall be available also in monopolar operation mode.

The control and protection system shall have full redundancy in all vital parts. The protection for a HVDC converter station shall comprise protection functions for AC busbar(s), Harmonic filter(s), Converter transformer(s), Pole(s)/Converter(s) as well as DC busbar(s)/line(s), DC Neutral, and DC filter(s). The protections shall detect and clear faults and faulty equipment within an HVDC system to protect stability of the GB transmission network as well as the HVDC system.

The control functions for an HVDC system shall include despatch control, operational control as well as Supervisory Control and Data Acquisition (SCADA) functions.

Informative: Despatch control concerns link transfer, ramping set points, control mode selection, Power Oscillation Damping (POD) and SSR control selection. Operational control concerns manual switching of individual AC or DC plant items at an HVDC converter station.

The HVDC facility shall be divided into a number of separately protected and overlapping zones as illustrated in Figure 1 of Appendix B. A protection function shall only act upon a specific type of fault within a designated zone and shall be stable to other types of disturbances or faults external to the relevant zone.

Every protective zone shall be protected by two main protection functions (preferably using a different protection principle) and one back-up protection function. Where different protection principles cannot be used, duplicated protections shall be used.

The protections shall be as independent as possible from the control system and, such that control failure shall not limit the functionality of these protections, and vice versa. Each of these protection systems shall always remain active and shall be powered by separate, independent power supplies.

Where protection and control functions are integrated within a same Intelligent Electronic Device (IED), the design shall satisfy the requirements for normal operations, maintenance as well as failure modes. Supplier(s) shall declare the integration arrangement in Table 1 of Appendix A (form TS 3.24.90.A).

All the protection and control functions for a HVDC system shall be co-ordinated with those ones for the interfacing feeder(s) and rest of connected AC network as appropriate, including but not limited to AC protection schemes, Tripping and Intertripping arrangement, Operational Tripping Schemes (OTS), Converter blocking sequence, Delay Auto Re-close (DAR) schemes, over-loading requirements etc.

The converter station design, CT characteristics and protection system shall be designed in such way that the AC protection of the converter and adjacent AC substations are not affected by the normal, transient and dynamic behaviour of the DC system.

The protection and control system for a HVDC converter station shall be designed to ensure that no single failure of equipment shall cause the total failure of an HVDC system.

It shall be possible to repair, maintain and test the pole on outage whilst maintaining unhindered normal operation of the remaining pole.

Isolation facilities shall be provided to allow on-line maintenance of the redundant control & protection equipment/system.

1.2 Engineering Interface

Engineering interface shall be provided with HVDC protection and control system for the setting configuration, commissioning, diagnostic and other engineering purposes. Software/Firmware version shall be clearly identifiable within the interface.

Auditoria shall be provided for version changes of configuration within the engineering interface.

1.3 Hardware and Accommodations

All the hardware, cubicles and other General Arrangements associated with the required functions in this specification shall comply with the relevant electrical, environmental and ancillary requirements in TS3.24.15 (RES), TS 2.19 (RES) as well as EATS48-4.

2 PROTECTION FUNCTIONS

2.1 AC Busbar Zone Protection

2.1.1 Double Busbar Arrangement

For HVDC systems connected to double busbar substations, the busbar protection shall be provided in accordance with TS 3.24.34 (RES).

On operation, busbar protection shall

a) Initiate converter blocking sequence

b) Trip the Main CB(s) at AC substation.

c) Initiate CBF protection where appropriate.

d) Be selectable to initiate DTT to the remote end(s) of the circuit.

Informative: The specific tripping scheme to clear busbar faults may vary depending upon the topology of converter stations.

2.1.2 Mesh Corner Arrangement-

For HVDC systems connected to mesh substations, Mesh Corner(MC) protection shall be provided. On operation, mesh corner protection shall

a) Initiate converter blocking sequence

b) Trip the associated CBs.

c) Initiate CBF protection where appropriate.

d) Lockout MCDAR where appropriate.

e) Be selectable to initiate DTT to the remote end(s) of the circuits connected to the same corner.

2.2 Converter Transformer Zone Protection

Where applicable, protection shall be provided to cover the connection between converter transformer(s) and converter(s).

2.2.1 Tapping Sequence Protection

Converter transformer tapping sequence shall be monitored to ensure correct operation of on load tap changers. When a fault is detected, the protection shall

a) Trip tap-changer MCB(s)

b) Generate an alarm

c) Block converter as necessary

2.3 DC Converter/Pole Zone Protection

DC Converter/Pole protection shall independently oversee the system and ensure equipment safety. For each converter/Pole there shall be two independent DC protection systems, Main1 and Main 2.

2.3.1 Asymmetry Protection

Asymmetry Protection shall be provided to detect persistent presence of fundamental and 2nd harmonic voltages or current between the DC terminals of the pole.

When the magnitude of the RMS voltage (fundamental and second harmonic frequencies) exceeds preset thresholds the protection shall operate with an inverse time characteristic in two stages:

a) Stage 1: As soon as a fault is detected an alarm shall be initiated.

b) Stage 2: If the fault persists, the pole shall be taken out of service.

2.3.2 Pole Differential Protection

Pole DC Differential Protection shall be provided to detect ground faults on the DC side of the converter.

On operation, the protection shall take the pole out of service by

a) Initiate converter blocking sequence

b) Trip associated AC CBs necessary

c) Generate an alarm

d) Isolate Line and Neutral

Informative: This protection shall co-ordinate with DC line protection 0 as a ground fault on the HVDC bus may also operate the DC line protection. This protection shall block before the DC line protection initiate a restart.

Pole DC Differential Protection shall have two levels of sensitivity settings, at the lower level the delay time is longer (at typically 30ms). If the mismatch exceeds the higher level the protection shall act faster (the delay before operating is brought down to typically 3ms).

Informative: The delay is introduced to avoid spurious triggering if the protection detects mismatches during energisation caused by charging currents.

2.3.3 DC Overcurrent

DC Overcurrent shall be provided to detect overcurrent in the HVDC link and take the pole out of service if a fault is detected.

On operation, the protection shall;

a) Initiate converter blocking sequence

b) Generate an alarm

c) Trip Associated AC CBs necessary

d) Line and Neutral isolation as appropriate

The protection shall have an inverse definite minimum time (IDMT) characteristic

2.3.4 AC>DC Differential

AC>DC Differential protection shall be provided to detect a valve short circuit, other phase-to-phase short circuits which give rise to high AC currents and low DC currents and in response take the pole out of service.

On operation, the Protection shall

a) Initiate converter blocking sequence

b) Generate an alarm

c) trip Associated AC CBs necessary

2.3.5 DC>AC Differential

DC>AC Differential shall be detected to detect converter failures and if the fault persists take the pole out of service.

On operation, the Protection shall

a) Initiate converter blocking sequence

b) Generate an alarm

c) Trip Associated AC CBs necessary

Informative: This is the opposite of the AC > DC Differential above. In this case the sense of the difference indicates a converter failure where DC current flow bypasses the AC connections. This protection needs to be co-ordinated with AC system protections as well as the asymmetry protection.

2.3.6 AC Overcurrent

AC Overcurrent protection shall be provided to detect overcurrents in any of the valve winding connections which can result from phase to phase valve connection faults or control failure and initiate protective actions on detection. The protection shall contain both two stages and inverse characteristics selectable for an application.

On operation, the Protection shall

a) Initiate converter blocking sequence

b) Generate an alarm

c) Trip Associated AC CBs necessary

The protection shall have an inverse definite minimum time characteristic (IDMT).

2.3.7 AC Overvoltage Line Side

AC Overvoltage Line Side Protection shall be provided to detect overvoltage in the line winding side that could stress the equipment. It shall take the pole out of service if persistent AC overvoltage is detected.

On operation, the Protection shall

a) Initiate converter blocking sequence

b) Generate an alarm

c) Trip Associated AC CBs necessary

Informative: Overvoltage is tolerated for a certain time, depending on the voltage level, - if the overvoltage is removed within this time then the protection does not operate. If the overvoltage persists, or if the overvoltage is removed but recurs within the cooling period allowed, then the protection operates.

The equipment is required to be protected for AC system voltage excursions beyond the specified range resulting from a system disturbance. The overvoltage protection characteristic is defined here based on the equipment capability.

The line side overvoltage characteristic is based on the worst case of the converter transformer overfluxing in the event of overvoltage. The converter transformer overfluxing characteristic associated with the maximum tap at full frequency (50 Hz) is selected as it encompasses the requirement of all the equipment connected to the line terminal.

The operation of this protection shall be coordinated with the tap changer control and the tap limit protection to allow for normal operation. Provision shall also be made so that the settings do not give rise to unnecessary alarms and tripping due to permanent AC network voltage changes or switching actions.

2.3.8 AC Overvoltage Valve Side

AC Overvoltage Valve Side protection shall be provided to detect overvoltage in the valve winding side that could stress the equipment. It shall take the pole out of service if persistent AC overvoltage is detected.

On operation, the Protection shall

a) Initiate converter blocking sequence

b) Generate an alarm

c) Trip Associated AC CBs necessary

Informative: The voltage is measured on the line winding side of the converter transformer and calculated for the valve winding using the measured tap position.

Overvoltage is tolerated for a certain time, depending on the voltage level, - if the overvoltage is removed within this time then the protection does not operate. If the *overvoltage persists, or if the overvoltage is removed but recurs within the cooling period allowed, then the protection operates.*

The equipment is required to be protected for AC system voltage excursions beyond the specified range resulting from a system disturbance. The overvoltage protection characteristic is defined here based on the equipment capability.

For the transformer valve winding side overvoltage protection, the characteristic with respect to time is defined by the valve surge arrester capability, followed by the expected voltage on the eventual tripping of the AC filters and the consequent protective tap-changer lowering of the converter transformer.

The operation of this protection shall be coordinated with the tap changer control and the tap limit protection to allow for normal operation. Provision shall also be made so that the settings do not give raise to unnecessary alarms and tripping due to permanent AC network voltage changes and switching actions (such as Line and shunt reactor switching).

2.3.9 AC Undervoltage

AC Undervoltage protection shall be provided to monitor the line-to-line AC system voltage. If the AC undervoltage persists for a fixed period of time, the protection shall block and/or trip the pole.

On operation, the Protection shall produce

a) Inform relevant control functions such as Valve Base Electronics

b) Initiate converter blocking sequence

c) Trip associated AC CBs as necessary

d) Generate an alarm

Informative: The voltage is measured on the line winding side of the converter transformer and calculated for the valve winding using the measured tap position.

If any valve winding line voltage falls below the set level and remains below it for longer than a definite time, an indication to the control system that the AC voltages are too low to maintain the charge on the Valve unit power supplies is sent.

Following restoration of the voltage level, the control system shall be held for a predefined period to allow time for the gate unit to be fully charged. If the converter is de-blocked, it produces block and trip after a fixed delay when undervoltage is detected.

2.3.10 DC Undercurrent Protection

DC Undercurrent Protection shall be provided to prevent prolonged operation of either a rectifier or inverter operating into an open circuit, i.e., when one side fails to de-block.

When the DC current goes below a preset value for a preset time, then the DC current protection shall

a) Initiate converter blocking sequence

b) Generate an alarm

2.3.11 Tap Limits Protection

Tap Limits Protection shall be provided to prevent long-term voltage stress that may cause harm to the equipment, e.g. over-excitation of the converter transformer.

On operation, the Protection shall

a) Generate an alarm

b) Inhibit tapping to increase voltage

c) Force tapping to Lower voltage

Informative: Valve line side voltages are measured and compared with pre-set thresholds. For moderate voltage stress, the control is inhibited from raising the tapchanger position. For severe voltage stress the tapchanger is forced to tap down to acceptable levels. The overfluxing of the converter transformer is frequency dependent. The settings of this protection shall not interfere with normal tap changer control.

2.3.12 Thermal Protection

Protection shall be provided to prevent valve temperatures to exceed the thermal limits.

On operation, the Protection shall

a) Initiate converter blocking sequence

b) trip associated AC CBs necessary

c) Apply Full Cooling as appropriate

d) Generate an alarm

2.4 Neutral Zone Protection

The following protections shall be used to detect and clear faults and faulty equipment on the DC neutral.

Common Neutral Area Protection

Common Neutral Area Protection shall be provided to detect a short circuit in common neutral area including the electrode line. The protection covers the common neutral bus between the poles and the electrode line area outside of the pole differential protection or filter protection zones.

On operation, the Protection shall

a) Initiate converter blocking sequence

b) Trip associated AC CBs necessary

c) Generate an alarm

d) Initiate NBGS sequence as appropriate

Informative: In the case of monopole operation, the protection will block the pole. In the case of bipole operation, the protection action is to introduce a pre-trip level which will close the Neutral Bus Grounding switch (NBGS) when a neutral area earth fault is detected. If the earth fault is caused by a flash over to ground, by providing a parallel low impedance path to *ground, the fault current can be diverted allowing the earth fault to extinguish. In doing so, the scheme may continue to operate without resorting to tripping both poles. Control action is used to balance the currents of the two poles to minimise the current to station ground. If the fault is cleared, the operator can then decide to open the NBGS to disconnect the temporary station ground. For persistent common neutral area faults, the protection shall initiate a converter blocking sequence to block both poles.*

2.4.1 Neutral Bus Overvoltage Protection

Neutral Bus Overvoltage Protection shall be provided to detect DC overvoltage on the neutral bus.

On operation, the Protection shall

a) Initiate converter blocking sequence

b) Trip associated AC CBs necessary

c) Alarm

d) Initiate Neutral Bus Grounding Switch sequence

The neutral voltage shall be compared against preset threshold levels to determine the integral operating time which has a logarithmic time characteristic, with definite minimum time (DMT), and IDMT sections.

Informative: For single pole operation NBGS is closed on detection of a fault. For bipole operation, it checks if the other pole has also found this fault and if so it will close the NBGS.

2.4.2 Neutral Bus Grounding Switch (NBGS) Protection

NBGS Protection shall be provided to protect the neutral bus grounding switch from failure to open.

The NBGS current shall be measured and compared with a preset threshold. The protection shall operate when its threshold is exceeded after a preset period of time.

On operation, the Protection shall

a) Generate an alarm

b) Issue close command to the NBGS

2.4.3 Neutral Bus Switch Protection

Neutral Bus Switch Protection shall be provided to protect the neutral bus switch from failure to open.

The neutral bus switch current shall be measured and compared with a preset threshold. The threshold is exceeded for a preset period of time, the Protection shall

a) Generate an alarm

b) Issue close command to the NBGS

2.4.4 Electrode Line Fault Detector

Electrode Line Fault Detector shall be provided to detect faults on Electrode line.

On operation, the Protection shall produce alarm “Electrode Line Fault”

2.4.5 Neutral Current Unbalance

Neutral Current Unbalance protection shall be provided to monitor the “spill” current from each pole, measured by DC CT and provide protection action on detection of the failure of the bipole current balancing or a main circuit fault.

On operation, the Protection shall produce Alarm “Neutral Current Unbalance”

The operating time shall be determined by an inverse response with a definite minimum time (IDMT) characteristics. There shall be an operating level below which the protection will not operate.

2.4.6 Metallic Return Earth Fault Protection

Where applicable, Metallic Return Earth Fault Protection shall be provided to detect faults in the DC metallic return.

The function may be achieved by monitoring the earth return or electrode line current in two stages:

c) Stage 1: generate alarm only if the current is above a preset threshold;

d) Stage 2: Initiate converter blocking sequence if the current is above a higher threshold.

2.4.7 Metallic Return Transfer Breaker (MRTB) Protection

Where applicable, the Metallic Return Transfer Breaker (MRTB) Protection shall be provided to protect against failure of the MRTB to commutate current from the ground return to the metallic return.

The metallic return transfer breaker current shall be measured and compared to a preset threshold. When the threshold is exceeded for a preset period of time, the Protection shall produce

a) Generate alarm

b) Re-close the MRTB

2.4.8 Ground Return Transfer Switch Protection

Where applicable, the Ground Return Transfer Switch (GRTS) Protection shall be provided to protect against failure of the GRTS to commutate current from the metallic return to the ground return.

The ground return transfer switch current shall be measured and compared with a preset threshold. When the threshold is exceeded for a preset period of time, the Protection shall

a) Generate an alarm

b) Issue close command to the GRTS.

2.4.9 NBGS Overcurrent

NBGS Overcurrent protection shall be provided with IDMT characteristic to detect overcurrent in NBGS.

On operation, the Protection shall

a) Initiate converter blocking sequence

b) Generate an alarm

2.4.10 Electrode Line Balance Protection

Electrode Line Balance Protection shall be used in a scheme where the electrode line has two conductors. This protection detects mismatch between the two electrode line conductors DC current signals measured by DC CTs.

On operation, the Protection shall produce Alarm “Electrode Line Unbalance”.

2.4.11 Electrode Line Overload

Electrode Line Overload protection shall be provided IDMT characteristics with to detect overload in one of the electrode line conductors. Sudden trip of one of the parallel electrode lines may cause overload on the other line.

On operation, the Protection shall produce Alarm “Electrode Line Overload”.

Informative: An integral timer is used so that a recurring overload has cumulative effect. In order to reset the integral when the current is below the operating threshold, a reset characteristic is defined.

2.4.12 Neutral/Earth Overcurrent

Neutral/Earth Overcurrent protection shall be provided IDMT characteristics with to detect overcurrents in the electrode line or earth current.

On operation, the Protection shall

a) Initiate converter blocking sequence

b) Trip associated AC CBs as necessary

c) Generate an alarm

2.5 HVDC Transmission Link Zone Protection

The following protections shall be used for the HVDC Transmission link either Cables or Overhead lines.

2.5.1 DC Line Fault

DC Line Fault protection shall consist of two main protections capable of detecting ground faults on the DC link either overhead lines and/or submarine cables.

Informative: The fault current is brought to zero for a period of time to allow the arc to de-ionise. If the fault is between an overhead line and ground the Delay Automatic Re-close (DAR) scheme may in general be used to restart power transmission following de-ionization time. The protection of DC cables is similar to that for overhead lines. Since cable faults are generally permanent no DAR schemes are used. If however, the line consists of both overhead and cable segments, then the DAR may be used for the overhead line faults.

On operation, the Protection shall

a) Initiate converter blocking sequence

b) Generate alarm “DC Line Fault”

c) Line and Neutral isolation

Informative: DC Line protection is only active at the rectifier. To distinguish between faults in the DC system and at the inverter the telecommunication system may be needed to send to the rectifier, status signals indicating inverter failure or telecomm failure.

To prevent operation if a single phase, or more, fault occurs on the rectifier AC system, i.e. a fault outside the protection zone, the function is inhibited via AC Fault detection. The protection is also inhibited when the converter is blocked.

If the above inhibits are not active and the rectifier is de-blocked, DC line faults may be detected either by the presence of a negative rate of change of DC voltage (dVdc) below a threshold or, persistently low DC voltage and the presence of DC Current.

Following the protection operation, if the DC voltage has not recovered within a specified period of time, the DC line fault is assumed to be still present and the process shall be repeated. If the DC voltage and DC current does not recover after a preset number of retries the converter shall be blocked and the associated AC circuit breakers shall be tripped.

Informative: The pure undervoltage detector may also be needed to detect a DC Line Fault for cases when the differentiated DC voltage does not decrease below its threshold.

Due to the fast operation portion of DC Line Protection, the detection of DC Line Faults shall be co-ordinated so it does not operate for faults beyond the smoothing reactor on the inverter side.

2.5.2 Cable Pair Sharing Protection

Cable Pair Sharing Protection shall be used where a pair of DC cables is used to implement the transmission link. It detects mismatch between the same polarity of DC current signals measured by DC CTs indicating the faulty cable

Informative: The mismatch is derived by taking the absolute value of the difference between the DC current input signals.

The protection shall operate when the mismatch current exceed a preset threshold for a preset period of time. On operation, the Protection shall produce Alarm “Cable Pair Sharing Faulty”.

2.5.3 Cable Balance Protection

Cable Balance Protection shall be provided where DC cables of opposite polarity in a bipole scheme are crossed. It detects mismatch between the opposite polarity of DC current signals measured by DC CTs.

The protection will operate when the mismatch exceeds its pre-set threshold for a pre-defined period of time. On operation, the Protection shall produce Alarm “Cable Unbalance”

Informative: The mismatch is derived by taking the absolute value of the difference between the DC current input signals.

2.5.4 Cable Overcurrent

Cable overcurrent protection shall be provided where DC cables are used, to detect the cable current exceeding the normal continuous rating.

The DC current shall be compared with a pre-set threshold, when its threshold is exceeded for a pre-defined period of time, the protection shall operate to generate Alarm "Cable Overcurrent".

2.5.5 DC Under-Voltage

DC Under-voltage protection shall be provided to detect remote ground faults on DC overhead lines or submarine cables.

On operation, the protection shall

a) Initiate converter blocking sequence

b) Isolating Neutral as necessary

c) Trip associated AC CB(s) as necessary

d) Generate an alarm

2.5.6 DC Over-Voltage

DC Over-Voltage protection shall be provided to detect DC overvoltage on the HV bus.

Informative: Large overvoltage of considerable duration may occur due to peak rectification if a pole is started against an open DC line or if the rectifier is de-blocked against blocked inverter. At the same time the direct current may be very low due to the open circuit.

On operation, the protection shall

a) Initiate converter blocking sequence

b) Inhibit Raise Voltage

c) Forced lower voltage as necessary

d) Generate an alarm

2.5.7 DC Filter Overload

DC Filter Overload protection shall be provided to detect overload in the DC filters.

Informative: The filter overload capability is based on the filter element with the minimum overload capability. Cooling time applied to the integrator function may be related to the filter time constant, and allows for the cumulative effect of the filter current.

On operation, the protection shall generate Alarm "DC Filter Overload".

2.6 Harmonic Filter Zone Protection

Informative: Harmonic filter may be of manufacturer dependent design. It usually comprises Capacitors, Reactors as well as Resistors and other equipments.

2.6.1 Overall Protection

An overall protection shall be provided for the Harmonic Filter. The protection shall be responsive to both phase and earth faults. The protection shall be provided with self-supervision and CT supervision functions.

The setting range of the protection shall include 10 % - 50 % of the rated current of the filter.

If the overall protection is of high impedance type, a fully duplicated overall protection system driven from a common current transformer shall be provided for the filter.

2.6.2 Overcurrent Protection

Back-up protection having an overcurrent function capable of responding to both 50Hz and to up to 35^{th} harmonics with both DTOC and IDMT characteristics shall be provided for the Harmonic filter.

The back-up protection function shall consist of three phase overcurrent and a residually connected earth fault protection.

The DTOC function shall be provided with a current setting range of 50 % - 200 % and 20-80% (based on 1 A secondary corresponding to approximately full load current of the filter) for overcurrent protection and earth fault protection respectively and a time setting range of 0.1s – 5 s in step of not greater than 0.1 s.

The back-up protection shall be stable for any inrush or outrush transients.

The back-up protection function shall on operation:

a) Trip the filter CBs.

b) Initiate CBF protection

2.6.3 Capacitor Protection

Capacitor protection functions shall be provided for each capacitor segment within the filter. Each shall comprise excessive RMS overcurrent protection, overvoltage protection and out-of-balance protection unless the Contractor can demonstrate that the capacitor bank is adequately protected by alternative protection functions.

The Contractor shall declare how the capacitor protections are applied to each capacitor bank.

Where the discharge current which occurs due to the short circuit of a capacitor unit is of sufficient magnitude to cause unacceptably high voltages on the secondary wiring of the out-of-balance protection, effective means of limiting this voltage shall be employed.

The operation of the above protections shall produce

a) Trip to the filter CBs

b) An alarm

2.6.4 Reactor Thermal Overload Protection

Where reactors are used for the Harmonic filter, and are of the dry type, two-stage thermal overload protection shall be provided. The first stage shall be for alarm purposes and the second stage for tripping. The current setting range of the protection shall include 50 % - 150 % of the rated current of the reactor.

2.6.5 Resistor Thermal Overload Protection

Where the Harmonic filter contains resistors, Two-stage thermal overload protection shall be provided for each resistor bank. The first stage shall be for alarm purposes and the second stage for tripping. The current setting range of the protection shall include 50 % - 150 % of the rated current of the resistor bank.

2.6.6 Resistor Open Circuit Protection

Resistor Open Circuit Protection shall be provided for each resistor bank. The protection shall be able to detect resistor open circuit and high resistance fault conditions.

The protection shall be stable for inrush or outrush transients and harmonics and shall not give an unwanted operation under any normal operating conditions or external fault conditions.

The supplier shall declare the method of measurement employed by the Resistor Open Circuit Protection.

The protection shall give a trip output after a time delay. The setting range for the time delay shall include 0.1 s – 5 s in steps of not greater than 0.1 s.

2.7 DC Smoothing Filter Zone protection

DC Smoothing Filter protection shall be provided to detect faults and faulty components within the filter.

Informative: DC Smoothing Filter protection may include a number of protection functions depending upon the HVDC technology and filter design.

On operation, the protection shall

a) Initiate converter blocking sequence

b) Trip associated AC CB(s) as necessary,

c) Generate Alarms (associated with operated protection functions)

2.8 Valve & Ancillary System Protection

Informative: The protective zone for these protections is normally within the Converter zone.

Valve & Ancillary system protections shall be provided to detect and clear faults associated with equipment failure that may cause the power transfer level to be compromised, harm the converter or compromise the integrity of the main components of the DC equipment, such as failure of the Converter Cooling Plant.

2.8.1 Valve Unit Protection

All the components in the converter valve units shall be monitored to ensure the number failed components do not exceed the redundancy level to affect normal performance of the converter.

If the number of failed components exceed certain preset numbers, the following actions shall be taken in stages as appropriate:

a) Generate alarms

b) Initiate converter block sequence

c) Trip associated AC CB(s)

d) Emergence shut-down of the converter

2.8.2 Converter Cooling Plant Protection

The converter cooling plant protection including but not limited to the following protective functions shall be provided to detect the faults or failure of the cooling plant. On operation, those protections shall block and/or trip a pole as appropriate and necessary.

a) Valve Cooling Water Flow Rate

b) Valve Cooling Expansion Vessel Water Level

c) Valve Cooling Water Conductivity

d) Valve Cooling Water Temperature

e) Valve Hall Dew Point

2.8.3 Valve Hall Fire Detection Protection

Each valve hall shall be equipped with a duplicated fire detection system to protect the Converters against fire hazards.

On operation, the fire detection system shall produce

a) Alarms,

b) Any other actions as specified in the Contract.

2.8.4 Valve Hall HVAC System

The Valve HVAC system shall be provided to ensure that the temperature in the valve hall does not go above preset values.

When excessive valve hall temperature is detected, the protection function shall take the pole out of service by

a) Initiating converter block sequence

b) Tripping Associated AC CBs necessary

c) Generating an alarm

2.9 Circuit Breaker Fail (CBF) Protection

Circuit Breaker Fail (CBF) protection shall be provided as per NGTS 3.24.39 (RES) for all AC system circuit breakers associated with the HVDC converter.

On operation CBF protection shall:

a) Trip other CBs connected to the same busbar or mesh corner.

b) Initiate the DTT send functions of each transformer and feeder connected to the same mesh corner where appropriate.

c) Lockout DAR where appropriate.

2.10 Converter Blocking Fail Protection

Converter Blocking Fail protection shall be provided to cater for the failure of blocking sequence for a HVDC converter.

On operation, the protection shall:

a) Trip associated AC CBs to electrically isolate the converter

d) Initiate the DTT send functions as appropriate

e) Lockout DAR where appropriate.

2.11 Voltage Transformer Gas and Oil Actuated Protection

Where a wound oil-filled voltage transformer is used, then it shall be provided with a gas and oil actuated relay to protect against gas accumulation, loss of oil and oil surge.

On operation, the Mechanical protection shall

a) Initiate converter blocking sequence as necessary

b) Trip the associated AC CB(s).

c) Initiate CBF protection

d) Lockout DAR as appropriate.

2.12 Tripping Arrangements

2.12.1 Tripping systems

Two separately energised independent tripping systems shall be provided for all the protection functions specified in this TS.

The tripping systems shall be designed to operate from 110V DC battery systems specified in TS 2.12 (RES).

Each tripping system shall be provided with a separately protected supply fed from different battery systems.

High burden self resetting trip relay(s) shall be provided for each tripping system.

The outputs of all protections shall operate in to both tripping systems.

Operation of the tripping systems from the protections shall be conditioned by auxiliary switches on the appropriate primary disconnectors to inhibit tripping when the protected AC and/or HVDC system are disconnected from the transmission network.

2.12.2 Trip Outputs

The trip relays of each tripping system shall provide output contacts for initiation into the following;

a) Tripping of the associated circuit breaker(s).

b) Intertripping to associated remote circuit breaker(s) where appropriate.

c) Circuit Breaker Fail protection.

The protection system shall provide outputs for initiation of

a) Disconnector sequential isolation where required.

b) Trip relay resetting where required.

2.12.3 Direct Transfer Trip (Intertripping)

Receipt of a Direct Transfer Trip (DTT) shall

a) Initiate converter blocking sequence,

b) Trip the Main CB(s).

c) Initiate CBF protection where appropriate.

d) Lockout DAR where appropriate.

3 CONTROL FUNCTIONS

3.1 Control Systems

3.1.1 Architecture

The control system shall be structured in an hierarchical manner. The following levels (ref. IEC 60633) shall be identified in the software and if applicable in the hardware for each converter:

a) System control

b) Master control

c) Station control

d) Pole control

e) Converter unit control

f) Valve unit control

Only one converter station shall have the active control of the HVDC transmission system at the same time (this station is called the MASTER station, and the other corresponding converter station is called the SLAVE station). The HVDC transmission system shall normally be controlled from the MASTER station or associated control points. Switching of the MASTER function between the converter stations shall not result in an unintentional jump in the power transmission nor in any electrical disturbances or unintended control actions.

Switching of the MASTER function shall be done in the SLAVE station (from LOCAL or REMOTE control) by taking over the active control from the MASTER station.

3.1.2 Control Points

An HVDC link shall be equipped for remote control from the control centres. The control system shall automatically prepare all signals and changes in analogue values from the converter control system for transmission to the control centres without delay.

The response time shall comply with the following requirements:

a) Maximum time from a command is received from the control centre until the breaker is operated: 1 sec.

b) Maximum time from a digital channel is changed until the value is transmitted to the control centre: 1 sec.

c) Maximum time from an analogue value of a high priority channel is changed until the value is transmitted to the control centre: 1,5 sec.

There shall be no limitations in the transmission capacity to the control centre other than the limitations given by the available communication speed and the communication protocol.

There shall be selectable three level control points for an HVDC system:

a) Local Control Points (LCP) where a specific plant item and associated functions within a HVDC converter station e.g. converter transformer bay, can be operated;

b) Station Control Points (SCP) where all the plant items and their associated functions within an HVDC converter station can be centrally operated;

c) Remote Control Points (RCP) where all the plant items and associated functions for a HVDC system can be remotely operated.

It shall be possible to have multiple Remote Control Points, each with two independent communication routes (“A” and “B”) to each converter station. The ‘A’ routes shall normally be in service, reverting to the ‘B’ route on loss of functionality of the ‘A’ route or hardware.

It shall be possible to split control functions for a converter station into dispatch controls and operational controls, and assign only one type of controls to a specific Remote Control Point.

An HVDC system shall have control arbitration mechanism to ensure that only one control point has control authority (active) to operate a plant item or function at a time. Selected control points shall be clearly annunciated at the HMIs of all the control points.

HVDC systems shall normally be unmanned and operated from remote control points. The HVDC link shall also be suitable for manned operation.Control Point Selections

The system shall be designed to permit a free choice for the control and monitoring of the link from either the station control room (SCP) at one of the converter stations or from one of the remote control centres (RCPs). Switching between station and remote control shall only be possible at the SCP of converter stations. Further details shall be determined in the detailed engineering of the control system design.

3.1.3 Test and Operation mode for Remote Control

It shall be possible to switch the remote control between the two states OPERATION and TEST,

On OPERATION:

a) All indications, alarms and measured values from the HVDC station to the remote control equipment shall be in an updated state.

b) All commands and set-point values from remote control equipment shall be active in the HVDC station

On TEST:

a) All indications and alarms to the remote control equipment shall be frozen by the remote control interface when position is changed to TEST. A marking shall be used to clearly indicate that the indications and alarms as presented in the control centre are not reflecting the actual status of the HVDC-link.

b) All measured values to remote control equipment shall be in an updated state.

c) All commands and set-point values from remote control equipment shall be inactive, i.e. blocked in the remote control interface.

3.2 Dispatch Controls

The control system shall contain automatic control features that enable the HVDC-link to function under steady state, transient, dynamic operating conditions. Where Line Commutation Converter (LCC) is used, the HVDC systems shall comply with IEC 60919 Part 1, 2 and 3 as appropriate.

For dispatch control, at least the automatic functions described in Clauses 01 – 0 shall be available.

3.2.1 Converter Control Modes

The converter stations shall have three control modes:

a) PV where constant Active Power (P) and Voltage (V) are controlled as pre-defined targets;

b) PQ where constant Active Power(P) and Reactive Power (Q) are controlled

c) Frequency (f) is controlled as predefined targets.

Each converter station shall be capable of operating in PQ and PV independently. The selection of control mode shall be available from the Local and Remote despatch controls. The supplier shall declare control strategy priorities for the control design.

It shall be possible to apply a schedule of settings for a rolling preset period of time. Within this period, it shall be possible to adjust the scheduled despatch or to over-ride the schedule by manual adjustment of the setting parameters.

3.2.2 Start-Up and Shut-Down of HVDC transmission

It shall be possible to automatically start up or shut down the DC-link transmission by setting a power order in the range between minimum and maximum power.

An automatic start against an open end at the other converter station shall not be possible.

3.2.3 PV Control

In PV mode, it shall be possible, from all despatch control points, to select the active power set point from -200% to +200% of the link nominal rated active power in a preset step ranged from 5 to 100 MW. There shall be a minimum operating point of the converter stations to be defined in the Contract in the percentage of rated current.

It shall be possible to select the target AC system voltage from 80% to 120 % of nominal system voltage with preset increment ranged from 0.5 kV to 5 KV steps. The deadband for AC system voltage control shall be no more than ± preset threshold from the target voltage.

3.2.4 PQ Control

In PQ mode, it shall be possible, from all despatch control points, to select the active power set point -200% to +200% of the link nominal rated active power in a preset step ranged from 5 to 100 MW. There shall be a minimum operating point of the converter stations to be defined in the Contract in the percentage of rated active power.

It shall be possible to select the target reactive power in the range of -200% to +100% of rated active power in MVar with a preset increment ranged from 1 to 50MVAr. The deadband for the reactive power control (actual MVAr exchanged between the converter station and AC system) shall be no more than a preset value ranged from ± 1 – 200 MVar from the target.

3.2.5 Frequency Control

Frequency control shall be provided from the HVDC converter to support re-synchronising in the event of a system split. The control shall have manual and automatic operating modes.

When operating in automatic mode, the frequency control shall be initiated if the frequencies measured at the converter stations differ by a predefined frequency with a pre-defined time delay. The frequency range shall be 0 to 1Hz in 0.1Hz steps. The time delay range shall be 0 to 120s in 1s steps.

The droop setting shall be adjustable between 1% and 10% with 1% increment step of the nominal frequency.

3.2.6 Power Ramping

It shall be possible to increase or decrease the transmitted DC-power with a constant predefined rate-of-rise or rate-of-fall.

The ramp rate shall be selectable, from all despatch control points, in the range of 1 to 500MW/min with a preset increment between 1 to 50 MW.

3.2.7 Power Reversal

It shall be possible to reverse the direction of power flow with a changeover period between blocking and de-blocking not exceeding a specified time, in the range of 0 – 600 seconds.

3.2.8 Pole Balance Control

The control system shall act to balance the loads of each pole of the bi-pole to minimise earth currents. The maximum permitted continuous earth current shall not exceed 5 amps. This limit shall only be exceeded for the duration of converter or cable earth faults.

3.2.9 Reactive Compensation and Harmonic Filter Control

Harmonic filter control shall be provided to achieve compliance with the specified harmonic performance requirements by switching harmonic filters. The function shall also provide Reactive Compensation and/or AC Voltage support including Temporary Over Voltage (TOV) control by switching the same filter banks. Supplier shall declare the control strategy and design to achieve those requirements.

Three control modes shall be provided for the switching of reactive compensation and harmonic filters:

a) MW Mode where the filters are switched at pre-determined MW transfer levels,

b) Target Voltage mode where the filters are switched when preset high and low voltage threshold limits are exceeded

c) MVAR mode where filters are switched when threshold MVAR transfer levels are exceeded.

The specified harmonic performance requirements shall not be comprised under any circumstance during operation of all above control modes.

The control system shall have mechanism to ensure the equal switching duty among the harmonic filters.

Where applicable, the Reactive Compensation and Harmonic Filter control shall co-ordinate with the Dynamic Var Compensation Equipment for the purpose of Reactive Compensation and/or Voltage control. Supplier shall declare the control strategy to be agreed by National Grid.

3.2.10 Emergency Power Control/Power Demand Override

Where required, functions for helping either one of the two AC grids during special system conditions (e.g. extreme AC frequency, extreme AC voltage or defined circuit breaker operations) shall be available. Additional entries shall be available for future use.

Informative: as an example, the over and under frequency protection functions settable using the HVDC control interfaces may be required within HVDC control systems.

3.2.11 Power Oscillation Damping

Where specified, a Power Oscillation Damping (POD) function shall be provided as part of the HVDC control system to enhance the damping of electromechanical oscillations on the transmission system.

It shall be possible to tune the POD to accommodate a range of system conditions.

Facilities shall be provided at all designated control points to modify the characteristics of the POD manually or automatically should system conditions require.

Where an HVDC system operates with the Dynamic Reactive Compensation e.g. Static Var Compensators (SVCs) and where both with POD functions, co-ordination between the two controllers shall be provided to ensure optimum damping for all expected operational combinations of these equipments. The supplier shall be responsible for all aspects of this co-ordination, including the provision of all communication equipment and cabling if necessary.

POD performance shall be demonstrated by means of studies and tests according to the criteria and principles specified in the Contract.

3.2.12 Sub Synchronous Resonance (SSR) Damping

All protection and control functions/devices shall have sufficient immunity to potential SSR and shall not either de-function or mal-function under any foreseeable SSR conditions.

Where specified, the converters shall be equipped with a control function for damping of sub-synchronous resonance between converter and generators in the vicinity of the converter stations.

3.2.13 Change Over Mechanism

Where protection and control equipment is duplicated, a dedicated changeover mechanism shall be installed at each level of the controls i.e. station, bipole and pole level to monitor the availability and health of the equipment.

If one protection or control is failed, it shall automatically change over to the redundant one. In the event of the redundant control being unavailable due to for example maintenance or faulty, the associated pole shall be blocked and/or tripped.

When both station controls become unavailable, an alarm shall be raised to alert the operator and the bipole and pole controls shall maintain the prevailing power transfer until the operator intervenes. Provision shall be made to allow a ramp to minimum power and controlled shut down.

For a bipole design, the control system shall freeze the previous orders from the station controls until the operator intervenes. In the same manner, failure of both duplicated controls at the bipole level shall cause an alarm to be raised and the previous orders from the bipole controls shall be latched at pole level until operator intervention. Provision shall be made to allow a ramp to minimum power and controlled shut down.

3.2.14 Automatic Pole Switching

Where a bipole design is used, the Automatic Pole Switching function shall be provided to re-configure bipole operation into Monopole operation when one of the poles is tripped.

3.3 Manual Operation

Informative: the manual operation is mainly intended for test purposes and emergency operation.

3.3.1 Starting, Stopping and Regulation of the DC Transmission

It shall be possible manually to start up and shut down the whole DC-power transmission. The manual control mode is mainly intended for tests and maintenance but shall also permit operation of the link in case of loss of the telecommunication between the converters. For this purpose a tracking function shall allow slow ramping of power on the HVDC link.

A manual start against an open end at the other converter station shall as far as possible be avoided through interlocks.

3.3.2 Open Converter/Line Test Modes

An open-line test arrangement shall be provided in the converter control system to enable voltage testing of the HVDC line/cable. From each of the two HVDC converters it shall be possible to make a controlled increase of the DC voltage from zero to 1.05 times the rated DC cable voltage against an open inverter.

This shall be done without risk for reflection in the open end, resulting in unacceptable cable voltage levels. The open-line test shall also be possible without the HVDC cable connected. This Function shall only be available in the local control room.

Informative: the following protections will need to be sensitised or desensitised as no current should flow through the converter during this test:

a) *AC>DC Differential*

The DC signal input need to be set to zero to sensitise the protection during Open Circuit Test Mode.

b) *AC Over-Current Protection*

As no current flow through the converter during the test this protection will need to be sensitised by shifting IDMT characteristic down to a new pick-up level.

c) *DC Over-Current Protection*

As no current flow through the converter during the test, this protection will need to be sensitised by shifting IDMT characteristic down to a new pick-up level.

d) *DC Differential protection*

This protection needs to be sensitised when Open Circuit Test Mode is selected to protect against flashovers.

e) *DC Line Fault protection*

This protection needs to be sensitised to enable persistent DC line faults to be detected during open circuit test mode

f) *DC Under-Voltage Protection*

-Inhibited.

g) *DC Under-Current Protection*

-Inhibited.

3.4 SCADA Functions

A SCADA system shall be provided for the HVDC converter station.

Manual Control

All the CBs and disconnectors shall be provided with open and close controls that can be initiated from any control points.

It shall be possible to manually tap converter transformers at all the control points

3.4.1 Controls, Indications and Alarms

All the specified manual control and automatic functions shall be provided with IN/OUT selection facilities at LCPs, SCPs and pre-defined RCPs via the converter Station SCADA System.

All CBs and disconnectors within a HVDC converter station shall have double point indications to show “Open”, “Close” and “D.B.I” status which shall be alarmed.

Each specified function shall provide alarms and indications as appropriate, to the associated LCPs, all the SCPs and RCPs, including but not limited to:

a) All the control selections & indications

b) Controls and indications of all circuit breakers, disconnectors and earth switches

c) Circuit breaker, transformer, disconnector, filter, fixed reactive compensation, Dynamic Reactive Compensation and instrument transformer plant alarms & condition monitoring data.

d) Control mode status

e) Pole status

f) Valve cooling system status

g) Converter transformer tapchanger position indications.

h) AC current, voltage, power and reactive power per pole

i) AC system overall power and reactive power and frequency

j) AC filter & Dynamic Reactive Compensation reactive power

k) DC current, voltage magnitude and polarity

l) Earth current

m) Rectifier delay angle

n) Inverter extinction angle

o) Station auxiliary systems e.g. fire, environmental, security as well as other domestic services.

Informative: The alarms and indications that are to be provided as per this TS and other relevant functional specifications.

For alarm handling (local, remote and grouping information), refer to the Generic Equipment Model (GEM).

Protection operation or failure shall annunciate through the substation alarm & event logging system.

The following protection output alarms shall be provided;

a) Protection operated alarm for each electrical and mechanical protection.

b) Trip relay operated indication (where required).

c) Protection supply supervision alarm for each fused supply.

If the protection equipment is of the static (analogue or digital) type, an alarm output of equipment inoperative shall be provided for the loss of DC auxiliary energising supply and internal relay failures.

All MCB operations shall be correctly alarmed, and shall not trip the system unnecessarily.

Each function shall provide information that can be accessed via a communications port (Informative interface).

3.4.2 Time Synchronisation

Each function shall be provided with a substation time reference which shall be based on GPS.

All events and alarms generated by the control system and external input signals (events and alarms) to the control system shall be stored in the control and protection system. All recordings and messages shall be given with a real time stamp. Correct time tagging shall be ensured.

The accuracy and resolution of the time tagging shall at least be 1 ms. The station master clocks of both HVDC converters shall be synchronised. In case of loss of synchronisation, the station master clocks shall continue operation with the internal crystal with an accuracy of 1 ppm.

3.4.3 Interlocking

An Interlocking function shall be provided to ensure safe operation of the AC and DC switchgears within a converter station.

3.4.4 Sequential Isolation

HVDC system shall be provided with disconnector sequential isolation where required. The contract will state if this is required.

3.4.5 Synchronising

The AC system of an HVDC converter station shall be provided with check synchronising and system synchronising functions as necessary.

The AC VT shall provide a voltage input (incoming voltage) to the Synchronising functions mentioned.

3.4.6 Voltage Selection

The AC VT shall provide inputs to the substation voltage selection function.

The converter substation AC voltage selection function shall provide a voltage reference input (running voltage) that represents the voltage of the busbar to which the HVDC is selected to for the Synchronising functions.

3.4.7 Ferro-resonance Detection and Quenching

Ferro-resonance detection and quenching facilities shall be provided. Where required, an F4 ferro-resonance scheme shall be provided unless otherwise specified.

3.4.8 Phases Unbalanced Detector

A phase unbalanced detector function shall be provided to the AC system to initiate an alarm for a sustained unbalanced load current.

3.4.9 AC CB Pole Discrepancy Tripping

AC CB pole discrepancy tripping function shall be provided for the AC CBs.

Informative: Pole discrepancy has traditionally been known as 'phases not together' within the UK electricity supply industry.

3.4.10 Instrument Transformers supervision

Functions which use signals from VTs shall be provided with a VT supervision function.

The VT supervision function shall initiate an alarm on VT failure.

3.4.11 Interfacing with Special Protection and Operational Tripping Schemes

The converter station control systems shall provide interfaces to AC network special protection and operational tripping schemes (SPS/OTS).

On receipt of commands from the SPS/OTS, an HVDC control system shall be capable of taking the actions including but not limited to (subject to the Contract):

a) Converter block

b) Converter De-block

c) Converter ramp up/down at a pre-defined rate to a pre-defined set point

d) Enable/disable/modify POD control

e) Enable/disable/modify SSR control

3.5 Communications

Where communication is required for an HVDC control, duplicated channels shall be provided to ensure no single failure shall result the loss of communication between two converters.

Standard IEC communication protocols such as the IEC 60870-5-101, the IEC60870-5-104 and IEC61850 shall be used for the local and remote communications for an HVDC system.

All the communication channels for protection and control systems shall be supervised and alarm if they become faulty.

3.6 Metering

Operational metering functions shall be provided to give indications to the SCADA of:

a) AC system Voltage

b) AC active and reactive power

c) Harmonics as appropriate

If required, Settlement metering functions shall be provided

3.7 Recording & Monitoring

3.7.1 Fault Recording

Fault recording shall be provided for both AC and DC system within a HVDC converter station.

3.7.2 Quality of Supply Monitoring

Quality of supply monitoring function shall be provided as appropriate.

3.7.3 Cable Monitoring

The control system shall integrate measurement and status signals from the cable condition monitoring function.

3.8 Test Facilities

3.8.1 Test / Normal Facility

A Test / Normal facility shall be provided by means of a ‘lockable’ selector switch for each IED. When in the “Test” position the following shall apply;

a) Isolate the initiation of converter blocking sequence

b) Isolate the Tripping functions

c) Disable the DTT Send function (if applicable)

d) Generate alarm(s) when in the “Test” position for each affected protection function

Informative: ‘Lockable’ shall be by means of a unique key or padlock facilities to accept a 5mm diameter and 30mm hasp.

3.8.2 Routine Protection Operation Test Facility

A secure Routine Protection Operation test facility shall be provided to initiate the tripping of the main CB(s) from the all the main protection by simulating internal faults. The facility shall initiate tripping, I/T, DAR (if applicable), Auto-Switching (if applicable), CBF, fault recorders, blocking converter sequence etc.

3.9 Auxiliary Supply

Two independent 110V DC battery systems shall be provided.

Power Supply Supervision

All the control and protection cubicles shall be provided with power supply supervision.

4 PERFORMANCE REQUIREMENTS

4.1 General

All the HVDC protection and control functions shall perform correctly in accordance with the requirements of this specification, and RES Technical Specifications, for the range of power system conditions specified in TS1 (RES) and the range of environmental conditions specified in TS 3.24.15 (RES).

The performance of the protection shall not be adversely affected by the worst conditions of magnetising inrush, current transformer saturation or harmonics.

4.1.1 Minimisation of Non-Characteristic Harmonics

The control system shall be designed to minimise the generation of non-characteristic harmonic currents.

4.1.2 Failure of Telecommunications

All the communications facilities for automatic control of the HVDC system shall be duplicated and functionally independent. The channels shall be continually supervised providing annunciation of degradation or failure to all control points.

Any telecommunication failure shall not cause any unintentional operation of the control system. If the telecommunication link between the MASTER converter control system and corresponding remote control centre breaks down during remote operation, the initiated orders shall be completed. The operators shall have the possibility to switch MASTER converter station to the other one for normal operation during such failure on the telecommunication link.

When the telecommunication link is re-established, the normal control of the power transmission shall automatically be re-established. All alarms and indications issued in the HVDC converter during the failure shall be transmitted in chronological order to the control centre.

An HVDC link operation shall not deviate from its operating point in the event of total failure of the communications channels.

The supplier shall declare the limitations of the operation of the HVDC link and loss of functionality in the event of total communications system failure. The supplier shall also detail the required manual actions to maintain normal operation, effect start-up and shutdown sequences, change control modes, modify set-points and operating parameters under this circumstance.

All the equipment shall be resilient to the partial and/or total failure of hardware. Appropriate alarms shall be generated when the failure(s) detected.

5 FORMS AND RECORDS

TS 3.24.90.A Function Integration Table

PART 2 - DEFINITIONS AND DOCUMENT HISTORY

6 DEFINITIONS

The definitions in BSEN 60633: 1999 apply to this specification.

CB	Circuit Breaker
CBF	Circuit Breaker Fail
CT	Current Transformer
CTS	CT Supervision
DAR	Delayed Auto-Reclose
DTT	Direct Transfer Trip
EIDMT	Extremely Inverse Definite Minimum Time
ENCC	Electricity Network Control Centre
IED	Intelligent Electronic Device
HV	High Voltage
IDMT	Inverse Definite Minimum Time
I/T	Inter-Trip
LV	Low Voltage
MC	Mesh Corner
POD	Power Oscillation Damping
OC	Over Current
SCS	Substation Control System
TS	Technical Specification
CSC	Current Sourced Converter
VSC	Voltage Sources Converter

7 AMENDMENTS RECORD

Issue	Date	Summary of Changes / Reasons	Author(s)	Approved By (Inc. Job Title)
1	February 2014	First issue		

8 IMPLEMENTATION

8.1 Audience Awareness

Audience	Purpose Compliance (C) / Awareness (A)	Notification Method Memo / letter / fax / email / team brief / other (specify)

8.2 Training Requirements

Training Needs N/A / Informal / Workshop / Formal Course	Training Target Date	Implementation Manager

8.3 Procedure Review Date

5 years from publication date.

PART 3 - GUIDANCE NOTES AND APPENDICES

9 REFFERENCES

TS 1(RES) Ratings and General Requirements for Plant, Equipment and Apparatus for the NGT System and Connection Points To It

TS 3.24.15 (RES) Environmental and Test Requirements for Electronic Equipment

TS 3.24.34 (RES) Busbar Protection

BS EN 50328: 2003 Semiconductor converters. General requirements and line commutated converters. Specification of basic requirements

IEC 60146-1-2 Semiconductor converters – General requirements and line commutated converters - Part 2: Application guide

BS EN 50329: 2003 Semiconductor converters. General requirements and line commutated converters. Transformers and reactors

BS EN 60146-2: 2000 Semiconductor converters – Part 2: Self commutated semiconductor converters including direct d.c. converters

BS EN 60700-1: 1998 + A2: 2008 Thyristor valves for high-voltage direct current (HVDC) power transmission. Electrical testing

BS EN 60633: 1999 Terminology for high-voltage direct current (HVDC) transmission

IEC/TR 60919-1 Performance of HVDC systems with line commutated converters – Part 1: Steady state conditions

PD/IEC/TR 60919-2 Performance of HVDC systems with line commutated converters – Part 2: Faults and switching

IEC/TR 60919-3 Performance of HVDC systems with line commutated converters – Part 3: Dynamic conditions

BS EN 62501: 2009 Voltage Sourced Converter (VSC) valves for high-voltage direct current HVDC power transmission – Electrical testing

IEC/PAS 61975 System tests for HVDC installations

DD/IEC/PAS 62001: 2004 Guide to the specification and design evaluation of a.c. filters for HVDC systems

DD/IEC/PAS 62543: 2008 DC transmission using Voltage Sourced Converters (VSC)

DD/IEC/PAS 62544: 2008 Active filters in HVDC applications

BS EN 61378-2: 2001 Converter transformers. Transformers for HVDC applications

BS EN 60076-10: 2001 Power transformers. Determination of sound levels

BS IEC 60747-6: 2000 Discrete semiconductor devices and integrated circuits. Thyristors

Engineering Recommendation (Er) G5/4 Levels Of Harmonic Distortion.

APPENDIX A - FUNCTION INTEGRATION TABLE

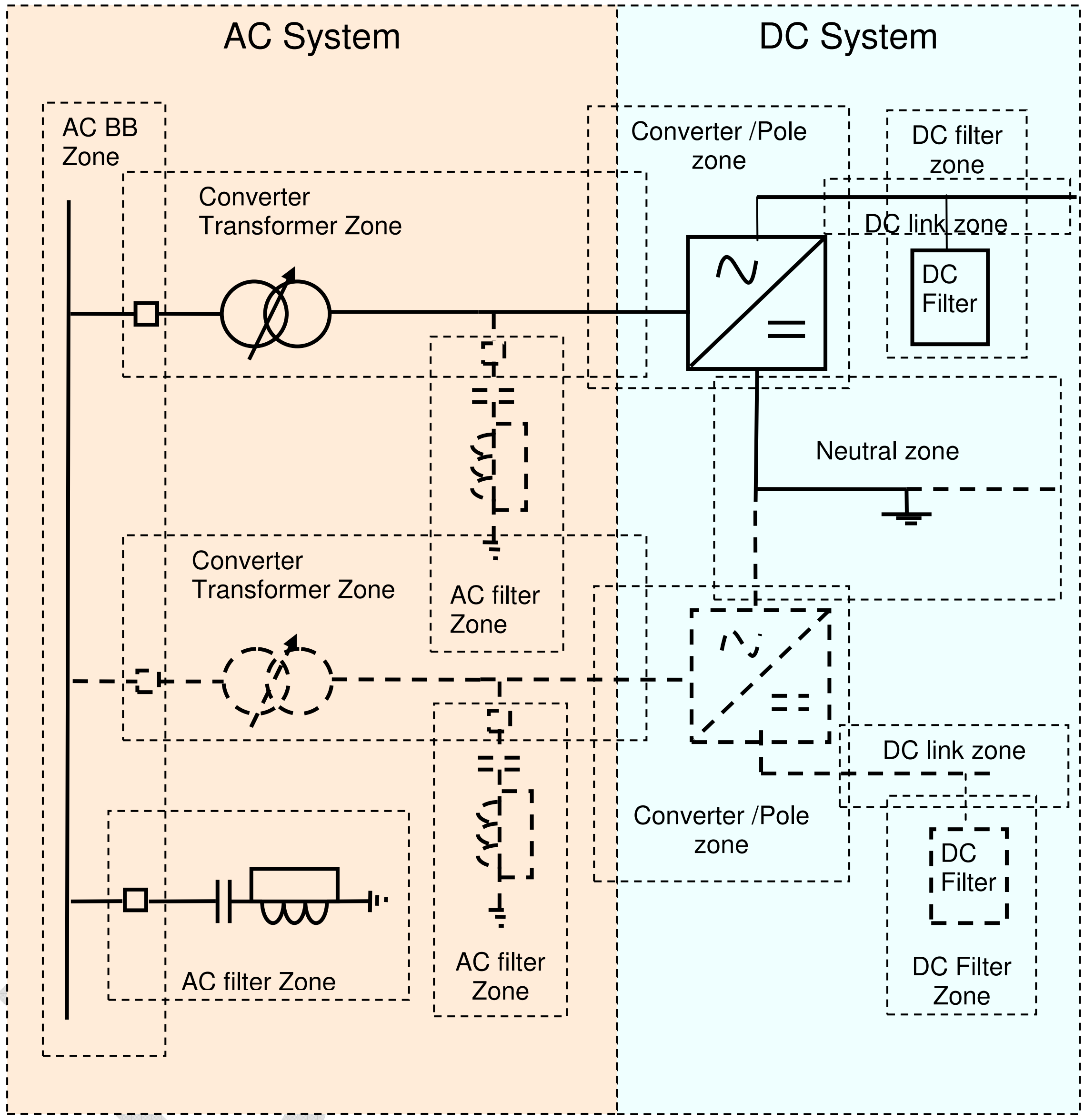
FUNCTION DESCRIPTION	BOX 1	BOX2	BOX3	BOX4	BOX5	BOX6
PROTECTION FUNCTIONS						
AC Busbar Zone Protection						
Double Busbar arrangement						
Mesh Corner Arrangement						
Converter Transformer Zone Protection						
Converter Transformer Protection						
Tapping Sequence Protection						
DC Converter/Pole Zone Protection						
Asymmetry Protection						
Pole Differential Protection						
DC Overcurrent						
AC>DC Differential						
DC>AC Differential						
AC Overcurrent						
AC Overvoltage Line Side						
AC Overvoltage Valve Side						
AC Undervoltage						
DC Undercurrent Protection						
Tap Limits Protection						
Thermal Protection						
Neutral Zone Protection						
Common Neutral Area Protection						
Neutral Bus Overvoltage Protection						
Neutral Bus Grounding Switch (NBGS) Protection						
Neutral Bus Switch Protection						
Electrode Line Fault Detector						
Neutral Current Unbalance						

FUNCTION DESCRIPTION	BOX 1	BOX2	BOX3	BOX4	BOX5	BOX6
Metallic Return Earth Fault Protection						
Metallic Return Transfer Breaker (MRTB) Protection						
Ground Return Transfer Switch Protection						
NBGS Overcurrent						
Electrode Line Balance Protection						
Electrode Line Overload						
Neutral/Earth Overcurrent						
HVDC Transmission Link Zone Protection						
DC Line Fault						
Cable Pair Sharing Protection						
Cable Balance Protection						
Cable Overcurrent						
DC Under-Voltage						
DC Over-Voltage						
DC Filter Overload						
Harmonic Filter Zone Protection						
Overall Protection						
Overcurrent Protection						
Capacitor Protection						
Reactor Thermal Overload Protection						
Resistor Thermal Overload Protection						
Resistor Open Circuit Protection						
DC Smoothing Filter Zone protection						
Valve & Ancillary System Protection						
Valve Unit Protection						
Converter Cooling Plant Protection						
Valve Hall Fire Detection Protection						
Valve Hall HVAC System						

FUNCTION DESCRIPTION	BOX 1	BOX2	BOX3	BOX4	BOX5	BOX6
Circuit Breaker (CBF) Fail Protection						
Converter Blocking Fail Protection						
Voltage Transformer Gas and Oil Actuated Protection						
CONTROL FUNCTIONS						
Control Systems						
Control Points						
Control Point Selections						
Test and Operation mode for Remote Control						
Dispatch Controls						
Converter Control Modes						
Start-Up and Shut-Down of HVDC transmission						
PV Control						
PQ Control						
Frequency Control						
Power Ramping						
Power Reversal						
Pole Balance Control						
Reactive Compensation and Harmonic Filter Control						
Emergency Power Control/Power Demand Override						
Power Oscillation Damping						
Sub Synchronous Resonance (SSR) Damping						
Change Over Mechanism						
Automatic Pole Switching						
Manual Operation						
Starting, Stopping and Regulation of the DC Transmission						
Open Converter/Line Test Modes						
SCADA Functions						
Manual Control						

FUNCTION DESCRIPTION	BOX 1	BOX2	BOX3	BOX4	BOX5	BOX6
Controls, Indications and Alarms						
Time Synchronisation						
Interlocking						
Sequential Isolation						
Synchronising						
Voltage Selection						
Ferro-resonance Detection and Quenching						
Phases Unbalanced Detector						
AC CB Pole Discrepancy Tripping						
Instrument Transformers supervision						
Interfacing with Special Protection and Operational Tripping Schemes						
Communication Supervision						
Metering						
Operational Metering						
Settlement Metering						
Recording & Monitoring						
Fault Recording						
Quality of Supply Monitoring						
Cable Monitoring						
Test Facilities						
Routine Protection Operation Test Facility						
Test / Normal Facility						
Power Supply Supervision						

APPENDIX B - AN EXAMPLE OF AN HVDC SYSTEM ARRANGEMENT



ANCILLARY SERVICES BUSINESS MONITORING

This document is for Relevant Electrical Standards document only.

PURPOSE AND SCOPE

This document details the functional and performance requirements for Ancillary Services Business Monitoring (ASBMON).

Equipment topologies other than those proposed in this specification are acceptable where such solutions can be demonstrated by the supplier to meet the overall functional and performance requirement specified herein.

PART 1 – PROCEDURAL

1 FUNCTIONAL AND PERFORMANCE REQUIREMENTS

1.1 General

1.1.1 ASBMON is the current system used to collect data from generators selected by the Electricity National Control Centre (ENCC) for frequency response to determine their performance against their contract for frequency response provision.

1.1.2 Access to system data, parameter settings and the configuration of equipment shall be via a secure network connection

1.1.3 ASBMON system shall comprise:

a) A data acquisition unit.

b) Data storage

1.1.4 The Data Acquisition Units shall have at least 1 x Ethernet ports, 1 x internal 56K modem, 1 x Generator Response Data Output (GRDO) RS232 port, and 1 x USB port

The USB port or a second Ethernet port shall be utilised to update the firmware locally and provide access to system configuration locally.

1.2 Inputs

1.2.1 The following inputs shall be provided as a minimum.

- 1 x GRDO RS232 port (if signal is derived from OMS)
- 3 x analogue current (if input is derived directly from Instrument Transformers)
- 3 x Analogue voltage (if input is derived directly from Instrument Transformers)

1.3 Time Keeping

1.3.1 Time keeping shall be derived from the Operation Metering Summator or Network Timing Protocol via Ethernet.

1.4 Continuous Time Series Data

1.4.1 All data acquired by the Data Acquisition Unit shall be continuously stored.

1.4.2 The storage rate shall be capable of at least 1 sample per second, with an overall accuracy of +/- 0.5 seconds if derived from OMS, or 2 samples per second with an overall accuracy of +/- 1% if derived from transformer HV Instrument Transformers.

1.4.3 Non-volatile static memory shall be provided for storage of a minimum of 28 days data, prior to overwriting on a first in first out basis.

Informative: Overall accuracy refers to the accuracy of the ASBMON unit, not the overall system accuracy.

1.5 Parameters to be measured as Continuous Time Series Data

1.5.1 System Frequency

- This shall be derived from the GRDO if using an OMS inputs, or number of cycles if using analogue input.

1.5.2 Active Power

- The accuracy of all power values shall be +/- 2.5% or better.

1.5.3 Reactive Power (if using analogue input)

- The accuracy of all power values shall be +/- 2.5% or better.

2 DATA & USER REQUIREMENTS

2.1 Software and Firmware

2.1.1 ASBMON firmware shall be available to NG free of charge and on an as required basis to enable upgrade activities.

2.2 Client User Interface

2.2.1 Informative: *The normal mode of operation will be for NGET engineers to have direct access to data for viewing and analysis, via a web browser interface.*

2.2.2 The data required for display shall be selectable from any Data Acquisition Unit on the system.

2.2.3 All data selected for display shall be clearly identified by its source.

2.2.4 The units of time shall be appropriate to the period selected for display.

2.2.5 Export of data should be in a range of common formats such as .CSV, .XLS, .MDB

2.3 Communication Architecture

2.3.1 Each Data Acquisition shall have the capability to independently sense, acquire and store data and then to transfer the data via a LAN to the master substation server

2.3.2 If data is stored on a central server, the central server shall collect all the data from the remote Data Acquisition Units on a pre-determined regular interval, with the option to access the data on request.

2.3.3 The data should then be accessible to NGET by web browser.

3 HARDWARE PLATFORMS

The following applies to all hardware items, as appropriate to the equipment item.

3.1.1 Hardware platforms used within a substation environment shall comply with the requirements of TS 3.24.15 (RES).

3.1.2 The following Status Outputs shall be provided

a) Equipment healthy.

b) Out of service mode.

3.2 CT and VT Inputs

3.2.1 The nominal value of CT inputs (In) shall be 1 amp.

3.2.2 The nominal value of VT inputs (Vn) shall be 110 V / √3.

4 CONTRACT SPECIFIED OPTIONS

None.

5 OTHER REQUIREMENTS

5.1.1 The calibration period over which performance requirements are met shall be defined.

6 TEST REQUIREMENTS

6.1 General

6.1.1 The requirements of TS 3.24.15 (RES) shall apply. For the purposes of electrical environmental tests all equipment shall be classified as “substation equipment”.

6.1.2 During and after all environmental tests, all equipment shall meet with the requirements of this specification. No additional derogation is given for influence quantities.

6.1.3 Performance requirements are inclusive of the effects of all external accessories e.g. current shunts and current transformers.

6.1.4 All equipment shall be CE marked, suited for application in an industrial environment

7 FORMS AND RECORDS

Not applicable

PART 2 - DEFINITIONS AND DOCUMENT HISTORY

8 DEFINITIONS

CT	Current Transformer
DAU	Data Acquisition Unit
GPS	Global Positioning System
LAN	Local Area Network
Vn	Nominal input voltage
In	Nominal input current
VT	Voltage Transformer

9 AMENDMENTS RECORD

Issue	Date	Summary of Changes / Reasons	Author(s)	Approved By (Inc. Job Title)
1	Feb 2014	First Issue		

10 IMPLEMENTATION

10.1 Audience Awareness

Audience	Purpose Compliance (C) / Awareness (A)	Notification Method Memo / letter / fax / email / team brief / other (specify)

10.2 Training Requirements

Training Needs N/A / Informal / Workshop / Formal Course	Training Target Date	Implementation Manager

10.3 Compliance

None

10.4 Procedure Review Date

3 years from publication date.

PART 3 - GUIDANCE NOTES AND APPENDICES

11 REFERENCES

11.1 National/International Standards

IEC 61000	Electromagnetic Compatibility

11.2 National Grid Documents

TS 3.24.15 (RES)	Environmental and test requirements for the hardware units
TS 3.02.04 (RES)	Current Transformers for Protection and General Use

BACK-UP PROTECTION GRADING ACROSS NETWORK OPERATOR INTERFACES

This document is for Relevant Electrical Standards document only.

PURPOSE AND SCOPE

This Policy defines protection grading at interfaces between NGET and Network Operators to ensure that adequate discrimination of NGET back-up protection with that of Network Operators is achieved.

This Policy applies to the Network Operators overcurrent and earth fault protections and it sets out the protection settings requirements which when applied, will ensure compliance with The Grid Code requirements on protection discrimination.

PART 1

a) Protection settings, and other information, which are to be used for protection grading purpose, shall be exchanged between NGET and the Network Operators as required to ensure the secure and reliable operation of the combined networks.

b) When the required grading given in this document cannot be achieved, reference should be made to NGET.

1.1 Supergrid/132 kV Auto-transformers

1.1.1 Overcurrent protection on the outgoing feeders and transformers at 132 kV

a) Overcurrent protection shall be set to provide both current and time grading with NGET back-up overcurrent protection installed at incoming Supergrid/132 kV autotransformer 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 (outgoing feeder, transformer, reactor etc.) protection is smaller than the SGT overcurrent protection. In cases where overcurrent protection is also installed on the 132kV side of an auto-transformer, the DNO current setting shall be smaller than the lower of the HV and LV SGT 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 taking into account the following factors:

e) 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 3-phase fault level.

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

1.1.2 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 the NGET backup overcurrent (Stage 1 of the HV 2-Stage overcurrent protection), and with the SGT LV overcurrent protection, where installed. Grading shall be on a 1:1 basis.

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

c) See clause d), section 1.1.1, for the 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) NGETs policy is to set the 132 kV residually connected earth fault protection such that its operate time is not greater than 2.4 seconds for a 132kV single phase to earth fault at the transfomer LV terminals. The Network Operators earth fault protection on a feeder or transformer shall be set so as to provide adequate minimum grading margin with the SGT earth fault and overcurrent protection at the SGT maximum allowable single phase to earth let through fault. The grading shall be on a 1:1 basis.

1.2 Supergrid/66 kV or lower voltage double-wound transformers

1.2.1 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 SGT backup overcurrent protection installed at incoming Supergrid/66 kV Double-Wound Transformers on a 1:1 basis (See clause c, section 1.1.1, for current grading principle, clause d, section 1.1.1, for the time grading principle and clause e, section 1.1.1, for the minimum grading margin).

b) NGETs policy is to set Stage 1 of the 2-Stage HV overcurrent protection such that its operate time is not greater than 2.4 seconds for a 3-phase fault on the LV busbar/bushing. The Network Operators overcurrent protection on a feeder or transformer shall be set so as to provide adequate minimum grading margin with the SGT overcurrent protection at the SGT maximum allowable let through fault. The grading shall be on a 1:1 basis.

1.2.2 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 SGT 2-stage unrestricted earth fault protection (Standby Earth Fault) on the LV side of the transformer. (See clause d, section 1.1.1, for time grading principle and clause e, section 1.1.1, for the minimum grading margin).

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

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

1.3 Grading with the NGET owned 132kV or lower voltage bus sections and couplers

1.3.1 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 NGET overcurrent protection on the bus sections/couplers (see clause d, section 1.1.1, for the time grading principle and clause e, section 1.1.1, for the minimum grading margin).

b) Current grading shall be achieved to ensure that the current setting deployed on the Network Operators plant (outgoing feeder, transformer, reactor etc) protection is smaller than the overcurrent protection on the NGET 132 kV or Lower Voltage Bus Sections/Couplers.

c) The Network Operators current setting shall take into account relay and CT errors.

1.3.2 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 NGET earth fault protection on the bus sections/couplers (see clause d, section 1.1.1, for the time grading principle and clause e, section 1.1.1, for the minimum grading margin).

b) Current grading shall be achieved to ensure that the current setting deployed on the Network Operators plant (outgoing feeder, transformer, reactor, etc) protection is smaller than the current setting on the NGET 132 kV or Lower Voltage Bus Sections/Couplers. The current setting shall also be smaller than the current setting of the bus section/coupler overcurrent protection. The Network Operators current setting shall take into account relay and CT errors

1 FORMS AND RECORDS

Not applicable

PART 2 – DOCUMENT HISTORY

2 AMENDMENTS RECORD

Issue	Date	Summary of Changes / Reasons	Author(s)	Approved By (Inc. Job Title)
1	February 2014	New Document.		

2 IMPLEMENTATION

2.1 Audience Awareness

Audience	Purpose Compliance (C) / Awareness (A)	Notification Method Memo / letter / fax / email / team brief / other (specify)

2.2 Training Requirements

Training Needs N/A / Informal / Workshop / Formal Course	**Training Target Date**	**Implementation Manager**

2.3 Compliance

Text here.

2.4 Procedure Review Date

5 years from publication date.

PART 3 - GUIDANCE NOTES AND APPENDICES

3 REFERENCES

None

MANAGEMENT OF RISE OF EARTH POTENTIAL AT NEW AND REFURBISHED TOWERS

This document is for Relevant Electrical Standards document only.

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 earth potential rise (EPR).

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.

PART 1 – POLICY

1 POLICY STATEMENTS

The need for and design of mitigation measures to be applied to towers should be determined through consideration of predicted EPR 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] and BS EN 50522 [3].

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 NGET 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 (OFT). 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 NGET guidance documents, which are available on request.

PART 2 – DOCUMENT HISTORY

2 AMENDMENTS RECORD

Issue	Date	Summary of Changes / Reasons	Author(s)	Approved By (Inc. Job Title)
1	February 2014	New Document.		

1 IMPLEMENTATION

1.1 Audience Awareness

Audience	Purpose Compliance (C) / Awareness (A)	Notification Method Memo / letter / fax / email / team brief / other (specify)

1.2 Training Requirements

Training Needs N/A / Informal / Workshop / Formal Course	Training Target Date	Implementation Manager

1.3 Compliance

Text here.

1.4 Procedure Review Date

5 years from publication date.

3 REFERENCES

[1] BS EN 50341 Overhead Electrical Lines Exceeding AC 45kV 2002.

[2] EATS 41-24 Electricity Association Technical Specification 41–24. Guidelines for the design, Installation, Testing and Maintenance of Main Earthing Systems in Substations. 1992.

[3] BS EN 50522 Earthing of power installations exceeding 1kV a.c.

GUIDANCE FOR WORKING IN PROXIMITY TO LIVE CONDUCTORS - REDUCING THE RISKS

This document is for Relevant Electrical Standards document only.

TABLE OF CONTENTS

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 NGET. Following these guidelines does not, however, absolve the designers of their responsibilities for their design under CDM regulations.

PART 1 – GUIDANCE

1 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 NGET's National Health & Safety Standard NS-MP1]

2 DESIGN PRINCIPLES

2.1 It is essential that the Safety Distances (specified in the NGET's Safety Rules Handbook) to exposed live HV conductors are not infringed either deliberately or accidentally during any work activity.

2.2 In order to comply with 2.1 above, 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.

2.3 Designers must take account of relevant UK legislation, NGET's Safety Rules and relevant Technical Specifications (formerly NGTS's) when considering methods of performing work activities. The procedures defined in the NGET's National Safety Instructions (NSIs) must also be considered (although other procedures that meet the legal/Safety Rule requirements may be accepted at the discretion of NGET).

2.4 It is NGET 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.

2.5 In assessing what is reasonably practicable, designers may wish to use the ALARP (As Low As Reasonably Practicable) principle outlined in NGET's 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 NGET. Refer to Appendix A for application limitations.

2.6 Practically, it is impossible to eliminate exposed live HV conductors from a substation during work (with the exception of GIS substations). TS 2.1(RES) specifies the following maximum outage conditions:

The design of the substation shall permit installation, extension, operation and maintenance (preventive and corrective) with a maximum of one circuit (including any circuit requiring intervention) and one busbar section out of service simultaneously.

Informative: A section of busbar is taken to be a part of either the main or reserve busbars or a mesh corner. Associated busbar section and busbar coupler circuits may be considered to be part of the busbar section.

Substation designs shall be based on these requirements.

2.7 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.

2.8 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 Appendix A

3 DESIGN GUIDANCE FOR ACCESS FROM GROUND LEVEL OR PERMANENT PLATFORM

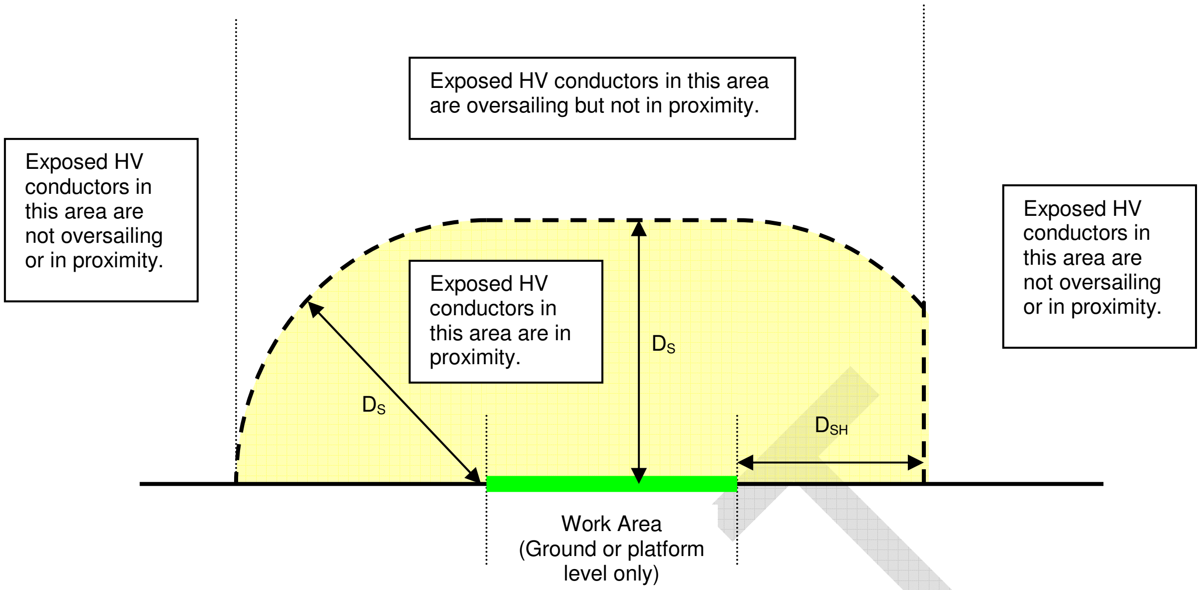
The design objective is to allow personnel to move freely around the substation at ground level and to safely use:

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 1) has been achieved from all exposed live conductors.

Conductors that are not in proximity but still oversail the work area shall be accepted by NGET (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 TS2.1 (RES).

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.

3.1 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).

3.2 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.

3.3 In areas where conductors in proximity cannot be eliminated then access shall be limited as specified in TS 2.1(RES) Clause 4.4. Such a limitation will not be accepted by NGET 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.

3.4 The use of mobile steps for operational access in substations is non-preferred. Where the use of such access is agreed by NGET, then the designer shall ensure that clearances (D_S)

as defined in Table 1 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.

4 DESIGN GUIDANCE FOR ACCESS BY TEMPORARY FIXED-HEIGHT PLATFORM

4.1 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.

4.2 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.

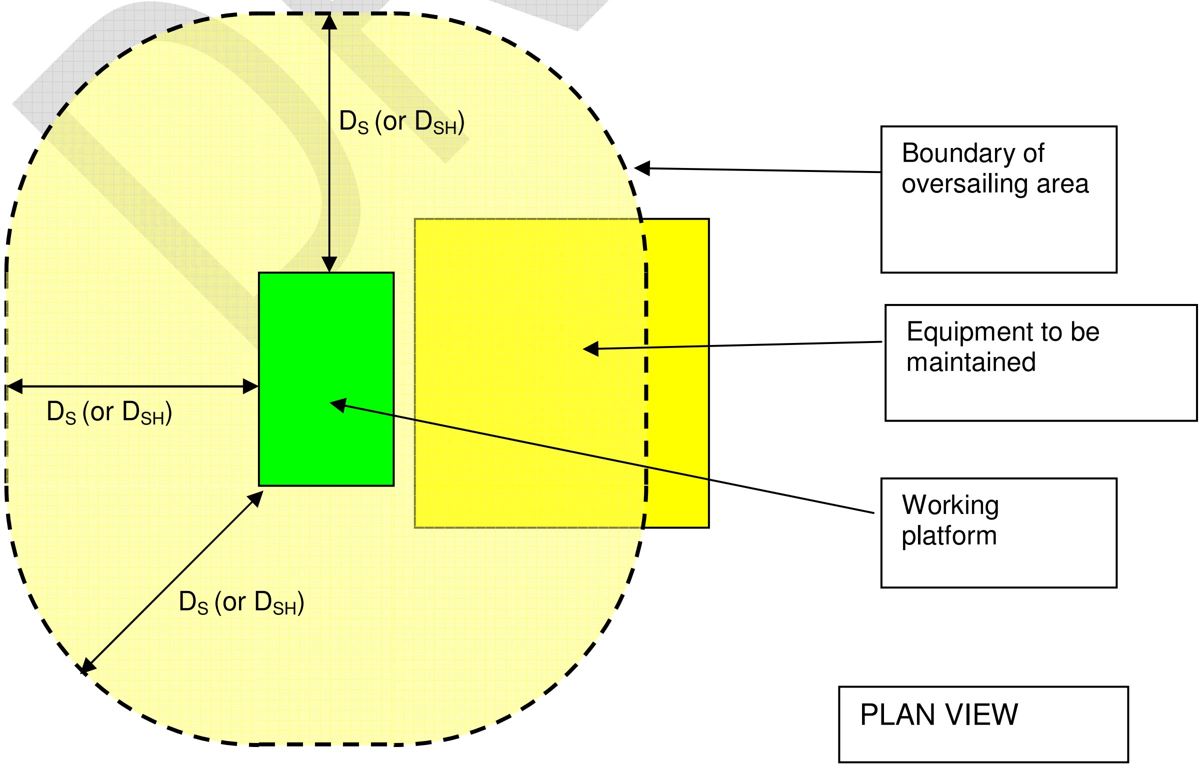
b) Plot an area around the platform with its perimeter measured D_S from the edge of the platform (where D_S is the design clearance for safety specified in Table 1 and in TS 2.1(RES)).

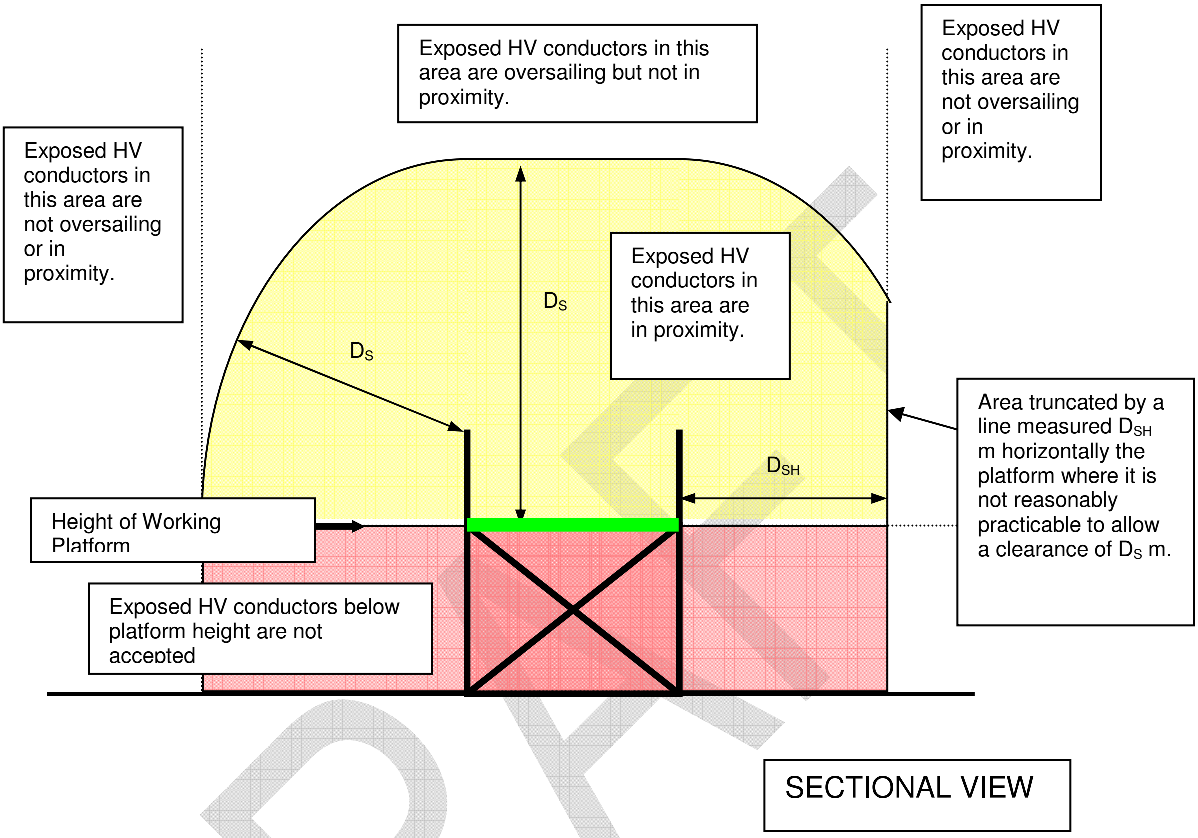
Note: The reduced horizontal design clearance for safety D_{SH} may be utilised in the substation design where the designer can demonstrate that it would not be reasonably practicable to incorporate the specified vertical clearance.

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 ≤ D_S (measured vertically or at any angle) from any part of the floor of the fixed-height platform will be considered a conductor in proximity.




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.
Exposed HV conductors in this area are in proximity.
Ds
Ds
DSH
Area truncated by a line measured DSH m horizontally the platform where it is not reasonably practicable to allow a clearance of Ds m.
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.

4.3 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.

4.4 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.

4.5 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.

5 DESIGN GUIDANCE FOR ACCESS BY MEWP

5.1 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, NGET 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.

5.2 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 D_A from the edge of the area (where D_A is the horizontal design clearance for safety specified in TS 2.1(RES) + 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.

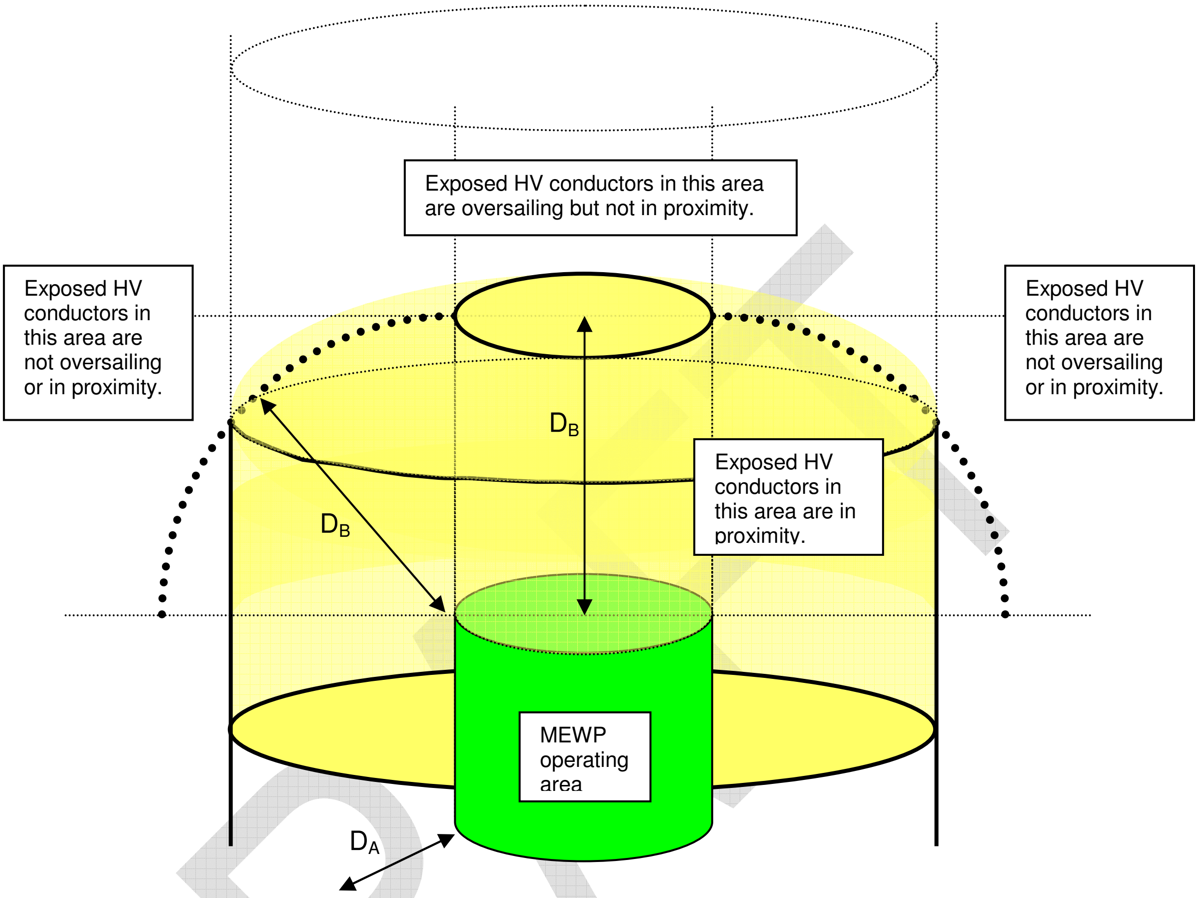
Note: Exposed conductors which are not live by virtue of the isolation procedures necessary to carry out the work activity are excluded from this definition.

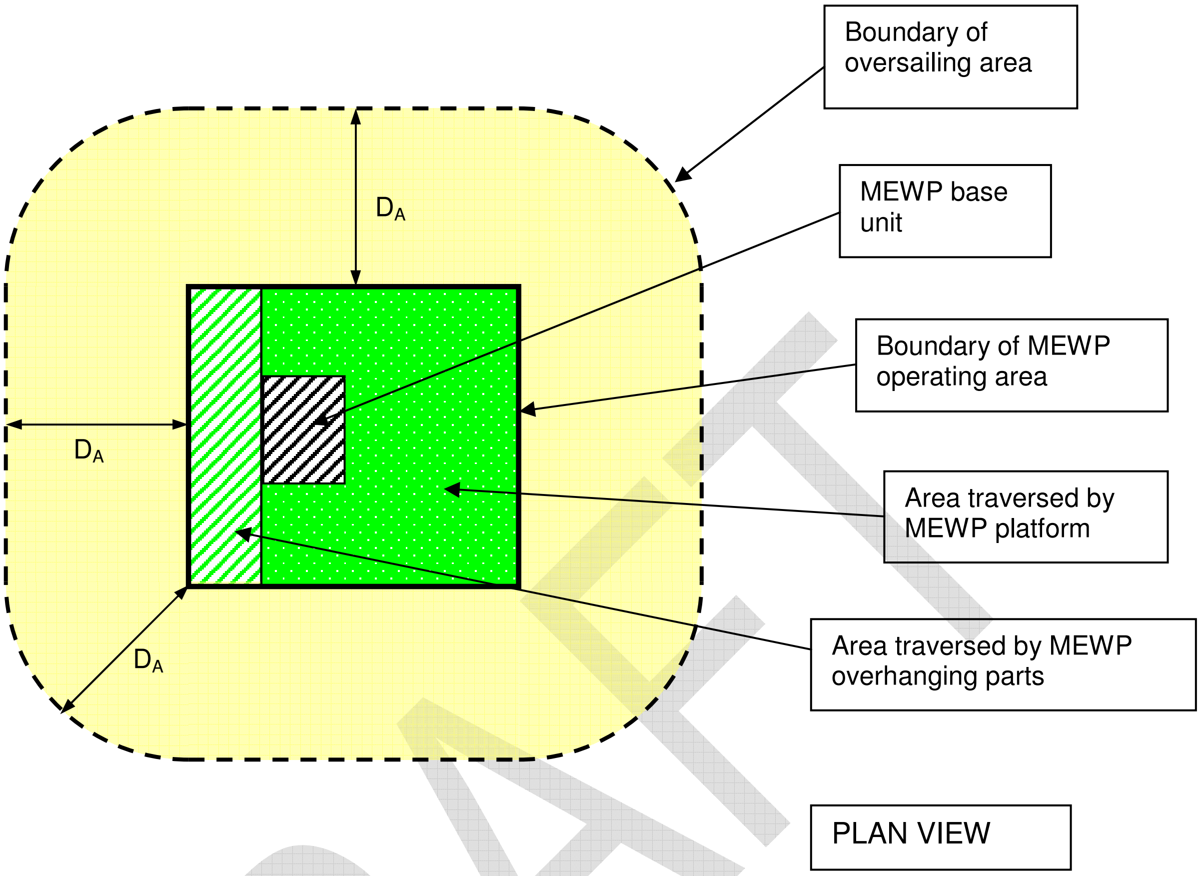
d) The vertical dimension of the MEWP operating area will be determined by the maximum height that the base of the MEWP platform is required to reach to carry out the work activity. Unless otherwise defined, this height will be taken to be the maximum height of the equipment being maintained.

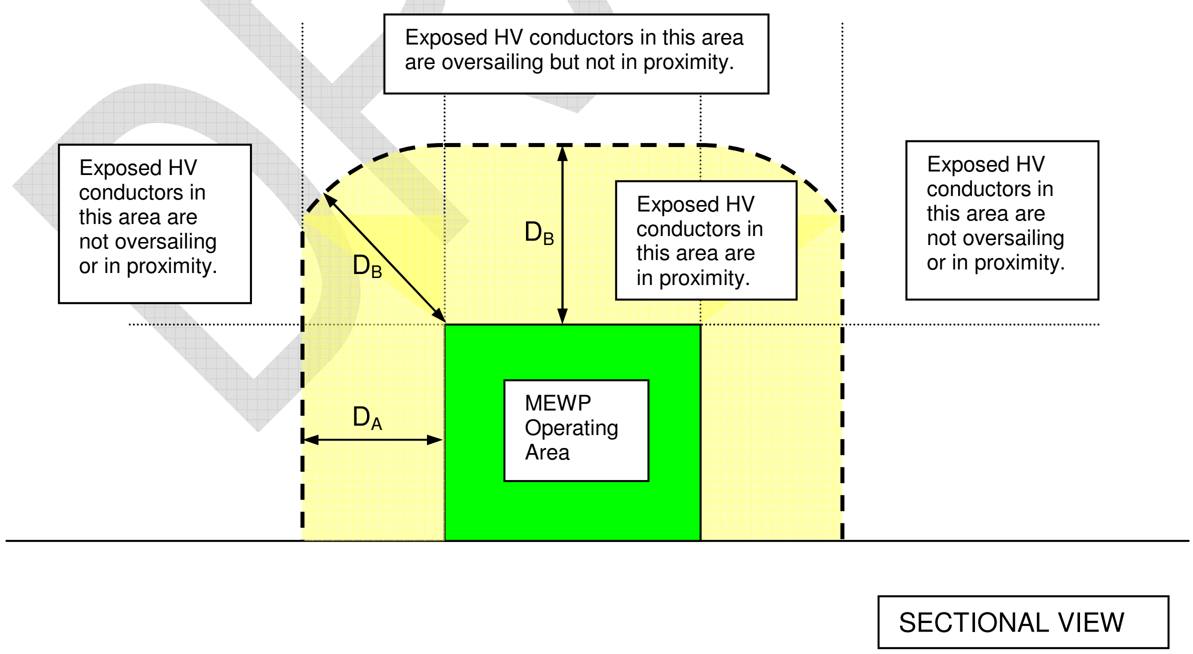
e) Any exposed HV conductor that crosses the zone at a distance $\leq D_B$ (measured vertically or at any angle) from any part of the MEWP operating area will generally be considered a conductor in proximity, (where D_B is the vertical design clearance for safety specified in TS 2.1(RES) + 2 m).

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 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.
DB
DB
Exposed HV conductors in this area are in proximity.
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


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 in proximity.
Exposed HV conductors in this area are not oversailing or in proximity.
DB
DB
DA
MEWP Operating Area
SECTIONAL VIEW

5.3 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 NGET, details of which can be obtained from NGET'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.

5.4 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.

5.5 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.

5.6 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.

6 FORMS AND RECORDS

Not applicable.

PART 2 - DEFINITIONS AND DOCUMENT HISTORY

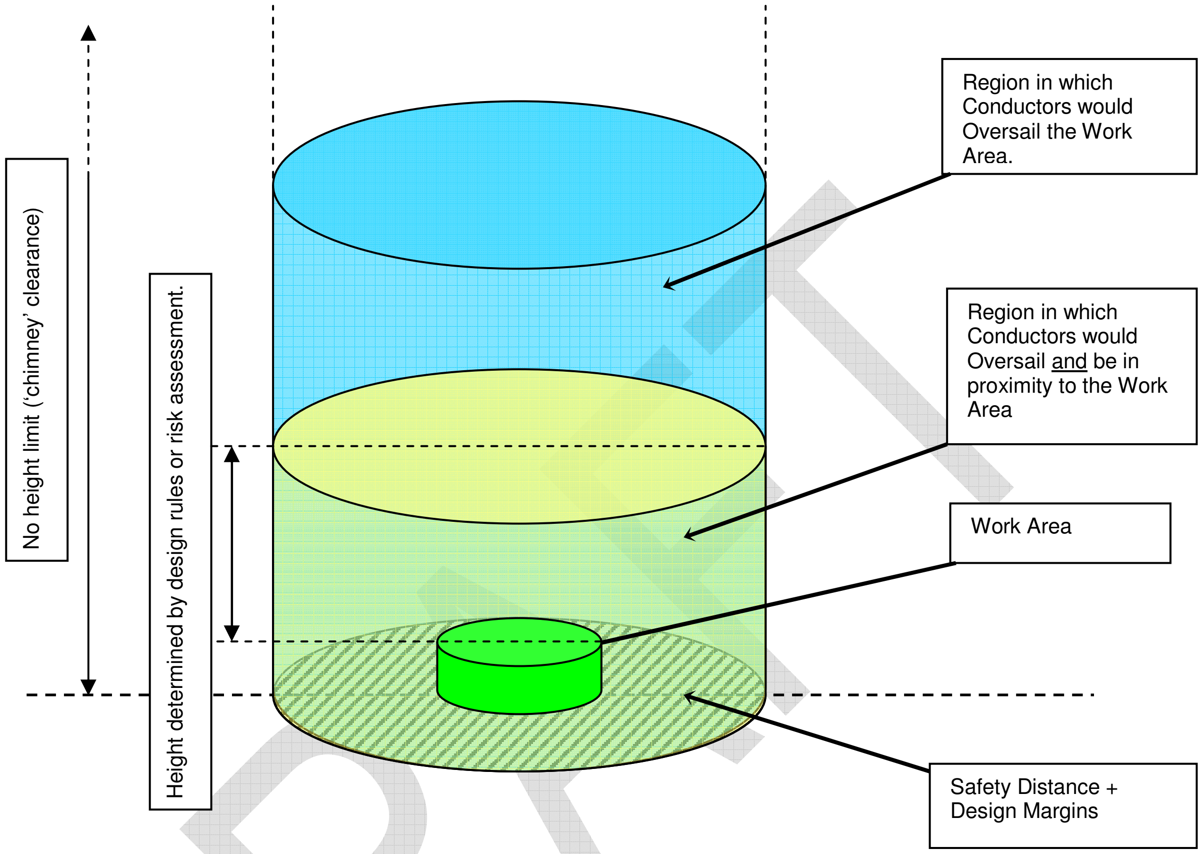
7 DEFINITIONS

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.

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.



7.3 Design Clearance for Safety (Vertical) [D_S]

The sum of the relevant Safety Distance (from the NGET's Safety Rules) and the maximum vertical reach of a person (taken to be 2.4 m) previously known as Section Clearance.

7.4 Design Clearance for Safety (Horizontal) [D_{SH}]

The sum of the relevant Safety Distance (from the NGET's Safety Rules) and the maximum horizontal reach of a person (taken to be 1.5 m).

Note: The horizontal reach dimension adopted in NGET substation design practice is 100 mm greater than that specified in BS7354.

7.5 Design Clearance for MEWP Operation (Horizontal) [D_A]

The sum of the relevant Safety Distance (from the NGET'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.

7.6 Design Clearance for MEWP Operation (Vertical) [D_B]

The sum of the relevant Safety Distance (from the NGET'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 NGET system voltages are tabulated in Table 1 below.

Nominal System Voltage (kV)	11/22/33	66	132	275	400
NGET 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 1 - Values of minimum clearances (mtrs) for NGET system voltages

***Informative: Values given above are based upon the Electricity Safety, Quality & Continuity Regulations 2002. TS 2.1(RES) 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.*

7.7 Non-Primary System Work

Any work in a substation which is not directly associated with equipment forming part of the NGET system.

8 AMENDMENTS RECORD

Issue	Date	Summary of Changes / Reasons	Author(s)	Approved By (Inc. Job Title)
1	February 2014	New document.		

9 IMPLEMENTATION

9.1 Audience Awareness

Audience	Purpose Compliance (C) / Awareness (A)	Notification Method Memo / letter / fax / email / team brief / other (specify)

9.2 Training Requirements

Training Needs N/A / Informal / Workshop / Formal Course	Training Target Date	Implementation Manager

9.3 Compliance

9.4 Procedure Review Date

3 years from publication date.

PART 3 - GUIDANCE NOTES AND APPENDICES

APPENDIX A - 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 NGET's	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 Section 3.	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 Section 3.	Oversailing conductors acceptable. For design guidance on eliminating conductors in proximity see Section 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 Section 5.

	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 Section 3.	Oversailing conductors are not acceptable except where it is not reasonably practicable to eliminate them. For design guidance on eliminating conductors in proximity see Section 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 Section 5.
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 TS 2.1(RES)	Required circuit outages must not exceed the maximum conditions as detailed in TS 2.1(RES)	Required circuit outages must not exceed the maximum conditions as detailed in TS 2.1 (RES)
	Oversailing conductors acceptable. For design guidance on eliminating conductors in proximity see Section 3.	Oversailing conductors are not acceptable except where it is not reasonably practicable to eliminate them. For design guidance on eliminating conductors in proximity see Section 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 Section 5.

	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 Section 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 Section 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 Section 6.

** Includes mobile steps, although they are non-preferred.

GUIDANCE FOR CONDUCTOR JOINTING IN SUBSTATIONS

This document is for Relevant Electrical Standards document only.

TABLE OF CONTENTS

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 in accordance with TS 3.1.2(RES) 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.

PART 1 – GUIDANCE

1 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.

Appendix A & B 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.

2 BOLTED JOINTS

2.1 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 Appendix A. 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.

2.2 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.

2.3 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.

2.4 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.

3 OTHER METHODS OF JOINTING

This section briefly describes jointing techniques, other than bolting, with an indication of their effectiveness, security and problems.

3.1 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.

3.2 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.

3.3 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 Transco (NGT).

3.4 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.

3.5 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.

4 SURFACES IN CONTACT

4.1 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 NGT 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 NGT.

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.

4.2 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 1.

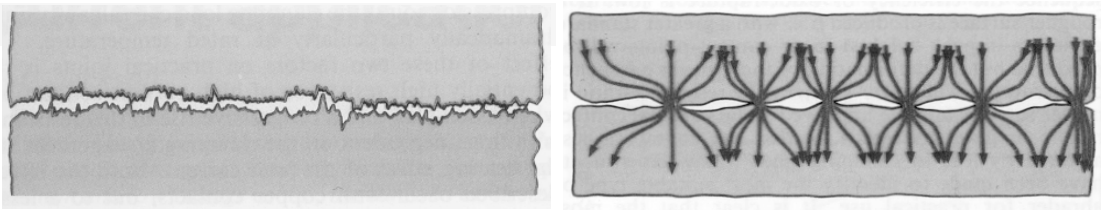


Figure 1 - Surfaces in Contact and Current Flow

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 2 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.

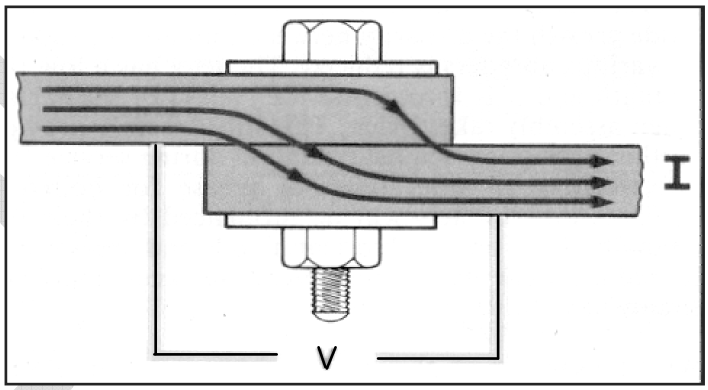


Figure 2 - Joint Resistance

4.3 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.

4.3.1 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 1, results in many small height peaks coming into contact and the plastic deformation of each peak is relatively small.

Figure 3 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.

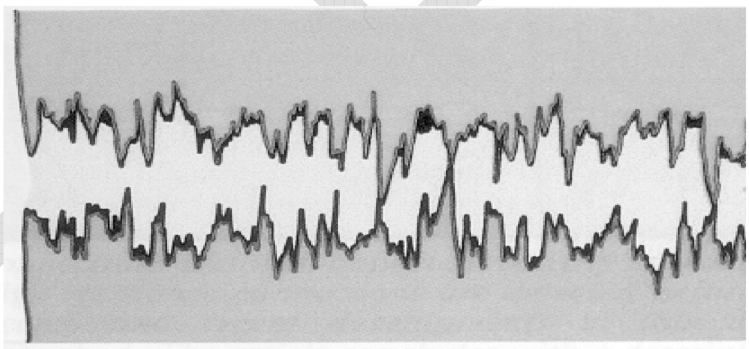


Figure 3 - Surfaces in Contact

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.

4.3.2 Clamping Pressure

Clamping pressure can be best achieved and maintained by using:

a) a larger number of small sized bolts (rather than a few large bolts)

b) a bolt material that minimises creep relaxation and relative thermal expansion

c) thick washers under the bolt head and nut

d) 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.

4.4 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.

5 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 4 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.

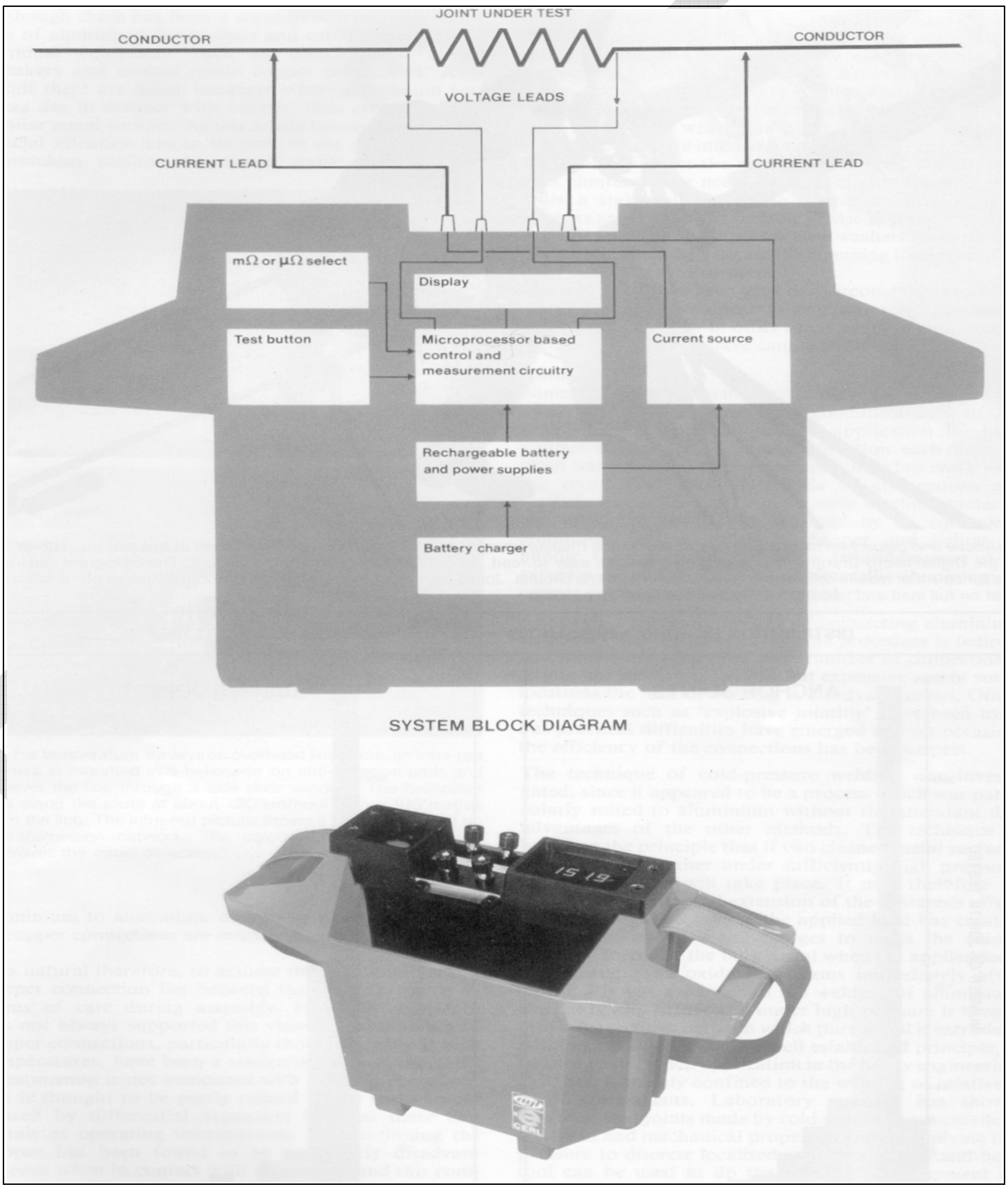


Figure 4 - A typical Digital Micro Ohmmeter (DMO)

6 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 5.

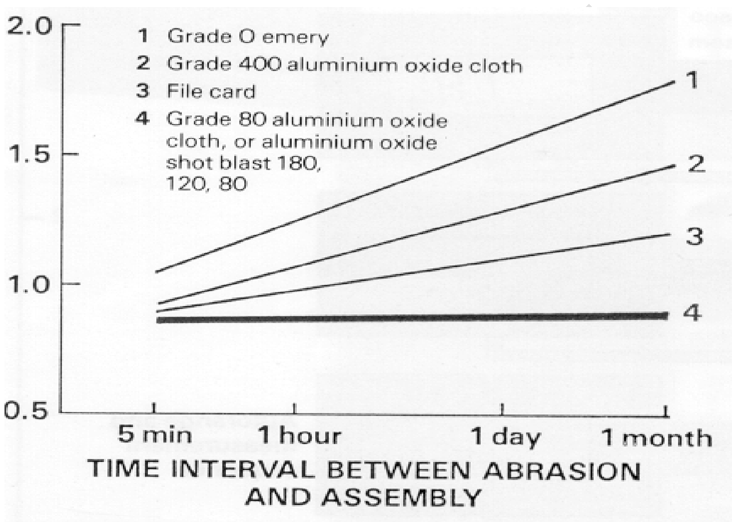


Figure 5 - Initial Resistance of Bolted Aluminium Joints

Figure 6 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 6 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.

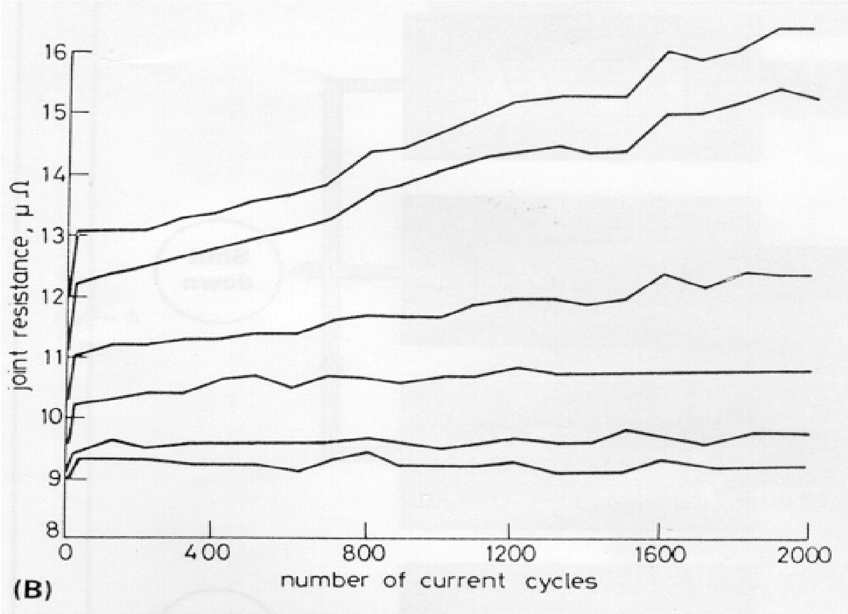


Figure 6 - Load Cycle Performance measurements of Bolted Aluminium Joints with differing initial contact resistances

7 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:

a) The clamping load is more uniformly distributed over the overlap area.

b) There is more strain energy in the clamping assembly which minimises loss in clamping load due to creep in service.

c) 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:

d) Total clamping load N (Newton per bolt x number of bolts) divided by current rating (kA) should be not less than 50 i.e. $N/A \geq 50$.

e) 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 1 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 1 - Bolting Guide for Aluminium Joints

8 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.

9 FORMS AND RECORDS

Not applicable

PART 2 - DEFINITIONS AND DOCUMENT HISTORY

10 DEFINITIONS

Not applicable.

11 AMENDMENTS RECORD

Issue	Date	Summary of Changes / Reasons	Author(s)	Approved By (Inc. Job Title)
1	February 2014	New document		

12 IMPLEMENTATION

12.1 Audience Awareness

Audience	Purpose Compliance (C) / Awareness (A)	Notification Method Memo / letter / fax / email / team brief / other (specify)

12.2 Training Requirements

Training Needs N/A / Informal / Workshop / Formal Course	Training Target Date	Implementation Manager

12.3 Compliance

How is compliance to this procedure going to be met?

12.4 Procedure Review Date

3 years from publication date.

PART 3 - GUIDANCE NOTES AND APPENDICES

13 REFERENCES

1 THOMAS, A.G. and RATA, P.J.H.: "Aluminium Busbar" (Hutchinson, 1960)

2 Aluminium electrical conductor handbook (The Aluminium Association, New York 1971)

3 JACKSON, R.L.: "Significance of surface preparation for bolted aluminium joints", IEE Proc. C, Gen., Trans. & Distrib., 1981, 128,(2), pp. 45-54

4 "Aluminium in contact with other materials", Information bulletin 21, The Aluminium Development Association, 1955

5 JACKSON, R.L.: "Electrical performance of aluminium/copper bolted joints", IEE Proc. C,

6 Gen., Trans. & Distrib., 1982, 129,(4), pp. 177-184

13.1 Subsidiary References

7 COPPER DEVELOPMENT ASSOCIATION, 1988, "Copper for Busbars", C.D.A. Publication No.22

8 JACKSON, R.L.: "Proposals for the elimination of hot joints on generator flexible connections", CERL Note No. TPRD/L/2270/N82

9 JACKSON, R.L.: "The CERL Transition washer", CERL Report No. TPRD/L/2440/R83

10 JACKSON, R.L.: "The preparation and performance of bolted joints using grade 1350 aluminium busbar", CERL Report No. RD/L/R2010

11 JACKSON, R.L. AND PRICE, C.F.: "A test set for low resistance measurements", CERL Note No RD/L/IN252/73

12 JACKSON, R.L.: "Jointing by cold pressure welding", Distribution Developments, September 1987

13 JACKSON, R.L.: "Cold pressure lap welding of copper earthing strip", CERL Note No TPRD/L/2896/N85

14 PARR, D.J.: "Cold pressure lap welding of thick aluminium and copper earth strip", CERL Note No. RD/L/N185/79

15 PARR,D.J: "Development and service application of cold pressure welding for jointing thick aluminium and copper earth strip", CERL Note No. TPRD/L/2395/N82

16 PARR,D.J: "Weathering trials on earth strip joints", CERL Note No. TPRD/L/2825/N85

APPENDIX A - SUITABILITY OF BOLTED JOINTS

BOLTED JOINT TYPES	SUITABILITY	SPECIAL REQUIREMENTS	ACCEPTABLE CRITERIA
Aluminium-Aluminium	*	Protect outdoor joints (◊)	Resistance checks required -See Section 5
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 Section 5
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 2.3
Brass interface e.g transition washer – see 5.4

APPENDIX B - 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