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National Grid

National Grid
Technical
Specification

**Transformer Bay Functions
(comprising HV, LV and Tertiary)
for double busbar application**

NGTS 3.24.8
Issue 1
September 2001

CONTENTS	Page
1 Scope	1
2 References	2
3 Definitions	3
4 HV Circuit Breaker Functional Requirements	3
5 HV Connections Functional Requirements	4
6 Transformer HV Functional Requirements	5
7 Transformer LV Functional Requirements	7
8 Transformer Tertiary Functional Requirements	11
9 General Functional Requirements	13
10 Interface Requirements	17
11 Implementation Requirements	19
12 Contract Specific Requirements	19
APPENDIX A - Interconnection Diagrams	20
APPENDIX B - Acceptable Integration Options	45

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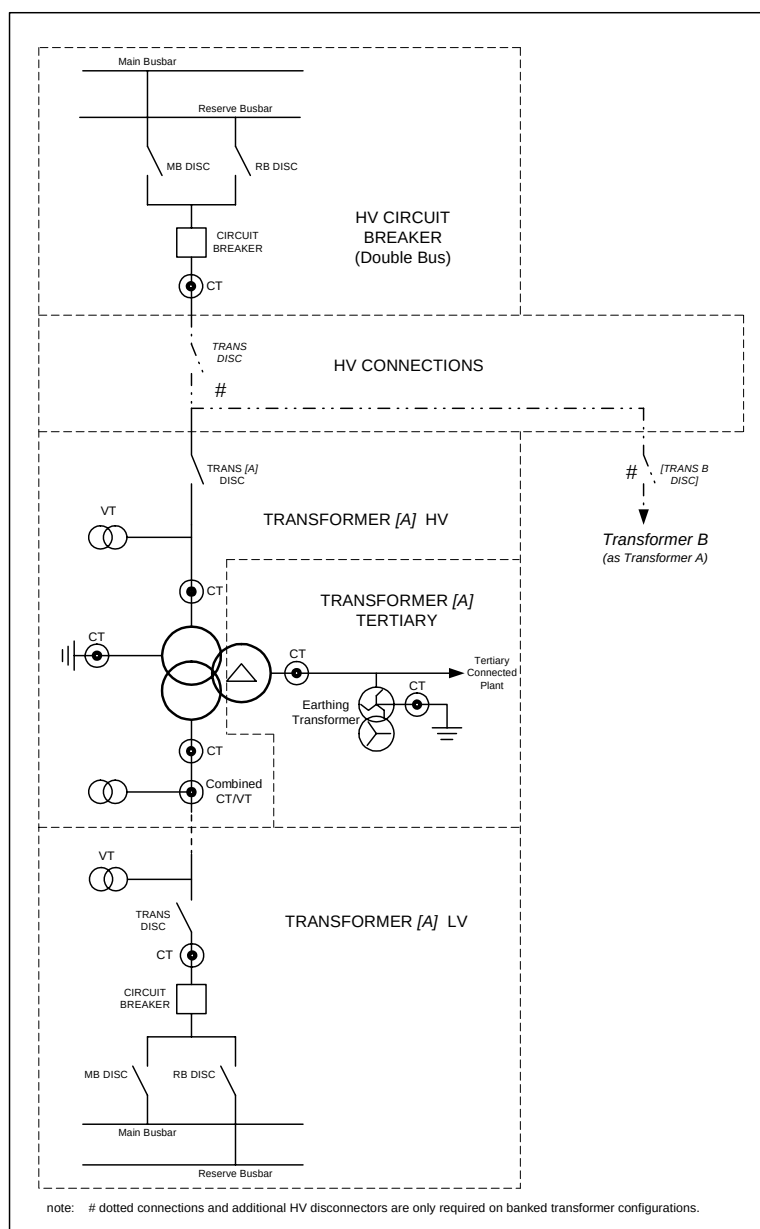
TRANSFORMER BAY FUNCTIONS

FOREWORD

This is a Bay Level Specification which is part of a suite of specifications that describe requirements for light current equipment on National Grid's transmission system. The transformer bay is divided into separately specified modules as indicated below. This specification also includes details relevant to banked transformer configurations but this information is a guide and should not be taken as comprehensive.

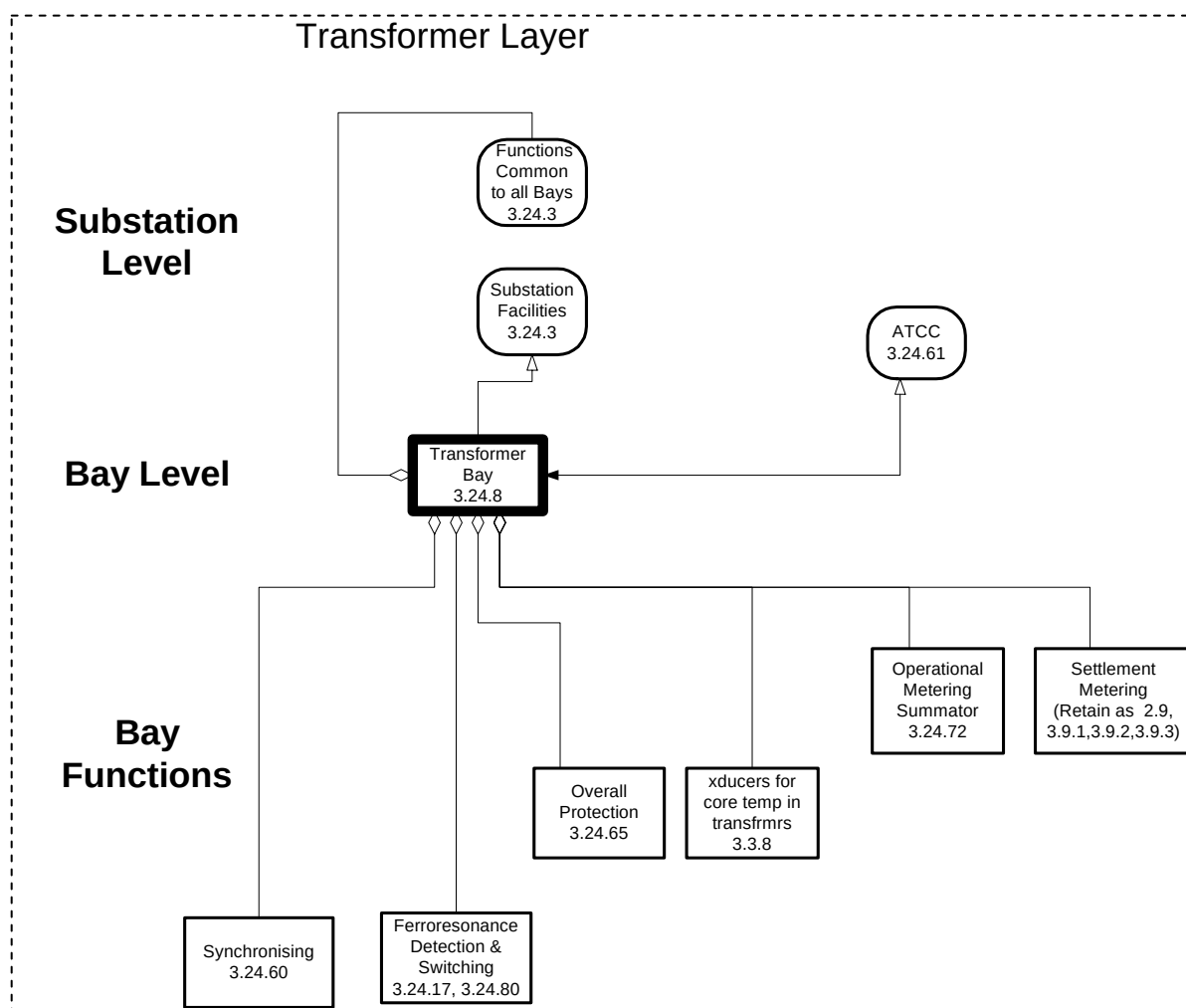
1 SCOPE

This specification, in conjunction with related functional specifications, details the protection, control and measurements functions and the associated interconnectivity which are required within light current systems on transformer bays at double Busbar substations on National Grid's 400, 275 and 132kV transmission system. It also describes interfaces with other substation functions.



2 REFERENCES

Substation Information, Control, Protection and Metering Functional Relationships for a Transformer HV Bay



Additional References:

NGTS 2.3 Transformers and Reactors
 NGTS 3.2.4 Current Transformers for Protection and General Use
 NGTS 3.2.5 Voltage Transformers for Protection and General Use
 NGTS 3.2.6 Current and Voltage Transformers for Settlement Metering
 NGTS 3.3.4 Tapchangers
 NGTS 3.24.34 Busbar Protection
 NGTS 3.24.36 Teleprotection (Command Based)
 NGTS 3.24.38 Overcurrent Protection
 NGTS 3.24.39 Circuit Breaker Fail Protection
 NGTS 3.24.73 Electrical Measurement Transducers

[Banked Transformer Installations]

NGTS 3.24.16 Delayed Automatic Reclosing (DAR)
 NGTS 3.24.75 DAR Interlocking (Trip Relay Reset)
 NGTS XXXXX Banked Transformers HV DAR
 NGTS XXXXX Banked Transformers HV Auto Isolation

3 DEFINITIONS

Transformer: - a load carrying high voltage coupling between two dissimilar potentials, including associated circuit breakers (CB), disconnectors, earthing switches, instrument transformers, conductors and insulators, and light current equipment. The transformer may have a double or single (auto) main winding, a tertiary winding and a tap changer.

AIS:- Air Insulated Switchgear

CB:- Circuit Breaker

CBF:- Circuit Breaker Fail

CT:- Current Transformer (Instrument)

DTT:- Direct Transfer Trip

GIS:- Gas Insulated Switchgear

HV:- High Voltage

LV: Low Voltage

VT:- Voltage Transformer (Instrument)

Informative: DTT has traditionally been known as 'intertipping' within the UK electricity supply industry.

4 HV CIRCUIT BREAKER FUNCTIONAL REQUIREMENTS

Informative: This section describes all of the functions that may be needed for a transformer HV Circuit Breaker, and gives circumstances where functions may not be required.

HV Circuit Breaker Fail Protection

- 4.1** Circuit Breaker Fail (CBF) protection (see NGTS 3.24.39) shall be provided for the transformer HV Circuit Breaker (CB) at 275 and 400kV.
- 4.2** On operation CBF shall
- (a) Cause other CBs connected to the same busbars to trip
 - (b) Initiate transformer LV and tertiary DTT send functions (see section 6.9)
 - (c) Lockout HV CB DAR (see section 6.12)

Informative: HV CB DAR will only be required for particular installations (i.e. with banked transformers). The contract will specify this.

HV Busbar Protection

- 4.3** The transformer HV shall interface with the HV substation Busbar protection system (see NGTS 3.24.34).
- 4.4** On operation, busbar protection shall
- (a) Trip the HV circuit breaker
 - (b) Lockout HV CB DAR (see section 6.12)
 - (c) Initiate HV CB Fail (see section 4.1)

and be selectable to

- (d) Initiate transformer LV and tertiary DTT send functions (see section 6.9)

Informative: HV CB DAR will only be required for particular installations (i.e. with banked transformers). The contract will specify this.

HV CB Pole Discrepancy Tripping

- 4.5** A pole discrepancy tripping function shall be provided for the transformer HV circuit breaker.

Informative: Pole discrepancy has traditionally been known as 'phases not together' within the UK electricity supply industry.

HV CB Phase Unbalance Alarm

- 4.6** A phase unbalance detector function shall be provided that initiates an alarm for a sustained unbalanced load current.

HV CB Trip Circuit Supervision

- 4.7** A trip circuit supervision function shall be provided to monitor the complete tripping circuit associated with each CB trip coil irrespective of the CB position. The complete tripping circuit shall include all associated fuses, links, wiring, resistors, trip coils, plant auxiliary contacts and relay contacts – excluding those relay contacts which initiate CB tripping.
- 4.8** The trip circuit supervision function shall initiate an alarm should a persistent fault be detected.

5 HV CONNECTIONS FUNCTIONAL REQUIREMENTS

Informative: This section describes all of the functions that may be needed for a transformer HV Connections, and gives circumstances where functions may not be required.

HV Connections Protection

- 5.1** Preferably single overall unit protection of the numeric type (see NGTS 3.24.65) with self-supervision and CT supervision (see NGTS 3.24.65), shall be provided.

Informative: If the protection is of the high impedance type, then duplicate overall protection with CT supervision and driven from a common CT, shall be provided. Voltage limiting devices shall also be provided if the voltage developed across the relay circuit during maximum internal fault conditions is greater than 3kV. The characteristic of the voltage limiting device provided shall be declared by the supplier.

- 5.2** HV Connections back up protection (see NGTS 3.24.38) shall be provided, if required.

Informative: Separate back up protection for the HV Connections is required in configurations where the HV Connections is not covered by the transformer back up protection (i.e. with banked transformers). The contract will specify this.

- 5.3** HV Connections protection functions shall, on operation

- (a) Trip the HV circuit breaker
- (b) Initiate transformer LV and tertiary DTT send functions (see section 6.9)
- (c) Initiate HV CB Fail (see section 4.1)
- (d) Lockout HV CB DAR (see section 6.12)

Informative: HV CB DAR will only be required for particular installations (i.e. with banked transformers). The contract will specify this.

6 TRANSFORMER HV FUNCTIONAL REQUIREMENTS

Informative: This section describes all of the functions that may be needed on a transformer HV, and gives circumstances where functions may not be required. Details of the transformer LV and tertiary functions are contained within sections 7 and 8 respectively.

Transformer HV Main Protection

- 6.1** A main protection, preferably of the numeric type, providing two protection functions driven from a common CT, shall be provided. At least one protection shall be an overall unit protection, which is responsive to both phases to phase and phase to earth faults on the transformer and its associated connections. The other protection shall, as a minimum, be sensitive to earth faults on both HV and LV windings. The protection shall be provided with self-supervision and CT supervision (see NGTS 3.24.65).

Informative: An acceptable example is a combination of an overall biased differential protection (see NGTS 3.24.65) and a restricted earth fault protection (see NGTS 3.24.65). For double wound transformers there would be separate HV and LV restricted earth fault protection but for auto-transformers there would be a common restricted earth fault protection.

Informative: If the protection is of the high impedance type, then duplicate overall protection driven from a common CT, shall be provided. Voltage limiting devices shall also be provided if the voltage developed across the relay circuit during maximum internal fault conditions is greater than 3kV. The characteristic of the voltage limiting device provided shall be declared by the supplier.

- 6.2** The protection shall be capable of accommodating a change of transformer ratio of ∇ 20% of nominal and shall not produce an unwanted operation for any transformer energising conditions such as inrush or magnetising conditions.
- 6.3** The primary operating current for earth faults shall be between 10% and 60% of the full load current for the HV winding and, for double wound transformers, between 10% and 25% of the full load current of the LV winding. The protection shall not give an unwanted operation under any normal operating conditions or external fault conditions.

6.4 Transformer overall unit protection functions shall, on operation

- (a) Trip the HV circuit breaker
- (b) Initiate transformer LV and tertiary DTT send functions (see section 6.9)
- (c) Initiate HV CB Fail (see section 4.1)
- (d) Initiate Automatic Switching (see section 9.29)

Informative: Automatic Switching will only be required for particular installations (i.e. with banked transformers). The contract will specify this.

Transformer HV Back Up Protection

6.5 Back up protection functions having the following characteristics (see NGTS 3.24.38) shall be provided.

- (a) Two stage HV 3-phase IDMT overcurrent protection
- (b) HV 3-phase instantaneous overcurrent protection with low transient overreach characteristics

6.6 The back up protection functions shall, on operation have the selectable option to

- (a) Trip the HV circuit breaker
- (b) Initiate transformer LV and tertiary DTT send functions (see section 6.9)
- (c) Initiate HV CB Fail (see section 4.1)
- (d) Initiate Automatic Switching (see section 9.29)

Informative: Automatic Switching will only be required for particular installations (i.e. with banked transformers). The contract will specify this.

Informative: The first stage of the two stage overcurrent (6.5(a)) would normally be selected to trip the transformer LV CB only and not initiate Automatic Switching and HV CB Fail.

Transformer, Combined CT/VT and HV Wound VT Mechanical Protections

6.7 Mechanical protection functions shall be provided for a number of the following devices, all or some of which are supplied on transformers, combined CT/VT units and wound VTs.

- (a) Gas accumulation and oil surge detector devices
- (b) Winding temperature devices
- (c) Oil level devices

6.8 Mechanical protection functions shall, on operation have the selectable option to

- (a) Trip the HV circuit breaker
- (b) Initiate transformer LV and tertiary DTT send functions (see section 6.9)
- (c) Initiate HV CB Fail (see section 4.1)
- (d) Initiate Automatic Switching (see section 9.29)

Informative: Automatic Switching will only be required for particular installations (i.e. with banked transformers). The contract will specify this.

Informative: The winding temperature (6.7(b)) would normally be selected to trip the transformer LV CB only and not initiate Automatic Switching and HV CB Fail.

HV Direct Transfer Tripping (DTT) Functions

- 6.9** There shall be a Direct Transfer Tripping (DTT) function between the HV and each LV circuit end and a Direct Transfer Tripping (DTT) function between the HV and any tertiary connected plant.

Informative: Dual transformer DTT functions shall be provided, and each one should reside in a different hardware unit.

Informative: The DTT function can be via a direct wire connection, a cross-site fibre or via an Operational Telecommunications Service (TS). The contract will specify this.

- 6.10** Receipt of a DTT at the HV from an initiation at the LV shall, on operation

- (a) Trip the HV circuit breaker
- (b) Initiate HV CB Fail (see section 4.1)
- (c) Initiate Automatic Switching (see section 9.29)

Informative: Automatic Switching will only be required for particular installations (i.e. with banked transformers). The contract will specify this.

- 6.11** Receipt of a DTT at the HV from an initiation at the Tertiary shall, on operation

- (a) Trip the HV circuit breaker
- (b) Initiate HV CB Fail (see section 4.1)
- (c) Initiate Automatic Switching (see section 9.29)

Informative: Automatic Switching will only be required for particular installations (i.e. with banked transformers). The contract will specify this.

HV CB DAR

- 6.12** HV CB DAR shall be provided, but will only be required for particular installations (i.e. with banked transformers). The contract will specify this.

- 6.13** DAR of the HV CB shall allow closure of the HV CB

- (a) if the necessary auto isolation of the faulted plant is complete.
- (b) If the corresponding transformer LV is dead.

7 TRANSFORMER LV FUNCTIONAL REQUIREMENTS

Informative: This section describes all of the functions that may be needed on a transformer LV (including the LV Circuit Breaker), and gives circumstances where functions may not be required. Details of the transformer HV and tertiary functions are contained within sections 6 and 8 respectively.

LV Circuit Breaker Fail or Interlocked Overcurrent Protection

- 7.1** Circuit Breaker Fail (CBF) protection (see NGTS 3.24.39) or Interlocked Overcurrent (INT OC) protection (see NGTS 3.24.38) shall be provided for the transformer LV Circuit Breaker (CB).

Informative: CBF shall be provided for 400 and 275kV circuit breakers. Interlocked Overcurrent shall, if required, be provided for 132kV and lower voltage circuit breakers.

7.2 On operation CBF shall

- (a) Cause other CBs connected to the same busbars to trip
- (b) Initiate transformer HV and tertiary DTT send functions (see section 7.16) and also initiate the banked transformer LV DTT send functions, if applicable.
- (c) Lockout LV CB DAR (see section 7.21)

Informative: LV CB DAR will only be required for particular installations (i.e. with banked transformers). The contract will specify this.

7.3 On operation INT OC shall

- (a) Initiate transformer HV and tertiary DTT send functions (see section 7.16) and also initiate the banked transformer LV DTT send functions, if applicable.
- (b) Lockout LV CB DAR (see section 7.21)

Informative: LV CB DAR will only be required for particular installations (i.e. with banked transformers). The contract will specify this.

LV Busbar Protection

7.4 The transformer LV shall interface with the LV substation Busbar protection system (see NGTS 3.24.34).

7.5 On operation, busbar protection shall

- (a) Trip the LV circuit breaker
- (b) Initiate LV CB Fail or enable Interlocked Overcurrent (see section 7.1)
- (c) Lockout LV CB DAR (see section 7.21)

Informative: LV CB DAR will only be required for particular installations (i.e. with banked transformers). The contract will specify this.

LV CB Pole Discrepancy Tripping

7.6 A pole discrepancy tripping function shall be provided for the transformer LV circuit breaker.

Informative: Pole discrepancy has traditionally been known as 'phases not together' within the UK electricity supply industry.

LV CB Phase Unbalance Alarm

7.7 A phase unbalance detector function shall be provided that initiates an alarm for a sustained unbalanced load current.

LV CB Trip Circuit Supervision

7.8 A trip circuit supervision function shall be provided to monitor the complete tripping circuit associated with each CB trip coil irrespective of the CB position. The complete tripping circuit shall include all associated fuses, links, wiring, resistors, trip coils, plant auxiliary contacts and relay contacts – excluding those relay contacts which initiate CB tripping.

Informative: The trip circuit supervision function shall initiate an alarm should a persistent fault be detected.

LV Connections Protection

- 7.9** Preferably single overall unit protection of the numeric type (see NGTS 3.24.65), with CT and internal supervision (see NGTS 3.24.65), shall be provided.

Informative: If the protection is of the high impedance type, then duplicate overall protection with CT supervision and driven from a common CT, shall be provided. Voltage limiting devices shall also be provided if the voltage developed across the relay circuit during maximum internal fault conditions is greater than 3kV. The characteristic of the voltage limiting device provided shall be declared by the supplier.

- 7.10** LV Connections protection functions shall, on operation

- (a) Trip the LV circuit breaker
- (b) Initiate transformer HV and tertiary DTT send functions (see section 7.16) and also initiate the banked transformer LV DTT send functions, if applicable.
- (c) Initiate LV CB Fail (see section 7.1)

Transformer LV Back Up Protection (Auto Transformers)

- 7.11** Back up protection functions having the following characteristics (see NGTS 3.24.38) shall be provided.

- (a) LV 3-phase IDMT overcurrent protection
or
- (b) LV IDMT earth fault protection where the transformer LV side connects directly to a feeder

- 7.12** The back up protection functions shall, on operation

- (a) Trip the LV circuit breaker
- (b) Initiate LV CB Fail (see section 7.1)

Transformer LV Back Up Protection (Double Wound Transformers)

- 7.13** Back up protection functions having the following characteristics (see NGTS 3.24.38) shall be provided.

- (a) 2 stage unrestricted earth fault

- 7.14** The stage 1 back up protection functions shall, on operation

- (a) Trip the LV circuit breaker
- (b) Initiate LV CB Fail (see section 7.1)

- 7.15** The stage 2 back up protection functions shall, on operation

- (a) Trip the LV circuit breaker
- (b) Initiate LV CB Fail (see section 7.1)
- (c) Initiate transformer HV and tertiary DTT send functions (see section 7.16) and also initiate the banked transformer LV DTT send functions, if applicable.

LV Direct Transfer Tripping (DTT) Functions

- 7.16** There shall be a Direct Transfer Tripping (DTT) function between the LV and the HV, a Direct Transfer Tripping (DTT) function between the LV and a banked transformer LV (if applicable) and a Direct Transfer Tripping (DTT) function between the LV and any tertiary connected plant.

Informative: Dual transformer DTT functions shall be provided, and each one should reside in a different hardware unit.

Informative: The DTT function can be via a direct wire connection, a cross-site fibre or via an Operational Telecommunications Service (TS). The contract will specify this.

- 7.17** Receipt of a DTT at the LV from an initiation at the HV shall, on operation

- (a) Trip the LV circuit breaker
- (b) Initiate LV CB Fail (see section 7.1)

- 7.18** Receipt of a DTT at the LV from an initiation at the Tertiary shall, on operation

- (a) Trip the LV circuit breaker
- (b) Initiate LV CB Fail (see section 7.1)

- 7.19** Receipt of a DTT at the LV from an initiation at the banked transformer LV (if applicable) shall, on operation

- (a) Trip the LV circuit breaker
- (b) Initiate LV CB Fail (see section 7.1)

- 7.20** Receipt of a DTT at the LV from an initiation at the banked transformer Tertiary (if applicable) shall, on operation

- (a) Trip the LV circuit breaker
- (b) Initiate LV CB Fail (see section 7.1)

LV CB DAR

- 7.21** LV CB DAR shall be provided, but will only be required for particular installations (i.e. with banked transformers). The contract will specify this.

- 7.22** The LV CB DAR will be initiated by the Automatic Switching.

Informative: The LV CB DAR facilities shall comply with the specified performance requirements contained in NGTS 3.24.16.

- 7.23** DAR of the LV CB shall allow closure of the LV CB

- (a) If the LV busbar is dead
- (b) if there is synchronism between the transformer LV and the LV busbar voltages.

Informative: The check synchronisation between transformer LV and LV busbar voltage is performed by the synchronising function mentioned in section 7.25.

LV Circuit Breaker DAR Conditioning

7.24 The following selectable DAR conditioning functions for the transformer LV CB shall be provided that will

- (a) inhibit the LV CB DAR on receipt of a signal from the LV CB.

Informative: No other inhibit is normally required. The LV CB DAR will only initiate closure of the LV CB when the transformer LV becomes live following closure of the HV CB. Therefore, the necessary inhibits are covered by the HV DAR Interlocking.

- (b) lockout the LV CB DAR on receipt of a signal from the LV CB.
(c) lockout the LV CB DAR for manual LV circuit breaker close operation.
(d) lockout the LV CB DAR on operation of the LV busbar protection.
(e) lockout the LV CB DAR on operation of the LV CB fail protection or interlocked overcurrent protection.
(f) lockout the LV CB DAR from the HV DAR conditioning (interlocking) in section 9.30.

Informative: The DAR conditioning function has traditionally been performed on National Grids system by electrically reset trip relays and the associated trip relay reset schemes and the use of DTT signals maintained for different, predetermined times.

LV CB Synchronising

7.25 LV circuit breakers shall be provided with check synchronising and, if applicable, system synchronising functions (see NGTS 3.24.60).

7.26 The transformer LV VT shall provide a voltage input (incoming voltage) to the Synchronising functions mentioned in section 7.25.

Voltage Selection

7.27 The transformer LV VT shall provide inputs to the substation LV voltage selection function.

7.28 The substation voltage selection function shall provide a voltage reference input (running voltage) that represents the voltage of the busbar to which the transformer LV is selected to the Synchronising functions mentioned in section 7.25.

8 TRANSFORMER TERTIARY FUNCTIONAL REQUIREMENTS

Informative: This section describes all of the functions that may be needed on a transformer tertiary, and gives circumstances where functions may not be required. Details of the transformer HV and LV functions are contained within sections 6 and 7 respectively.

Transformer Tertiary Main Protection

8.1 A main protection, preferably of the numeric type, providing two protection functions shall be provided. One protection, an overall unit protection, shall be provided to protect the tertiary connections between the tertiary winding bushings and the tertiary connected equipment circuit breaker. The protection shall be responsive to both phase to phase and phase to earth faults on the transformer and its associated connections. The other protection shall, as a minimum, be sensitive to earth faults within the earthing transformer HV winding, transformer tertiary winding and associated tertiary connections to the tertiary connected equipment circuit breaker. The protection shall be provided with self-supervision and CT supervision (see NGTS 3.24.65).

Informative: An acceptable example is a combination of an overall biased differential protection (see NGTS 3.24.65) and a restricted earth fault protection (see NGTS 3.24.65).

Informative: If the protections are of the high impedance type, then voltage limiting devices shall be

provided if the voltage developed across the relay circuit during maximum internal fault conditions is greater than 3kV. The characteristic of the voltage limiting device provided shall be declared by the supplier.

Informative: If the earthing transformer is to be used to provide LVAC supplies, then its LV winding shall be provide with a restricted earth fault protection. The contract will specify this.

- 8.2** The overall unit protection shall have a setting range of 10% - 50% of the available earth fault current and shall be adjustable.

Informative: Where a neutral earthing resistor (NER) exists and a setting within this range cannot be achieved an instantaneous earth fault protection shall in addition be supplied as specified in section 8.4(c).

- 8.3** Transformer tertiary main protection functions shall, on operation

- (a) Trip the tertiary connected plant circuit breaker
- (b) Initiate transformer HV and LV DTT send functions (see section 8.8) and also initiate the banked transformer tertiary DTT send functions

Transformer Tertiary Back Up Protection

- 8.4** Back up protection functions having the following characteristics (see NGTS 3.24.38) shall be provided.

- (a) Tertiary 3-phase IDMT overcurrent protection
- (b) Tertiary IDMT unrestricted earth fault protection

Informative: 'Unrestricted earth fault' has traditionally been known as 'standby earth fault' within the UK electricity supply industry.

- (c) Tertiary instantaneous earth fault protection

Informative: Where the minimum earth fault current is less than twice the minimum available fault setting of the tertiary connected plant overall unit protection, an additional instantaneous earth fault protection shall be provided. The protection shall be energised from the same CT as the unrestricted earth fault protection.

- 8.5** The tertiary back up protection functions shall, on operation

- (a) Trip the tertiary connected plant circuit breaker
- (b) Initiate transformer HV and LV send functions (see section 8.8) and also initiate the banked transformer tertiary DTT send functions

Transformer Tertiary and Earthing Transformer Mechanical Protections

- 8.6** Mechanical protection functions shall be provided for a number of the following devices, all or some of which are supplied on the transformer tertiary and earthing transformer.

- (a) Earthing transformer gas accumulation and oil surge detector devices
- (b) Tertiary winding temperature

- 8.7** Mechanical protection functions shall, on operation have the selectable option to
- (a) Trip the tertiary connected plant circuit breaker
 - (b) Initiate transformer HV and LV send functions (see section 8.8) and also initiate the banked transformer tertiary DTT send functions

Informative: The tertiary winding temperature (8.6(b)) would normally be selected to trip the tertiary connected plant circuit breaker only.

Tertiary Direct Transfer Tripping (DTT) Functions

- 8.8** There shall be a Direct Transfer Tripping (DTT) function between the tertiary and the HV, a Direct Transfer Tripping (DTT) function between the tertiary and each LV circuit end and a Direct Transfer Tripping (DTT) function between the tertiary and any banked transformer tertiary connected plant.

Informative: Dual transformer DTT functions shall be provided, and each one should reside in a different hardware unit.

Informative: The DTT function can be via a direct wire connection, a cross-site fibre or via an Operational Telecommunications Service (TS). The contract will specify this.

- 8.9** Receipt of a DTT at the Tertiary from an initiation at the HV shall, on operation
- (a) Trip the tertiary connected plant circuit breaker
- 8.10** Receipt of a DTT at the Tertiary from an initiation at the LV shall, on operation
- (a) Trip the tertiary connected plant circuit breaker
- 8.11** Receipt of a DTT at the Tertiary from an initiation at the banked transformer LV (if applicable) shall, on operation
- (a) Trip the tertiary connected plant circuit breaker
- 8.12** Receipt of a DTT at the Tertiary from an initiation at the banked transformer tertiary (if applicable) shall, on operation
- (a) Trip the tertiary connected plant circuit breaker

9 GENERAL FUNCTIONAL REQUIREMENTS

Informative: This section describes all of the general functions that may be needed on a transformer bay, and gives circumstances where functions may not be required. Specific details of the transformer HV, LV and tertiary functions are contained within sections 6, 7 and 8 respectively.

Tripping

- 9.1** At 400kV and 275kV the protections shall operate into two independent tripping systems. At 132kV and below the protections shall operate into a single tripping system.

Trip Relay Reset

- 9.2** Where electrical reset trip relays are employed, then an automatic trip relay resetting function shall be provided (see NGTS 3.24.75).