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Specification

Substation Auxiliary Transformer from Rectifier Transformer Secondary

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1.0	27/04/2022	First issue
2.0	10/04/2024	Second issue. Changes to previous content are the inclusion of requirements for 1500 V dc metro systems

Preface

This specification is the second issue.

This document specifies the requirements for substation auxiliary transformers that are used on the TfNSW metropolitan heavy rail passenger network and 1500 V dc metro network within the metropolitan rail area.

All information required to ensure that the auxiliary transformer is electrically suitable for the TfNSW heavy rail passenger network and 1500 V dc metro electrical network is contained in this document or referenced by this TS document.

Appendix A is the technical schedule which is required to be completed by the manufacturer.

Appendix B details the data set requirements associated with the transformer.

Appendix C details integrated support requirements.

Appendix D details the whole of life cost requirements.

The changes to previous content in EP 05 00 00 01 SP version 2.1 which had been imported into the transport standards portal as TS 03682:1.0 are the inclusion of requirements for 1500 V dc metro systems.

The terms 'normative' and 'informative' are used in asset standards to define the application of the appendices to which they apply. A 'normative' appendix is an integral part of an asset standard, whereas an 'informative' appendix is only for information and guidance.

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1 Scope

This document provides the specifications for three-phase auxiliary transformers, which are supplied from the secondary of the rectifier transformers inside of traction substations, designed for use in the TfNSW metropolitan heavy rail passenger network and 1500 V dc metro network within the metropolitan area.

2 Application

The requirements of this document apply to the purchase of auxiliary transformers installed at traction substations for use in the TfNSW heavy rail passenger network and 1500 V dc metro lines within the metropolitan rail area.

The requirements of this document are not applicable to existing auxiliary transformers currently in service.

3 Referenced documents

The following documents are cited in the text. For dated references, only the cited edition applies. For undated references, the latest edition of the referenced document applies.

International standards

EN 60404 *Magnetic materials – Part 1: Classification*

Australian standards

AS/NZS 60076.1 *Power transformers, Part 1: General*

AS/NZS 60076.5 *Power transformers, Part 5: Ability to withstand short circuit*

AS/NZS 60076.10 *Power transformers, Part 10: Determination of sound levels*

AS 60076.11 *Power transformers, Part 11: Dry-type transformers*

AS 62271.301 *High voltage switchgear and controlgear, Part 301: Dimensional standardisation of terminals*

AS 60529 *Degrees of protection provided by enclosures (IP Code)*

Transport for NSW standards

TS 03744 (EP 00 00 00 13 SP) *Electrical Power Equipment – Design Ranges of Ambient Conditions*

TS 03742 (T HR EL 00002 PR) *Electrical Power Equipment – Integrated Support Requirements*

TS 00011 *Common Requirements for Electric Power Equipment*

TS 03825 (EP 03 00 00 01 TI) *Rectifier Transformer and Rectifier Characteristics*

TS 03817 *Transformer Loss Evaluation*

TS 01505 (T MU AM 01001 ST) *Life Cycle Costing*

TS 01517 (T MU AM 01002 MA) *Maintenance Requirements Analysis Manual*

TS 06178 (T MU MD 00005 GU) *Type Approval of Products*

TS 01547.1 (T MU MD 00006 ST) *Engineering Drawings and CAD Requirements*

4 Terms, definitions and abbreviations

The following terms, definitions and abbreviations apply in this document:

AMB Asset Management Branch

dry-type transformer a transformer of which the magnetic circuit and windings are not immersed in an insulating liquid

HV winding high voltage winding; the winding having the highest rated voltage

IP ingress protection

LV low voltage: a voltage exceeding 50 V ac or 120 V ripple-free dc but not exceeding 1000 V ac or 1500 V dc

LV winding low voltage winding; the winding having the lowest rated voltage

primary winding the winding that receives the active power from the supply system, usually the winding having the highest rated voltage

principal tapping the tapping to which the rated quantities are related

secondary winding the winding that delivers the active power to the load circuit, usually the winding having the lowest rated voltage

TAO Technically Assured Organisation

TfNSW Transport for NSW

5 Type approval

Transformers procured to this document shall be type approved by TfNSW AMB prior to being connected to the electrical network.

The AMB process for type approval is given in TS 06178.

6 Functional characteristics

The substation auxiliary transformer provides the supply for the auxiliary services in traction substations. The transformer primary winding is supplied from one of the secondary windings of a rectifier transformer. The rectifier transformer supplies a rectifier for the 1500 V dc traction system.

The auxiliary services include lighting, low voltage power, dc power supplies, ventilation and compressed air. They are not used for supplying dc traction loads.

In new and most existing locations on the TfNSW metropolitan heavy rail passenger network the auxiliary transformers are typically 600 V/433 V and are less commonly 600 V/220 V transformers. However, older locations with quad zig zag transformers use 2420 V/220 V transformers.

Specifications for the 2420 V/220 V auxiliary transformers may be developed if a request is submitted to TfNSW.

7 Performance characteristics

The auxiliary transformers covered in this document shall be in accordance with the performance requirements as stated in Table 1, Table 2 and Table 3. Where not specifically detailed in this document, the performance characteristics of the transformer shall be in accordance with AS/NZS 60076 (all parts).

Table 1 – General requirements

Parameter	Designation
General	Indoor Separate windings Three-phase
Type of cooling	Air natural (AN)
Transformer type	dry type
Transformer enclosure IP rating	IP21 as define in AS 60529
Transformer enclosure IP rating (metro)	IP 31 as defined in AS 60529
Noise Level (metro)	60 dBA

Table 2 – Transformer electrical characteristics

Parameter	Designation
Rated voltage – primary (heavy rail)	600 V (rms)
Rated voltage – primary (metro)	1.2 kV (rms)
Rated voltage – secondary (heavy rail)	415 V (rms) 220 V (rms) (Note 1)
Rated voltage – secondary (metro)	400 V(rms)
Rated power (preferred ratings, other sizes subject to TfNSW's approval)	3 phase: 50, 75, 100 kVA (Note 2), 250 & 400 kVA for metro
Rated frequency (f _r)	50 Hz

Parameter	Designation
Neutral terminal	Star point or neutral of LV winding shall be connected to a suitable terminal and fully insulated from earth. The neutral terminal shall be sized to be capable of carrying the same current as the phase terminals.
Method of neutral earthing of the system	Non-effectively earthed
Connection symbol	Dyn1
Primary winding tapping range	Full kVA tapplings at $\pm 2.5\%$ and $\pm 5\%$ of the principal tapping. The tapplings shall be selected by off-circuit bolted links.
Primary winding tapping range (metro)	Off load tap changer fitted on the primary voltage winding side $+5\%$ to -5% in 2.5% steps as specified
System highest voltage – primary	3.6 kV (rms)
System highest voltage – secondary	1.1 kV (rms)
Rated insulation level – primary Power frequency withstand voltage Lightning impulse withstand voltage	10 kV (rms) 20 kV (peak)
Rated insulation level – secondary Power frequency withstand voltage Lightning impulse withstand voltage	5 kV (rms) Not applicable
Insulation class (heavy rail)	Class H (180°C) in accordance with AS 60076.11
Insulation class (metro)	Class F in accordance with AS 60076.11
Impedance	Refer to Table 1 of AS/NZS 60076.5

Note 1: 600/220 V transformers are only to be used at locations where the existing LV auxiliary system uses 220 V and are not to be used at new locations.

Note 2: The AMB shall be consulted for transformers above 100 kVA in heavy rail applications.

Table 3 – Ambient temperature, sound level, environmental, climatic and fire behaviour classes

Parameter	Designation
Ambient temperature range (heavy rail)	Refer to TS 03744
Ambient temperature (metro)	45° C
Environment class	E0 for above ground installations E1 for below ground installations (in accordance with AS 60076.11)
Climatic class	C1 in accordance with AS 60076.11
Fire behaviour class	F0 for above ground installations F1 for below ground installations (in accordance with AS 60076.11)
Sound level	Refer to AS/NZS 60076.10

8 Technical requirements

8.1 General

The auxiliary transformers covered in this document shall be in accordance with the technical requirements as stated in Section 8.2 through to Section 8.14.

8.2 Rated insulation level

The primary windings are connected to the unearthed secondary of the rectifier transformer. During fault conditions, the voltage to earth of this winding can exceed 3.5 kV dc. The rated insulation level shall comply with requirements specified in Table 2.

8.3 Harmonic voltages

The rectifiers create high harmonic distortion of the current waveform. This distorted current waveform interacts with the impedance of the rectifier transformer resulting in harmonic voltages. The design of the auxiliary transformer shall therefore take these harmonic currents and voltages into account. Refer to TS 03825 for further details.

8.4 Temperature-rise limits

The transformer shall be capable of continuous operation at rated power without exceeding the maximum temperature-rise limits in accordance with Section 11 of AS 60076.11-2006 (R2016). Special consideration shall be taken to the ambient temperature as they differ from the ambient temperatures outlined in TS 03744.

8.5 Temperature monitoring (metro)

For metro, a thermal control unit shall be provided in the auxiliary transformer, to provide high temperature warning alarm when the winding temperature exceeds 120°C, and to provide a trip signal to the incoming protection device when the temperature exceeds 140°C. The warning alarm and trip signal shall be provided as voltage free contact for connection to the SCADA system.

8.6 Rating plate

A rating plate made of pacified stainless steel in accordance with the requirements of AS/NZS 60076.1 shall be firmly attached to the transformer.

In addition to the requirements of AS/NZS 60076.1 the rating plate shall also include the following:

- a diagram of connections
- the TfNSW specification number and version
- the insulation, environment, climatic and fire behaviour classes.

The rating plate shall be located so that it can be easily read from ground level with the naked eye from the expected viewing distance.

A terminal marking plate complying with the requirements of Section ZB7 of AS/NZS 60076.1:2014 shall also be attached to the transformer.

8.7 Terminal arrangement

The primary and secondary winding terminals shall be located on opposite sides of the transformer frame.

The distance between LV terminals should be appropriate for the number and size of cables connected. The standard terminal dimensions shall be in accordance with AS 62271.301 for accommodation of individual cables.

The three primary winding cables and the four secondary winding cables shall be brought out from each transformer winding and terminated on screwed terminal studs suitable for use with crimp lugs. The terminals shall be suitably proportioned and marked to the requirements in Section ZB4 of AS/NZS 60076.1:2014. An insulated barrier shall separate the primary terminals and the secondary terminals from the transformer case. The complete arrangement shall be enclosed in the transformer enclosure.

8.8 Construction

All live and exposed parts of the transformer shall have suitable mechanical strength to ensure that mechanical stresses from inrush and short circuit currents and the like do not cause undue deterioration or failure of the transformer. The transformer frame shall be constructed from material suitable to last the full life of the transformer and treated such that no maintenance is required. The preferred material to be used is steel.

A minimum IP21 enclosure shall be provided for the transformer in accordance with TS 03744. The enclosure shall be removable without the need for disconnection of terminals from the transformer. The enclosure shall be constructed such that all ventilation and entry points to the enclosure are vermin proof.

A method for securing the primary and secondary cables shall be incorporated into the enclosure.

For metro, the auxiliary transformer shall be enclosed in an enclosure, with ventilated screen, suitable for natural air ventilation. The enclosure shall be of sheet steel of minimum thickness 2 mm, suitably braced to form a rigid structure.

8.9 Earth terminal

An earthing terminal suitable for the connection of a 70 mm² cable shall be located externally on the transformer enclosure.

8.10 Lifting attachments

Transformers shall be designed to enable them to be secured during transport and to be able to be lifted for installation using either of the following methods:

- suitable lifting lugs shall be provided for lifting the transformer (with and without enclosure) and for securing to vehicles during transport using standard slings
- suitable base channels or brackets for insertion of forks from forklift trucks to allow the transformer to be lifted. Such brackets shall not be less than 100 mm from the ground.

8.11 Mounting

The transformer shall be ground mounted and fitted with C channel type mounting brackets suitable for floor mounting. The mounting brackets shall have the following characteristics:

- corrosion free for the life of the transformer
- structurally support the weight of the transformer
- be capable of being removed, if required

- include 15 mm diameter mounting holes that are accessible when the transformer is mounted against a wall
- allow for mounting without the removal of the transformer cover
- ensure that the clearance between the transformer enclosure and the mounting surface allows for sufficient ventilation to meet the heat rise requirements.

8.12 Finish

The transformer shall remain corrosion free for the life of the transformer. All welds shall be made smooth, rough edges rounded and weld splatter removed. All internal and external surfaces shall be treated with a coating that provides protection against corrosion caused by water such as hot dipped galvanising or powder coating in accordance with Section 8.13. Manufacturers fabricating transformer enclosures with stainless steel that is suitable for the environmental conditions it is to be installed in is also acceptable.

8.13 Painting

The external surfaces of the transformer shall be painted in accordance with TS 00011.

8.14 Labelling

All labelling of the transformer shall be in accordance with the requirements of TS 00011.

9 Tests

9.1 General

The transformer shall be completely assembled in the factory. TfNSW reserves the right to witness any of the tests. All test results shall be provided to TfNSW by the transformer manufacturer.

9.2 Type tests

Type tests as stated in AS/NZS 60076.1 and AS 60076.11 shall be carried out on one transformer of a batch. Type test certificates for each of these tests shall be accepted if it can be demonstrated that the transformer supplied is of a similar design to a previously type tested transformer.

A short circuit withstand test is not required; however, the manufacturer is required to provide the short circuit design calculations.

9.3 Routine tests

Routine tests as stated in AS/NZS 60076.1 and AS 60076.11 shall be carried out on each transformer.

9.4 Special tests

Special tests as stated in AS/NZS 60076.1 and AS 60076.11 for transformers with environment class E1 and fire behaviour class F1 shall be carried out.

Appendix A Technical schedule (normative)

This appendix has the technical schedule which shall be completed at the time of tender and details the descriptive information that is required to be submitted at the time of tender.

A.1 Auxiliary transformer technical schedule

The information listed in this technical schedule is provided by the manufacturer with the tender for each transformer.

Transformer details	Answer
Name of the manufacturer	
Country of manufacture	
Design life	Years
Number of phases	
Type of cooling	
Rated primary voltage	V
Rated secondary voltage	V
Rated primary current	A
Rated secondary current	A
Rated frequency	Hz
Rated power	kVA
Tapping range	
Connection vector symbol	
Maximum temperature rise of windings	°C
Impedance voltage at rated current and 75°C	%
No-load current with rated voltage applied to the principal tapping	%
No-load current with 110% of rated voltage applied to the principal tapping	%
No-load loss	W
Load loss at 75°C	W
Maximum temperature rise of winding	°C
Short circuit capability (current & duration)	A for sec
Maximum inrush current	A
Thermal time constant – winding	Mins
Sound power level	dB(A)

Protective treatment applied to transformer enclosure	Answer
Internal surfaces	
External surfaces	

Construction details	Answer
IP rating	
Type of core steel – hot or cold rolled	
Brand or trade name and grade of core steel	
Maximum flux density on the net cross-section of steel with rated volts at rated frequency applied to the centre tapping	
Limbs	T
Yoke	T
Material used for primary winding	
Material used for secondary winding	
Class of insulation on windings	
Environment class	
Climate class	
Fire behaviour class	
Is heat-shrink material provided on the primary terminals?	Yes/No

Transformer overall dimensions (with enclosure fitted)	Answer
Length	mm
Width	mm
Height	mm

Terminal clearances in air	Answer
Primary – between phases	mm
Primary – phase to earth	mm
Secondary – between phases	mm
Secondary – phase to earth	mm

Transformer mass	Answer
Mass of complete transformer	kg
Mass of transformer core and windings only	kg
Mass of transformer enclosure	kg

Rated insulation levels – Primary terminals	Answer
Lightning impulse withstand voltage	kV rms
Power frequency withstand voltage	kV rms

Rated insulation levels – Secondary terminals	Answer
Power frequency withstand voltage	kV rms

A.2 Reliability data

The transformer reliability data is required to be submitted. Refer to TS 01517 for details of TfNSW requirements.

This manual supports the TfNSW Asset Management Policy with detailed processes for undertaking a maintenance requirement analysis.

A.3 Additional descriptive transformer details and information

In addition to the technical schedule, the following information shall also be submitted with the tender:

- outline drawings: Fully dimensioned outline drawings showing all fittings and terminal arrangements. The general arrangements and layouts shall be adhered to in the final design unless written approval is obtained from TfNSW. The drawing requirements are detailed in Appendix B
- core material characteristics: Typical curves of flux density versus ampere turns per metre for the core material
- core information: Detailed description of the core type, methods of making joints, insulation between laminations, treatment of edges, core bolt insulation and method for minimising hot spots in limbs. Include details of the proposed method for verifying core hot spot temperature and method for how the core is earthed
- other information: Any other information considered necessary by the manufacturer
- features of the transformer design: Provide details of the transformer design. This should include a description of the following:
 - the overall transformer design
 - the method for electrically, thermally and structurally modelling the design
 - lessons learnt from previous similar designs and how this has been addressed in this design
 - quality processes during design and manufacture to ensure the design will meet the TfNSW and appropriate Australian and international standards and how the manufacture of the transformer will be in accordance with the design.
- departures from standard: If there any departures from the requirements of this document the details shall be provided on a separate sheet.

Appendix B Data set associated with the equipment (normative)

Section B.1 through to Section B.4 provide details of the data that shall be supplied by the manufacturer and maintained for the transformer. This data will remain the property of TfNSW.

B.1 Drawings and information

All drawings shall conform to the requirements of TS 01547.1. All the drawings should contain the transformer serial numbers.

The following is the minimum set of drawings and attributes that should be included in the drawings:

- transformer arrangement drawings that are drawn to scale with the following details:
 - complete details of the transformer with complete views of all sides of the transformer and detailed sections as required
 - dimensions, including overall size, position of primary and secondary connectors relative to the centre lines of the transformer enclosure and the level of the floor
 - mass of the complete transformer, mass of the core and windings and mass of the enclosure (where it can be removed)
 - complete listing of all fittings, accessories and parts with the associated manufacturer, part or model number and relevant ratings

- schematic and wiring diagrams:

Schematic diagrams of the transformer windings showing connections, tappings and tabulations of current and voltage rating of all windings.

- rating plate drawings:

Details shown on the rating plate drawings should match the plates fixed to the transformer.

B.2 Technical schedule

The information listed in the technical schedule of Appendix A should be completed by the manufacturer and engineering assurance provided by the design TAO for each transformer.

B.3 Life cycle costing

All the data and assumptions pertaining to the determination of the whole-of-life cost (see Appendix D) calculations of the transformer shall be recorded by the design TAO including the transformer loss calculations in accordance with TS 03817.

B.4 Test results

The results of all tests relating to the transformer including acceptance tests, periodic tests and corrective maintenance tests shall be recorded.

Routine test certificates and a type test certificates showing the results of each test performed shall be supplied in searchable PDF format, in English.

Appendix C Integrated system support requirements (normative)

C.1 Integrated support objectives

The transformer manufacturer shall establish and provide the information required to operate and maintain the equipment throughout its operational life. This shall be done in a cost-effective manner, to a level that is consistent with the planned operational performance and usage of the transformer.

This includes the following:

- specifying maintenance requirements
- spares support (availability of spares – timeframe, where they are held)
- support equipment and tooling.

C.2 Equipment supplier deliverables

The integrated support requirements are a significant deliverable in the procurement of new transformers. Documentation and other support deliverables shall be in accordance with TS 03742.

C.3 Operation and maintenance manual

An operation and maintenance manual is not required.

C.4 Training

Training is not required.

Appendix D Whole-of-life cost (normative)

This appendix is provided for TAOs to assess the whole-of-life cost as required by TS 01505.

The selection of the most suitable transformer shall be made based on minimising the whole-of-life cost. The following factors should be considered in determining the whole-of-life cost:

- cost of decommissioning and disposal
- cost of maintenance
- discount rate
- electrical losses
- initial purchase price
- lifetime of equipment.

If this transformer has not previously been type approved by the AMB in accordance with TS 06178, then the costs for this process shall be included in the whole-of-life cost.