

Specification

Auxiliary Transformer Specification

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1 PURPOSE

The purpose of this specification is to specify the minimum requirements of auxiliary transformers, when installed and used within DC traction substations on the Yarra Trams network in order to provide 415 volt 3 phase supply for the substation auxiliary loads. The transformer primary can be either high voltage (HV) or low voltage (LV) taken from the secondary supply of the substation rectifier transformer.

Refer to Infrastructure – Network Power – Substation – Design and Construction [CE-021-ST-0023], specifically section 5.1.

The configuration, ratings and any other project specific equipment details shall be provided by Yarra Trams in the accompanying *Scope of Works* document.

2 SCOPE

The scope of this specification encompasses the design and construction requirements for all new auxiliary transformers. This specification does not apply retrospectively to existing auxiliary transformers on the Yarra Trams network. However, this specification is applicable if an existing auxiliary transformer is being altered, modified or replaced.

This specification applies to any party who is involved in the design or construction of auxiliary transformers for Yarra Trams.

3 COMPLIANCE

Any party who is involved in the design or construction of auxiliary transformers for Yarra Trams shall fully comply with this specification. Deviation from this specification is only permitted when a deviation or waiver has been formally requested and approved by the Engineering Design Authority at Yarra Trams.

The Yarra Trams Engineering Change Management Procedure [CE-021-PR-0020] shall be followed in all circumstances where change is proposed to this specification.

The following definitions apply throughout the specification:

- ‘Shall’ statements are mandatory in the context of compliance with requirements stipulated in this specification.
- ‘Should’ statements are considerations in the context of compliance with requirements stipulated in this specification.
- ‘Information’ statements provide additional content for clarification purposes only and are not requirements in the context of compliance with this specification.
- ‘So far as is reasonably practicable’ statements must at a minimum result in the provision of a technical risk assessment including proposed list of design controls to demonstrate compliance to this specification.



4 REQUIREMENTS

4.1 Service conditions

4.1.1 Operating conditions

- 4.1.1.1 The auxiliary transformer shall be indoor or underground.
- 4.1.1.2 The operating conditions are defined in Infrastructure - Network Power – Substation Design and Construction [CE-021-ST-0023].

4.1.2 Transport and storage conditions

- 4.1.2.1 The transport and storage conditions are defined in the Infrastructure - Network Power – Substation Design and Construction [CE-021-ST-0023].
- 4.1.2.2 The *Designer* shall detail the minimum storage requirements. This information shall be contained in the equipment manuals, which are outlined in Table 6.

4.1.3 Noise

- 4.1.3.1 The permissible noise levels inside and outside the substation are defined in the Infrastructure - Network Power – Substation Design and Construction [CE-021-ST-0023].
- 4.1.3.2 The sound power level shall not exceed the Reduced Limit specified in AS 60076.10 and AS 60076.10.1.

4.1.4 Electromagnetic compatibility (EMC)

- 4.1.4.1 In accordance with clause 12 of AS 60076.1, auxiliary transformers shall be considered as passive elements in respect to emission of, and immunity to, electromagnetic disturbances.
- 4.1.4.2 All other requirements are defined in Infrastructure - Network Power – Substation Design and Construction [CE-021-ST-0023].

4.2 General requirements

4.2.1 General

- 4.2.1.1 The auxiliary transformer shall be a vacuum-impregnated epoxy coil, cast-resin dry-type transformer complying with AS 60076.1 and AS 60076.11.
- 4.2.1.2 Preference shall be made in design for the auxiliary transformer to be installed in a separate, locked room and shall not require an adjacent isolation of the transformer to access it. If a separate room is not possible, then the auxiliary transformer needs to be



properly designed for safety, clearances, prevention of material ingress and be designed to be barricaded and not be free standing in the main switchroom floor of the substation.

4.2.1.3 The auxiliary transformer design shall be defined in the *Scope of Works*. There are two possible primary supplies for an auxiliary transformer as follows:

- Connected to HV AC: The auxiliary transformer is supplied from a dedicated circuit breaker on the HV AC switchgear.
- Connected to rectifier transformer: The auxiliary transformer is supplied from the secondary winding of the rectifier transformer.

4.2.1.4 The auxiliary transformer shall meet the following characteristics:

Table 1: General requirements

Description	Requirement
Connection symbol	Dyn11
Rated frequency	50 Hz
Primary: Configuration	Three-phase windings
Primary: Rated voltage	Connected to HV AC: As defined in the <i>Scope of Works</i> Connected to rectifier transformer: To be determined by the <i>Designer</i>
Secondary: Configuration	Three-phase windings; secondary star point to have provision for earthing connection.
Secondary: Rated voltage	400 or 415 V AC RMS
Isolation between primary and secondary windings	Yes
Rated power	To be determined by the <i>Designer</i> . Standard transformer kVA ratings preferred.
Tapping range	± 7.5 % in steps of ± 2.5 % (7 tap positions)
Tapping type	Off-load tap-changer
Tapping location	Installed on the primary or secondary windings
Short circuit impedance [%]	To be determined by the <i>Designer</i>
System earthing	TT
Type of cooling	AN (Air Natural) preferred ¹
Climatic class	C1
Environmental class	E0
Fire behaviour class	F0
Winding temperature-rise limits	Class H (according to Table 2 of AS 60076.11)



Description	Requirement
Earthed screen between primary and secondary windings	Yes (then specify isolation level)
¹ The <i>Designer</i> shall carefully consider section 4.1.3 prior to the selection of AF (Air Forced) equipment.	

4.2.1.5 The *Designer* is fully responsible for providing suitable ratings for the auxiliary transformer and shall therefore verify the values in Table 1.

4.2.1.6 If the primary rated voltage is 6.6 kV, the design of the auxiliary transformer shall allow the primary rated voltage to be increased to 11 kV at a later date. Yarra Trams acknowledges that this may require a different connection symbol, depending on the primary rated voltage.

4.2.1.7 If the primary rated voltage is 11 kV, the design of the rectifier transformer shall allow the primary rated voltage to be increased to 22 kV at a later date. Yarra Trams acknowledges that this may require a different connection symbol, depending on the primary rated voltage.

4.2.1.8 In accordance with clause 8.4 of AS 60076.11, the auxiliary transformer shall work without damage for 5% overvoltage.

4.2.1.9 In accordance with clause 7 of AS 60076.11, the auxiliary transformer shall fulfil the requirements in AS 60076.5 regarding its ability to withstand short circuits. The *Scope of Works* shall state if a test is required to demonstrate this fulfilment.

4.2.2 Insulation coordination

4.2.2.1 The insulation levels are defined in the Infrastructure - Network Power – Substation Design and Construction [CE-021-ST-0023].

4.2.3 Earthing and bonding

4.2.3.1 The earthing requirements for the auxiliary transformer are the following:

- The primary winding of the auxiliary transformer shall not be earthed; and
- The secondary winding neutral point of the auxiliary transformer shall be earthed.

4.2.3.2 The enclosure and frame of the auxiliary transformer shall be earthed.

4.2.3.3 All other requirements are defined in the Infrastructure - Network Power – Substation Design and Construction [CE-021-ST-0023].



4.2.4 Enclosure

General

When considering the enclosure requirements, there are two possible auxiliary transformer installation types:

- Indoor, where the transformer is located in a separate dedicated room;
- Indoor, where the transformer is not located in a separate dedicated room, and the transformer shall have its own protected enclosure.

4.2.4.1 The general enclosure requirements for each auxiliary transformer installation type are outlined in Table 2. These requirements are to prevent contact with live conductors.

Table 2: Enclosure – General requirements

Installation type	Is an enclosure required?	Minimum degree of protection provided by the enclosure (according to AS 60529)
Indoor, where the transformer is located in a separate dedicated room	No	IP00
Indoor, where the transformer is not located in a separate dedicated room	Yes	IP21

4.2.4.2 Indoor auxiliary transformer enclosures shall be metallic and sufficiently ventilated to allow natural or forced cooling to be effective.

4.2.4.3 Interlocking requirements are outlined in section 4.2.6 as well as Infrastructure - Network Power – Substation Design and Construction [CE-021-ST-0023].

4.2.4.4 If the auxiliary transformer is located in a separate dedicated interlocked room, no equipment separates to the transformer requiring inspection or frequent maintenance shall be located in the room. Examples of such equipment include control panels, air filters, fans, and fire extinguishers.

Dimensions

4.2.4.5 The auxiliary transformer enclosure shall be designed to minimise its overall size (and subsequently the physical size of the substation) while meeting the requirements of specifications and standards.

Covers and doors

4.2.4.6 The covers and doors which are part of the enclosure shall be metallic. When they are closed, they shall provide the same degree of protection as specified for the enclosure. Covers and doors shall not be made of woven wire mesh, expanded metal or similar.



Ventilating openings

4.2.4.7 Ventilating openings and vent outlets shall be arranged or shielded so that they provide the same degree of protection as specified for the enclosure. Such openings may make use of wire mesh or the like provided that it is of suitable mechanical strength.

4.2.5 Protection

General

4.2.5.1 The auxiliary transformer shall include at least the following protection:

- Overcurrent protection
- Surge protection
- Thermal protection

Overcurrent protection

4.2.5.2 When the auxiliary transformer is HV/LV wound, it shall be protected by a dedicated HV AC circuit breaker. When the auxiliary transformer is a LV/LV transformer supplied from the secondary winding of the rectifier transformer, it shall be supplied from removable fuse links. The fuse links shall be accessible for easy replacement of fuses and for isolation of the auxiliary transformer.

Information: For auxiliary transformers connected to the rectifier transformer, the connection point to the star winding of the rectifier transformer and the fuse links are usually located in the rectifier converter cubicle.

Surge protection

4.2.5.3 Care shall be taken to avoid transmission of inadmissible voltage surges between primary and secondary windings and vice versa. This may be achieved by selecting suitable insulation or by careful selection of surge protection devices.

Thermal protection

4.2.5.4 The auxiliary transformer shall have temperature sensors on its windings. The thermal protection system shall provide two levels:

- Temperature alarm: The first level shall operate the ventilation fans (for air-forced rectifier transformers only). An indication of the temperature alarm shall be provided to a local indicator and to the SCADA system; and
- Temperature fault: The second level shall cause the protection to operate, as shown in Table 3. An indication of the failure shall be provided to a local indicator and to the SCADA system.



Table 3: Summary of protection

Protection description	Auxiliary HVCB Trip	Lockout	Indication on control panel	Indication to SCADA system	Notes
Auxiliary Thermal Protection relay					
Temperature alarm [ALARM]			✓	✓	Thermal protection
Temperature fault [FAULT]	✓		✓	✓	Thermal protection
Enclosure access protection [FAULT]	✓		✓	✓	

4.2.5.5 Once the temperature has fallen below the temperature fault level, the rectifier HVCB and DCCB may be closed (the temperature fault shall not lockout devices). However, the local indication shall remain set to indicate that the thermal protection has operated. This local indication shall be manually reset.

4.2.5.6 The thermal protection limits shall be adjustable as a percentage of the maximum allowable temperature.

4.2.5.7 Thermal Protection relay

- A thermal protection relay system shall be provided for the Auxiliary Transformer by a suitably calibrated thermal device. The system shall be a two level thermal sensing system. The first level shall provide an over temperature alarm to the SCADA System, operate an indicator on the Rectifier Circuit Breaker panel and shall operate the ventilation fan contactors. The second level shall trip the rectifier AC circuit breaker, give a temperature trip indication to the SCADA System, and operate a local flag indication on the rectifier circuit breaker panel.
- The thermal protection shall have an adjustable differential temperature setting such that the drop out temperature can be set as a percentage of the selected maximum temperature.
- Reliable analogue type devices are preferred over electronic types unless the Contractor can demonstrate reliability through service life.
- An automatic reset facility shall be provided to operate upon the return to normal temperature conditions. The local flag shall remain set to indicate that the over-temperature protection has operated. This flag shall be manually reset on the rectifier panel.

4.2.5.8 The temperature sensors and their measurement leads shall meet the electromagnetic compatibility requirements defined in section 4.1.4 and shall be suitably insulated from the high voltage windings.

Information: The thermal protection may be provided using a device on the rectifier transformer itself or may be incorporated into the HV AC switchgear protection relay. Yarra Trams have accepted both solutions in past installations.



4.2.6 Interlocking

4.2.6.1 The definitions of interlocking are defined in the Infrastructure - Network Power – Substation Design and Construction [CE-021-ST-0023].

4.2.6.2 The auxiliary transformer shall include at least the interlocking outlined in Table 4.

4.2.6.3 The *Designer* shall provide a detailed enclosure access procedure on the auxiliary transformer enclosure.

Table 4: Summary of interlocking

Interlocking description	Interlocking type	Prerequisite conditions ¹	Notes
Auxiliary transformer enclosure	Mechanical	All of the following: - Relevant HV AC rectifier circuit breaker earth switch is closed. - If the auxiliary transformer is connected to the star secondary winding of the rectifier transformer/converter, then the auxiliary transformer shall be isolated at its fuse links. - Downstream LV AC system is isolated.	

¹The order of the prerequisite conditions does not necessarily represent the order of switching operations.

4.2.7 Control panel

4.2.7.1 If the auxiliary transformer has a control panel, the control panel shall be located in an area which can be accessed without any switching operations.

4.2.8 Equipment interfaces

SCADA

4.2.8.1 The auxiliary transformer shall include at least the SCADA points outlined in Table 5. Each point shall be brought to the SCADA cubicle. The interpretation of Table 4 and additional SCADA requirements shall be in accordance with Infrastructure - Network Power – Substation Design and Construction [CE-021-ST-0023].

Thermal protection relay and its functions are outlined in 4.2.5.

Table 5: Summary of SCADA points

Point description - 'Plant'	Point description - 'Designation'	Point description - 'Quantity'	Analogue, Status or Command	Hardwired or Digital	Details	Conditions or Controls
Transformer	X ¹	Temperature Alarm	Status	Digital	1 Bit	0 = Alarm 1 = Normal [Normal]
Transformer	X ¹	Temperature Fault	Status	Hardwired	1 Bit	0 = Fault 1 = Normal [Normal]
¹ The designation shall be determined by the <i>Designer</i> . Depending on project specific details, this may be "+T01" or "+T02" etc.						

4.2.8.2 Yarra Trams understands that the SCADA points outlined in Table 4 are only a minimum requirement. The *Designer* shall include additional SCADA points, where required for the effective operation and diagnostics of the equipment.

4.2.8.3 If the *Designer* is planning to include additional SCADA points or deviate from the points outlined in Table 4, this information shall be provided to Yarra Trams in accordance with Infrastructure - Network Power – Substation - Design and Construction [CE-021-ST-0023].

4.2.8.4 There are no SCADA interfaces for the equipment other than temperature alarm and fault as detailed above. The equipment shall be controlled and monitored via the HV AC Switchgear.

Cables

4.2.8.5 Requirements for the cables are given in the Cable Specification [IN-021-ST-0003].

LV distribution

4.2.8.6 Interfaces with the LV distribution are given in the LV Switchboards Specification [IN-021-ST-0009] and the *Scope of Works*.

HV AC switchgear

4.2.8.7 Interfaces with the HV AC Switchgear system are given in the HV Switchgear and Control Specification [IN-021-ST-0012] and the *Scope of Works*.

Rectifier transformer

4.2.8.8 Interfaces with the rectifier transformer are given in the Rectifier Transformer Specification [IN-021-ST-0002] and the *Scope of Works*.

4.2.9 Labelling and identification

Warning Labels



4.2.9.1 In accordance with AS 2067, warning labels shall be provided on the enclosure and on the auxiliary transformer coils.

4.2.9.2 The procedure for accessing the auxiliary transformer enclosure shall be labelled on the enclosure in accordance with the switching operations described in section 4.2.6.

Cubicle Identification

4.2.9.3 Cubicle identification shall be in accordance with IEC 60445.

4.2.9.4 Additionally, the equipment designation, which is defined in the *Scope of Works*, shall be clearly marked on the enclosure.

Nameplate

4.2.9.5 The auxiliary transformer shall be fitted with a nameplate identifying the entries as per clause 9.1 of AS 60076.11.

4.2.9.6 In addition to the mandatory entries, the nameplate shall include the following:

- Indoor;
- The standards the auxiliary transformer is compliant with;
- Arrangement of tap settings and instructions required for tap changing;
- No load current;
- Inrush current (peak and time constant); and
- Service conditions which differ from standard conditions (e.g. -5°C to 50°C).

4.2.9.7 The nameplate shall be mounted in accordance with clause 9.2 of AS 60076.11.

4.3 Testing

4.3.1.1 The tests defined below shall be compliant with the relevant parts of AS 60076.1 and AS 60076.11.

4.3.1.2 Testing shall at least comprise the items outlined in Table 6.

Table 6: Summary of tests

Test	Type test ¹	Routine test	Special test	Commissioning test
Measurement of winding resistance		M		M
Measurement of voltage ratio and check of phase displacement		M		M
Measurement of short circuit impedance and load loss		M		
Measurement of no-load loss and current		M		
Separate-source AC withstand voltage test		M		M



Induced AC withstand voltage test		M		O
Lightning impulse test	M			
Partial discharge measurement		M	O	
Temperature-rise test	M			
Measurement of sound level			O	
Short circuit test			O	
Environmental test			O	
Climatic test			O	
Fire behaviour test			O	
Determination of transient voltage transfer characteristics			O	
Measurement of the harmonics of the no-load current			O	
Check thermal protection device(s) and threshold settings				M
M: Mandatory O: Optional. The <i>Scope of Works</i> shall detail if any of these tests are required. ¹ Type tests shall be performed for all rectifier transformers not having a type test certificate.				

4.4 Reliability, Availability, Maintainability and Safety (RAMS)

- 4.4.1.1 Taps shall be accessible for maintenance activities including cleaning and adjustment.
- 4.4.1.2 All other requirements are defined in the Infrastructure - Network Power – Substation Design and Construction [CE-021-ST-0023].

4.5 Documentation

- 4.5.1.1 Submitted documentation shall at least comprise the items outlined in Table 7. This documentation shall be provided for the auxiliary transformer throughout the procedure outlined in EMS Design Acceptance Standard [CE-023-ST-0020].

Table 7: Documentation

Documentation	Step 1: System Design Specifications (SDS)	Step 2: Acceptance Test Criteria	Step 3: Preliminary Design	Step 4: Detailed Design	Step 5: Production	Step 6: Installation/Site Assembly	Project completion
Statement of compliance			✓				
Technical specification			✓				
Single-line diagram of main circuit			✓				
General layout			✓				
Detailed drawings of electrical circuits (main and auxiliary)				✓	✓	✓	✓ ¹
Detailed drawings of mechanical arrangement, including cable boxes				✓	✓	✓	✓ ¹
Connection guide (conductors, earthing, auxiliary circuits, etc)			✓	✓	✓	✓	✓ ¹
Bill of materials				✓	✓	✓	✓ ¹
Detailed drawing of nameplate					✓	✓	✓ ¹
Tap connections diagram					✓	✓	✓ ¹
Type test certificates					✓	✓	✓
Test reports					✓	✓	✓
Installation manual(s)			✓ ²		✓	✓	✓
Operation manual(s)			✓ ²		✓	✓	✓
Maintenance manual(s)			✓ ²		✓	✓	✓
List of recommended spare parts and their availabilities			✓ ²		✓	✓	✓
¹ Drawings shall be submitted into PTV's Drawing Management System Compliant library according to the requirements of clause 4.5.1.2. ² Only typical non-project specific documentation required.							

4.5.1.2 The documentation shall be compliant with the requirements defined in Infrastructure - Network Power – Substation Design and Construction [CE-021-ST-0023].



5 DIAGRAMS AND GUIDANCE

Refer to Infrastructure – Network Power – Substation Design and Construction [CE-021-ST-0023] for preferred and typical auxiliary transformer configurations and installations.



6 RELATED LEGISLATION & DOCUMENTS

- 6.1.1.1 The design and construction of auxiliary transformers shall be consistent with the best engineering practices and shall comply with all the referenced documents listed in this section. These referenced documents shall be read in conjunction with this specification.
- 6.1.1.2 All referenced documents shall refer to the most recent published versions of them at the time of invitation to tender.
- 6.1.1.3 Wherever a conflict exists in the requirements of these documents, the order of precedence shall be observed as defined in the Infrastructure - Network Power – Substation – Design and Construction [CE-021-ST-0023].

Table 8: Referenced documents

Name	Document number
Yarra Trams	
EMS Design Acceptance Standard	CE-023-ST-0020
Infrastructure - Network Power – Substation Design and Construction	CE-021-ST-0023
LV Switchboards Specification	IN-021-ST-0009
Cable Specification	IN-021-ST-0003
HV AC Switchgear and Control Specification	IN-021-ST-0012
Rectifier Transformer Specification	IN-021-ST-0002
Public Transport of Victoria	
PTV Infrastructure Drafting Standards	VRIOGS 007.2
Regulations & other legislative documents	
Refer to Infrastructure - Network Power – Substation Design and Construction (CE-021-ST-0023)	
Industry codes of practice, guidelines, policies, and rules	
Refer to Infrastructure - Network Power – Substation Design and Construction (CE-021-ST-0023)	
Australian Standards	
Substations and high voltage installations exceeding 1 kV a.c.	AS 2067
Power transformers – General	AS 60076.1
Power transformers – Ability to withstand short circuit	AS 60076.5
Power transformers – Determination of sound levels	AS 60076.10
Power transformers – Determination of sound levels – Application guide	AS 60076.10.1
Power transformers – Dry-type transformers	AS 60076.11



Degrees of protection provided by enclosures (IP Code)	AS 60529
International Standards	
Basic and safety principles for man-machine interface, marking and identification – Identification of equipment terminals, conductor terminations and conductors	IEC 60445

DOCUMENT VERSION CONTROL

Table 9: Document version control

Version History	Date	Detail
1.0	28/07/2021	Original approved issue
1.01	30/07/2021	Referenced Documents table updated
1.02	2/09/2021	Minor typing errors corrected
1.09	13/05/2025	Periodic review. No change
1.10	10/3/2026	Periodic review. No change
1.11	30/06/2026	Changed from a Standard to a Specification. Document number changed from CE-019-ST-0058 to CE-019-SP-0058. Logo updated to YJM.

DEFINITIONS & ABBREVIATIONS

Table 10: Glossary - Words

Word	Definition
<i>Scope of Works</i>	The <i>Scope of Works</i> is a key document that defines the specific project-related requirements such as the configuration and rating of equipment to be installed. It prevails over all the specifications.
Designer	The party who is fully responsible for the suitability and compliance of the design of the DC traction substation and all its equipment and subsystems.

Table 11: Glossary - Abbreviations

Abbreviation	Definition
AC	Alternating Current
DC	Direct Current
EMC	Electromagnetic Compatibility
EMS	Engineering Management System (internal Yarra Trams abbreviation)
FAT	Factory Acceptance Test



Abbreviation	Definition
HV	“High Voltage” means a nominal voltage exceeding 1000 V AC or exceeding 1500 V DC
LV	“Low Voltage” means nominal voltage exceeding 50 V AC / 120 V DC but not exceeding 1000 V AC / 1500 V DC
PTV	Public Transport of Victoria
RAMS	Reliability, Availability, Maintainability and Safety
RMS	Root Mean Square
SCADA	Supervisory Control and Data Acquisition

APPENDIX B – TENDER REQUIREMENTS

Table 12 summarises the information which shall be defined by Yarra Trams in the *Scope of Works* at the time of tender.

Table 12: Summary of information to be defined in the *Scope of Works*

Description	Requirement
Equipment designation	
Auxiliary transformer design	Connected to HV AC / Connected to rectifier transformer
Primary: Rated voltage (to be defined if auxiliary transformer is connected to HV AC)	
List of special tests which are required	

Statement of compliance

The *Designer* shall return a clause by clause statement of compliance to this specification. The Yarra Trams statement of compliance template and deviation procedure for specifications is provided within the Infrastructure - Network Power – Substation Design and Construction [CE-021-ST-0023].

Equipment selection principles

The equipment selection principles are defined in Infrastructure - Network Power – Substation Design and Construction [CE-021-ST-0023].