Equipment Strategy for Overhead Conductor and Earthwire

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1. Introduction

1.1 Purpose

Equipment strategies document Powerlink's vision for equipment technologies, to provide both Powerlink and suppliers with consistent planning and project management platforms for the life of the strategy. The document expresses Powerlink's vision in terms of the equipment performance requirements. It is not a detailed contract specification.

Equipment strategy documents are intended to be shared with potential suppliers and therefore consideration has been given to the principles outlined in the Procurement Standard in the development of the documents.

The equipment strategy for Overhead Conductor and Eathwire has been developed with input from relevant teams in Powerlink.

1.2 Scope

This Equipment Strategy covers the requirements for purchase of overhead conductor and earthwire for the Powerlink's HV and EHV transmission network, both greenfield and brownfield.

It is intended that the equipment strategy will be reviewed on a regular basis so that changes can be incorporated at the most opportune time. The Equipment Strategy will have a life of five (5) years, with a significant review in the third (3rd) year reviewing service experience and if there are new alternative technology solutions.

1.3 Defined terms

Terms	Definition
1120	1120 type aluminium Alloy
6210	6201 type aluminium alloy
/AC	Aluminium clad
/GZ	Galvanised
AAAC	All aluminium alloy conductor
AACSR	Aluminium alloy conductor steel reinforced
ACSR	Aluminium conductor steel reinforced
ACSS	Annealed conductor self-supporting
Brownfield	Works conducted for existing assets for retrofit, life extension or refurbishment activities
Greenfield	Works conducted for new assets
HTC	High temperature conductor
HTLS	High temperature low sag
OHEW	Overhead earthwire
OPGW	Optical fibre ground wire

1.4 Monitoring and compliance

This equipment strategy will guide development of the technical specification for purchasing and well as the electrical design specification for overhead lines. The success is monitored through regulatory information notices, annual reporting and SAP records review of installed equipment.

The success of this strategy is measured by monitoring life cycle costs as well as availability and service history associated with this equipment.

The minimum records required are:

- Technical specification
- Tender evaluation report
- Period contract or standing offer
- Purchase orders
- Manufacturers test reports

2. Strategy

This Equipment Strategy intends to cover all transmission line overhead conductor and earthwire purchased over the next five years for use on Powerlink and customer networks. The function of overhead conductors is to transmit electricity and overhead earthwires to shield the conductors from direct lightning as well as forming part of the interconnected earthing system.

The vision that drives equipment strategy documents is based on historical experience, research and investigations into new products available on the market, reliability centred maintenance analysis and lifecycle cost experience over the expected service life. The main features of Powerlink's vision for conductor and earthwire for transmission lines are as follows:

General

- Evaluation and assessment through life cycle cost analysis (LCCA).
- Meet a 50 year service life for conductors and 40 years for OHEWs in Queensland climatic conditions.
- Compliance with all relevant international standards.
- Adequately sized to meet current and future fault levels under backup clearing times.
- Resilience to damage from lightning.
- High availability, reliability and cost competitive on a whole of life basis.
- In the case of brownfield applications, conductor and OHEW that can reliably replace existing non-standard in-service items.
- In the case of greenfield applications, standard conductor and OHEW products to simplify the spare, logistics and tooling considerations.
- Designed to have no (or minimal) maintenance requirements.
- Supports live-line and bare-hand maintenance.

Safety and environmental

- High reliability to minimise the risk of major injury or fatality or environmental risk due to a dropped conductor

Maintenance level

Powerlink's preference is to procure equipment which has:

- No or minimal maintenance requirements.

- Simple, reliable and proven technology.

2.1 Projected use of equipment

Transmission line conductors for the Powerlink network operate at system voltages of 66 kV up to 500 kV.

Conductor size and bundle configuration is chosen to meet the required maximum load flow whilst minimising electrical discharge, audible noise and interference. Conductor characteristics such as diameter, tension, and sag are crucial to limiting structure costs.

Transmission line earthwires are designed to shield the phase conductors below from direct lightning strikes. Direct lightning strikes on phase conductors would generally cause an insulator flashover and consequent loss off supply. Lightning strikes to earthwires are channelled to earth via the bonding of earthwires to adjacent structures to reduce outages. Earthwires are sized to ensure that the risk of damage from direct lightning strikes is minimised.

Earthwires are also installed and sized to address the expected maximum short time prospective fault current for the worst case protection clearing time that may occur for faults to earth on the interconnected system between substations.

2.1.1 Conductor

Powerlink utilises All Aluminium Alloy Conductor (AAAC 1120) and Aluminium Conductor Steel Reinforced (ACSR) for the majority of installation applications on its network. The maximum permissible layout temperature for AAAC Powerlink design applications is 90 degrees Celsius for (n-1) and emergency circuit operation, but lower operating temperatures (typically capped at 75 deg C under (n))regularly nominated for normal operation to minimise effects of annealing and associated loss of conductor strength over the defined service lifetime.

Design principles shall consider differences in generating patterns for renewable technologies compared to operating temperature profiles for the regulated network. Renewable energy generation patterns have placed a higher degree of scrutiny on operating temperature profiles within the annealing guidelines above for AAAC 1120 for the selection of conductor size in the design process. In some extreme cases, non-regulated connections may now operate with special protection schemes and non-firm resulting in sustained higher operating temperatures.

Where the standard range of AAAC conductors cannot meet this operating temperature requirement due to high capacity factors, Aluminium Conductor Steel Reinforced (ACSR) conductors are utilised which allow higher continuous operation temperatures up to 120 degrees Celsius (n-1) or 100 degrees C (n) without appreciable loss of strength. However, higher electrical losses will result.

Powerlink continues to utilise AAAC for both cyclonic and non-cyclonic project applications in-line with established Asset Strategies design principles. The 1120 grade alloy offers advantages over an equivalent size ACSR conductor in the areas of improved conductivity, lower breaking load and mass (involving savings in structure design), and lower capital and operating costs.

Powerlink supports the use of High Temperature Conductor (HTC) and High Temperature Low Sag (HTLS) conductor for greenfield and brownfield applications where it can be demonstrated through a comparative study that a HTC or HTLS solution provides a more cost-effective solution over the asset life cycle than traditional conductor technologies, is practical, and technically feasible. The comparative study shall consider the environmental performance, cost of losses, ease of use particularly installation and repair, operating envelope of the network meeting the required level of reliability and market obligations, maintenance practices including live-line compatibility and costs variance considering:

- Line layout
- Tower design
- conductor and associated hardware
- Stringing as well as the additional cost associated with field based trials, re-tooling, staff training and work methods development
- extensive conductor testing to validate performance and properties, particularly focussed on specialised conductor cores of carbon fibre, wire rope and ceramic matrix technologies
- procurement of adequate spare conductor and any specialised associated materials and tooling
- engineering on-costs in the development of new design standards and methodologies

- Line losses

Table 1 outlines the standard AAAC and ACSR conductor sizes used for both greenfield and brownfield applications. Powerlink may also be required to purchase conductors not listed in Table 1. These additional items would most likely be special applications, or for like-for-like future brownfield project applications, including maintenance and emergency stock requirements to maintain the network. These would be the ACSR/GZ type and nominally in the range from Lime to Paw Paw.

Conductor Name	Type
19/3.75 mm “Neon”	AAAC/1120
37/3.75 mm “Phosphorus”	
61/3.25 mm “Selenium”	
61/3.75 mm “Sulphur”	
7/3.50 + 30/3.50 “Lime”	ACSR 1350
7/3.00 + 54/3.00 “Mango”	
7/3.25 + 54/3.25 “Orange”	
19/2.25 + 54/3.75 “Paw Paw”	

Table 1

2.1.2 Earthwire

Traditionally, galvanised and aluminium clad steel earthwires are utilised on the Powerlink network. With rising substation earth fault levels, and to minimise issues encountered with earthwire corrosion, ACSR and AACSR earthwires have been widely adopted for capital projects in the last 20 years. These earthwire types have also been adopted for earthwire retrofits projects in conjunction with the parallel installation of a new Optical Fibre Ground Wire (OPGW) on existing transmission assets. Earthwires are required to be paired with OPGW’s electrical parameters, to ensure a controlled split of fault current occurs and results in no one earthwire / OPGW in the parallel configuration being electrically overloaded due to the resulting current split characteristics.

In order to nominate preferred earthwire types and size, a distinction is made between the requirements for greenfield applications (established or new tower designs), or brownfield projects where earthwires retrofitted to existing transmission line structures require coordination with the structural capacity and condition of the existing structure.

Earthwire retrofit projects require earthwires that optimise diameter and strength to mass ratio so that existing structure duties are not violated to achieve higher thermal fault capacity. Accommodating both between new projects and retrofits increases the number of preferred Powerlink earthwire types.

The standard earthwire sizing philosophy for Powerlink applications are as follows:

- Earthwire system to address 63kA fault levels for maximum of 0.25s clearing time
- Earthwire system to address 50 kA fault levels for maximum of 0.50s clearing time
- Earthwire system to address 40 kA fault levels for maximum of 0.50s clearing time
- Earthwire system to address 30 kA fault levels for maximum of 0.50s clearing time

AACSR/AC 1120 are the preferred earthwire types for implementation on new capital projects incorporating new tower designs, and have been the assumption for development of tower loadings for all recent structure designs.

For implementation on existing tower family designs, and also for retrofit to existing structures in high fault level areas (>30 kA), AAAC 6201 earthwires are preferred. For existing lines and retrofit projects in lower fault level areas (< 30 kA), ACSR/AC and AACSR/AC earthwires are preferred.

Table 2 summarises the five standard earthwire sizes and types for standard use. Powerlink may also be required to purchase OHEW’s not listed in Table 2 to meet maintenance and emergency stock requirements to maintain the network and for like-for-like replacements.

OHEW Name	Type	Application
30/3.0 & 7/3.0 “Lemon[1]”	AACSR/AC/1120	Greenfield
8/4.50 & 7/2.50 “Wrestling”		
8/3.60 & 7/2.00 “Volleyball”		Greenfield & Brownfield
19/3.25 “Opal”	AAAC/6201	Brownfield
4/3/3.75 “Tennis”	ACSR/AC	Brownfield[2]

Table 2

2.2 Technologies available now

Powerlink has relied predominately on the use of conventional conductors for its network. However, alternative conductor designs are available that match the diameter of existing conductors adopted by Powerlink, but offer substantially higher thermal capacity. The available technologies can be broken down into the following broad areas:

- ACSS (Annealed Conductor Steel Supported) is a thoroughly installed and type tested conductor technology with many manufacturers worldwide. It has been sold widely in the USA for more than 40 years. It consists of fully annealed aluminium strand layers (1350-O) over a high strength or extra high strength steel core. All other characteristics are similar to conventional ACSR however enhanced handling care is required due to the annealed (soft) outer aluminium layers. Designs are available that can operate at up to either 200 degrees Celsius, or 250 degrees Celsius that uses a specialised zinc 5% aluminium-mischmetal alloy. Preliminary investigations show ACSS/TW to be a viable alternative for implementation into re-conductoring projects for uprating (Brownfield).
- (Z)TACSR/AW Thermal Resistant Aluminium-Alloy Conductor Steel Reinforced is similar to conventional ACSR conductor with hard drawn aluminium wires of heat resistant aluminium allow allowing elevated continuous operation above 150 degrees Celsius. Conductors however sag like conventional ACSR at the elevated temperatures so tower height adjustments made in the greenfield project design layout can economically make allowance for increased sag with revised tower heights.
- TACIR/ZTACIR (Heat resistant Aluminium Conductor INVAR steel Reinforced) conductors which can operate up to temperatures of 150 degrees Celsius (TACIR) and 230 degrees Celsius (ZTACIR). The TACIR/ZTACIR conductor is composed of heat resistant alloy aluminium strands with an INVAR steel core (alloy of Iron and Nickel). Typical thermal rating up to twice an equivalent sized conventional ACSR conductor. The INVAR core adds expense to the capital cost but reduces sag at elevated temperatures making this variation suitable for Brownfield applications
- Gap-type conductors (GTACSR/GZTACSR) using heat resistant aluminium over a steel core. When the conductor is strung, it is tensioned on the steel core alone and there is a small gap between the steel and outer aluminium strands. This results is a much lower knee point temperature of the GAP type compared with standard ACSR. Typical current capacity is 1.6 times (GTACSR) to 2 times (GZTACSR) the equivalent sized conventional ACSR conductor. Whilst less expensive than INVAR, installation cost is high and requires specialist installation techniques. Interest has waned internationally with this approach in light of other material developments and resulting conductor technologies.
- Aluminium Conductor Composite Reinforced (ACCR). Core strands are composed of wires formed from aluminium oxide fibres embedded in high purity aluminium and referred to as a fibre reinforced metal matrix. The outer aluminium strands are composed of an aluminium-zirconium alloy, and available as either round or trapezoidal wire. The zirconium additive provides heat resistance and prevents annealing. Typical thermal rating is at least twice an equivalent sized conventional ACSR conductor.

[1] Nominated only for 500 kV.

[2] Special applications only for structural capacity constrained retrofits or like-for-like replacements

- ACCC (Aluminium Conductor Composite Core) along similar lines to the ACCR conductor above, but utilises a carbon and glass fibre core to allow high temperature and low sag operation. These are in commercialised and developmental phases from several manufacturers with recipe variations for the core itself.
- Aerodynamic conductor. Several manufacturers offer smooth surface conductors that reduce the wind drag factor and hence reduce tower loading at high wind speeds by as much as 40%. This permits existing towers to utilise a larger diameter conductor without exceeding the existing tower design load cases, with an associated benefit obtained from an increased thermal rating associated with the new larger diameter conductor.

HTLS options with specialised cores involve a substantial increase in conductor price to conventional conductor, but should be considered in selected applications where it can be demonstrated that they provide a cost positive solution to traditional conductor methods. HTC and HTLS conductor types become a primary consideration for uprating and refurbishment projects where existing structures can be utilised to achieve high thermal capacity.

HTC (TACSR) using heat resistant (zirconium) alloys are a modest increase to capital cost of conductor.

Project specific investigation would be carried out to determine if any of these types of non-conventional conductors offer economical advantage over the use of the conventional design.

2.3 Equipment strategy elements

Conductors and earthwires should include the following main features:

- Designed to have no maintenance requirements.
- Easy handling.
- Able to withstand fault level and clearing times applicable to the Powerlink network.
- Meet a 50 year service life for conductors and 40 years for OHEWs in all corrosion regions.
- Compliance with all relevant international standards.
- Resilience to damage from lightning.
- High availability, reliability and cost competitive on a whole of life basis.
- In the case of brownfield applications, conductor and OHEW that can reliably replace existing non-standard in-service items.
- In the case of greenfield applications and the exception of special circumstances, standard conductor and OHEW products to simplify the spare, logistics and tooling considerations.

2.4 Concurrent investigations

In view of continuous technological improvement, it is important that close examination of the available technologies be made to ensure that they meet Powerlink's requirements and adopt the most appropriate technology. Prior to the commencement of adopting new technology, either a trial project or a review of fleet performance and maintenance costs within the industry be performed.

2.5 Summary

The equipment strategy detailed in this document will be applied to all future requirements for transmission line conductor and earthwire, unless otherwise specified for reasons not identified in this document.