BACK-UP PROTECTION GRADING ACROSS NATIONAL GRID / DISTRIBUTION NETWORK OPERATOR INTERFACES AND OTHER THIRD PARTIES

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PURPOSE AND SCOPE

This Relevant Electrical Standard (RES) policy defines protection grading at interfaces between National Grid (NG) and Distribution Network Operators (DNOs) and other third parties to ensure that adequate discrimination of NG back-up protection with that of DNOs/third parties is achieved. It also emphasises the need to exchange all information required for the purpose of protection grading between NG and DNOs/third parties.

This policy applies to DNO overcurrent and earth fault protection and sets out the protection settings requirements which, when applied, will ensure adequate grading margins and compliance with discrimination requirements set out in The Grid Code. Any instances where the required grading margin is not achievable or the setting guidance in this document cannot be applied must be referred to National Grid and formally agreed between all parties.

Part 3/Appendix A provides the background and necessary guidance on its application.

Note: Protection grading policy at interfaces between National Grid and DNOs - Policy Statement PS(T)044 is replaced by this revised Policy Statement PS(T)010 (RES).

PART 1 – POLICY

1 POLICY STATEMENT

a) Protection settings and other related information required for the purpose of protection grading shall be exchanged between NG and DNO/third party in line with The Grid Code requirements.

b) Back-up overcurrent and earth fault protection settings on DNO/third party protection system shall be set in line with the requirements provided in this document.

c) Where the required grading margin stipulated in this document is not achievable, it must be referred to National Grid and formally agreed between National Grid and DNO/third party.

d) The policy is based on the requirements covered in NG Policy Statement PS(T)010 – "Application and Protection Setting Policy for the National Grid UK Transmission System", and the application guidance is provided in Part3/Appendix A.

1.1 Supergrid/132 kV Auto-transformers

1.1.1 Overcurrent protection on the DNO/third party feeders and equipment at 132 kV

a) NG policy is to deploy two stages of HV overcurrent protection using the IEC Standard Inverse (SI) characteristics for Supergrid/132 kV auto-transformers. There are some legacy installations which have been equipped with an additional LV overcurrent protection with Extremely Inverse (EI) characteristics. Both Stage 1 HV overcurrent, and LV overcurrent (where installed), trip the SGT LV circuit breaker.

The Stage 1 HV overcurrent protection is set to achieve operating time not greater than 2.4 s for a 3-phase short circuit at the SGT LV terminals with zero source impedance. The Stage 2 HV overcurrent protection, if required, trips the SGT HV circuit breaker after an additional 0.3 s delay.

NG policy also provides Circuit Breaker Fail (CBF) protection on all 400 kV and 275 kV circuit breakers to achieve a fault clearance time of no more than 0.3 s.

The policy ensures that the strength and capability of 132 kV equipment (rated at 3 s) is not exceeded e.g. any 132 kV fault resulting in Stage 2 SGT HV overcurrent protection operation followed by the HV CB failure would be cleared in 3 s (2.4+0.3+0.3 = Stage 1 HV overcurrent + Stage 2 Timer + CBF) by back-tripping all HV infeeds.

b) DNO/third party overcurrent protection shall be set to provide both current and time grading with NG back-up overcurrent protection installed at incoming Supergrid/132 kV auto-transformer sites on a 1:1 basis.

The current setting deployed on the back-up protection of DNO feeders and equipment shall be lower than the SGT overcurrent protection and LV overcurrent protection (where installed).

The time multiplier on the DNO/third party back-up protection shall be set such to provide adequate minimum grading margin up to the maximum allowable 3-phase fault level (3 phase let through MVA) on a 1:1 basis.

c) The grading must take cognisance of factors such as relay type, relay and Current Transformer (CT) errors, relay overshoot, safety margin etc.

d) Part 3/Appendix A provides the necessary guidance.

1.1.2 Earth fault protection on the DNO/third party feeders and equipment at 132 kV

a) NG policy requires the provision of a residually connected earth fault protection using IEC SI characteristics on the 132 kV side of an SGT. It is set to grade with the DNO/third party earth fault protection. The residually connected earth fault protection trips the SGT LV circuit breaker and is set to achieve an operating time no greater than 2.4 s in the event of a 132 kV single phase to earth fault at the SGT LV terminals.

b) DNO/third party earth fault protection shall be set to provide both current and time grading with residually connected earth fault protection and SGT (HV and LV) overcurrent protection installed at the incoming Supergrid/132 kV auto-transformer on a 1:1 basis.

The current setting deployed on the DNO/third party protection for feeder and equipment shall be lower than the SGT residually connected earth fault and SGT (HV and LV) protection setting.

The time multiplier setting on the DNO earth fault protection shall be set such that it provides adequate minimum grading margin, at the maximum allowable single phase to earth fault MVA (single phase let through MVA), on a 1:1 basis with the following protection;

(i) SGT residually connected earth fault protection

(ii) SGT HV overcurrent protection

(iii) SGT LV overcurrent protection (where installed)

c) The grading must take cognisance of factors such as relay type, relay and CT errors, relay overshoot, safety margin etc.

d) Part 3/Appendix A provides the necessary guidance.

1.2 Supergrid/66 kV or Lower Voltage Double-wound Transformers

1.2.1 Overcurrent protection on the DNO/third party feeders and equipment at 66 kV or lower voltages

a) NG policy is to deploy two stages of HV overcurrent protection using IEC SI characteristics for Supergrid/66 kV and lower voltage double wound transformers. There are some legacy installations with an additional LV overcurrent protection that use Extremely Inverse (EI) characteristics. Both Stage 1 HV overcurrent, and LV overcurrent (where installed), trip the SGT LV circuit breaker.

The Stage 1 HV overcurrent protection is set to achieve an operating time no greater than 2.4 s for a 3-phase short circuit at the SGT LV terminals with zero source impedance. The Stage 2 HV overcurrent protection trips the SGT HV circuit breaker after an additional 0.3 s delay, as required.

b) DNO/third party overcurrent protection shall be set to provide both current and time grading with NG back-up overcurrent protection installed at incoming Supergrid/132 kV auto-transformer sites on a 1:1 basis.

The current setting deployed on the back-up protection of DNO feeders and equipment shall be lower than the SGT HV overcurrent protection and LV overcurrent protection (where installed).

c) The time multiplier on the DNO/third party overcurrent protection shall be set such that it provides adequate minimum grading up to the maximum allowable 3-phase fault level on a 1:1 basis.

d) The grading must take cognisance of factors such as relay type, relay and CT errors, relay overshoot, safety margin etc.

e) Appendix A provides the necessary guidance.

1.2.2 Earth fault protection on the DNO/third party feeders and equipment at 66 kV or lower voltages

a) NG policy is to provide a 2 stage unrestricted earth fault protection which is hitherto described as Standby Earth Fault (SBEF), or Neutral Current Protection (NCP) by DNOs. This protection uses a CT in the neutral of the SGT to supply resistance earth

systems which are generally earthed at source via a solid or Liquid Neutral Earthing Resistor (LNER/NER). The LNER/NER generally limits the earth fault current to the full load current of the SGT so as to prevent damage to equipment and systems, and to limit the rise of earth potential.

The stage 1 unrestricted earth fault protection uses the IEC Long Time Inverse (LTI) characteristic and is set to 15% of the available earth fault current to achieve an operating time of 5 s for an earth fault at the SGT terminals. The stage 1 trips the SGT LV circuit breaker.

The stage 2 unrestricted earth fault protection trips the SGT HV circuit breaker and uses the IEC LTI characteristic. It is set to 20% of the available earth fault current to achieve an operating time of 8 s for an earth fault at the SGT terminals.

b) DNO/third party earth fault protection shall be set to provide both current and time grading with the SGT 2-stage unrestricted earth fault protection.

The earth fault setting deployed on the DNO outgoing feeders and equipment shall be lower than the stage 1 unrestricted earth fault and SGT (HV and LV) overcurrent protection setting.

c) The time multiplier on the DNO/third party earth fault protection shall be set such that it provides adequate minimum grading up to the maximum allowable 1-phase fault level on a 1:1 basis.

d) The grading must take cognisance of factors such as relay type, relay and CT errors, relay overshoot, safety margin etc.

e) Part 3/Appendix A provides the necessary guidance.

1.3 Grading with 132kV or Lower Voltage Bus Sections and Couplers

1.3.1 Bus section/ bus coupler overcurrent protection at 132 kV or lower voltages

a) The overcurrent setting shall provide back-up protection for Busbar, and substation close-up faults, independent of SGT back-up protection subject to clause (e) below.

b) The setting shall ensure non-operation of protection for short-term overload currents on DNO / third party networks which are likely to arise under credible emergency conditions.

c) The overcurrent setting must provide fault clearance within the switchgear rating limitations for all sustained multiple fed faults.

d) The overcurrent setting shall grade with SGT (HV and LV) overcurrent settings for all credible running arrangements to provide adequate minimum grading margin whilst taking due cognisance of relay type, relay and CT errors, relay overshoot and safety margin.

e) With reference to clause (a), it is subject to the constraint that a primary means of fault clearance remains at the SGT selected to the busbar in the event any of the following faults:
   (i) a busbar fault
   (ii) a substation close-up fault.
   (iii) DNO CB Fail condition

f) Part3/Appendix A provides the necessary guidance.

1.3.2 Bus section/ bus coupler earth fault protection at 132 kV or lower voltages

a) The earth fault setting shall provide back-up protection for busbar and substation close-up faults, independent of SGT back-up protection subject to clause (d) below.

b) The earth fault setting must provide fault clearance within the rated switchgear rating for all sustained multiple fed faults.

c) The earth fault setting shall grade with SGT residually connected earth fault and SGT HV overcurrent and SGT LV overcurrent protection (where installed). Under all credible running arrangements it shall provide adequate minimum grading margin whilst taking due cognisance of relay type, relay and CT errors, relay overshoot and safety margin.

d) With reference to clause (a), it is subject to the constraint that primary means of fault clearance remains at the SGT selected on the busbar in the event any of the following faults:
(i) a busbar fault
(ii) a substation close-up fault.
(iii) DNO CB Fail

e) Part 3/Appendix A provides the necessary guidance.

2 FORMS AND RECORDS

Not applicable

PART 2 - DOCUMENT HISTORY

This document is based on the National Grid Policy Statement PS(T)010 - Application and Setting Policy for the National Grid UK Transmission System.

3 AMENDMENTS RECORD

Issue	Date	Summary of Changes / Reasons	Author(s)	Approved By (Inc. Job Title)
1	July 2017	New document based on the requirements in the previously issued Policy Statement PS(T)044 RES. Application guidance is now included.	Dr Indy Sokhey Engineering and Asset Management Directorate	Stewart Whyte Asset Policy Manager

2 IMPLEMENTATION

2.1 Audience Awareness

Audience	Purpose Compliance (C) / Awareness (A)	Notification Method Memo / letter / fax / email / team brief / other (specify)
Technical Assurance Engineering and Asset Management Directorate	C	e-mail

Training Requirements

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

2.2 Compliance

National Grid, DNOs and Third Parties.

2.3 Policy Review Date

8 years from publication date.

PART 3 - GUIDANCE NOTES AND APPENDICES

APPENDIX – A

The guidance is based on the NG Policy Statement PS(T)010 which defines the policy for the protection arrangements and settings to be applied on its 400 kV and 275 kV transmission network and equipment connected at lower network voltages at 132 kV, 66 kV, 33 kV and 13 kV.

The following summarises protection grading considerations that apply to interfaces between National Grid and DNOs/third parties. The main aim is to ensure that adequate discrimination of NG back-up protection with the DNO/third party back-up protection is achieved.

Exchange of protection settings information is pivotal in undertaking protection grading studies across the interfaces between NG and DNOs/ third parties. It is vital to ensure that an adequate grading margin is maintained across the interfaces – any protection settings change must also be communicated to all the affected parties.

SGT back-up protection is provided for both phase and earth faults as follows:

A.1 National Grid SGTs, for economic and technical reasons, are equipped with a 2-stage HV three phase overcurrent protection in preference to separate HV and LV overcurrent protection. The first HV overcurrent stage trips the LV circuit breaker, and provides back-up protection for any uncleared LV faults on the distribution network including LV busbars. The second stage after a fixed time delay, usually 300 ms, trips the HV circuit breaker, and provides back-up to the main transformer, LV connections and HV connections (depending on the location of CTs) protection.

The two stage HV overcurrent protection setting is based on achieving the best possible sensitivity whilst guaranteeing that there would only be operation for load currents which could result in transformer damage. NG Transformer Loading Guide provides the acceptable overload limit for on-load tap changing operations. The overload limit is dependent on the transformer design - NG TGN(T) 029 specifies an overcurrent limit of either 130% or 150% of the SGT nominal rating.

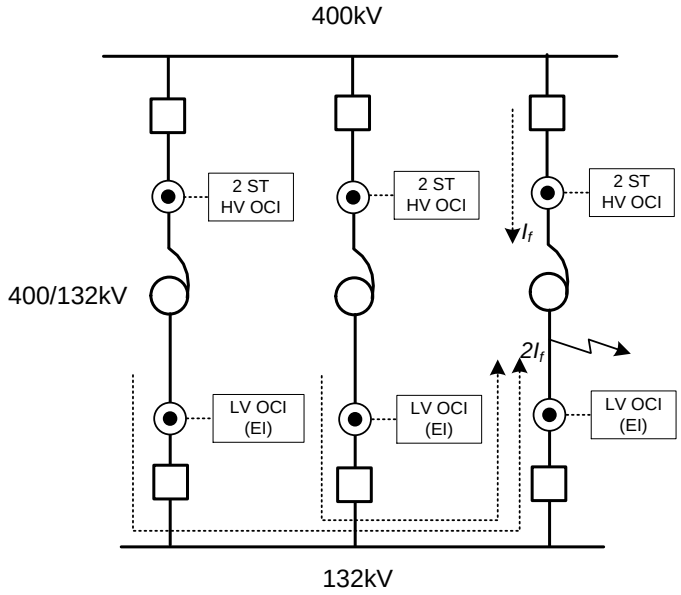
All SGTs with on-load tap-changers where the acceptable overload limit for on-load tap-changing operations is 130% shall have an HV overcurrent setting of 145% and the ones with 150% shall have an HV overcurrent setting of 165% of the SGT nominal rating.

Overcurrent relays with IDMT or SI (Inverse Definite Minimum Time/ Standard Inverse) characteristics are best suited to achieve the necessary grading. Grading is provided on a 1 to 1 basis which is the worst case scenario i.e. one Supergrid/Lower Voltage transformer is graded

against an outgoing DNO feeder or grid transformer, as appropriate.

A2 There are some legacy SGT installations that have been equipped with an additional LV overcurrent protection with IEC EI characteristic. This provides faster clearance of faults on the LV connections in the event of a failure of the LV connections/main transformer protection compared with a Standard Inverse relay or the HV overcurrent protection. In the absence of an extremely inverse LV overcurrent protection, a failure of the LV connections/main transformer protection would result in total loss of supply to the 132 kV busbars for substations where more than 2 SGTs operate in parallel.

Figure below illustrates how an LV overcurrent protection with EI characteristic provides faster discriminative clearance of LV connections fault in the event of a failure of the LV connections/main transformer protection.



LV OCI (EI) : LV overcurrent protection with extremely inverse (EI) characteristics
2 ST HV OCI : 2 stage HV overcurrent protection with standard inverse (SI) characteristics

Figure showing discriminative clearance of LV connections fault using an LV overcurrent protection with EI characteristics

The stage 1 HV overcurrent protection and the extremely inverse LV overcurrent are set to operate at the same operate time at the single phase to earth fault let through MVA – the maximum allowable fault infeed an SGT can feed into a single phase to earth fault at the SGT LV terminals. The extremely inverse LV overcurrent protection provides a much faster fault clearance on the LV connections in the event of a failure of LV connections protection due to the 132 kV infeed provided by other SGTs that operate in parallel. LV overcurrent protection with EI characteristic provides discriminative clearance of an LV connections fault providing protection operate time of around 300- 400 ms using the EI overcurrent characteristic.

A.3 National Grid provides a residually connected LV earth fault protection with Standard Inverse characteristic for all auto-transformers 400/132 kV and 275/132 kV. It is energised by suitable CTs in the 132 kV/lower voltage circuit breaker for the 400/132 kV, 275/132 kV and Supergrid/lower voltage SGTs.

Its purpose is to provide back-up protection for any uncleared earth faults on 132 kV or lower voltage distribution network or uncleared 132 kV or lower voltage busbar faults. The earth fault protection is energised from the LV CTs in preference to the HV CTs because the delta tertiary

winding on the SGTs shunts the zero sequence current away from the HV CTs thus making an HV connected earth fault protection less responsive to 132 kV earth faults.

A.4 National Grid provides an unrestricted earth fault protection applied to the neutrals of transformers supplying resistance earthed systems. DNOs also deploy unrestricted earth fault on distribution systems commonly operating at voltages 66 kV, 33 kV and 11 kV. These systems are generally earthed at source via a solid or Liquid Neutral Earthing Resistor (LNER) to limit the earth fault current to generally the full load current of the SGT to prevent damage to equipment and systems and limit the rise of earth potential.

Like the HV overcurrent protection, the unrestricted earth fault protection is implemented in two stages – the first stage trips the LV circuit breaker and the second stage trips the HV circuit breaker. It provides back-up protection for any uncleared earth faults on the distribution network and has a long operating time, usually up to a few seconds, to discriminate with the distribution network protection. It also offers protection to the LNER against the effects of a sustained fault. It is energised by a CT the primary of which is connected in series with the LNER.

The unrestricted earth fault (NCP/SBEF) must be implemented using long time inverse (LTI) to IEC characteristics. Not only does it allow adequate discrimination with the distribution network protection but also it helps to provide protection to the LNER as the LTI curve matches the thermal characteristics of the LNER. Settings must be chosen carefully so as not to exceed the thermal withstand capability of the LNER especially for the solid ones.

The current practice within National Grid is to specify the two stages of unrestricted earth fault protection in two separate hardware devices/Intelligent Electronic Devices (IEDs). Stage 2 provides back-up to the transformer main protection and as such must be independent from the transformer main protection.

The earth fault current on the LV system is generally limited to the rated full load current of the SGT and the SGT HV overcurrent protection which is set to 145% or more of its rating, would fail to detect any earth fault on the SGT HV side - see A.1 above. National Grid protection policy requirement to be able to clear a genuine fault in the event of a single failure cannot be achieved if both stages of the unrestricted earth fault protection are implemented in a single relay. This policy also enables National Grid to reliably discharge their obligation as a “Supplier” under the Electricity Safety, Quality and Continuity (Amendment) Regulations that require the “Supplier” to be responsible for the application of protective devices with appropriate settings to his network to clear faults from the network with sufficient rapidity to prevent danger.

A.5 Historically National Grid has used a fixed 0.4 s discriminating margin at protection interfaces between National Grid and DNO/third parties. The back-up protection study carried out following the 2003 system incidents found inconsistent and inadequate grading margins at protection interfaces between National Grid and DNOs/third parties. As a result National Grid defined protection grading policy at interfaces between National Grid and DNOs - Policy Statement PS(T)044 which was recently replaced by this Policy Statement PS(T)010 RES. The new policy PST010 RES now also includes additional application guidance.

An insufficient grading margin can result in unnecessary loss of supply to some customers and lead to difficulties in fault location.

Factors that need to be taken into consideration to ensure adequate/sufficient grading margin at protection interfaces between National Grid and DNOs/third parties are as follows.

(i) Fault current interrupting time of the circuit breaker

(ii) Relay timing errors as defined in IEC 60255 for National Grid and DNOs/third parties relays

(iii) Relay overshoot time

(iv) CT errors for National Grid and DNO/third parties

(v) Safety margin (typically 0.05 - 0.1 s)

The following guidance shall be applied to achieve adequate grading margins at the interfaces between National Grid and DNOs/third parties to achieve a more consistent approach. Any instances where the required grading margin is not achievable or the setting guidance in this document cannot be applied must be referred to National Grid and formally agreed between all parties.

Factor (i) – the fault current interrupting time is an important factor that determines the time when the discriminating relay ceases to be energised by the fault current. For 132 kV and lower voltage circuit breakers, it shall be taken as 100 ms unless otherwise specified by the CB manufacturer.

Factor (ii) depends on the relay technology used at the upstream (NG) and downstream (DNO/third party) circuit breakers. IEC 60255 specifies a relay index error that determines the maximum timing error for a given type of relay technology used in an application. This timing error must be taken into consideration in determining the grading margin requirement.

Factor (iii) also depends on the relay technology used. For instance, the relay overshoot time is larger for electro-mechanical relays as compared to numerical or static ones. The relay overshoot is a direct result of any stored energy that may result in the relay disc or relay timing to continue even after the cessation of the fault current.

Factor (iv) CT errors result in the CT secondary current not being an exact replica of the primary current which result in relay timing errors, which if not accounted for, may result in insufficient grading margin at the interfaces.

In addition to all of the factors (i) - (iv), a safety margin dependent on the relay technology is also applied. The overall accuracy limits specified for an IDMT overcurrent relay manufactured to IEC 60255–4 are :

2.5 x the declared error at 2 x Setting

1.5 x the declared error at 5 x Setting

1.0 x the declared error at > 10 x Setting

It can be seen that relay errors are higher at lower fault currents or lower Plug Setting Multiplier (PSM). NG concluded that it is not advisable to use of a fixed grading margin.

Table below specifies the factors (ii), (iii) and (v) that must be used to determine the adequacy of grading margin at National Grid interfaces with DNOs/third parties.

Relay Technology	**Typical Timing Error (%)**	**Relay Overshoot (ms)**	**Safety Margin (ms)**
Electro-mechanical e.g. Relay type CDG, TJV, TJM, PBO, PG3…..	7.5	50	100
Static, Digital or Numeric	5.0	30	50

e.g. Relay type MCGG, 2DCC, KCGGs, 7SJ645, all modern relays in use on NG system			

Assuming an SI characteristic for the DNO/third parties and NG back-up protection, the maximum likely percentage timing errors due to the 5P 20 CT application is calculated by the accumulative timing error due to each protection. It is calculated taking the worst case scenario which is with a 5% lower CT secondary current for the DNO/third party protection and a 5% higher for the NG back-up protection. For the average PSMs associated with both the DNO and NG back-up protection, the above criteria gives an overall percentage timing error of 6%.

To account for all of the above factors, the following formula shall be used to calculate the required grading margin between the DNO/third parties and NG back-up protection.

$$\text{Required Grading Margin (ms)} = \max\left[400\,\text{ms},\ \left(\left(\frac{e_{R1}+e_{R2}+e_{CT}}{100}\right)t + t_{CB} + t_{OS} + t_{SM}\right)\right]$$

where:

e_{R1} = DNO/third party % relay timing error to IEC 60255-4

e_{R2} = NG % relay timing error to IEC 60255-4

e_{CT} = Overall DNO/third party and NG % timing error due to CT error (taken as 6%)

t = DNO/third party BU protection operate time (ms)

t_{CB} = DNO/third party nominal CB fault interruption time (ms)
(To be taken as 100 ms unless otherwise specified by CB manufacturer)

t_{OS} = DNO/third party Relay overshoot time (ms)

t_{SM} = Safety margin (ms)

Note that the minimum acceptable grading margin is 400 ms if the calculation yields a lower value.

A.6 National Grid owns 132 kV or lower voltage busbars at sites where more than one DNO and/or third party are supplied. At those sites, the current practice is to specify the BS/BC overcurrent settings, independent of third party considerations, to meet the following criteria:

(a) The overcurrent setting should provide back-up protection for busbar and substation close-up faults, independent of SGT back-up protection.

(b) The overcurrent setting should ensure non-operation of protection for short-term overload currents likely to arise under credible emergency conditions.

(c) The overcurrent setting must grade with SGT overcurrent settings for all credible running arrangements.

(d) The overcurrent setting shall provide fault clearance within the rated switchgear rating for all sustained multiple fed faults.

(e) With reference to clause (a), it is subject to the constraint that primary means of fault clearance remains at the SGT selected on the busbar in the event any of the following faults:
(i) a busbar fault
(ii) a substation close-up fault.
(iii) DNO CB Fail condition

A.7 The following considerations apply in choosing the overcurrent setting for a 132 kV BS/BC to meet the criterion in A.6 (a).

The data used is as follows:

Typical summer fault level at 400 kV	25000 MVA
Typical Interbus SGT impedance of a 400/275 kV SGT	1.6% @100 MVA base
Typical SGT impedance of a 275/132 kV SGT	8.33% @100 MVA base
Corresponding minimum phase-phase fault level at 132 kV	838 MVA. of 1.3
Corresponding BS/BC overcurrent setting with a factor of 1.3 for fault detection	< 2820 A @ 132 kV
Chosen BS/BC overcurrent Setting	2400 A @ 132kV

The chosen setting allows a short term overload in excess of 200% of full load current of a 240 MVA SGT - see A.6 (b) above.

A.8 The time multiplier (TM) setting is chosen to meet the criteria in A.6 (c) above.

For those sites with more than 2 SGTs at a substation, it is necessary to ensure that a grading margin of at least 400 ms is obtained between the bus section/bus coupler and the SGT LV circuit breaker for a 132 kV 3-phase close-up feeder fault fed by 2 SGTs.

Grading margin calculation using the criteria given in A5 may yield higher values than 400 ms. Should the grading margin calculation based on the criteria in A5 result in difficulties to accommodate all the grading stages, it is considered acceptable to use 400 ms for the purpose of BS/BC grading with the SGT HV and/or overcurrent protection. In all other instances, the criteria given in A5 shall be used.

A time multiplier setting 0.425 using the IEC SI characteristic whilst carrying twice the maximum allowable 3 phase let through MVA (2 x 1200 MVA) of 2400 MVA would provide an operate time around 2.0 s.

This would provide the required minimum grading margin of 400 ms against the SGT HV overcurrent protection set to operate at 2.4 s.

For substations with 2 SGTs, a careful selection of grading order would provide the required back-up for busbar or close-up substation faults i.e grading the outgoing DNO/third party circuit breaker with BS/BC followed by the SGT LV circuit breaker.

Again a grading margin of 400 ms between the various grading stages would suffice. The primary means of fault clearance would remain at the infeeding SGT selected on the faulted busbar.

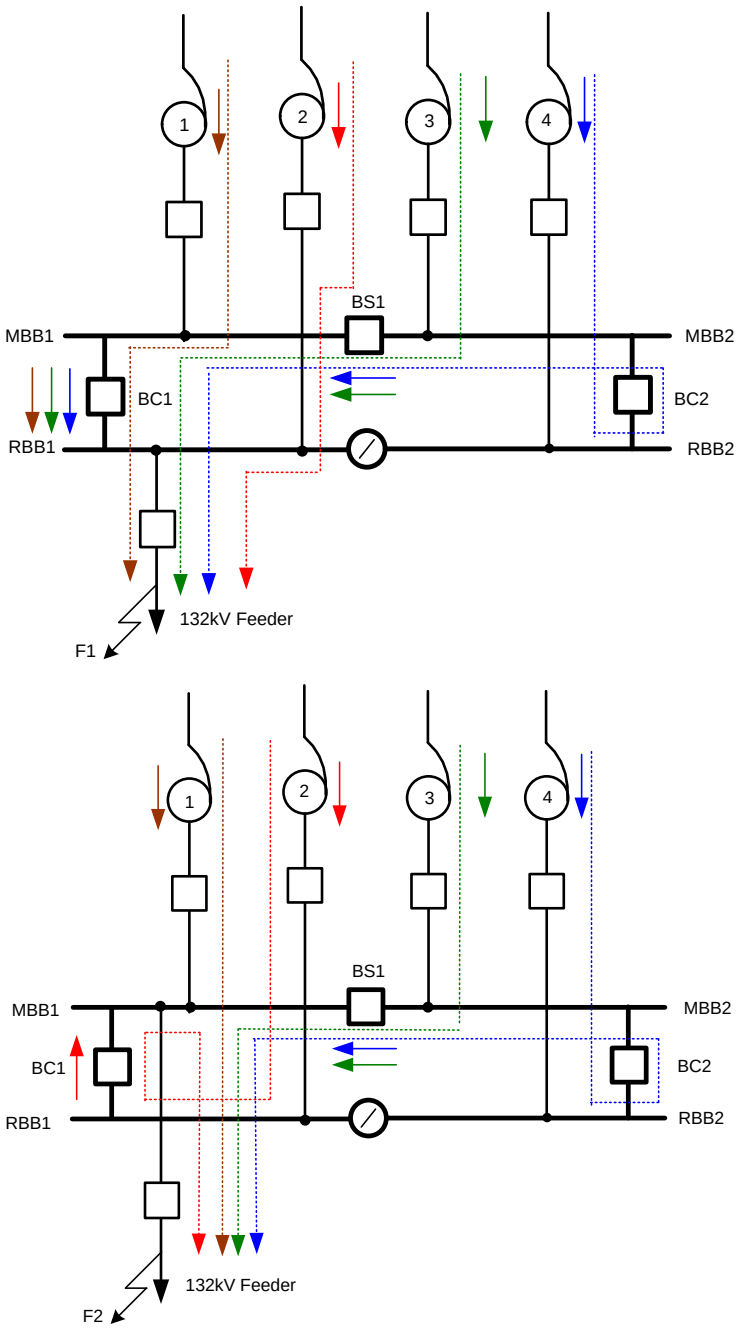
A.9 For 132 kV substations with more than 2 SGTs, the following considerations apply in order to achieve adequate grading with SGT HV and LV overcurrent protection.

Consider the following 3 phase fault scenarios F1 and F2 for a 132 kV double busbar substation with 4 in-feeding SGTs shown in figure below.

It can be seen that for both faults F1 and F2 the bus section BS1 carries fault infeed from two SGTs 3 and 4 i.e. twice the maximum allowable 3 phase let through MVA. Equal SGT impedances are assumed.

Likewise, similar fault positions on an outgoing feeder fed from MBB2 and RBB2 (say fault positions F3 and F4 not shown), the bus section BS1 will carry fault infeed from SGTs 1 and 2

i.e. the bus section BS1 always carries fault infeed which is twice the let through MVA of an SGT.



Typical National Grid Double Busbar 132 kV substation with 4 incoming SGTs

National Grid policy requires SGT HV overcurrent protection setting to achieve an operate time not greater than 2.4 s for a 3-phase fault at its LV terminals with zero source impedance (an infinite source). Therefore, by ensuring that the bus section/couplers operate at 2.0 s whilst carrying twice the fault infeed fed by the infeeding SGTs, a grading margin of 400 ms is achieved between the SGT and BS/BC overcurrent protection. Failure to achieve adequate grading margin between the SGT and BS/BC back-up protections may result in a total loss of

supply in the event of an uncleared 132 kV feeder fault.

It is equally important to ensure adequate grading margin between the 132 kV feeder and BS/BC overcurrent protection.

A.10 The following considerations apply in choosing the overcurrent setting for a 66 kV BS/BC to meet the criterion in A.6 (a).

The data used is as follows:

Typical summer fault level at 400 kV	25000 MVA
Typical Interbus SGT impedance of a 400/275 kV SGT	1.6% @100 MVA base
Typical SGT impedance of a 275/66 kV SGT	11.1% @100 MVA base
Typical SGT impedance of a 400/66 kV SGT	13.9% @100 MVA base
Out of the two options, corresponding minimum phase-phase fault level at 66 kV	506 MVA.
Corresponding BS/BC overcurrent setting with a factor of 1.3 for fault detection	< 4075 A @ 66 kV
Chosen BS/BC overcurrent Setting	3600 A @ 66 kV

The chosen setting allows a short term overload in excess of 200% of full load current of a 180 MVA 400/66 kV or 275/66 kV SGT - see A.6 (b) above.

It is important to note that 66 kV overcurrent settings are dependent on the SGT impedance and should be chosen accordingly.

A.11 An extract of the NG Setting Policy PS(T)010 for SGTs and BS/BCs is given below for reference:

(A) Supergrid/132 kV SGTs

	Functionality	Setting	
a	**Stage 1 HV 3-phase overcurrent**	Curve	SI to IEC characteristics
		Current setting	145% or 165% rated $I_{SGT\ HV\ WINDING}$ Refer to section A.5.
		TM setting	Set to achieve a stage 1 operating time of not greater than 2.4 s for a 3-phase fault on the transformer LV busbar or LV bushing with a zero source impedance.
b	**Stage 2 HV 3-phase overcurrent function**	Current setting	145% or 165% rated $I_{SGT\ HV\ WINDING}$ Refer to section A.1.
		Timer setting	0.3 s Note that the Stage 2 timer shall be set to zero for SGTs with an exclusive use of an HV circuit breaker and no loads connected to tertiary.
c	**LV Earth Fault**	Curve	SI to IEC characteristic
		Current setting	480 A
		TM setting	Set to achieve adequate grading margin with DNO/third party LV back-up protection for a close up LV fault (single phase to earth) on the distribution network with a zero source impedance. Under no circumstances, shall the operating time be greater than 2.4 s. See section A.8..

(B) Supergrid/66 kV or Lower Voltage Double-wound SGTs

	Functionality	Setting	
a	**Stage 1 HV 3-phase overcurrent**	Curve	SI to IEC characteristics
		Current setting	145% rated $I_{SGT\ HV\ WINDING}$
		TM setting	Set to achieve a Stage 1 operating time of not greater than 2.4 s for a 3-phase fault on the transformer LV busbar or LV bushing with a zero source impedance.
b	**Stage 2 HV 3-phase overcurrent function**	Current setting	145% rated $I_{TX\ HV\ WINDING}$ Refer to section A.1
		Timer setting	0.3 s Note that the Stage 2 timer shall be set to zero for SGTs with an exclusive use of an HV circuit breaker and/or no loads connected to tertiary.
c	**2-stage Unrestricted Earth Fault**	Curve	LTI to IEC characteristic
		Stage 1 current Setting	15% of the available earth fault current
		TM setting	To achieve an operating time of 5 s for an earth fault at the transformer LV terminals.
		Curve	LTI to IEC characteristic
		Stage 2 current Setting	20% of the available earth fault current
		TM setting	To achieve an operating time of 8 s for an earth fault at the transformer LV terminals.

(C) 132 kV Bus Sections and Bus Couplers

a	**Earth Fault**	Curve	SI to IEC characteristics
		Current setting	600 A
		TM setting	0.5
b	**Overcurrent**	Curve	SI to IEC characteristics
	(i)	For substations with 2 SGTs or less, the overcurrent and TM settings shall be based on the largest rating of the SGTs connected to the substation as follows: 240 MVA 2400 A TM = 0.425 180 MVA 2000 A TM = 0.475 120 MVA 1500 A TM = 0.55 See section A.9 & A.10.	
	(ii)	For substations with 3 or more SGTs, the overcurrent setting shall be 2400 A . The TM setting shall achieve a maximum operate time of 2 s when the bus section/ bus coupler carries a fault current equivalent to twice the fault MVA through an SGT for a three phase fault at the SGT LV terminals fed from a source with zero impedance.	

(D) 66 kV Bus Sections and Bus Couplers

a	**Earth Fault**	Curve	SI to IEC characteristics
		Current setting	400 A
		TM setting	0.6

b	**Overcurrent**	Curve	SI to IEC characteristics
		The overcurrent and TM settings shall be chosen based on the voltage ratio of incoming SGTs: 400/66 kV 3600 A TM = 0.35* 275/66 kV 3600 A TM = 0.425* See section A.10	

REFERENCES

PS(T)010 – Application and Setting Policy for the National Grid UK Transmission System.