



Booster Transformer Equipment

Engineering Specification

Rail Commissioner

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Note: This engineering specification is based on and supersedes rail revitalisation specification *AR-MW-PM-SPE-02170321 Booster Transformer Equipment Specification*.

TABLE OF CONTENTS

1. Introduction	5
1.1. System Assurance.....	5
2. Scope	5
3. References	5
4. Acronyms	5
5. Requirements	6
5.1. General.....	6
5.2. Electrical Data	6
5.2.1. Terminals.....	8
5.2.2. Cable Entries	8
5.3. Earthing.....	9
5.3.1. Earth Bar	9
5.4. Construction Data.....	9
5.5. Electrical Data	9
5.5.1. Sealed Type	9
5.5.2. Free Breathing Type.....	9
5.6. Fittings.....	9
5.7. Booster Transformer Tanks	10
5.8. Gasket Seals	10
5.9. Radiators	10
5.10. Bushings.....	11
5.11. Booster Transformer Mounting	11
5.12. Booster Transformer Clearance.....	11
5.13. Booster Transformer Enclosure	12
5.14. Insulating Oil.....	12
5.15. Finish.....	12
5.16. Noise Emission.....	12
5.17. Logistic Data.....	13
5.17.1. Reliability	13
5.17.2. Maintainability.....	13
5.17.3. Availability.....	13
5.17.4. Service Life.....	13
5.17.5. Identification	13
5.17.6. Labels.....	13

5.17.7. Spare Parts List 13

5.17.8. Weight 14

5.17.9. Special Tools and Equipment 14

5.18. Electrical Data 14

5.18.1. Factory Tests..... 14

5.18.2. Routine Tests 14

5.18.3. Type Tests..... 14

5.19. Documentation 15

6. Bibliography 16

1. Introduction

The Department of Infrastructure and Transport (DIT) owns the Adelaide Metropolitan Passenger Rail Network (AMPRN) currently operated and maintained under the Rail Accreditation of third party. This specification lists the technical requirements for the Booster Transformers for use on the AMPRN Electrified Rail Network.

1.1. System Assurance

The engineering specification is produced to ensure that each technical requirement is:

1. Unique;
2. Unambiguous;
3. Understandable;
4. Achievable (feasible);
5. Traceable;
6. Complete;
7. Correct;
8. Consistent;
9. Concise;
10. Design independent;
11. Verifiable

2. Scope

The specification applies to Booster Transformers only.

This document is to be read in conjunction with the documents listed in Section 3.

3. References

- AS/NZS 60076 Power transformers
- AS/NZS 60076.3 Power transformers, Part 3: Insulation levels, dielectric tests and external clearances in air
- AS/NZS 60137 Insulated bushings for alternating voltages above 1000V
- AS 60296:2017 Fluids for electrotechnical applications - Unused mineral insulating oils for transformers and switchgear
- AS 1319 Safety signs for the occupational environment
- TP1-DOC-000390 Overhead Wiring System Requirements for the 25kV Electrified Train Network
- AR-EL-STD-0102 Guidelines for the protective provisions related to electrical earthing and bonding for The Adelaide metro electrified rail network.

4. Acronyms

ACRONYM	FULL NAME
AMPRN	Adelaide Metropolitan Passenger Rail Network
BT	Booster Transformer
EMC	Electromagnetic Compatibility

5. Requirements

5.1. General

1. The Booster Transformers shall comply with the requirements outlined in this specification.
2. Booster Transformers shall be pad mounted.
3. The design and construction of the Booster Transformers should be standardised to achieve interchangeability.
4. All the equipment shall be interchangeable as a whole or in part.
5. Any change or replacement shall not reduce the capability of the equipment to conform to the requirements of this Specification.

5.2. Electrical Data

1. The transformation ratio shall be 1:1 single phase. The booster transformer terminals shall be related to the windings such that the directions of current flow are from A1 to A2 through the primary winding and from a2 to a1 through the secondary winding.
2. The primary and secondary windings, including any bushings, shall meet the following Insulation voltages.
 - a) Primary Impulse Voltage - 200 kV
 - b) Primary Separate Source Voltage - 95 kV for 1 min
 - c) Secondary Impulse Voltage - 40 kV
 - d) Separate Source Voltage - 16 kV for 1 min
3. The Primary and secondary booster transformer windings shall be uniformly insulated as defined in AS 60076.3.
4. The impedance of the booster transformer primary, with the secondary short-circuited and the load losses at rated current shall not exceed the values given below

Rated Current A (r.m.s)	Rated Peak Current A (r.m.s)	Maximum 50 Hz Impedance	Load Loss (kW)
100	500	0.48 %	1.8
150	600	0.38 %	2.4
200	600	0.30 %	3.4
300	600	0.21 – 0.25 %	4.4 – 5.6

5. The minimum rated current and minimum rated peak current shall be as provided in the Equipment Data Sheet.

6. The Rated Current shall be taken as the r.m.s. average of the fluctuating load current which the booster transformer is required to carry continuously and which establishes its minimum thermal rating.
7. The Rated Peak Current shall be taken as the maximum r.m.s. current at which the booster transformers are required to comply with specified ratio and phase angle accuracy.
8. Sealed-tank type booster transformers shall be capable of carrying the rated peak current for periods of 1 minute at intervals of every 15 minutes and, at all other times continuously carrying the rated current.
9. Sealed-tank booster transformers shall be capable of a repetitive 24 hours cycle rating of 22 hours at 75 % rated current followed by 2 hours at 125 % rated current exceeding the temperature rise limits.
10. Free breathing booster transformers shall be capable of carrying the rated peak current for periods of 1 minute at intervals of every 15 minutes and, at all other times continuously carrying the rated current.
11. The booster transformer shall be capable of withstanding, without deleterious effects, the singular and cumulative consequences of frequent through-fault current of 6 kA for up to 3 seconds duration arising from short circuits occurring on the overhead line Electrification System.
12. The primary and secondary booster transformer windings and connections shall be adequately braced, clamped and supported to withstand the forces associated with these fault currents and vibrations caused by harmonics and the proximity to a railway environment.
13. The booster transformer shall achieve the intended service life when exposed to the expected short circuit rate of 1 Fault/Route km/year (approximately 40 faults per year).
14. The booster transformer shall be capable of withstanding, without deleterious effects, the singular and cumulative consequences of:
 - a) the inrush current arising from charging due to transition of trains from section to section
 - b) the frequent sudden application and removal of load arising from the passage of trains, including the shorting out of the primary winding when each train pantograph passes through the associated overhead line overlap span.
15. The magnetising current shall not exceed 1 A with the rated peak current flowing through the primary and shall not exceed 6 A with a primary current of 150 % of the rated peak current.
16. The magnetising current shall not exceed 10 mA when the primary is connected to a 30 V, 800 Hz sinusoidal supply so as to check the performance for phosphometric frequency currents.
17. As the harmonic voltages generated across the windings result in harmonic currents in the alternate ground path which can cause undesirable effects from an EMC viewpoint, the flux density in the core shall be maintained below saturation

level under normal conditions in order to minimise the frequency harmonic contents of the magnetising current.

18. With the rated burden connected to the secondary winding, the secondary current shall differ from the primary current by less than 1% in magnitude and by less than 1° in phase angle when the 50 Hz primary current is between the limits of 100 A and 400 A.
19. An accuracy of 1% in magnitude and 1° in phase angle shall apply at harmonic frequencies at the following currents and burdens:

Frequency (Hz)	Rated Current (A r.m.s)	Burden
50	300	0.8 + j1.4 ohms
+150	60	0.8 + j4.2 ohms
450	20	1.1 + j13 ohms
750	6	1.3 + j20 ohms
1050	4	1.5 + j29 ohms

20. At short circuit currents, the composite errors at 50 Hz as a percentage of the primary current shall be nominated by the Supplier

5.2.1. Terminals

1. The primary and secondary bushings shall be fitted with palms or other suitable means for terminating the cable connections from the 25 kV supply and return conductors. The disposition of the bushings and palms shall facilitate cable connection to these points and in addition, shall provide a point of attachment for the clamps of portable earthing leads for earthing during maintenance.
2. A1 and a1 terminals shall be in a separate dedicated compartment from A2 and a2.
3. All terminals and their accessories shall be of copper or copper alloy material.
4. Terminals shall make provision for the connection of surge arrestors from A1 and A2. The surge arrestors shall be bonded to the Equipment Earth Bar. Surge arrestors shall only be included within the BT enclosure where the length of cabling between the Overhead Wiring System and the BT exceeds the protected zone afforded by a pole mounted surge arrestor.

5.2.2. Cable Entries

1. Provision shall be made for the entry and connection of the 25 kV cables, Return Conductor cables and Bonding cables. Provision shall also be made for connection of each 25 kV cable and return cable screen to a suitable Earth terminal.
2. All cables shall enter the booster transformer enclosure from below via ducts incorporated into the pad foundation.
3. Cables shall be supported in such a manner that the cable insulation is not degraded by virtue of the cable supports and that no undue stress is placed on the booster transformer terminations.

5.3. Earthing

1. The Earthing of the pad and surrounding area is to be consistent with the requirements of AR-EL-STD-0102 shall be sufficient to limit the touch, step and transfer potentials to a safe value.
2. The booster transformer pad shall have a local buried Earthing system comprising of electrodes and buried copper mesh to comply with the requirements of AR-EL-STD-0102

5.3.1. Earth Bar

1. An equipment Earth Bar shall be mounted on the inside of the enclosure on insulators providing at least 5 kV insulation to Earth. The equipment Earth Bar shall have a Minimum continuous rating of 1000 A and a fault rating of 6 kA for 3 seconds.
2. The equipment Earth Bar shall be sized to accommodate, duplicate bonds from the Traction Earth system, bonds from the pad Earthing system, connection of surge arrestors, duplicate bonds to the booster transformer tank, duplicate bonds to the enclosure and bonds from HV cable screens.

5.4. Construction Data

Booster transformers shall be either of the sealed tank type, mineral oil or synthetic liquid filled or of the free breathing type, mineral oil filled.

5.5. Electrical Data

5.5.1. Sealed Type

1. The internal pressure, in service, of sealed-tank booster transformers shall not exceed 0.35 bar. The expansion space above the insulating fluid level shall be filled with dry inert gas. Sealed-tank type booster transformers shall be equipped with a pressure busting disc with flag indicator visible from ground level.
2. Sealed-tank type booster transformers shall be delivered filled with insulating fluid to normal level with a further 5 litres added to allow for sampling.

5.5.2. Free Breathing Type

1. Free breathing type booster transformers shall incorporate an expansion tank (conservator) and a desiccant filled type breather to ensure only dry air comes into contact with the insulating fluid. The desiccant dryer should be designed so that the change out interval of the granules is aligned with the overall project maintenance requirements taking into account nominal environmental conditions.
2. The breather shall be fitted such that its base is just above the base of the booster transformer.
3. Booster transformers shall be delivered filled with insulating fluid to normal level. Any additional oil which may be required for topping up free breathing booster transformers shall be delivered in sealed containers with the booster transformer.

5.6. Fittings

1. Booster Transformers shall be supplied with the following standard fittings and features:

- a) metallic; rating and connection plates
 - b) means of identification of each main terminal
 - c) provision for slinging and lifting upright by crane and securing for transport
 - d) provision for draining, sampling, filling and filtering of oil
 - e) tank earthing terminals on diagonally opposite corners
 - f) over-pressure relief device with visual indicator and alarm contacts
 - g) oil level indication, marked to indicate normal level at 25°C and over the full range of operating temperature.
2. Any lifting accessories included shall be marked with their safe working load and provided with valid certificates. They shall be removable for testing.
 3. Fittings, which require visual inspection, shall be positioned so that they can be easily inspected. The insulating oil sampling point shall be positioned so as to give a representative sample of the oil and be easily accessible.

5.7. Booster Transformer Tanks

1. Booster Transformer tanks and covers which are exposed to the weather shall be so constructed as to prevent the accumulation of moisture. Covers may be welded to a flange on the tank top to form a sealed joint or may be bolted provided a high quality gasket is used to seal the joint.
2. All booster transformer tanks, covers and flanges shall be of sufficient rigidity to prevent distortion. To ensure sufficient rigidity of the tank, continuously welded tank stiffeners, gussets shall be provided where appropriate. Corrugated booster transformer tanks shall not be employed.
3. The centre lines, the centre of gravity and oil level to just cover the top of the windings at 25°C shall be marked on the outside of the tank. These markings shall be permanent and shall not deteriorate with time.
4. Booster transformer tanks shall be capable of withstanding full vacuum without permanent distortion and shall be constructed so as to withstand all the stresses likely to be encountered during transport, erection and service.
5. The supplier shall provide documented evidence that:
 - a) the design of the booster transformer tank will be suitable for the temperature conditions specified
 - b) at the lowest oil temperature the bushing extensions inside the tank will be adequately covered by oil
 - c) at the highest oil temperature resulting from the combined effects of ambient temperature, solar radiation and the passage of normal rated current, the pressure inside the booster transformer tank is well below the pressure which the booster transformer tank and its accessories and fittings have been designed to withstand.

5.8. Gasket Seals

1. Gasket seals shall be constructed, as far as practicable, to ensure that leakage does not occur during the service life of the booster transformer. If leakage does occur the seal shall be repairable. Where a seal must be broken to gain access to equipment, restoration to its original sealing performance shall be practicable.

5.9. Radiators

1. Removable booster transformer radiators are preferred. These shall be connected to the tank via tamperproof oil shut-off valves giving reliable external visual indication of fully OPEN and fully CLOSED positions. These valves SHALL allow

the radiator unit(s) to be removable without lowering the insulating fluid level in the tank.

2. Each radiator bank shall be fitted with a means of venting trapped air and draining insulating fluid prior to removal. Radiators shall be designed and positioned so as to prevent the accumulation of moisture but allow inspection and the application of a protective finish without their removal from the booster transformer tank.

5.10. Bushings

1. The ends of all windings shall be connected to vandal resistant High and Low Voltage bushings complying with AS/NZS 60137 and suitable for the stated insulation levels.
2. The bushings shall be preferably of a composite type but may be of porcelain. They shall be of the bolted flange type arranged so that it is possible to remove and replace them without removing the core and coils from the tank.
3. Each bushing shall withstand, without rotation, a torque of 35 Nm when applied to the external portion of the stem.
4. The primary and secondary bushings shall meet the impulse voltage and separate source voltage withstands levels stated below:
 - a) Primary Impulse Voltage - 250 kV
 - b) Primary Separate Source Voltage - 95 kV for 1 min
 - c) Secondary Impulse Voltage - 45 kV
 - d) Secondary Separate Source Voltage - 16 kV for 1 min
5. Each bushing shall be capable of being replaced without disturbance to other bushings or the removal of the core and coils from the tank such that:
 - a) access to bushing terminals within the booster transformer tank shall be via inspection covers positioned such that the minimum amount of insulating fluid needs be removed when access is required
 - b) access can be easily gained when the booster transformer is mounted on the pad.
6. Booster transformer design and construction shall be such that bushing changes or other internal maintenance of sealed-tank booster transformers shall not require the use of vacuum equipment when re-charging with inert gas.

5.11. Booster Transformer Mounting

1. The Booster transformers shall be outdoor type suitable for a pad mounted arrangement having an integral base frame and an overall enclosure. The pad shall be located at least 200 mm above the finished ballast level at the closest point to the track and be designed to ensure that no water can pool against the booster transformer steelwork.
2. Bunding is to be provided around the base of the booster transformer to fully contain the insulating oil in the case of an oil spill.

5.12. Booster Transformer Clearance

1. The booster transformer shall be mounted to achieve the following Minimum air clearances to other components:
 - a) Not less than 480 mm from metal energised at 25 kV

b) Not less than 150 mm from metal energised at return conductor voltage.

5.13. Booster Transformer Enclosure

1. The booster transformer weatherproof enclosure shall be designed to provide:
 - a) mechanical protection to reduce the risk of damage due to vandalism
 - b) convenient access to the terminals for the connection of the cables
 - c) convenient access for all necessary maintenance activities
 - d) free air movement around the unit to ensure that the booster transformer maximum temperature rise is not exceeded.
2. Bolted removable covers or lockable doors shall be provided for maintenance and inspection; these shall comply with all relevant regulations pertaining to access to High Voltage chambers from a public access area. Guillotine style doors are not acceptable.

5.14. Insulating Oil

1. The interior of any oil-filled chamber shall be cleaned of all scale or rust by blast-cleaning or other approved method and given an oil resisting coating prior to being filled with oil.
2. Booster transformers shall be filled to their normal energised operating levels with either inhibited mineral oil or synthetic liquid.
3. Inhibited mineral oil shall comply with AS 60296:2017 Table II (Specification for inhibited mineral insulating oil) and be certified to be free of polychlorinated biphenyls.
4. Synthetic liquids shall have suitable electrical insulating properties, shall have a flash point of not less than 2150°C, and a fire point of greater than 300°C.
5. The Supplier shall nominate the brand and grade of oil to be supplied with the booster transformer.

5.15. Finish

1. Enclosures, equipment metalwork, components, accessories, fittings and fastenings (e.g. nuts, bolts, washers etc.) shall be protected against corrosion, including galvanic corrosion of dissimilar materials, for the life of the equipment at the specified location.
2. All external nuts, bolts and washers shall be of non-ferrous metal or be steel galvanised and shall not require painting.
3. External surfaces of the booster transformer enclosure and tank may be finished in accordance with the manufacturer's standard procedure provided such procedures are in accordance with the best modern practice and achieve the finish and longevity required of the coatings.
4. The finish used shall be capable of being restored to its full protective standard on site. Routine inspection of areas susceptible to corrosion shall be made possible without the need to remove the equipment from service.
5. Damage to paintwork incurred during transport shall be made good by thoroughly cleaning the damaged area and using the same number of paint coats applied before the damage was caused.

5.16. Noise Emission

1. The booster transformers shall operate with a level of noise and vibration not exceeding 56 dB(A) when the booster transformer is operating at peak rated current and has rated burden connected to the secondary winding.

5.17. Logistic Data

5.17.1. Reliability

1. The design of the Booster Transformer shall be such that it operates reliably between designated inspection periods.
2. The Supplier shall nominate the Mean Time Between Failure (MTBF) for reliability and incorporate this into the calculation of the device Availability.
3. For equipment where insufficient historical data is available The Supplier shall state the methods used to determine Reliability performance

5.17.2. Maintainability

1. The equipment shall be designed for Minimum maintenance. The booster transformer and ancillary devices shall not require a shutdown for more than five hours in any four year period in order to carry out routine Preventive Maintenance such as inspection and oil sampling.
2. The Supplier shall nominate the Mean Time To Repair (MTTR) for Maintainability and incorporate this value into the calculation of the device Availability.
3. The Supplier shall provide an Equipment Maintenance Plan for the BT as necessary to meet the nominated service life and Reliability.
4. Access for maintenance will be with the booster transformer under isolation and/or de-energised.

5.17.3. Availability

1. The Availability (derived from MTBF and MTTR) of the BT shall be nominated by The Supplier.

5.17.4. Service Life

1. The equipment, including components but excluding consumable items, shall be capable of complying with the requirements of this document for least 30 years without deterioration in Reliability and Preventive Maintenance in excess of that nominated in 'Maintainability'.

5.17.5. Identification

1. The booster transformer shall be provided with a rating plate containing the relevant information required by AS 60076 Power transformers.

5.17.6. Labels

1. All access doors to High Voltage compartments or equipment shall be provided with durable "Danger High Voltage" warning labels which comply with AS1319.

5.17.7. Spare Parts List

1. The Supplier is to provide a full list in the O&M Manual of the manufacturer's recommended spares for normal maintenance purposes identifying:

a) part numbers

- b) catalogue numbers
- c) supplier
- d) approximate lead time (at time of purchase)

2. Where possible an exploded view of any components with multiple parts is to be supplied to aid identification.

5.17.8. Weight

1. The supplier shall provide the total weight of the BT when filled with oil as nominated on the data sheet.

5.17.9. Special Tools and Equipment

1. The supplier shall advise any special tools and test equipment required for the installation, operation and maintenance of the booster transformer.
2. To enable the booster transformer to be operated and maintained, two sets of special tools and test/inspection equipment shall be provided. This shall include testing and filtering devices.

5.18. Electrical Data

5.18.1. Factory Tests

1. The equipment and components or sub-assemblies shall be made available for routine inspections during assembly and on completion at the site works.
2. Valid calibration certificates, from an accredited calibration service, shall be made available for inspection for all test equipment prior to any testing.

5.18.2. Routine Tests

1. The booster transformers and their associated components or sub-assemblies shall be made available for final inspection upon completion. The equipment shall be subject to the following routine tests, in accordance with AS/NZS 60076 prior to dispatch:
 - a) separate source AC rated frequency withstand voltage test
 - b) short duration induced AC withstand voltage tests, including measurement of partial discharge
 - c) measurement of winding resistance
 - d) winding ratio
 - e) measurement of no-load loss and current
 - f) measurement of full load loss
 - g) measurement of short circuit impedance
 - h) measurement of insulation resistance to Earth of the windings
 - i) Dissolved Gas Analysis (DGA) and oil property tests
 - j) functional tests including simulated operation of all external devices
 - k) any additional tests specified in the System Design Specification.

5.18.3. Type Tests

1. Type Tests shall be carried out on one sample of each size and rating of booster transformer in accordance with the relevant Australian Standard, European Standard, International Standard or National Standard
2. The equipment shall be subject to Type Tests in accordance with AS/NZS 60076 for the following:

- a) temperature rise tests, suitable to verify the specified load cycle
 - b) lightning impulse tests to the primary winding
 - c) lightning impulse tests to the secondary winding
 - d) measurement of magnetising current to verify 50 Hz and 800 Hz requirements
 - e) short circuit tests
 - f) noise level tests.
3. Test equipment used for measuring test values shall be calibrated and have valid current calibration certificates from an accredited calibration service.
 4. Test certificates shall be provided in duplicate and shall include both test results and all other relevant data.

5.19. Documentation

1. The supplier is to provide the following design documentation:
 - a) Booster transformer general arrangement details, including accessories, components and parts (include safety harness anchor points)
 - b) rated plate drawing
 - c) equipment label drawing(s)
 - d) tank design drawings
 - e) general arrangement, electrical schematics of ancillaries and termination diagram for ancillaries and marshalling cubicle (if provided).
 - f) materials list
 - g) transportation dimension drawing (including component weights)
 - h) insulation assemblies, core and coil arrangement drawing(s)
 - i) fixing arrangement and details for mounting the booster transformer to pad.
2. The Supplier shall provide two complete hard copy sets and electronic files of operating and maintenance manuals for each type of transformer. The manuals shall include adequate information relating to individual items of equipment to assist the Principal in becoming familiar with the plant.
3. Operating and Maintenance manuals shall include, but not be limited to, the following, in addition to any other details identified in the supplier's Installation manual:
 - a) Technical Summary outlining the booster transformer's key parameters
 - b) The manufacturer/type/model/ratings of all auxiliary and ancillary items, weights.
 - c) Detailed diagrams and exploded drawings of the booster transformer.
 - d) Complete sets of preliminary erection, operating, and maintenance instructions. In particular, comprehensive and detailed instructions on:
 - (i) nitrogen and dry air equipment
 - (ii) handling and installation of bushings and draw leads
 - (iii) vacuum treatment, oil filling and maintenance of oil
 - (iv) full details of precautions and procedures to be followed for the application of vacuum
 - (v) specific requirements for blanking off plates
 - (vi) pressure equalisation to be applied for isolatable sections of the cooling system conservator
 - (vii) all inspections and tests required during erection and prior to commissioning the plant.

- e) Equipment maintenance plan defining:
 - (i) methodologies and frequency of all Preventative Maintenance to achieve the design life
 - (ii) methodology of key Corrective Maintenance tasks.
- f) A complete list of handling equipment, tools and test equipment.
- g) Provision to include the factory, site test reports and manufacturer's test reports for all other purchased items supplied as part of the transformer.
- h) Full details for the calibration of oil and winding temperature thermometers (if applicable).
- i) Specification sheets, and the setting and testing guides for the winding and oil temperature thermometers and the gas actuated relays (if applicable).
- j) Spare parts listing

6. Bibliography

- TP1-DOC-000390 Overhead Wiring System Requirements for the 25kV Electrified Train Network