

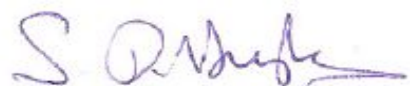
**Capital Delivery
Design Handbook**

Application & Setting of Substation LVAC Supply Equipment

DH 06

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Authorised by:



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1. PURPOSE

The purpose of this Design Handbook is to supplement the existing Technical Specifications and Protection Application & Setting Policy for LVAC supplies. This includes supplies from DNO, Tertiary, Auxiliary/Earthing Transformers, Power Stations and Diesel Generators.

Where a Tertiary winding is supplying Reactive Compensation equipment then the requirements for the HV protection application and settings are adequately covered in PS(T) 10. In this case there may also be a voltage regulator to maintain the LVAC voltage to within limits defined in TS 2.12. See **Appendix B**.

Where the Tertiary is supplying an earthing/auxiliary transformer exclusively for LVAC supplies then this Design Handbook should be referenced for correct protection application and settings.

The need or otherwise for an off-load tap changer or voltage regulator supplied with the auxiliary transformer should be considered at the design/development stage taking into account the historic normal running voltage of the substation busbars. National Grid have experience of a substation historically running at 406kV, more recently running at 396kV due to local wind farm connections.

The complete LVAC system design will consist of a number of Circuit Breakers (ACBs or MCCBs with integral protection modules), and Switch/Fuse units. Calculation reports should be produced to demonstrate discrimination as far as reasonably practicable with all these devices.

2. REFERENCES

PS(T) 010 – Application & Setting of Protection
TS 2.12 – Substation Auxiliary Supplies
TS 3.12.3 – Substation LVAC Supplies
British Electricity Boards Specification for Transformers and Reactors:1966 (BEBS T2)
TS 3.1.2 – Earthing
TPS 3/13 – 415 Volt Auxiliary Supplies for Transmission Substations - **Archived**
TPS 5/11 Parts 1 & 2 – Protection arrangements for transmission plant on 400 and 275kV systems - **Archived**

3. RESPONSIBILITIES

3.1 Suppliers

It is the supplier's responsibility to produce a design fully compliant to National Grid's Technical Specifications. This document is intended to give guidance on the implementation and application of these technical standards when designing Substation LVAC systems.

3.2 National Grid

It is National Grid's responsibility to ensure the supplier is aware of all the relevant Technical Standards and to review the design for compliance with these standards and the contract requirements.

4. REQUIREMENTS

4.1 INTRODUCTION

LVAC supplies shall be provided to the requirements of PS(T) 68 and TS 3.12.3. This Design Handbook provides application and protection setting guidance for the most commonly derived LVAC supply arrangements at National Grid Substations. These are namely:

- (a) 13kV Tertiary Derived Supplies
- (b) DNO derived supplies
- (c) Supplies derived from the LV side of Double wound SGTs
- (d) Diesel Generator supplies
- (e) Adjacent Generating Substation

4.2 EARTHING

4.2.1 13/0.4 kV Transformers

The 13kV winding is earthed via an Earthing Transformer. Modern units are designed such that their zero sequence impedance limits the earth fault current to approximately 830A. Older units may have a neutral earthing resistor/reactor to limit the current and therefore the earth fault current will be determined by the rating of these.

The 400V winding is solidly earthed on the LVAC Board side of the Neutral CT as shown in **Appendix C**. There may be Neutral/Earth linking facilities at the 13/0.4kV Auxiliary Transformer and this link must be checked as 'removed' for correct operation of the 400V REF scheme. A warning label should be attached adjacent to the earth link to prevent inadvertent replacement.

4.2.2 DNO LVAC Supplies

Refer to **Appendix D**

Requirements for earthing the DNO transformer LV winding are defined in TS 3.1.2 - see figures 2 & 3. Where the DNO transformer is within the NG substation boundary the earth shall be at the transformer LV winding star point. Where the DNO transformer is outside the substation boundary the earthing point shall be at the LVAC board.

There is no requirement for Restricted Earth Fault protection for a Distribution Transformer, (usually 11/0.4kV) either DNO or NG owned. The HV protection devices adequately protect LV winding faults and the short length of LV connections.

4.2.3 Diesel Generators

The star point of the generator is required to be earthed. The location of this earthing point depends on whether REF protection is located at the LVAC Board or the Generator.

For new LVAC installations, REF is not required at the LVAC Board and therefore the generator star point is earthed at the diesel generator position. In this case the new generator will have integral REF protection which should be enabled. See **Appendix E**.

Where REF exists at the LVAC Board and is to be retained, then the location of the earth point should be at the LVAC board on the busbar side of the REF CTs. The Generator star point earth link, in this case, should be permanently removed. A warning label should be applied adjacent to this link to prevent inadvertent replacement. The integral generator REF, if present, should be disabled as the LVAC Board REF protects the 400V cable and generator winding. See **Appendix F**.

4.2.4 Circuit Breakers (ACBs or MCCBs)

Three-pole CB devices are normally installed at the generator or transformer location. Four-pole CB devices are normally installed at the LVAC board incomers and therefore it is essential that the neutral/earth link is on the supply side of the CB so as not to remove the earth from the source of supply when the CB is open.

4.3 400V ISOLATION & EARTHING

Due to lack of earthing facilities at both LV and 13kV (including portable primary earths), NG safety rules and NSI 2 require double LV isolation as a minimum requirement,

Double LV Isolation can be achieved by use of two or more of the following:

- LV CBs with 'locking off' facilities
- LV CBs that can be racked out and shutters locked off
- LV Disconnector at the auxiliary Tx with locking off facilities
- Switch Fuse Unit with locking off facility at the Auxiliary Tx. (existing sites only)

Acceptable methods of achieving double isolation may be as follows:

Method 1

LV Disconnector at the auxiliary Tx with locking off facility **and**
Circuit Breaker (without locking off facility) at the Auxiliary Transformer **and**
Circuit Breaker which can be racked out or locked off at the LVAC Board.

Method 2

Circuit Breaker with locking off facility at the Auxiliary Transformer **and**
Circuit Breaker which can be racked out or locked off at the LVAC Board.

Method 3

Switch Fuse Unit with locking off facility at the Auxiliary Tx **and**,
Circuit Breaker which can be racked out or locked off at the LVAC Board

Alternatively, an earth switch could be installed on the HV connections in which case only single LV isolation is required as a minimum.

The earthing provisions above must be considered at the development/design stages and the Substation SAP consulted at this time to ensure compliance with NG Safety Rules and NSI2. Refer to **Appendix C**.

4.4 APPLICATION & SETTINGS

4.4.1 Tertiary Supplies

Historically, Tertiary derived 13kV compensation equipment and LVAC supplies have been designed via a two stage scheme as per TPS 5/11. See **Appendix B**. The Stage 1 scheme has been used where the tertiary connection is used exclusively for LVAC supplies. If, in the future, it is decided to add 13kV compensation equipment then the stage 1 scheme is modified to become a stage 2 scheme.

The protection settings to apply to 13kV Tertiary systems connecting both static compensation equipment and LVAC supplies (Stage 2 scheme) are already defined in PS(T) 010.

The following guidelines are applicable **where there is no compensation equipment installed** and therefore the settings are related more specifically to the 13/0.4kV supply (Stage 1 scheme). Application and Setting policy, in this instance, is not currently covered in PS(T)10.

If future 13kV reactive compensation is installed (Stage 2) then all the settings for the tertiary system should be reviewed to ensure compliance with current setting policy.

13kV 3 Phase Instantaneous Overcurrent (MP)

This protection would be converted to a full Overall Differential scheme under future stage 2 works.

For stage 1 only, the setting is similar in terms of criteria to High Set Overcurrent protection. Therefore, the setting should be:

- (a) Not less than 150% of the fault current fed from the HV system for a 400V three phase fault on the LV terminals under maximum plant conditions and
- (b) Not greater than 50% of the fault current fed from the HV system to a phase to phase fault at the transformer HV bushings under minimum plant conditions.

13kV Instantaneous Earth Fault (MP)

This protection would be converted to a full REF scheme under future stage 2 works. For stage 1 only, the setting is as per PS(T)10:

Current – 30% Rated $I_{\text{NEUTRAL EARTHING TRANSFORMER}}$

13kV 3 Phase Overcurrent (BUP)

Normally, this is set to 150% rated $I_{\text{COMPENSATION EQUIPMENT}}$. Where the Tertiary is supplying LVAC only then this setting can be related to the rating of the auxiliary transformer ie. 150% rated $I_{\text{AUXILIARY TRANSFORMER}}$.

The HV full load current of an 800KVA Auxiliary Transformer is 36A requiring an ideal setting of 54A. On 3000/5 CTs the relay setting range is unlikely to accommodate this setting and therefore the relay should be set to its minimum setting available equal to or greater than 150% rated $I_{\text{AUXILIARY TRANSFORMER}}$.

Current Setting - $\geq 150\%$ rated $I_{\text{AUXILIARY TRANSFORMER}}$

Set the TM as per policy ie. TM - 0.15 (with SI Curve) or 1.0 second with DT characteristic.

Note: When converting to the Stage 2 scheme this protection will need to grade with the shunt compensation overcurrent protection. A minimum 0.4 second margin would be expected and so the down stream overcurrent protection should operate in 0.6 seconds. The main purpose here is to ensure a maximum 1.0 second clearance due to the fault rating of the 13kV equipment.

13kV Unrestricted Earth Fault (BUP)

As per PS(T)10 –

SI Curve to IEC Characteristic

Current - 15% of the available 13kV earth fault current

TM – Set to achieve an operating time of 1second for an earth fault at the tertiary 13kV connections.

Note: When converting to the Stage 2 scheme this protection will need to grade with the shunt compensation earth fault protection. A minimum 0.4 second margin would be expected and so the down stream earth fault protection should operate in 0.6 seconds. This is to ensure adequate discrimination for all earth faults on the 13kV system.

400V Restricted Earth Fault (MP)

As per PS(T)10:

Current – 15% of the fault current available for an earth fault on the 400V terminals under minimum plant conditions – to grade with the protection on the 400V side of the auxiliary transformer. See **Appendix A**.

Where an earthing/auxiliary transformer is provided for 13kV earthing only, ie. the 400V winding is unused, then in lieu of REF, apply unrestricted earth fault protection and shroud the R,Y & B phase connections to minimise the risk of phase to phase faults in this zone. The setting should be as above ie. 15% instantaneous.

4.4.2 SGT LV Derived LVAC Supplies

These are supplies derived from the LV side of double wound transformers, typically 66 & 33kV. The Auxiliary Transformer 66kV or 33kV winding is protected by the SGT protection systems. The Auxiliary Transformer 400V winding should be protected by application of REF protection similar to the tertiary derived supply.

The REF setting should be 15% of the fault current available for an earth fault on the 400V terminals under minimum plant conditions – to grade with the protection on the 400V side of the auxiliary transformer. See **Appendix A**.

Where an earthing/auxiliary transformer is provided for 66kV or 33kV earthing only, ie. the 400V winding is unused, then in lieu of REF, apply unrestricted earth fault protection and shroud the R,Y & B phase connections to minimise the risk of phase to phase faults in this zone. The setting should be as above ie. 15% instantaneous.

4.4.3 DNO derived LVAC Supply

Protection for the DNO transformer is the responsibility of the DNO as it is normally their asset. Restricted Earth Fault protection is not required. Grading must be achieved between the DNO HV protection and the NG LV CBs.

Protection on the Transformer LV CB should also grade with the LVAC board incoming and outgoing circuit devices. Grading between the Transformer LV CB and LVAC board incomer is preferred but may be compromised if necessary to achieve downstream discrimination.

It is a requirement that the CB protection is set to discriminate with both the LVAC board outgoing circuits and DNO HV devices. The priority will be such as to grade with the DNO protection in the first instance.

4.4.4 Generator Derived Supply

Generator packages to TS 3.12.3 will have their own protection systems, typically restricted earth fault (covering generator zone), delayed overcurrent, short circuit or reverse power. These systems will trip the Generator CB and initiate electrical generator shutdown.

The Generator sets are supplied with a CB with integral overcurrent characteristics (& sometimes earth fault), therefore, any Generator overcurrent, short circuit and reverse power protection should be disabled and this will be carried out by the generator supplier commissioning engineer.

Settings for the Generator protections are usually the responsibility of the generator supplier. Where NG employs a main Substation contractor for other works associated with LVAC supply provision and the Diesel generator and/or LVAC board works are subcontracted then the overall responsibility for settings and discrimination reports lies with the main Substation contractor. However, this does not preclude the requirement for the Generator supplier to provide their commissioning and protection setting information. The two parties must liaise with each other so that National Grid receives a holistic design and protection setting report.

It is understood that there can be, in some instances, a small zone (30mm) between Generator CTs and the ACB connections without overcurrent & earth fault protection but the risk of a fault here is small and would likely damage the CTs on failure in any case. Additional insulated shrouding can be applied at this point to minimise the fault risk. Other generator devices should operate for this scenario, eg under voltage, low frequency etc which result in tripping of the generator CB and electrical shutdown.

Protection on the Generator CB should grade with the LVAC board incoming and outgoing circuit devices, based on generator fault infeed. Grading between the Generator CB and LVAC board incomer is preferred but may be compromised if necessary to achieve downstream discrimination.

All protection, including generator settings, should be recorded on Live Link MARS.

4.4.5 Air Circuit Breakers (ACBs) & Moulded Case Circuit Breakers (MCCBs)

Where integral protection modules are fitted these should ideally have both overcurrent and earth fault protection functions (LSIG). It may be acceptable to provide overcurrent functions only if it can be demonstrated that the magnitude of earth fault current is similar or greater than the phase fault current but bearing in mind that zero phase sequence impedances of cables are often two to three times