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Signalling Power Systems

ESS-09-02

Applicability

ARTC Network Wide

SMS

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Amendment Record

Amendment Version #	Date Reviewed	Clause	Description of Amendment
1.0	31 Oct 23	Various	Updated battery housing requirements and other minor changes. Document renumbered to align with document numbering procedure EGP-01-02.

Table of Contents

1 General

1.1 Purpose

The purpose of this document is to provide the minimum requirements for railway signalling power supply systems on the ARTC network.

1.2 Scope

Reliable power supply is fundamental to the operation of the Signalling systems and hence to the safety and on-time running of the trains.

This specification covers the general design and construction requirement of the signalling power systems. This specification is applicable to the entire ARTC network.

High voltage and traction power requirement are not included in this document.

This Specification shall be read in conjunction with all other relevant Signalling documents referenced within this document.

1.3 Document Owner

The Head of Engineering Standards is the Document Owner. For any query, initial contact to be made at standards@artc.com.au.

1.4 Responsibilities

The Project Manager, Signal Design Manager, Signal Design Engineer and Signalling personnel are responsible for the implementation of this standard in new or altered signalling power supply systems.

1.5 Safety Aims

This document defines the means for maintaining the safety of the Signalling system and its power supplies by control of the following hazards and consequent risks:

1. Loss of power supply to the Signalling system

    - Consequence:

    Loss of Signalling controls and indications, - This can lead to degraded modes of operation including manual working that are inherently less safe than the engineered systems.

    Signalling functions and circuits rely upon electrical power to maintain the logic function based on a sequence of events or a set of conditions. The loss of electrical power can interrupt the retention of that status of the preceding operational events and may result in the signalling system responding in an unsafe manner.

    Controls:

    Redundancy of supplies and supply equipment; protection from overcurrent and overvoltage.

2 Supply voltage higher or lower than design limits

- Consequence:

Excessive supply voltage may result in damage to equipment or wiring, resulting in loss of control of Signalling equipment.

Too-low voltage may cause temporary loss of control, or function of some items of control equipment.

Controls:

Design to limit load-induced voltage variations; voltage monitoring and disconnection from out-of-range supply.

3 Overcurrent exceeding rating or wiring or supply

- Consequence:

Current exceeding the rating of conductors or supply equipment may cause excessive heat to rise that results in overheating, fire, fusion of conductors or failure of equipment.

Controls:

Design to ensure that loadings are less than the ratings of wiring and supply equipment; use of overcurrent protection devices to disconnect from supply in the event of currents of excessive magnitude and duration.

4 Extreme overvoltage – surges and lightning

- Consequence:

Immediate or delayed damage to Signalling control equipment, especially electronics, resulting in loss of control of Signalling equipment.

Controls:

Use of surge protection devices to limit the effects of damaging voltages reaching the sensitive equipment; application of installation practices to prevent the induction of damaging voltages from unprotected (‘dirty’) circuits to surge-protected (‘clean’) circuits.

5 Live conductive surfaces

- Consequence:

Physical contact with a live conductive surface, completing a circuit between two points connected to different potentials on the same supply will lead to the passage of current through the body. Depending on the intensity, waveform and duration of the current, the effects of this can range from negligible and unnoticed, through varying physical effects including muscle spasm and heart fibrillation, to severe tissue damage.

Controls:

A. System of protection

Application of a system of wiring protection which ensures that body currents resulting from direct or indirect contact with a single live conductor are restricted to a low value that will not result in a harmful electric shock; the Signalling electrical system complies with the IT system of protection as defined in EN 60364.1.

B. Insulation (ref AS/NZS 3000 Cl 1.5.4.3)

Live parts permanently covered with durable insulating materials, combined with provisions for detecting faults in or deterioration of the insulating materials, by application of devices for continuous monitoring of insulation integrity and procedures for periodic measurement of insulation resistance.

C. Barriers or enclosures (ref AS/NZS 3000 Cl 1.5.4.4)

Enclosing live parts inside enclosures that provide protection against unintentional contact.

D. Obstacles (ref AS/NZS 3000 Cl 1.5.4.5)

Installation of live equipment in housings where access is restricted to competent persons or persons under the direct supervision of competent persons; such access being dependent on the use of security keys or equivalent devices.

1.6 Definitions

In this document, the following definitions of terms shall apply:

ARTC – Australian Rail Track Corporation

ARTC's Representative – A person, company or authority nominated by ARTC to make engineering determinations on ARTC's behalf.

Contractor – A person, company or authority nominated by ARTC or ARTC's primary contractor to manage a specific contract.

Extended voltage

Nominal voltage of a power distribution mains operating at low voltage, defined in AS/NZS 3000, but not less than 230/240VAC and normally not exceeding 480VAC

Electric shock

The physical effect of contact with a live conductive surface that results in touch current that is hazardous by having intensity, waveform and duration that may lead to harmful physiological effects. Most, but not all, electric shocks are characterised by recognisable immediate physiological effects ranging from tingling and startle reactions to pain and muscle spasm.

Fault (AS7703 Cl. 1.5.6)

Any unintended connection between two conductors or between a live conductor and earth, which is capable of passing current of a magnitude that may result in unsafe operation, damage to equipment or injury to personnel.

Power supply (signalling power supply)

The supply of electrical energy to power the signalling controls and equipment

Power supply unit

"Device that transforms, modifies or produces the alternating current or direct current for the signalling power system from the primary power source" (AS7703 – "power supply")

Touch current (IEC 61201 Cl. 3)

The electric current passing through a human body or through an animal body when it touches one or more accessible parts of an installation or of equipment

Touch voltage (IEC 61201 Cl. 3).

The voltage between conductive parts when touched simultaneously by a person or an animal

NOTE - The touch voltage may be different from the open circuit voltage between those conductive parts.

Threshold (IEC 61201 Cl. 3)

A point at which a stimulus is just strong enough to produce a response.

NOTE – A threshold is not the same as a limit which must include risk assessment, safety margins, etc.

Voltage threshold for muscular reaction (IEC 61201 Cl. 3)

Minimum derived value of touch voltage for the population for which a current flowing through the body is just enough to cause involuntary contraction of a muscle, not including startle reaction, such as inability of let go from an electrode.

Voltage threshold for ventricular fibrillation (IEC 61201 Cl. 3

Minimum derived value of touch voltage for the population for which a current flowing through the body is just enough to cause ventricular fibrillation.)

Work (electrical)

Electrical work in the context of signalling systems refers to any changes to wiring, including connection or disconnection of fuses or links on open terminal blocks, or the removal or installation of un-insulated wires and lugs on terminations, or jointing and termination of cables irrespective of working voltage.

The term **electrical work** does not include: the closing or opening of switches, or the removal or replacement of fuses or link pins in fully enclosed (SAK type) terminal blocks, or the use of a meter to measure voltage, or use of a current tong or current clamp to measure current.

1.7 Quality

The standard of materials and workmanship shall ensure that the installed system is fit for purpose, over the lifetime of the asset in its physical and operational environment, in terms of safety and reliability.

All material and equipment shall be manufactured and assembled to provide a minimum service life of 20 years when maintained and/or overhauled at the manufacturer’s recommended intervals.

Quality of materials and workmanship shall be such that life cycle routine maintenance of the asset is minimised.

All material and equipment supplied to this document shall be warranted free of defect in manufacture or assembly for a period of twelve (12) months from delivery.

All of the equipment, including consumables, shall be warranted as complying with this or any referenced specification and as being fit for purpose.

1.8 Submissions for Approval

Where alternatives or new equipment types are proposed, the matter shall be submitted by the Proposer/Contractor with documented justification in writing, in accordance with ARTC's EGP-21-01 acceptance process for "New Equipment and Systems" approval.

1.9 Referenced Documents

The following documents are referenced in this specification:

1.9.1 Australian Standards

AS 7703	*Railway Signalling – Power Supply Systems*
AS 7663	*Railway Signal Cables*
AS/NZS 3000	*Electrical Installations (known as Australian/New Zealand Wiring Rules)*
AS/NZS 3008.1.1	*Electrical installations - Selection of cables – Part 1.1: Cables for alternating voltages up to and including 0.6/1 kV - Typical Australian installation conditions*
AS/NZS 60479.1	*Effects of current on human beings and livestock – General aspects*
AS/NZS 60479.2	*Effects of current on human beings and livestock – Special aspects*
AS/NZS 60896.1	*Electrical accessories—Circuit-breakers for overcurrent protection for household and similar installations Part 1: Circuit-breakers for AC operation.*
AS/NZS 61558.1	*Safety of transformers, reactors, power supply units and combinations thereof – Part 1: General requirements and tests*
AS2676.1	*Guide to the installation, maintenance, testing and replacement of secondary batteries in building - Part 1: Vented cells*

1.9.2 ARTC Standards

ESC-07-03	Small Buildings, Location/Terminal & General Purpose Cases
ESC-07-04	*Install of Equipment Racks & Termination of Cables & Wiring*
ESA-09-03	Mains Failure Plant
ESC-09-02	*Lightning and Surge Protection Requirements*
ESS-09-01	Solar Power Supply Systems
ESA-11-01	*Cables for Railway Signalling Applications – General Requirements*
ESC-11-01	Construction of Cable Route & Associated Civil Works
EGP-21-01	*New Equipment and System Approval*
SPS 02	*Environmental Conditions*
SPS 24	*Emergency Changeover Contactor Panel*

1.9.3 International Standards

DIN 41576-2	*Miniature Fuses; Indicating Cartridge Fuse-Links 250 V, Interchangeable, Medium Time-Lag*
IEC/TS 61201	*Technical Specification - Use of conventional touch voltage limits – Application guide*
IEC 60364-1	*Low-voltage electrical installations – Part 1: Fundamental principles, assessment of general characteristics, definitions*
IEC 61557-8	*Electrical safety in low voltage distribution systems up to 1 000 V a.c. and 1 500 V d.c. - Equipment for testing, measuring or monitoring of protective measures - Part 8: Insulation monitoring devices for IT systems*

2 Applicable Standards

Power supply arrangements for signalling systems involve a combination of mains supplies, generally in the form of feeds at 230/240VAC or higher from supply authorities, and consumer equipment operating usually at 110/120VAC or lower supplied via isolating stepdown transformers or power conversion equipment providing equivalent electrical isolation.

The two parts of the arrangement are termed “supply authority systems” and “signalling power systems”. The line of demarcation between the two systems is at the output terminals of the isolating transformer or conversion equipment.

All installation upstream of these terminals, including the transformer/power converter itself, shall comply with the MEN protection system and the customary interpretation of AS/NZS 3000. All installation downstream of these terminals shall comply with Australian Standard AS7703 *Railway Signalling Power Supply Systems* and the IT system of protection as defined in IEC 60364:2010 Part 1.

3 Environmental Considerations

All equipment covered by this document shall be capable of continuous operation at its maximum ratings in the conditions and environment in which it is installed.

Guidance on environmental conditions applicable is provided in ARTC standard SPS 02 – Environmental Conditions.

Enclosures and buildings should be designed to achieve these results through passive ventilation only, without reliance on mechanical cooling or air conditioning systems.

4 General Design Requirements, Power Supply Systems

4.1 General

This document sets out the standard practices followed in designing and installing Signalling power supply equipment for the Australian Rail Track Corporation.

4.2 Sources of Supply

The main form of electrical power used for signalling applications is 50Hz AC, at a nominal voltage of 110/120VAC.

AC power for signalling can be obtained either from available supply authority grids, motor-alternator plant, solar power supply systems or, inverters operating from battery standby supplies.

For general signalling purposes, AC supplies shall be duplicated, with separate supplies derived from independent high voltage feeders, or other sources.

At locations where two independent mains supplies are available, an automatic emergency changeover (ECO) panel shall be installed, to automatically transfer the load to the standby supply in the event of a loss of the main supply. Requirements for the ECO are detailed in Section 9 *Emergency Changeover Equipment (ECO).*

The selection of main and standby supply arrangements and the preferred type of load transfer will be determined by operational requirements, mainly the frequency of train services and the period of power outage tolerable without incurring a delay to trains.

In order of preference, the common main / standby arrangements are:

- Supply authority normal, alternate authority supply standby
- Supply authority normal, alternator standby
- Supply authority normal, battery / inverter standby
- Supply authority normal, battery standby

In areas where AC supplies are not available or where it is not justifiable to install AC power for a signalling supply, DC power may be supplied from solar photovoltaic cells.

Uninterruptible Power Supplies (UPS)

There is now a ready availability of reliable mains standby power systems based on inverters and high-capacity batteries, operating at normal commercial voltages of 110/120/230/240VAC single-phase and 415VAC three-phase, collectively described as Uninterruptible Power Supplies (UPS). Some of these include provision for charging by photovoltaic cells.

A reliable Signalling power supply may be derived from an appropriate UPS system operating at 110VAC to 480VAC, feeding directly to a single stepdown/isolating transformer.

4.3 AC Mains Supplies

4.3.1 Authority Supplies

'Authority supply' refers principally to mains provided by a local electrical supply authority, or an equivalent source or distributor of electrical power.

Authority supplies are available at the majority of locations across the ARTC network. In rural areas the authority supply may be distributed by means of a SWER (Single-Wire, Earth Return) system; this should have no impact on the configuration of the signalling power supply downstream of the main switchboard.

In some areas, the cost of providing an extension from the nearest existing supply point may prove prohibitive, and an alternative source of power may be considered.

4.3.2 AC Supply Voltage Limits

The signalling supply point voltage, at the output of the step-down / isolating supply transformer, shall be maintained within the range of 110/120VAC to 116V/127VAC.

Where the electrical supply system is not sufficiently well regulated to maintain supply within the voltage limits, such voltage regulation equipment shall be provided as is necessary to achieve the supply voltage limits.

4.3.3 Motor-Alternator Sets (Mains Failure Plant)

Where the mains power requirement exceeds a few hundred VA, and only a single reliable mains supply is available, the alternate AC supply shall be provided by suitably rated mains failure plant (a diesel-powered motor-alternator set fitted with automatic start-up and power transfer facilities) complying with ARTC standard ESA-09-03 *Mains Failure Plant (MG Sets)*.

This mains failure plant shall be equipped with a number of status and alarm indications which require to be repeated to and displayed at the nearest staffed operating point.

4.3.4 Uninterruptible Power Supply (UPS) Systems

Uninterruptible power supplies (UPS) shall be provided where a source of continuous AC power is required for loads which cannot tolerate even a momentary interruption when a mains changeover or extended loss of power occurs.

UPS output shall remain continuous during transfer from Normal to UPS supply, and during return from UPS to Normal supply.

The specific requirements for ‘run time’ shall be defined for each specific project within the Technical or Signalling Functional and Operational Specification (SFOS) document for that project.

4.3.5 Supplies for Computer-Based Interlocking Systems

Computer-based interlocking (CBI) systems from various manufacturers have different requirements in terms of their ability to handle momentary power supply interruptions, and the time taken to return to normal operation after a disruption.

The acceptable recovery time will depend on the density and importance of traffic at the location in question.

Most present-day CBI systems are designed to operate on DC supplies, with backup provided by batteries with dedicated battery chargers.

AC power supply systems for CBI installations may need to incorporate special arrangements such as transient protection, power conditioning, UPS and/or high-speed electronic changeover switches, for all or part of the CBI installation.

Such special arrangements shall be provided as are necessary to provide the level of operational availability specified for the particular installation.

4.3.6 Supplies for Signalling Electronic Systems (Non-Vital)

Signalling electronic and computer-based systems, including telemetry, train describers, passenger information systems and event loggers, are each different in terms of their operating supply requirements and ability to handle power supply interruptions.

This may be determined both by the design of the equipment itself, and the effects on rail operations of a disruption to its functions. Although a system is non-vital in a signalling sense, its failure can have a significant safety effect, in that it may force the railway to be operated in a less-safe fall-back mode.

Power supply systems may need to incorporate special arrangements such as power conditioning, UPS and/or high-speed electronic changeover switches, for all or part of the installation.

Such special arrangements shall be provided as are necessary to provide the level of operational availability specified for the particular installation.

4.4 DC Supplies – General

4.4.1 DC Signalling Supplies

For conventional relay-based signalling installations, the usual supply for all control circuits is 50 volts DC, full-wave rectified, unfiltered.

This is generally derived from the 110/120VAC mains by means of simple transformer-rectifier sets (unfiltered).

At all relay interlocking locations, separate 50VDC supplies shall be provided for internal and external circuits. The internal supply shall not be used for circuits which extend outside the relay room.

Diagram and non-vital supplies are generally 24VDC, full wave rectified, filtered.

Except where signalling controls are included at a level crossing location, 12VDC control circuits are generally not used.

4.4.2 Redundancy of DC Supplies

Generally, in interlockings, and where a power supply failure will affect the operation of a non-permissive signal, the outputs of two or more supply units shall be connected in parallel to the supply bus-bar to provide availability in case of the failure of a unit. This is not normally required in automatic signalling territory where regulations permit for a failed signal to be passed at stop or danger.

More than two units may be paralleled to achieve the required supply rating, applying the “N + 1” redundancy principle. Individual units shall be rated such that, when one unit fails, those remaining shall not be loaded above 75% of their rated capacity.

Where supply units are wired in parallel, power supply alarms shall be arranged to indicate the failure of any individual unit.

Redundant supply units shall be fitted with isolating diodes or similar arrangement to allow the units to be paralleled without cross-feeding and to ensure the independence of the individual supply indications.

Redundant DC supply units shall be so designed and connected that it is possible to replace a failed unit without disturbing the other unit or affecting the operation of the equipment powered by them.

4.5 No-Break DC Supplies

A no-break supply shall be used to feed those circuits for which a momentary de-energisation would affect the operation of stick circuits resulting in unsafe release of vital interlocking conditions, or requiring the time-out of time delay relays and the re-setting of routes resulting in unacceptable disruption to operations

The use of no-break supplies shall be provided only where the traffic density and operator workload is such as to produce an unacceptable number of train delays in the event of a power changeover.

The requirement or otherwise for No-Break DC supplies should be contained in the signalling design and/or nominated in the particular specification for that project of item of work.

4.5.1 No-Break Supplies - Capacitive

Where duplicate AC mains supplies are provided, the emergency changeover equipment will switch between supplies in less than one second.

In this situation, adequate no-break function may be provided by using DC power supply units having highly capacitive filtered outputs.

The rating of the transformer/rectifier is determined by the designed DC voltage and load, and the filtering capacitors shall be sized to provide an output voltage not less than 45VDC (for a 50VDC nominal supply) over a period of one second at the rated output current; the capacitor shall also be rated for the prospective ripple current under 100% loading.

The peak DC busbar voltage from such a supply shall not exceed 55VDC at any time.

4.5.2 No-Break Supplies - Battery

In cases where the alternate AC supply is provided by a motor-alternator set, the changeover period will exceed several seconds in duration, which exceeds the capabilities of a capacitive no-break supply. An arrangement shall be provided with low capacity batteries providing the standby power.

This comprises duplicate transformer-rectifier supplies in parallel with a single 50VDC battery, with diode isolation between them. A battery charger specifically designed for float-charging shall be provided for the standby batteries. The batteries shall be rated for their short term continuous current rating.

A combined power supply unit / battery charger may be used.

4.6 Battery Supplies

4.6.1 Battery Standby - Secondary Cells

In some smaller installations with single AC mains supplies of limited reliability, DC standby power may be provided, with a secondary battery rated for continuous operation of the installation and supplied by a charger designed to provide optimum charging for long battery life.

The principal application of secondary cells is in active level crossing installations. These are generally, high-reliability, long life batteries whose capacity is such that the level crossing equipment will operate correctly in accordance with the requirements of ESD-03-01 – Level Crossing Design under normal operating conditions.

Level crossing batteries shall be determined in accordance with the requirements of ESD-03-01 – Level Crossing Design and the types may include:

- Nickel Cadmium
- High performance sealed gel cell
- Lithium

Chargers designed to match the particular batteries' operating requirements shall be provided in all cases.

General purpose cells may be used where it is desired to provide battery standby for general signal circuits and signal lighting. Special housing and ventilation arrangements shall be in accordance with the requirements of AS2676.1 - Guide to the installation, maintenance, testing and replacement of secondary batteries in building - Part 1: Vented cells.

Battery Standby – Recovery after Full or Partial Discharge

Where batteries and chargers are used the chargers shall be capable of supplying the full load within voltage tolerances with the batteries removed and also supplying the normal operating load while recharging fully discharged batteries. The recovery time required under these conditions, to restore a fully discharged battery to at least 75% of full capacity, shall not exceed 10 hours.

Wiring shall be arranged so that either the charger or the batteries may be disconnected without interrupting the supply voltage to the bus-bar.

4.6.2 Photovoltaic Cells (Solar)

Solar cells may be used as per ESS-09-01 where access to AC mains is not justifiable.

The sizing and equipment for a solar power installation shall be selected in accordance with ESS-09-01 Solar Power Supply Systems.

5 AC Mains Supply – Design

5.1 Provision of Supply

Where existing supply points are to be used these should be nominated in the particular specification.

Two independent power supplies are typically required at each supply point.

Wherever possible these will consist of a 'normal' supply and stand-by supply and be consistent with the arrangements identified in Section 4.2.

5.2 Existing Supply Points

Where existing supply points are to remain, the Contractor shall be responsible for carrying out any necessary supply upgrading work.

Where the existing power supply building or enclosure is too small or unsuitable, the Contractor shall be responsible for the provision of a new building and/or modifications to existing power enclosures.

5.3 New Supply Points

Where supplies are provided from supply authorities or other grid systems and unless otherwise stated in the particular specification, the Contractor shall supply and install or negotiate with the supply authority to supply and install all poles, transformers, meter boxes, earthing, switchgear, surge protection, cables and trenching etc. required to make the required supplies available.

The Contractor shall make all the necessary arrangements for the provision of any supply required, and for its final inspection and connection by the relevant supply authority.

Where engine driven alternators are provided all work associated with their supply and installation shall be the responsibility of the Contractor.

5.4 Power and Lighting Circuits

5.4.1 General purpose lighting and power

Relay rooms in significant structures such as control centres or concrete bungalows may be provided with a single 15A 230/240V 50Hz supply distributed to GPO's (General Purpose Outlet) situated strategically in all rooms of the building.

Building illumination may be provided by means of a 230/240V lighting circuit, with double-insulated luminaires.

Where prevailing environmental conditions require that an equipment enclosure is fully sealed with air conditioning installed to maintain acceptable operating temperature, the air conditioner and its wiring shall be double-insulated from the signalling equipment housing structure.

5.4.2 Location lighting

Luminaires in signalling locations shall be LED devices, supplied from either low voltage DC or double-insulated AC sources.

5.4.3 Test Equipment supply

Signalling locations that contain electronic equipment and can be locally interfaced with a laptop computer shall be equipped with one or more (depending on the size of the location) AC supply outlets for use by test instruments and similar low-powered equipment fitted with universal (90V to 250V AC) power supplies, and standard 3-pin or 2-pin mains plugs.

The instrument supply outlet socket shall be a red general purpose outlet, clearly identified as an unearthed 110/120VAC supply for low-power devices, and its capacity shall be limited by a suitably low-rated circuit breaker, typically 4A.

6 AC Mains Supply – Distribution

6.1 General Requirements

Reticulation of signalling AC supplies will normally be at 110/120VAC unless specially authorised.

Reticulation of 50VDC supplies should be allowed for small loads.

All power cables shall be capable of handling a 15% increase in the estimated standing load to allow for future expansion. All voltage drop calculations shall make allowance for this increase.

The voltage at any point along a pair of mains shall not vary more than 10% from the nominal supply voltage under any static or dynamic load condition, when the supply bus bar is set at nominal voltage under normal operating load conditions.

Ring mains may be considered in some larger signalling equipment locations to manage voltage drop in the power supply system.

Booster transformers in mid run or auto transformers at any signalling equipment location shall not be used for mains distribution. Step up transformers shall not be used on mains distribution unless specifically approved by the ARTC or ARTC's representative.

Cable route installation shall be in accordance with Specification ESC-11-01 *Construction of Cable Route and Associated Civil Works*.

6.2 Extended Voltage Mains

Where a mains distribution run is of such a length as to make distribution at 110/120VAC impracticable, the installation of a higher voltage distribution, run in accordance with the following principles may be permitted.

a) Signalling supply at all load points shall be nominal 110/120VAC.

b) The extended distribution voltage shall be 'low voltage' as defined in AS/NZS 3000, but not less than 230/240VAC and normally not exceeding 480VAC.

c) Outgoing extended voltage mains shall be stepped up to the distribution voltage immediately prior to leaving the supply signalling equipment location and stepped down to 110/120VAC at each load point.

d) The supply to each extended voltage mains shall be controlled by an individual two-pole circuit breaker. The circuit breaker shall have provision to be secured in the 'open' position while work is being carried out on the mains.

e) At each load point two, two-pole isolators or circuit breakers, housed within the transformer enclosure, shall be provided to isolate the input to the step-down transformer and the outgoing mains to downstream signalling equipment locations. The isolator or circuit breaker shall have provision to be secured in the 'open' position while work is being carried out on the mains.

f) Extended voltage distribution mains shall be provided with Earth Leakage Detection (ELD) at the supply signalling equipment location. ELD alarm status shall be indicated in the supply signalling equipment location power supply alarms.

g) All extended voltage wiring shall be double insulated. Transformers, terminals, isolators or circuit breakers and surge protection of the extended voltage distribution shall be enclosed in suitable earthed metallic housings clearly identified with labels stating, “Caution XXX Volts”. Isolators and circuit breakers shall be mounted so that they can be operated from outside the housing.

h) Buried cable carrying extended voltage mains shall be identified by an orange coloured outer sheath.

6.3 Reticulation Design

The designer and installer shall ensure that any new or modified mains supply and distribution system will meet the specified requirements for voltage drop under all static and transient load conditions, with an adequate reserve capacity for future additions.

Notwithstanding any prior approval of system designs and calculations, the installer shall ensure that the final installed power distribution system complies with the specified requirements for loadings, supply regulation and voltage drops.

Appendix 1 *Reticulation Design Process* describes an acceptable method of calculating mains system design parameters and performance with explanation of the terms used in this process.

The signalling power system supplies a variety of load types and shall be designed such that these can all be accommodated within the normal daily operation of the system under current and known or proposed future system usage.

When developing a signalling power supply proposal, where manufacturer data is not available for this purpose, standard unit loads can be utilised to build a power requirement profile for a given signalling location, or where a number of locations are fed from the one supply point. This information is detailed in Appendix 2 - Standard Unit Load Values.

Where power feeders supply a number of signalling locations and mains or sub-mains are utilised, all transformers and fixed power supply equipment shall have their losses built into the system. The cables used for power distribution shall comply with the requirements of ESA-11-01 Cables for Railway Signalling Applications – General Requirements, and AS 7663:2012 Railway Signal Cables and the physical characteristics are detailed in Appendix 3 - Standard Cable Impedances and Preferred Cables Sizes for Mains Reticulation.

7 Mains Transformers

All isolating transformers shall be metal-encased double-insulated air-cooled type conforming to AS/NZS 61558.1 Class II. The insulation between primary and secondary windings shall be achieved by winding on separate insulating bobbins, or by insulation to an equivalent standard.

Earthing of the transformer housing is not required, in accordance with AS/NZS 61558.1 Clause 3.7.6.

8 Emergency Changeover Equipment (ECO)

8.1 ECO Panels - General

At signalling equipment locations where two independent mains supplies are available, an automatic emergency changeover panel system shall be installed, to automatically transfer the load to the alternate supply in the event of a loss of the main supply. The panel shall comply with ARTC standard SPS 24 *Emergency Changeover Contactor Panel.*

ECO units shall have a method to manually force the system from normal supply operation to the standby arrangement. This feature shall, where a MG is provided as the backup arrangement, initiate the auto-start sequence of the MG so it will come on line and provide supply once the MG system requirements have been met. When in this mode the ECO will remain using the standby supply until the system is restored to normal operation mode.

ECO units shall a method to ‘lock out’ the operation of the system to standby supply. This is essential during times of maintenance or other activity within the backup system where load cannot be supplied.

ECO units shall indicate availability of all supplies, and, which supply the system is currently operating from.

Where two independent AC supplies are located close together, there is the possibility that touch potentials equal to the sum of the two voltages may exist. The ECO panel layout shall provide protection against unintentional simultaneous contact with both supplies.

At a signalling equipment location provided with an engine driven alternator for standby supply, the changeover function shall be either incorporated in the mains failure plant controls or in a separate enclosure within the signalling power supply or equipment room.

For supplies rated at over 50 amperes, the preferred type of changeover contactor is a bar type, with single actuating coil energised when the 'normal’ supply is available. The changeover contacts shall be set to guarantee 'break before make' operation, to prevent the momentary interconnection of the two AC supplies.

The ECO panel shall use AC coils for the main contactor. DC coils using bridge rectifiers are not to be used.

The ECO panel shall incorporate voltage sensing, to force the ECO to standby supply if the normal supply voltage either drops 10% below or 15% above a predetermined level and return to normal supply when it is within the preset voltage range.

Where the supply feeds electronic equipment, which may be sensitive to repeated switching of the supply, the return to normal supply shall be made only after it has been continuously within the required voltage range for a period of at least 300 seconds.

Circuit breakers shall be provided in both the inputs and the output of the ECO panel for protection and isolation purposes.

Where special load requirements exist, the ECO may be replaced with a suitable high-speed electronic changeover unit. This shall incorporate guaranteed means to prevent any backfeed into an isolated supply line resulting from the short circuit failure of one or more electronic switching elements.

Static switches, whether installed as stand-alone devices or as part of a UPS system, shall isolate both active and neutral legs of the off-line supply.

9 Mains Failure Plant (Engine Driven Alternators)

9.1 Fixed Mains Failure Plant Installation

Where engine driven alternator sets are to be provided, they shall comply with all requirements of the ARTC standard ESA-09-03 Mains Failure Plant (MG Sets).

Any buildings constructed to house these units shall conform to the requirements of ESC-07-03 *Small Buildings, Location/Terminal & General Purpose Cases*.

9.2 Temporary Emergency Mains Failure Plant

Where a location is required to have provision for temporary connection of a portable motor alternator set, the connection and changeover facilities shall be located in the main switchboard.

The detailed arrangements for connection and changeover shall be as defined in ARTC specification ESA-09-03 Mains Failure Plant.

10 Switchboards

Different arrangements shall be provided for small signalling equipment locations, level crossings and relay rooms.

Where provided, individual, physically separated switchboards shall be provided for 230/240V MEN and 110/120V IT supplies.

10.1 Switchboard Facilities – 230/240VAC Supplies

Switchboards provided for 230/240VAC supplies derived from a supply authority supply, shall be normal commercially available load centres fitted with standard commercial circuit breakers.

10.2 Switchboards for Small locations

Small signalling equipment locations and level crossings 230/240VAC supplies – Main Switchboard to be physically isolated from Signalling equipment enclosure (by at least 2.5m ref AS3000 Clause 1.5.4.6).

Wiring to load centre in signalling equipment enclosure, and to 230VAC loads, to be double insulated. All circuits to signalling equipment location shall be fitted with RCD protection; combined RCD/2 pole OCPD is preferred.

10.3 Switchboard Facilities – 110/120VAC Supplies in Large Signalling Equipment Locations

Unless otherwise specified in the particular specification, each power supply location shall be provided with a switchboard for nominal 110/120VAC supplies including the following facilities:

A switching panel incorporating individual circuit breakers for:

a) Incoming AC supply to switchboard

b) Local AC bus-bars

c) Remote AC submains

d) AC supply to each DC power supply unit

e) DC supply to each DC bus-bar

Provision shall be made for convenient measurement of all busbar voltages, individual busbar currents, and voltages to earth from each side of each busbar.

This shall be in the form of appropriately arranged, readily accessible and labelled test terminals on the switchboard, complete with appropriate current transducers, or a dedicated metering panel incorporating the following facilities:

a) Main supply voltmeter (continuously metered).

b) Main supply ammeter showing total load on the supply (continuously metered).

c) Voltmeter and ammeter to measure voltages and current of all other AC supplies. (Separate meters giving a continuous indication of each supply or common switchable meters may be provided.)

d) Voltmeter and ammeter to measure voltages and current of all DC supplies. (Separate meters giving a continuous indication of each supply, or common switchable meters may be provided).

e) Meters and approved spring-return switches to measure the voltage to earth of each leg of the AC and of the 50 V DC internal and external supplies.

Note: *Where switchable meters are provided the contacts shall be arranged to maintain isolation between different supplies at all times.*

10.4 Construction

The switchboard shall be designed and constructed in accordance with the relevant parts of AS/NZS 3000.

The switchboard shall be arranged as a wall mounted cabinet, with all components, wiring and terminations easily accessible from the front by means of one or more opening front panels.

Cable entry shall be through the top or bottom of the housing.

Blanking plates are to be provided for all unused cable entries.

All hinged panels shall be bonded to the switchboard housing with flexible braided straps.

The switchboards shall be designed to have 20% useable spare space for future requirements. Panel openings for additional circuit breakers shall be fitted with appropriate blanking plates.

Switchboards shall not contain/incorporate emergency changeover equipment, transformers or DC power supply units.

All switchboard components shall be readily available in Australia.

Each item shall be so mounted and connected that it can be readily removed without having to disconnect or disturb other supplies or other components not involved with the component and its immediate circuit.

Wiring of circuit breakers and other components should be arranged so that power enters at the top of each device and exits at the bottom. If the devices are arranged horizontally, the power ‘flow’ should be from left to right.

All components and wiring shall be firmly supported to withstand vibration without damage to connections or terminals. Provisions for securing cables as they enter the switchboard enclosure are to be provided.

Switches and circuit breakers shall be clearly and permanently labelled to unambiguously indicate the function of each eg voltage and source or destination of the circuit controlled. The label shall be in the form of a traffolyte or similar engraved material such that it is presented as black writing on a yellow background for each CB or switch.

11 Circuit Protection

Signalling power supplies are subject to a number of hazards which may result in risk to equipment, operations or persons.

The Signalling power system shall include protection against at least the following hazards:

Hazard	Protection to Control Hazard
Unintentional contact with live conductive surfaces	Enclosure of equipment Earthing of equipment housings Use of enclosed terminals etc
Faults between live conductors and accessible parts of the equipment that may lead to persons working on or about the equipment making unintentional direct or indirect contact with live conductive surfaces and experiencing electric shock.	Earth leakage detection, Residual Current Devices Segregation of earthing systems
Faults between live conductors and parts of the equipment that may directly or indirectly result in unsafe false energisation of Signalling controls or indications.	Earth leakage detection
Faults between live conductors that may give rise to overcurrents resulting in the activation of OCPDs (overcurrent protection devices) and consequent loss of power to controls and indications.	OCPDs (overcurrent protection devices)
Excessive voltages from power surges or lightning which may cause damage leading to immediate or delayed failure of Signalling control equipment	Surge protection and filtering
Excessive voltages from earth potential rise cause by lighting or fault currents in an adjacent earthing system, which may cause damage leading to immediate or delayed failure of Signalling control equipment	Surge protection and filtering Segregation of earth systems
Excessive current caused by equipment overload or circuit fault, resulting in damage to supply equipment or overheating and possible fire in circuit wiring.	OCPDs (overcurrent protection devices)
Gross circuit faults resulting from physical damage from external causes, causing in overloads and overcurrents resulting in damage to supply equipment	OCPDs (overcurrent protection devices)

11.1 Protection Against Unintentional Contact with Live Surfaces

Wiring terminations (disconnect links and fuse holders) for busbars and circuits operating at voltages of 110/120VAC nominal or higher should be of a type on which it is not possible to make unintentional contact with live parts.

Any open terminals operating at voltages of 110/120VAC nominal or higher shall be fitted with securely attached protective covers which may be removed for testing purposes only, or when the equipment has been isolated to permit work to take place.

Any equipment housings and covers made of conductive material (metal) on equipment operating at voltages of 110/120VAC nominal or higher, in which an insulation fault may cause the housing to become live, shall be bonded to the signalling earth system.

The exception to the above is equipment powered directly from an supply authority (MEN) supply, in which case the housing shall be bonded to the MEN protective earth conductor. Where this equipment is located within a signalling location, it shall also be double insulated or within an insulating housing.

11.2 Protection against Overcurrent

Overcurrent protection devices (OCPDs) shall be provided to protect the supply equipment and cables.

Overcurrent protection for main supplies and busbars shall be by circuit breakers acting on both legs of the supply

Overcurrent protection for final circuits shall be by appropriate fuses, in the active or positive leg of the circuit; the corresponding common or negative leg of the circuit shall be provided with a suitable disconnection link to enable full isolation of the circuit.

11.2.1 Rating of OCPDs

In all normal Signalling power supply installations, cable and wiring conductor sizes shall be chosen to provide physical robustness or minimise voltage drop. As a consequence of this, it is very unlikely that conductor loading is more than a fraction of the cable’s maximum rating, and the principal aim of overcurrent protection shall be to protect the supply equipment.

OCPD ratings will therefore normally be much lower than the operating current limits of the wiring, and in the event of a low-impedance circuit fault the clearing time shall be more than adequate to protect the cable.

Furthermore, on AC mains, because it is not necessary to minimise OCPD clearing time by artificially increasing the prospective fault current, there is no requirement to install supply transformers of greater rating than what is necessary to supply present and predicted equipment loads.

Discrimination between OCPDs:

Discrimination shall be applied to OCPD ratings such that the circuit breaker or fuse closest to the fault shall be the one to open, so that a minimum of equipment is disconnected.

Circuit breakers shall be rated for the present and predicted equipment loads.

On supply bus-bars where the individual circuits are protected by DIN fuses, the rating of the bus-bar circuit breaker shall be at least equal to the standing load, plus a current equal to the highest rated fuse on the bus-bar.

To minimise the risk of nuisance tripping, normal loadings are not to exceed 75% of the rated value of any circuit breaker or fuse.

11.2.2 Fuses

Fuses used for protection of signalling power supplies shall be to Specification DIN41576/CEE, in rail mounted (`Klippon' type) holders, rated for the expected loading.

Fuses shall provide visible indication of rupture wherever possible.

DC Signalling control circuits shall be individually protected by 2A fuses. Other DC circuits shall be protected by fuses rated at 4A, 6A, 10A, and 15A as applicable.

AC Signalling circuits shall be protected by fuses rated at 4A, 6A, 10A, and 15A or by approved circuit breakers.

The required current rating of protection equipment shall not be obtained by connecting lower rated components in parallel e.g. circuit breakers, fuses, contacts etc.

11.2.3 Circuit Breakers

Circuit breakers used in signalling supplies shall be double pole thermal magnetic type, with standard current/time operating curve. They shall be designed to indicate, by lever/switch position, whether they have tripped or have been switched off. The preferred circuit breaker type for general signalling applications is standard C curve type, in the 'standard mount, standard connection' form.

Where circuit breaker nuisance tripping has been identified, the use of magnetic circuit breakers is recommended. This can be caused due to the wide range of ambient temperatures that may occur in signalling equipment housings (over 70^0C is not uncommon) the tripping point of thermal circuit breakers has been found to vary significantly, occasionally resulting in nuisance tripping and loss of signalling power. For this reason, circuit breakers which include thermal tripping should not be considered for use on signalling supplies.

Where circuit breakers including thermal tripping are proposed for installation, approval for use shall be subject to documented proof that changes in ambient temperature will not lead to nuisance tripping of the devices. Any circuit breakers with thermal tripping elements shall be compliant with AS/NZS 60898.1:2004 *Electrical accessories—Circuit-breakers for overcurrent protection for household and similar installations Part 1: Circuit-breakers for AC operation*.

The type of circuit breaker installed shall be appropriate to the type of supply – AC supplies shall be equipped with AC circuit breakers and DC supplies shall be equipped with specific DC circuit breakers.

The majority of circuit breaker manufactures design their circuit breakers to operate in 3 different operating regions, and each type is identified by a letter that corresponds to the particular characteristics of that type of circuit breaker.

- B Curve breakers: Trip between 3-5 times rated current in a short circuit situation. B curve MCBs should be applied where loads are resistive and do not have in-rush current. The ideal application is lighting or electronic circuits.
- C Curve breakers: Trip between 6-10 times rated current in a short circuit situation. C curve MCBs should be applied where the loads have a small amount of in-rush current on start-up. The ideal application is a circuit with a small transformer load.
- D Curve breakers: Trip between 10-15 times rated current. D curve MCBs should be applied where loads have a high level of in-rush current on start-up. The ideal application is a circuit with a motor load.

Where the signalling load includes a large number of transformers it is possible that a standard C curve circuit breaker may trip due to the high inrush currents at turn on or during an ECO transfer. In these instances D curve circuit breakers should be substituted for the Standard C curve circuit breaker and shall be selected to prevent openings for normal circuit conditions while providing protection against abnormal damaging conditions

In rural areas with single authority supplies and no standby AC supply, power outages due to failures or scheduled maintenance cause in signalling DC supplies and batteries to become significantly discharged and result in inrush currents that cause false tripping of circuit breakers. At locations where this may occur, designers should consider the use of Slow curve circuit breakers.

11.3 Protection Against Over/Undervoltage

The issue of supply voltages outside the normal operating range should normally be dealt with by suitable design of supply voltages and ratings and selection of suitable sources of supply. Where out-of-range supply cannot be guaranteed, the use of voltage sensing controlled supply transfer should be considered, to disconnect and protect the load equipment from over- and (more often) under-voltages.

11.4 Protection against Voltage Surges, Spikes and Noise

The power supply systems and the equipment shall be provided with protection against lightning and high voltage surges in accordance with ARTC standard ESC-09-02 *Lightning and Surge Protection Requirements*.

11.5 Protection Against Insulation Faults

Signalling power supplies use the IT system of protection as defined in IEC 60364 Part 1. The features of this system are that all live parts are isolated from earth ('I") or have one point connected to earth through high impedance, and exposed conductive parts have direct electrical connection to earth, independently of the earthing of any point of the power system ("T").

The intent of this is that unintentional contact with a live conductor will not result in a touch current that presents a significant risk to the person making contact, and a single insulation fault to earth will not enable the passage of any current that could cause the unsafe operation of signalling controls or indications.

The effectiveness of this safety control depends on the continued integrity of the insulation between live parts and earth, and continuous earth fault monitoring (also referred to as Earth Leakage detection") is mandated to maintain the safety of the system. IEC 60364 specifies that detection of a single earth fault should generate an alarm, while a second earth fault may trigger the isolation of the power supply; this requirement does not need to be followed if the isolation of the power supply would give rise to a greater risk.

11.5.1 Protection Against Faults to Earth – 230/240VAC supplies

230/240VAC circuits from the 230/240VAC main switchboard to equipment in a signalling equipment housing (load centre, stepdown transformer or other power conversion equipment) shall be provided with residual current device (RCD) protection.

230/240VAC power (GPO) and lighting circuits in signalling equipment locations shall be provided with RCD protection.

RCDs shall be to the standard operating specification of 30mA sensitivity and 0.4 Sec tripping time. RCDs should switch both active and neutral conductors and may be combined units including overload/isolator functions.

11.5.2 Protection Against Faults to Earth – Signalling power supplies

Earth leakage detectors shall be installed on all busbars supplying vital control circuits and equipment, including AC (110/120V nominal) and DC (50V, 24V or 12V) supply busbars. The detectors shall indicate the occurrence of a momentary or continuous earth fault, on either side of the supply bus.

Earth leakage detectors shall be installed on extended voltage mains and, where 110/120VAC ELD protection is required at load locations, individual ELDs shall be installed on the 110/120VAC bus-bar at each signalling equipment location.

Only a single ELD shall be installed on any signalling power supply busbar; ELDs in parallel are likely to mutually interfere.

11.5.3 Earth Leakage Detectors

The detection arrangement shall be such that any earthing caused by the detector will not under any circumstances cause interference to the signalling circuits.

Earth leakage detectors shall be continuously indicating and self-proving. A failure of the supply being monitored shall not produce an alarm indication.

The detection sensitivity shall be set by the manufacturer or be adjustable by means of an external control.

The alarm tripping delay should be about 5 seconds. This value is sufficient to avoid nuisance trips from fleeting contacts, while providing timely warning of any persistent fault.

It is desirable, but not mandatory, that new ELDs have two levels of detection sensitivity and indication. These should be the ‘alarm’ levels specified below and a second, ‘warning’ level at higher leakage resistance, to detect and indicate a deteriorating insulation condition.

The detection sensitivity shall be not less than the following:

Busbar voltage (nominal)	**12 DC**	**24 DC**	**50 DC**	**110/120 AC**	**415 AC**
ELD sensitivity – Warning (kΩ)	50	50	100	100	200
ELD sensitivity – Alarm (kΩ)	15	15	40	40	100
Equivalent leakage current (mA)	1	1.5	1.3	3	4.2

Table 1 - Earth Leakage Detector Sensitivities

The detector shall be designed such that, once having operated to a "fault" indication it will remain in that condition until deliberately reset. Terminals shall be provided for a remote reset by an external voltage-free contact.

A "test to earth" spring return switch shall be provided on the unit to facilitate checking of the unit's effectiveness. The Test Earth connection shall operate through an internal resistance valued at the maximum earth leakage resistance the unit will detect, to an independent test earth.

The unit shall provide the means by which to simply identify which side of the supply is subject to the detected earth fault. This shall be done by means of indicator lights on the detector. One green light shall be provided to indicate that each bus is normal - i.e. clear of earth fault.

Each detector shall incorporate its own built in "clear" and "fault" indications and have an output contact to accommodate an externally fed remote alarm circuit.

Each detector shall incorporate an option such that it can be connected via a network or ethernet connection to allow remote monitoring of all indications that are visible locally.

12 Earthing

12.1 Earthing at Signalling Supply Locations

At each power supply location, a Signalling earth system shall be installed in accordance with Specification ESC-09-02 *Lightning and Surge Protection Requirements.*

12.2 Segregation of Earths

Effective separation shall be maintained between the Signalling Earth (S&CES), authority supply (MEN) earth (CE), any high voltage earth (HVE), and any other earth system at the signalling supply location.

The ELD test earth shall be separate from the S&CES, with the test earth conductor insulated in a distinctive colour. Because the test earth is only connected momentarily, while an ELD test is being performed, the MEN earth may be used as ELD test earth, with the test earth conductor terminated on the MEN earth busbar.

Detailed installation requirements for effective separation of earths are provided in ARTC standard ESC-09-02 *Lightning and Surge Protection Requirements* (Appendix A).

12.3 Segregation from Traction Supplies / Earths

Supply authority (MEN) supplies entering the railway corridor in areas with electric traction shall be equipped with isolating transformers to provide galvanic isolation from DC or AC traction supply earths or returns.

12.4 Earthing of 230/240VAC Supplies

Where power is derived from an authority supply, the main switchboard shall be in a position physically separated from the signalling equipment location.

Earthing shall be in accordance with AS/NZS 3000, with the main earth for the installation located immediately adjacent to the main switchboard.

Where a 230/240VAC load centre is installed within the signalling equipment location, the neutral and earth bars shall be connected directly to the respective busbars in the main switchboard. The load centre shall be constructed of insulating material, to facilitate the separation of earths.

All authority supply mains wiring and equipment installed within a signalling equipment location shall be double insulated; this includes the isolating stepdown transformer. The housing of the step-down isolating transformer may be earthed to the signalling earth, in compliance with AS/NZS 61558.1 Clause 3.7.6 Note 6.

12.5 Earthing of General Purpose Power and Lighting Circuits

230/240VAC power (GPO) and lighting circuits in signalling equipment locations shall be installed as MEN circuits, in accordance with AS/NZS 3000.

Where the power and light circuit is supplied by a step-up/isolating transformer fed from the signalling 110/120VAC supply, the 230/240VAC circuit shall be installed as an MEN circuit, with the MEN neutral link and earth connected directly to the signalling earth at the main earth busbar.

The isolating transformer case and frame shall be bonded to the same earth.

12.6 Earthing of Signalling Supplies

All 110/120VAC signalling supplies, and all DC supplies, shall be installed in accordance with AS 7703. They shall be kept strictly free of earths, to maintain circuit integrity and safety in the event of any individual earth fault on a supply busbar.

A signalling earth (S&CE) shall be provided for the operation of surge protection equipment; it shall be installed in accordance with ARTC standard ESC-09-02.

12.7 Earthing of Exposed Metal Racking

All relay racks, cable troughs and equipment cabinets shall be bonded to the signalling earth with not less that $4mm^2$ earthing conductors.

Any exposed metal racking or cable tray which is carrying AC mains wiring that is not double-insulated shall be bonded to signalling earth with earthing conductors sized to comply with AS/NZS 3000, Table 5.1, with regard to the maximum size of the mains conductors carried by the racking or tray.

13 Alarms and Indications

13.1 General

Each transformer location and relay room shall be provided with power supply indications and alarms as described below. In addition, an alarm monitoring panel shall be provided in each main relay room. Specified alarms shall be displayed on the main Control Centre console.

13.2 Alarm Indications - General

Generally, alarm indications shall be in accordance with the following principles:

A green light shall indicate a 'Normal' status, indicating that a supply is operating normally.

A yellow light shall be used to indicate a 'Warning' status, indicating that part of a supply has failed, and the supply is operating in its standby mode, or that a standby supply has failed and is unavailable in the event of a loss of normal supply.

A red light shall be used to indicate an 'Alarm' or ‘Fail’ status, indicating that a supply has failed completely, with consequent loss of function in part of the signalling equipment, and the possible existence of a dangerous condition.

At staffed control locations, an audible alarm shall sound whenever any indication changes status, from 'Normal' to 'Warning' or 'Alarm', or back to 'Normal'. The alarm shall operate continuously until silenced by the console operator entering a command to acknowledge the change of status.

Indication lights shall be Light Emitting Diode (LED) bezels of the appropriate colour. These LED bezels shall be rated for continuous operation at the maximum working supply voltage. Indication lights shall not use incandescent globes.

Indication circuits shall be wired so that they produce no interconnection of supplies.

13.3 Power Supply Indications

The power supply indications listed below shall be provided, as applicable, for any signalling power supply installation. Other types of power supply or control equipment utilised provide their alarms and warnings via an ethernet or a network connection that is sent to a control centre. These data provided from this equipment can be accessed locally by technicians connecting to the same communications network and accessing the hardware via a OEM user interface. In these cases, the requirements of this table may be ignored.

Location	Indication	LED Bezel Colour	Relay
Transformer room	110/120V Normal supply to ECO available	Green	------
	110/120V Emergency supply to ECO available	Green	------
	UPS on-line and operating normally	Green	
	UPS warning	Yellow	
	UPS alarm	Red	
ECO Panel	110/120V Normal supply to ECO available	Green	2 C/O
	110/120V Emergency supply to ECO available	Green	2 C/O

Location	Indication	LED Bezel Colour	Relay
	110/120V Load supply available	------	2 C/O
Power Factor Correction	PF Correction unit on line	Green	2 C/O
Phase Detector	Correct phasing between adjoining AC supplies	------	2 C/O
DC Supply Unit (each unit individually)	DC output available	Green	2 C/O
DC Battery Charger	Charger output available	Green	3 C/O
	Battery low voltage alarm (Critical battery supplies only)		2 C/O
MG Control Panel	AC Normal supply available	-------	3 C/O
	MG operating & supply on line	Yellow	3 C/O
	MG Engine low oil pressure	Red	3 C/O
	MG Engine overheating	Red	3 C/O
	MG Fuel low – 12 hours supply	Yellow	3 C/O
	MG Fuel low – 30 minutes supply	Red	3 C/O
	MG output circuit breaker tripped	Red	3 C/O
Earth Leakage Detector	Bus 1 Clear	Green	------
	Bus 2 Clear	Green	------
	ELD clear/tripped	------	1 C/O
Control Panel / Console	Power supplies Normal	Green	
	Power supplies Warning	Yellow	
	Power supplies Fail	Red	
	ELDs clear ELD operated	Green Yellow	
	Power supplies – status change	Audible Alarm	
RELAY ROOM ALARM PANEL	AC Normal Supply to ECO available	Green	------
	AC Emergency Supply to ECO available	Green	------
	AC Load Supply ex ECO available	Green	------
	AC Bus bar Supply Available (each Int, Ext, Points supply)	Green	------
	110/120V Supplies available	------	3 C/O
	DC Bus bar Supply Available (Each B12, B15, B24, B50, Int, Ext bulbar)	Green	------

Location	Indication	LED Bezel Colour	Relay
	DC Supplies available (12v, 15v, 24v, 50v Int, Ext separately)		3 C/O
	DC Supply Unit Channel fail (Each B12, B15, B24, B50, Int, Ext bulbar)	Yellow	
	AC bus bar supply lost	Red	
	DC bus bar supply lost	Red	
	Battery Charger Output Fail (not loss of AC) (each battery supply)	Yellow	
	AC Emergency MG set on line	Yellow	
	MG Set – 12 hours fuel warning	Yellow	
	MG set fail to start or shut down	Red	
	Battery low volts alarm operated	Red	
	ELD tripped (all ELD’s grouped)	Yellow	

The indicating relay types shown in the list ("2C/O" and "3C/O") refer to plug-in non-vital relays equivalent in form and pin-configuration to 'Fuji' HH22PW-T and HH23PW-T types.

Indicating lamps/LEDs shall give clear and unambiguous indications under their normal ambient lighting.

14 Housings

14.1 General

Multiroom buildings built at power supply locations shall conform to ESC-07-03 *Small Buildings, Location/Terminal & General Purpose Cases*.

AC power supply equipment of over 110/120VAC including HV switchgear, regulators, transformers etc. shall be housed in a separate room with separate external access.

Access to all signalling equipment and power rooms shall be restricted to properly qualified and authorised staff.

Engine driven alternators shall be housed to conform with Section 10.0 of this Specification and ESC-07-03.

Batteries used for signalling and communication equipment shall be housed to meet the ventilation requirements of AS2676.1

Low voltage equipment including incoming surge protection panels, emergency changeover panels, battery chargers etc. may be mounted on the wall of the relay room adjacent to the AC power room and/or battery room or on free standing racks.

14.2 Alternative Housings for Power Supply Equipment

In sections of distributed signalling, where there is no central relay room provided, the signalling power supply equipment may be housed either in a self-contained building or else a more compact housing of suitable design.

Any such alternate housing shall conform to ESC-07-03 and take into particular account the following items:

a) Protection of the equipment from the elements, dust and vermin

b) Resistance to vandal attack

c) Service life of materials and construction; any special maintenance requirements

d) Free maintenance access

e) Ease of access to wiring, and ease of replacement of the equipment housed

f) Ease of installation of additional equipment

15 Disposition of Equipment

Where power is derived from a supply authority, the main MEN switchboard shall be located in a position physically separated from the signalling equipment location.

Where the signalling equipment housing is of metal or sandwich construction, the main MEN switchboard shall be in a separate housing or enclosure from the Signalling equipment housing with at least 2.5 metres between the two housings in accordance with, AS/NZS 3000 Cl.1.4.16.

Where the signalling equipment housing is constructed of non-conductive materials (masonry), the main switchboard may be located in a separate room with a non-conductive wall between the switchboard and signalling equipment.

Where a 230/240VAC load centre is installed within the signalling equipment location, the neutral and earth bars shall be connected directly to the respective busbars in the main switchboard. The load centre shall be constructed of insulating material, to facilitate the separation of earths.

All authority supply mains wiring and equipment installed within a signalling equipment location shall be double insulated.

At a major interlocking or control centre low-voltage control and supply equipment shall be housed in a room or enclosure, referred to in this document as the 'power room', separated from the signalling relay equipment room.

The power room shall house, at least, all equipment down to the 110/120VAC isolating / step-down transformers, and any supply surge protection panels with open terminals.

Any 230/240VAC lighting and GPO supply circuit breakers should be housed, with the supply authority signalling supply breaker, in a distribution panel in the power room.

110/120VAC ECO panels may be located either in the power room or in the relay room adjacent to the switchboard.

Any 110/120VAC signalling power supply equipment in the power room shall be located out of reach of all MEN equipment.

Where the ECO is not mounted in the power room, the outgoing 110/120VAC Normal and Emergency transformer feeds shall be provided with isolating switches (non-tripping circuit breakers), to permit isolation of supply equipment by electrical maintenance personnel.

16 Appendix 1 - Reticulation Design Process

This section sets the basic parameters for the design of power reticulation schemes for signalling works carried out on ARTC's Network.

It describes preferred methods for:

- Estimation of total location loading
- Allowances for design variation and future expansion
- Determination of mains cable sizes
- Preparation of Mains Distribution plans

The requirements listed in this section should be interpreted as representing the minimum requirements for any mains reticulation system.

The designer and installer shall ensure that any new or modified mains supply and distribution system will meet the specified requirements for voltage drop under all static and transient load conditions, with an adequate reserve capacity for future additions.

Notwithstanding any prior approval of system designs and calculations, the installer shall ensure that the final installed power distribution system complies with the specified requirements for loadings, supply regulation and voltage drops.

The following sections define an acceptable method of calculating mains system design parameters and performance.

16.1.1 Definitions - Types of Loading

16.1.1.1 Static Loads

These are devices presenting a continuous and essentially constant value of load, over extended periods e.g. Signal lights, and all transformer / rectifier sets.

16.1.1.2 Occasional Loads

These devices are not normally on but may be switched on at times for extended periods, generally not exceeding an hour e.g. Location lighting, and maintenance call lights.

16.1.1.3 Transient Loads

These devices are also not normally on, but when switched on, present significant loads for brief periods, generally of several seconds e.g. Train stops and points machines.

16.1.2 Power System Loading

16.1.2.1 Standard Unit Loads

A table of standard devices and their rated unit loads is provided in Appendix 2 of this document. This need not be reproduced by the Contractor, but the values listed shall be used for all calculations submitted, subject to the exceptions noted in the following paragraph.

16.1.2.2 Non-Standard Unit Loads

Unit loads for non-standard items shall be actual measured values, for identical equipment under normal operating conditions. Test documentation shall be submitted to substantiate any such values used in calculations.

Alternatively, for transformer-input devices, the rated load shall be the full rated VA output, plus a loss allowance equal to 33% of the full rated output.

If the device concerned is to operate at less than full rated output, then its unit load shall be the calculated output VA rating, plus the loss allowance equal to 33% of the full rated output.

Where DC supply units are duplicated and operate in parallel, their equivalent AC loading is the calculated output VA rating as before, plus the full loss allowance for each unit.

Where it is proposed to allow reduced load ratings in accordance with this paragraph, full details shall be submitted of the calculations used to determine the reduced rating, for each instance.

A list of all non-standard unit loads shall be included with the power reticulation design submitted for approval, showing for each device:

- the full rated output, in VA
- the rated mains loading, in VA

Additionally, for any item for which it is known that the actual mains loading exceeds or varies significantly from the standard unit load value listed in Appendix 1, and a different value is proposed to be used in the calculations, that device, with its rated loadings as proposed, shall be included in the table of non-standard loads.

Where an alternative load value is used, empirical test data shall be submitted to substantiate the value used.

16.1.3 Location Loadings

To calculate the total current in each section of a mains feeder, first estimate the total loading at each signalling equipment location fed by the mains in question, under conditions of both static loading (static loads only) and dynamic loading (including static, occasional and transient loads).

For each mains feeder in a design, the total loading on each section shall be the sum of the individual downstream load locations, plus the standard transformer losses for any signalling equipment location isolating transformers in the feeder.

Only devices actually connected to the AC supply system should be included in AC mains calculations. DC loadings from relays, etc should not be calculated directly into AC mains calculations, but instead be used to estimate the AC loading effect of the DC supply unit feeding them.

A location loading sheet shall be prepared for each location to be supplied by the mains in question, showing the following items:

16.1.3.1 Static Loads

For each type of device, list:

a) the total number in use at the location
b) the unit VA load of the device
c) the resulting total VA load due to the device

For the location, note:

a) the total static load, in VA
b) the total static load, in Amperes

16.1.3.2 Dynamic Loads, occasional and transient

For each type of device, list:

a) the total number of such device at the location
b) the maximum number that can operate simultaneously
c) the unit VA load of each
d) the maximum transient VA load

For the location, note:

a) the maximum total dynamic VA load
b) the maximum total dynamic load, in Amperes

16.1.4 Allowances

The following allowances shall be made, before calculating reticulation voltage drops:

16.1.4.1 Location Loads

Unless otherwise specified, the following additional load shall be allowed for future expansion, at each location:

a) 15% of the estimated static load; plus
b) One points machine, at the most remote points feed location, on each mains run which includes points feeds. Where separate points mains are provided, this does not apply to the non-points mains.

16.1.4.2 Cable Lengths

For calculation of voltage drops between signalling equipment locations, cable lengths between locations shall be as determined on the site and shall include suitable allowances for route deviation and cable termination. They shall be not less than the exact measured length along the actual cable route, plus 10 metres.

16.1.5 Cable Impedance Values

The values of cable impedance used to calculate feeder voltage drops shall be derived from the AC resistance and reactance values specified in AS/NZS 3008.1.1, Tables 30 and 34. (See Appendix 2 of this document).

16.1.6 Maximum Voltage Drops

The power supply reticulation system shall be designed to meet the following voltage drop criteria, under the defined load conditions:

a) On 110/120VAC signalling mains, the maximum voltage drop shall not exceed 10% of the nominal supply voltage for static and dynamic loads combined.
b) On mains with less than 20% difference between end-to-end voltage drops under static and dynamic loading conditions, the maximum voltage drop may be up to 15% of the nominal supply voltage. Provided that it does not exceed the input voltage rating of equipment installed near the supply point, the supply point voltage may be increased to give a static end-point voltage within 10% of the nominal supply voltage.

c) Mains incorporating extended voltage distribution, shall meet the above requirement, applied to the nominal 110/120VAC supply and end-use points.

d) On mains provided specifically for the supply of point machines, the maximum permissible voltage drop may, subject to specific approval, exceed that normally specified for general mains supplies, up to a limit of 15% of the nominal supply voltage.

16.1.7 Selection of Cable Sizes

Cable sizes shall be selected such that the final total voltage drop from the feed location to the extremity of each feeder does not exceed the specified limits. A list of cable sizes, current ratings, and voltage drops, with preferred cable sizes highlighted, is given in Appendix 2.

The cable size for each section between locations shall be selected to provide a consistent longitudinal voltage drop (volts / metre) along the full length of the feeder, subject to the constraints that

- The minimum cable size used in a nominal 110/120VAC mains shall be 16mmsq (7/1.70 mm).
- No cable may feed into a cable of greater cross-sectional area.

Cables used for power supply purposes shall comply with ARTC standard ESA-11-01 *Cables for Railway Signalling Applications – General Requirements*, and AS 7663:2012 *Railway Signal Cables*.

A list of cable sizes, current ratings, and voltage drops, with preferred cable sizes highlighted, is given in Appendix 2.

16.2 Calculations

Calculation of estimated voltage drops shall be carried out as described below, using the current loadings and cable lengths estimated above, selected cable sizes, and cable voltage drop values as specified in Appendix 2.

16.2.1 Voltage Drop Calculations

Two sets of voltage drop calculations shall be carried out, namely;

a) One for static loading conditions as defined in Section 6.3.3.1.

b) One, for `maximum demand' static and dynamic loading, as described below.

16.2.2 Static-Loaded Voltage Drop

The static loaded voltage drop calculation shall be carried out with all locations at their estimated static load, plus the 15% load allowance specified in Section. 6.3.4.1.

16.2.3 Dynamic-Loaded Voltage Drop

For the dynamic-loaded volt-drop calculation, the effective loading shall be calculated as follows:

a) Full static loading including 15% allowance, at all locations; plus

b) Location lighting turned on at the two most remote locations on each feeder, plus at every second location towards the feed point. (If door-operated cut-out switches are provided at all locations then only the two most remote locations need be included); plus

c) Any ‘occasional' load: ‘on'; plus

d) Point machines: On each feeder, allow the greatest possible combination of machines that can operate as the result of a single `push-push' route setting action by the signaller. (Include in this any normalisation of pre-existing conflicting routes, in going from one route to the `worst' opposite one, and both route setting and trapping.)

16.2.4 Calculation of Voltage Drop and Cable Size

The preferred approach to the selection of cable sizes is for each section of cable to be chosen to give a resulting voltage gradient along its length, which most closely approximates the average voltage gradient (volts per metre) for the complete cable run in question. This `target' voltage gradient is obtained by dividing the total permissible voltage drop for the cable run, by the length of cable in the run.

The size of each individual cable may be first approximated by selecting the cable size, which under the estimated current loading yields a voltage gradient nearest to, but less than, the `target' value. In a second pass, some cable sizes can be reduced to reduce the overall cable cost. Within any cable run, occasional sections may have a gradient, which exceeds the `target', so long as the end voltage falls within specified limits.

Subject to the limitations on the range of cable sizes available for use, and the desire to limit the number of cable sizes used in any one cable run, in an optimum design the individual location voltages will also lie close to a line conforming to the `target' voltage gradient, with some location voltages being `below' the target line.

The end-point target voltage is the nominal supply voltage, less the 10% permissible voltage drop.

16.3 Mains Reticulation Design

The completed mains reticulation design shall include the following information:

a) A mains distribution plan, showing the completed distribution scheme.

b) Location loading sheets, showing the details listed in Section 6.3.2.

Voltage drop calculation sheets, showing how the estimated voltage drops was arrived at Section 6.3.6.

16.3.1 Mains Distribution Plan

The completed mains reticulation design should be submitted on a copy of the track plan/s for the project, bearing the following information:

16.3.1.1 Permanent Data

(to form part of the final permanent track plan):

a) Feed location details (diagrammatically, using standard symbols), showing:

b) Sources of supply

c) Emergency changeover equipment

d) Surge protection

Simplified distribution switching

Cable details:

a) Active and Common cables
b) Identification of cable function (e.g. WG Bx120, WG Nx120)
c) Cable size in each section
d) Load location terminals.

16.3.1.2 Temporary Data

This is for approval purposes only:

a) Location load currents (Static and Dynamic)
b) Total current in each cable section (Static and Dynamic)
c) Calculated length of each cable section.
d) Estimated voltage drop in each cable section (Static and Dynamic).

16.3.2 Circuit Book

The diagrammatic representation of all the above information including temporary data shall be included as separate sheets in the Circuit Book.

The diagrams are not required to have a lateral scale.

17 Appendix 2 - Standard Unit Load Values

110/120VAC Unit Load Values for Power Distribution Calculations

For equipment using LED technology as a light source (signals, indicators etc), the designers shall consult with equipment manufacturers for specific typical loads to be used in these calculations.

Device	Load (VA)
Colour light signal (1 head) – incandescent	40
Colour light signal (2 head) – incandescent	80
Low speed light – incandescent	40
Shunt light – incandescent	40
Marker light – incandescent	40
‘Band of Lights’ – incandescent	120
Stencil route indicator – incandescent	60
Multi-lamp route indicator – incandescent	200
Dwarf position light – incandescent	120
Shunt, colour light – incandescent	120
Guards indicator – incandescent	40
Points machine - hydraulic	Refer to OEM to provide load based upon system design
Points machine – electric	1000
(For Point Machine VA calculation see paragraph 6.3.3)	
Track feed DC	20
Track feed DC-AC immune	20
Transmitter CSEE	60
Receiver CSEE	30
Transmitter Jeumont Schneider	50
Rectifier – Typical Level Crossing	750
FAdC Axle counter cardfile (Frauscher provide a free service to provide this information based on the specific layout of the system.)	Refer to OEM to provide load based upon system design
(For Location Light see paragraph 6.3.3)	

18 Appendix 3 - Standard Cable Impedances and Preferred Cables Sizes for Mains Reticulation

Conductor	Normal Conductor Arrangement	Maximum Current at 25C in ground, 40C in air	Conductor AC Resistance Ω/Km at 50Hz, 45C	Conductor reactance Ω/Km at 50Hz
1.5	2 x 7/0.50 *	19	14.9	0.167
2.5	2 x 1/1.78	27	8.14	0.153
4	2 x 7/0.85*	37	5.06	0.142
6	2 x 7/1.04	46	3.38	0.133
10	2 x 7/1.35	64	2.01	0.123
16	2 x 7/1.70*	85	1.26	0.114
25	2 x 19/1.35	113	0.799	0.109
35	2 x 19/1.53	139	0.576	0.104
50	2 x 19/1.78*	170	0.426	0.0988
70	2 x 19/2.14	215	0.0941	0.0941
95	32 x 7/1.78*	265	0.213	0.0924
120	2 x 37/2.03	307	0.17	0.0889
150	2 x 37/2.25	351	0.138	0.0885
185	2 x 37/2.52	403	0.111	0.0878

Notes:

Preferred cable sizes are marked with an asterisk (*).

Maximum currents, conductor resistances and impedances and voltage drop values are taken from Tables 10, 30 and 34, AS/NZS 3008.1.1:2017.

Current ratings are those applicable for single-phase circuits, two-core thermoplastic sheathed cables enclosed in air or ground and protected by circuit breaker.