2018-22
POWERLINK QUEENSLAND REVENUE PROPOSAL

Supporting Document - PUBLIC

Powerlink Queensland
Substation Asset Methodology - Framework

Delivering better value

Powerlink – Substation Asset Methodology - Framework

Policy stream	Asset Management	
Endorsed by	Manager High Voltage Asset Strategies	[redacted]
Authored by	Group Manager Strategy and Planning	[redacted]
Approved by	Executive Manager	[redacted]

Version history

Version	Date	Section(s)	Summary of amendment
3.0	05/03/2009	Whole document.	Re-formatting only.
4.0	05/03/2009	Section 3.	Spelling/grammar corrected. References updated. Template change due to AM Document Review
5.0	20/12/2010	Whole document	Consolidation from Substation Plant Strategy to Substation Asset Methodology
6.0	09/10/2014	Whole document	Updated asset age profile info and updated list of equipment and other updates info to reflect strategy changes.
7.0	28/10/2015	All	Document reviewed and to aligned with DMF

Table of contents

1. INTRODUCTION 5

1.1 Purpose 5

1.2 Scope 5

1.3 Objectives 6

1.4 References 7

1.5 Roles and responsibilities 8

2. FRAMEWORK 9

2.1 Asset Profile 9

2.2 Stakeholder Requirements 9

3. LIFECYCLE MANAGEMENT 12

3.1 The Planning and Investment stage 12

3.2 Operation, Maintenance and Refurbishment stage 13

3.3 End of Life involves 13

4. ASSET MANAGEMENT DRIVERS 14

4.1 Condition Assessment 14

4.2 Technical Investigations and Research 16

4.3 Innovation, Technology and Emerging Issues 17

5. ASSET MANAGEMENT ACTIVITIES 18

5.1 Planning and Investment 18

5.2 Operation, Maintenance and Refurbishment 18

5.3 End of Life 21

6. EMERGENCY RESPONSE AND NETWORK SECURITY 22

6.1 Emergency Response 22

6.2 Network Security 22

7. SUPPORTING ACTIVITIES 23

7.1 Risk Management 23

7.2 Project Handovers 23

7.3 Strategic Spares 23

7.4 Technical Training 23

7.5 Documentation 23

7.6 Strategic Linkages 23

8. ENVIRONMENT AND SAFETY 25

8.1 Safety Management 25

8.2 Environmental Management 25

9. FORWARD PLANNING 26

10. Distribution list 27

1. INTRODUCTION

For the purposes of this document, Substation Plant assets exist to provide safe, reliable and efficient delivery of electricity transmission services.

1.1 Purpose

The role of Powerlink's asset management system is to ensure the organisation's assets are managed in a manner consistent with its mission of responsibly delivering electricity transmission services that are valued by its shareholders, consumers, customers and the market. The practices seek to drive efficiency whilst effectively managing safety, reliability and other risks across Powerlink's portfolio of assets. In order to implement the organisation's Asset Management Strategy specific asset management methodologies must be developed for each major asset group within Powerlink.

This document sets out the whole of life management philosophy for Substation Plant including planning, design, construction, acquisition, operation, maintenance, renewal, life extension and disposal. It excludes project planning when it is related to augmentation drivers, as network augmentation is addressed via a joint network planning process.

It acts as a reference for the development of maintenance and project budgets and forecasts.

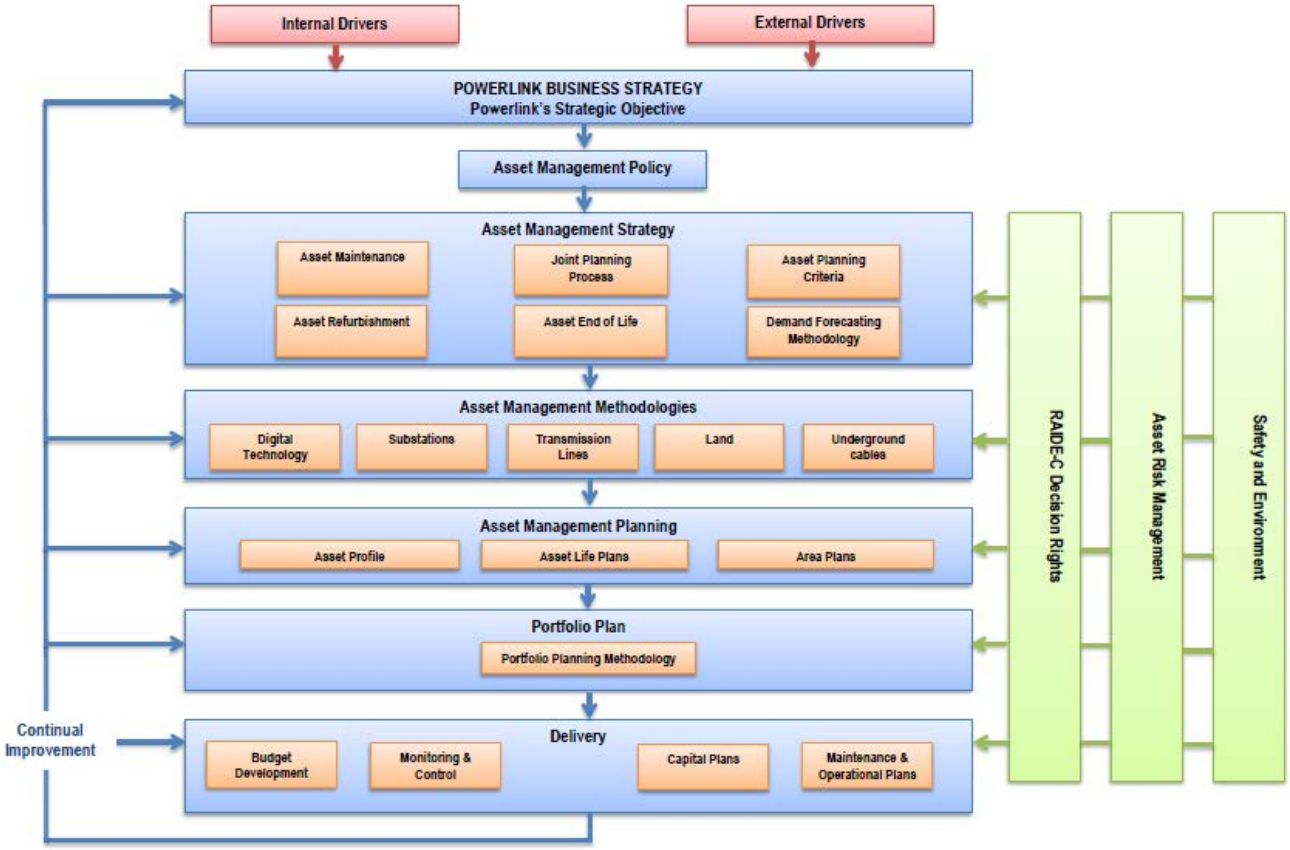
1.2 Scope

This document covers the asset life cycle of the following high voltage substation plant and substation infrastructure components:

- all high voltage substation equipment (incl. circuit breakers, disconnectors, instrument transformers, coupling equipment, earth switches, surge arrestors, power transformers, earthing transformers);
- all busbars and conductors (overhead) located inside substations and owned by Powerlink;
- all reactive plant (including all capacitor banks, series and shunt reactors, earth reactors/resistors, static VAr compensators, statcom devices);
- all substation site infrastructure including station supply transformers, direct current supply systems (battery banks, chargers, controllers), standby supply generators;
- all structures and foundations located within substations and owned by Powerlink, excluding communications structures;
- all substation land within the substation security fence and to a distance of five meters outside, earthing, fences, marshalling kiosks;
- all buildings, roadworks, cable trenches, switchyard lights and associated cabling located inside substations; and
- compressed air systems.

1.3 Objectives

The Substation Assets Methodology - Framework forms part of Powerlink's asset management system documentation with the following key elements:



The document set out how the following key performance areas are to be addressed:

- Asset Performance
- Asset Management activities (including maintenance, condition assessments, life extensions, technical investigations, reporting, auditing and benchmarking)
- Environmental and Safety Compliance
- Asset Management drivers.

1.4 References

Document code	Document title
ASM-I&P-STR-A969433	Asset Management Strategy
https://www.legislation.qld.gov.au/legisltn/current/e/electricalsa02.pdf	Electrical Safety Act 2002
https://www.legislation.qld.gov.au/legisltn/sls/2013/13sl213.pdf	Electrical Safety Regulation 2013
http://www.aemc.gov.au/Energy-Rules/National-electricity-rules/Current-Rules	National Electricity Rules
https://www.legislation.qld.gov.au/legisltn/current/w/workhsa11.pdf	Work Health and Safety Act 2011
https://www.legislation.qld.gov.au/legisltn/current/w/workhsr11.pdf	Work Health and Safety Regulation 2011 & relevant Codes Of Practice
WHS-P&C-FRA-A2108115	Powerlink's Safety Management System Standard
WHS-P&C–STD-A1955230	Electrical Safety Management System – Standard
ASM-I&P-FRA-A2417558	Asset Risk Management Framework

1.5 Roles and responsibilities

Who	What
Group Manager Strategy & Planning, Investment & Planning	Setting standards for substation asset management.
Manager High Voltage Asset Strategies, Investment & Planning	Setting preventive and corrective maintenance standards for all substation plant. Determines end of life for all high voltage assets.
Group Manager Technical and Network Services, O&FS	Ensure operational policies and procedures are in place in-line with this framework and perform audits on maintenance processes.
Group Manager Field Services, O&FS	Implementing substation asset methodology as part of field services
Group Manager Specialist Services, O&FS	Managing and auditing maintenance service of substation assets provided by Field Services , Ergon Energy and any other maintenance service provider (such as Aeropower, for example)
Group Manager Network Operation Services, O&FS	Provision of fault data and managing planned and forced outages to their full resolution.
Group Manager Infrastructure Delivery, ID&TS	Implementing substation asset design and construction as per substation methodology and other relevant asset management and technical standards. Ensuring all safety and other compliance aspects are met during substation construction.
Group Manager Infrastructure Technical Services, ID&TS	Aligning design and other technical services with substation asset design and asset methodology
Group Manager Infrastructure Management Systems, ID&TS	Auditing substation asset methodology in the design and construction phases, including contractors
Group Manager Network Property, ID&TS	Aligning planning, substation land selection, acquisition, land and rights protection and management, management and disposal of substation land in accordance with land and substation asset methodology
Senior Substation Strategy Engineer	Initiates and manages condition assessments for all substation plant assets. Initiates technical investigations and research projects as required. Recommends life extension methods. Monitors asset condition. Initiates and manages ultimate substation layout developments.
Substation Strategy Engineer	Initiates substation asset refurbishments and selective equipment and component replacement.

2. FRAMEWORK

2.1 Asset Profile

Powerlink owns and operates substation plant at a range of voltages. Powerlink nominal transmission voltages include 330kV, 275kV, 132kV and 110kV however substation plant also exists in the network at lower voltages for the purposes of providing customer connections, internal local supply as well as for some reactive support equipment. A summary of assets that are covered by this methodology is provided in the Asset Management Plan and Powerlink's Annual Report. For the purpose of this document, switching stations are treated as substations.

2.2 Stakeholder Requirements

Powerlink has a large number of stakeholders and their requirements are defined though various state and federal laws and regulations, connection agreements, procurement agreements, National Electricity Rules and community expectations.

2.2.1 Safety Compliance

Powerlink is required to ensure substations are owned, maintained and operated in a manner that is electrically safe and complies with the Electrical Safety Act 2002 and Electrical Safety Regulation 2013 and the Work Health and Safety Act 2011, Work Health and Safety Regulation 2011 and relevant Codes of Practice (including Safety in Design principles). These requirements are aligned in Powerlink Safety Management System and Electrical Safety Management System.

To ensure safe access to primary plant, Powerlink uses the Queensland Electricity Supply Industry Procedure for Safe Access to High Voltage Electrical Apparatus.

To ensure substations are electrically safe and are operated in a way that is electrically safe, Powerlink has established design and maintenance measures. Design measures include:

- adequate perimeter fencing (substation security fence)
- earth arrangements to restrict fault voltages
- earthing and other protection systems
- adequate and accurate signage
- adequate structural soundness
- adequate mechanical links
- adequate training for substation entry authorisation
- restricted/controlled access to substations (authorised personnel only).

Maintenance measures include:

- routine inspection of equipment and security fence
- monitoring of outage data
- routine earth resistance measurements
- routine service of major equipment
- on line condition monitoring as applicable.

The outcomes of the inspections are reviewed on a quarterly basis and audited on annual basis to ensure that any necessary actions are taken into account. In addition the annual calculation of fault levels is performed followed by the review of the continuous current and fault current ratings of substation plant.

2.2.2 Environmental Compliance

Over the asset life cycle, substations are operated and maintained in compliance with relevant environmental legislation.

During the planning and investment phase, environmental compliance issues within an existing or new substation under construction are managed within the Environmental Management Systems of Powerlink and its contractors, based on specific Environmental Management Plans that address the relevant compliance issues for the site and works. The handover of newly constructed assets into the operation and maintenance phase provides a stage-gate that ensures the assets meet environmental compliance criteria and that Environmental Work Plans are established for each site for ongoing management of environmental compliance issues under a structured approach that provides mechanisms for continual improvement or refinement of management practices.

In the operation and maintenance phase of the substation asset, significant environmental compliance issues include containment of insulating materials (hydrocarbons and SF_6) and suspended solids, soil erosion and sedimentation, site drainage and noise generated by substation plant.

Powerlink has implemented a range of compliance monitoring strategies that involve:

- establishment of oil containment systems, as per requirements
- routine testing and sampling of substation oil containment and discharge systems
- monitoring, detection and management of SF_6 leaks using on line SF_6 density trending and specialised detection camera technology
- programs of routine civil inspection to monitor the effectiveness of site drainage and presence of excessive soil erosion and sedimentation issues
- programs of routine substation electrical plant inspection to monitor the integrity of oil containment systems and any other vessels containing insulating fluids
- management of asbestos containing materials
- responsible disposal of contaminated materials and equipment.

Management of physical access to substations and the surrounding land (from five metres outside security fence) is addressed within the Land Asset Methodology -Framework.

The land inside the substation is managed in the same way but at different frequency to ensure adequate availability and reliability of electricity supply.

2.2.3 Reliability of Supply

Powerlink's reliability of supply obligations stem from a combination of our Transmission Authority, associated state legislation and the National Electricity Rules. For substation assets, a fundamental determinant for reliability of supply outcomes involves establishing the optimum substation configuration at the design stage of the lifecycle, which requires balancing reliability outcomes with the level of capital expenditure required for each configuration. For higher reliability requirements related to the 275kV transmission backbone and major customers, a more robust configuration is typically employed (e.g. breaker and a half arrangement). Where a lower level of reliability is considered appropriate, which generally applies to 132kV and 110 kV network assets, a less robust configuration is employed (e.g. folded bus or H bus arrangements). A separate asset management document for substation configuration informs development of options for the investment decision-making process.

In the operation and maintenance phases of the asset life cycle, the use of live substation techniques to reduce maintenance outages and improve reliability has been broadly implemented. Powerlink employs live substation techniques to significantly reduce the requirement for 275kV network outages, and higher risk outages affecting multiple network elements (e.g. busbars) and major customer loads. Further exploitation of live substation techniques is pursued as part of this methodology to continue to optimise reliability of supply outcomes.

On an ongoing basis, Powerlink monitors the performance of substation asset reliability using the Forced Outage Database and associated processes to continually review the root cause of each event and establish improvement actions. Monitoring of equipment performance and reliability is also achieved through annual

review of SAP defect notifications, change in equipment health indices, detailed condition assessments, maintenance audits and on-line monitoring of plant to identify change in reliability of substation assets.

2.2.4 Conformance with National Electricity Rules

As a registered Transmission Network Service Provider, Powerlink is obliged to conform to the relevant National Electricity Rules that govern the operation of the National Electricity Market.

In terms of conforming to the National Electricity Rules, the selection of plant and equipment forming part of the substation asset must support a range of outcomes, including but not limited to:

- function through a range of voltage and frequencies
- adequate thermal and short term (fault) ratings
- provide accurate metering installations through the installation of instrument transformers consistent with accuracy class requirements
- achieve required fault clearance times through installation of circuit breakers with appropriate operating characteristics, in conjunction with the associated protection system
- supply of adequate AC and DC systems to support required reliability and availability requirements for protection schemes.

2.2.5 Connection Agreements

Each connection agreement specifies requirements of the particular customer with regards to the availability and reliability of connection which impacts substation connection arrangements.

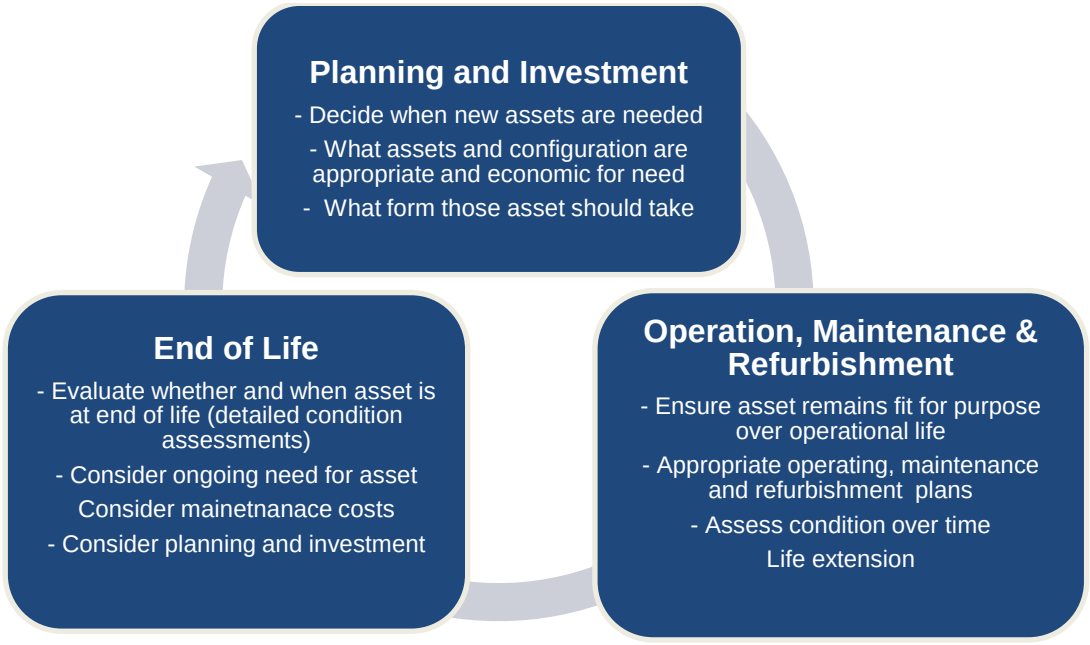
Powerlink has an established business process for obtaining outages that involves negotiation of a suitable time with all interested parties (generators and customers). In addition, Powerlink has the competency in Live work to help minimise the impact of maintenance on the electricity market. On an annual basis, Powerlink determines the minimal number of insurance and maintenance spares in order to meet the requirements of a dynamic and very diverse substation plant population. Where and when necessary Powerlink will also use Network Support agreements it maintains with a number of generators. All planned outages are managed and co-ordinated by Network Operations.

3. LIFECYCLE MANAGEMENT

In order to achieve the best outcome for its stakeholders, Powerlink must consider the asset's whole of life cost. Minimising this cost is the basis of Powerlink's asset management approach and involves the following:

- optimisation of the concept and the design process
- consideration of the asset's likely operating life
- the effective management of the asset's lifecycle through targeted maintenance, refurbishment, modifications, life extension, replacement and disposal activities.

This approach is often referred to as Lifecycle Management and includes three main stages:



3.1 The Planning and Investment stage

This stage involves network and property acquisition planning and design of the substation configuration that is the most suitable for the customer's needs, particular environment, function, required capacity and reliability and meets community expectations. Where a major electricity customer is involved, Group Manager Network Customers is responsible to ensure customer's needs are communicated and understood and the connection agreement complies with relevant legislation and regulatory framework.

A number of options are considered and costed to ensure the most economical option that meets all requirements is used.

Once all the requirements are clarified and agreed upon and majority of the layout is known, specific objectives are defined in order to:

- achieve the desired levels of service over the life of the asset
- ensure the expected or desired asset life is achieved
- optimise total lifecycle costs
- ensure the maintainability and supportability of the asset over its intended life
- allow for the potential use of live maintenance techniques.

At the end of this stage, all technical details are determined and the required documentation and drawings are produced.

The final phase of the planning and investment stage includes project scoping, estimating, determination of procurement methods, contracts, project and construction management, variations, testing, commissioning, production of "as per built" documentation, recording all required substation plant data in the computerised maintenance management system/ asset register (Powerlink utilises SAP for both) and final handover. The Group Manager Portfolio and Business Management is responsible for this final phase of the planning and investment stage.

3.2 Operation, Maintenance and Refurbishment stage

The Operation, Maintenances and Refurbishment stage is the longest stage of all. For the majority of substation assets this stage is expected to last typically for around 40 years.

It starts with final handover ensuring that all relevant substation plant data are readily available, that all relevant training is provided to all maintenance service providers and that all routine maintenance plans are established. This is the responsibility of Group Manager Technical and Network Services. In addition, it is the responsibility of Manager High Voltage Asset Strategies that all maintenance and operating policies and procedures are in place to ensure substations are operated within technical parameters and perform as per initial requirements.

Due to the different failure modes in some types of substation equipment and associated safety risk increase, 40 years service life is not possible for all substation equipment. It is the responsibility of the Manager High Voltage Asset Strategies to assess and determine end of life and initiate preventative replacement of such substation equipment. The strategy is to replace with alternative equipment that presents reduced safety exposure, if that is possible and commercially viable.

In contrast substation equipment in some operating context can be fully operational and safe to operate in excess of 40 years. To achieve this, both their condition and performance have to be monitored and relevant activities undertaken to ensure their optimum performance. Such activities may include, but are not limited to routine maintenance, condition based, emergency and deferred corrective maintenance and even partial component replacement and/or life extension, equipment modifications, desktop and detailed condition assessments, technical investigations, review of asset performance, reporting, audits and benchmarking.

Sometimes the maintenance activities identify a need for improvement of substation plant. The drivers for this can be related to work, health and safety or to ensure optimum service life expectancy. These can be made through Refurbishment and involves any activities required to bring them up to present day standards or to meet improved safety or operational requirements. Examples of such activities are:

- installation of improved physical security measures
- installation of noise suppression systems to meet environmental standards, where appropriate
- upgrade of substation earthing systems
- replacement of plant items containing polychlorinated biphenyl (known as PCB) or asbestos to meet WH&S requirements.

3.3 End of Life involves

End of Life involves the actions required to de-energise and then plan timely removal and disposal of an asset that is no longer required for successful operation of the network, or has reached a level of unacceptable risk if it was to remain energised. Manager High Voltage Asset Strategies is responsible to determine high voltage plant end of service life based on recommendations generated through detailed condition assessment reports.

It is the responsibility of Manager Regional Grid Planning and Manager Main Grid and Controls Planning to determine if the asset function is still required in the system. Group Manager Strategy and Planning is responsible to recommend reinvestment, taking into consideration economic analysis, enduring need, expected service life, development of new technologies and reduction of safety exposure for both public and personnel. .Disposal of equipment items that are no longer required needs to be carried out in an appropriate manner considering environmental and WH&S requirements.

4. ASSET MANAGEMENT DRIVERS

Substation plant assets represent a significant percentage of assets within Powerlink. Due to the nature of their design and construction with a typical service life of 40 years.

It is critical to manage these assets in such a way as to achieve not only the optimum operating life but to do so at the minimal lifecycle cost whilst maintaining required reliability of electricity supply and safe environment for personnel and public. This can only be achieved by setting appropriate asset management strategies from the beginning of each substation's lifecycle. However Powerlink assets live in a dynamic environment that needs to take into a range of internal and external factors (see below). Asset management strategies need to take these into account and respond appropriately and in a timely fashion.

Internal Influencing Factors

- Condition assessments
- Technical investigations and research
- Corporate Risk Framework
- Data modelling and reporting
- Fault and defect statistical data
- Substation plant ratings
- Changes in the equipment health indices
- Compliance issues
- Changes of work methods

External Influencing factors

- Demand and energy consumption
- Innovation and technology
- Environment and duty
- Emerging issues
- Change of legislation and/or engineering standards
- Change of customer requirements
- Change of regulatory environment
- Obsolescence (lack of availability of spare parts and/or technical support)

4.1 Condition Assessment

Most Powerlink substation plant assets deteriorate through a mixture of aging processes as a result of environmental conditions, wear out, electrical stress, exposure to faults and network loading. The end-of-life of a substation asset is dependent on the condition or performance of the plant item or items that comprise the asset. Typically, Powerlink substation assets are expected to last for 40 years however this can vary between plant items depending on design, construction, installation, maintenance, duty and environmental conditions. For example most modern transmission circuit breakers are expected to last up to 40 years depending on technology however circuit breakers that switch generators or reactive plant switch much more frequently and may require major refurbishment or replacement after half the nominal life.

Substation equipment condition and bay condition is monitored using equipment and health indices. These are updated on an annual basis. Based on these and information provided by maintenance service providers, desktop and detailed condition assessments are initiated. Condition assessment provides an indication of defective and deteriorated items and may initiate further investigation and analysis of the data to determine the level of deterioration. It provides estimated remaining service life for each asset, equipment and/or component. Where possible the holistic condition of assets and substations, is assessed collectively to arrive at the optimum solution for refurbishment or reinvestment.

4.1.1 Condition Assessment Process

For the purposes of condition assessment, substations can be viewed as a hierarchical construction of plant and equipment items. The items combine into functional groups that make up individual assets and the assets combine together to comprise a substation.

Powerlink applies condition assessments to assess the risks associated with substation plant from a range of perspectives including impact on business strategy, finance and contractual obligations, impact on major stakeholders, project costs, network operations, safety, environmental and cultural heritage and Powerlink employees. Condition assessments are also used as an input to the development of options for refurbishment or reinvestment where this is considered necessary. Economies of scale and difficulties in obtaining access to operational assets may lead to Powerlink carrying out replacement or major refurbishment projects at the asset level or even at a total substation level rather than replace individual plant items in a piecemeal fashion. For this reason it is important to consider options for replacement or major refurbishment at three different levels – plant item, asset and total substation before deciding on a strategy for replacement or refurbishment. The substation plant methodology includes condition assessment activities at each level to enable this to occur. These activities are initiated and managed by Powerlink High Voltage Asset Strategy team.

4.1.1.1 Condition Data

4.1.1.1.1 Plant Item Level

Plant items such as circuit breakers, instrument transformers, isolators, earth switches, power transformers, reactive power plant (capacitors, reactors and SVCs), busbars and substation structures are the building blocks from which the substation is constructed. The condition of these items is monitored during routine inspection and servicing as applicable. Defects are reported and recorded in SAP and the data is analysed annually using equipment and bay health indices. This information is used to identify corrective and condition based maintenance programs, as well as to initiate desktop and detailed condition assessments. Where common defects are noted for a population of items, the information can be used to trigger operational refurbishment projects.

Condition information for primary plant items can include details on:

- fluid containment and grades of metal corrosion from visual inspection
- contact and current carrying path resistances and localised hot spot temperatures
- insulation resistance, capacitance and dielectric information for graded insulation systems
- dissolved gas analysis and oil quality information from oil-insulated plant
- moisture and contaminant information from SF_6 insulated plant
- operations counts and hour run meters from mechanical switching devices
- electrical partial discharge measurements to detect insulation breakdown.

Determination of the complete condition of a plant item requires analysis of the appropriate parameters, weighting each result in a manner determined by the importance of the parameter and then combining the information to give a total result for each item. This provides a holistic representation of the condition or health of the item and provides a means to rank the condition of each item within the population. Powerlink uses a health index method for this.

Health index is a consistent and logical means of combining relatively complex and diverse condition information about a specific equipment item. It gives a total score representing the item's overall condition relative to that of the other items within the equipment population. It provides a means of ranking equipment based on condition.

Application of health index requires engineering expertise and judgement. To be of use in assessing future actions, the health index profile for an equipment type needs to bear a relationship with the probability of failure or hazard rate for equipment items, particularly those at the deteriorated end of the curve. This requires calibration with real failure data. In addition the algorithm is designed to provide a predictive assessment of how the health index profile will change in the future as an item's condition deteriorates.

Health index provides a means to identify items that are performing satisfactorily as well as those that are performing poorly and should be targeted now, or in the future, for repair, refurbishment or reinvestment. Health

index information is used to identify outliers for potential corrective maintenance and as input into the initiation process for operational refurbishment projects.

4.1.1.1.2 Asset Level

In Powerlink, most substation plant and equipment do not of themselves constitute an asset. Some examples of items that combine with others into substation primary plant assets are:

- a line isolator, line earth switch, set of line voltage transformers, circuit breaker, set of current transformers, bus isolator and their support structures and foundations that comprise a typical 110kV switching bay in a U bus layout
- a power transformer or oil-filled reactor
- capacitor cans, inrush limiting reactors and associated balance CTs that comprise a capacitor bank
- balance and line CTs, reactors, capacitor cans and other ancillary equipment (where required) that comprise a harmonic filter bank,

In most cases substations are constructed or augmented with multiple assets on a single capital project. Where these assets are expected to deteriorate or age at a similar rate it is usual to target reinvestment of the assets concurrently. To determine the condition of each asset, information from plant item condition assessments and health indices are used. This information is combined to give an overall picture of the health of the asset. At the same time all relevant risks are aggregated to the same level. Economic as well as additional factors such as the ability to replace the asset with minimal interruption of supply to the customers and electricity market operation, the availability of spares and technical support and future requirements for the assets are also considered prior to making a decision to either reinvest, extend asset's life (by partial plant replacement), disconnect it from the system or dispose of it.

4.1.2 Engineering Data

Engineering information relating to the designed performance of the asset is collated. This could include information on structure, electrical ratings and capacity, and layout design. It also includes consideration of an individual item's performance in the service environment, design vulnerabilities and assumptions, historical performance of similar assets and industry experience as well as any change in standards or legislation. This activity is undertaken by strategies and design groups.

4.1.3 Condition Assessment Report

The Condition Assessment Report for substation plant assets is the product of the Condition Assessment and Engineering Data investigations. The Condition Assessment Report will take the engineering, loading data and condition data and apply analytical techniques, modelling, expected future performance criteria, based on probability of failure curves and probabilistic evaluation to determine the decision criteria for the risk assessment. This activity will be undertaken by Powerlink strategies engineers, planning engineers and network customer managers (re future performance requirements) and design groups in consultation with the respective maintenance service provider for the asset.

The objectives of the Condition Assessment Report are to:

- determine the condition of the items or assets with respect to the decision criteria
- determine estimated remaining service life
- provide an input for
    - life extension
    - corrective maintenance recommendations
    - high level scope of work for refurbishment or
    - reinvestment into equipment, assets or substation.

4.2 Technical Investigations and Research

To support substation asset strategies, technical specialists are engaged from time to time to assist with investigations and recommend and review technical solutions. Investigations can be initiated by a task request for internal specialists or through a commercial arrangement with a subcontractor or industry specialist. These activities include research into new technologies (non-conventional instrument transformers for example),

providing design input for installation of semi pantograph disconnectors, ultimate substation layouts, investigations of various life extension methods, investigation of emerging issues (such as copper and silver corrosive sulphur phenomenon) and any other innovative ways of using new technology.

The Senior Substation Strategy Engineer will initiate technical investigations and research projects as required.

4.3 Innovation, Technology and Emerging Issues

4.3.1 Climate Change Adaptation

Climate change adaptation dictates that the resilience and durability of the transmission network needs to be assessed and its susceptibility to issues that may arise as a result of changes in climatic conditions. Climate change and its resulting impacts have the potential to shorten the life and reduce the capability of substation plant. The impact of the different physical parameters from climate change on individual substation items needs to be assessed to understand the potential risk to assets and the network.

Projected impacts of climate change in Queensland are:

- increase in number of days over 35^0 C
- increase in severe storm events and flash flooding
- more frequent and severe droughts and increased fire risk.

5. ASSET MANAGEMENT ACTIVITIES

Electricity transmission assets are high cost assets with a relatively long expected operating life. During the Planning and Investment phase it is important to influence design, configuration and topology aspects of the substation asset to provide a platform for achieving desired reliability, maintainability at minimal investment and life cycle cost. Once such assets are acquired, there are a number of additional asset management activities that can be used to:

- minimise overall lifecycle cost
- achieve the expected operating life in safe manner and within defined number of outages
- extend the expected operating life without impact on availability or safety
- organise timely replacement with minimal impact on the network operation and public.

5.1 Planning and Investment

At the Planning and Investment stage, the range of needs are considered and coordinated to ensure an optimum program of overall substation investment. An essential requirement for initiation of substation replacement is to establish the ongoing requirement for the asset to meet the long term needs of the network. Hence, there is an imperative for asset reinvestment planning to be structured to reflect future network needs and also for network planning to be undertaken with cognisance of the underlying conditions of the asset and anticipated end of life timing.

The approach to planning and investment also involves ensuring the proposed configuration of the substation plant asset, established through forums that steer network investment decisions, meets the high level Planning and Investment objectives discussed in Section 4.

5.2 Operation, Maintenance and Refurbishment

5.2.1 Operation

Geographically, Powerlink operates a long, skinny transmission system, most of which hugs the coast of Queensland. There is significant separation between load and generation centres. There is little meshing within the network. Outages are difficult to obtain and must be planned and coordinated carefully to minimise the number and duration.

Powerlink uses live working techniques to carry out maintenance in substations where prudent. These techniques are particularly useful in commissioning new or replacing existing assets in critical parts of the system and maintaining plant items without having to take bus outages.

5.2.2 Maintenance

Maintenance strategy for substation plant is established using a Reliability-Centred Maintenance (RCM) model.

RCM provides a rigorous and verifiable analysis framework for identifying only those maintenance tasks that are applicable and effective in managing possible failures. RCM analyses are undertaken by facilitated review teams of technical experts and field personnel with the greatest knowledge of the Network Assets being analysed. RCM also identifies those failures that cannot be dealt with effectively by maintenance alone, and thus require other approaches to deal with them. This ensures that only practical, achievable and effective maintenance tasks are adopted.

Prior to, or at the commissioning of a new type of substation plant item, a formalised Reliability-Centred Maintenance analysis is organised to analyse potential failure modes and countermeasures resulting in the development of the appropriate routine maintenance regime for that type of plant item.

Substation Plant consists of a mixture of static and moving plant of varying sophistication and complexity. Typical substation plant failure modes relate to their inherent design characteristics, surrounding environment, applied electrical load and stress, and duty cycle.

Powerlink's strategy for substation plant maintenance is based on an RCM applied philosophy of non-invasive local and remote performance monitoring and condition assessment by condition monitoring and testing, with invasive maintenance only being performed on a scheduled basis where there is no practical alternative.

Wherever it is cost effective to do so, remote performance and condition assessment of substation plant is undertaken.

5.2.2.1 Routine scheduled

The nature of failure modes of substation plant means that the RCM developed maintenance strategy is primarily based on the assessment of condition using visual inspection, condition monitoring, and testing. There is a limited amount of time or duty based scheduled restoration or discard tasks. Various levels of routine scheduled maintenance are applied as part of this strategy. They are:

5.2.2.1.1 Routine Substation Maintenance (RSM)

RSM is a non-invasive general visual inspection of all substation plant in a location, conducted on a regular basis as specified by the maintenance policy. All equipment will remain live during an RSM.

5.2.2.1.2 Service Level Maintenance

Service Level Maintenance is conducted on specified plant in accordance with the appropriate maintenance policy, and generally consists of more detailed and focused non-invasive condition monitoring and testing tasks, such as contact resistance checks, or the collection of oil or gas samples for dissolved gas analysis (DGA) testing. Where practical, service level maintenance is carried out on live equipment however planned outages will be required on most equipment.

5.2.2.1.3 Overhaul

Overhauls are conducted on specified plant in accordance with the appropriate maintenance policy. Overhauls are generally invasive requiring a planned outage.

5.2.2.2 Condition based

Continuous performance monitoring, routine scheduled maintenance, visual inspection, condition monitoring, and testing are all used to detect deterioration of condition or degradation of performance of substation plant that will, if allowed to continue, result in asset failure sometime in the future. Condition Based Maintenance restores the condition or performance of the asset to an acceptable level before failure occurs. Reduction of planned outage time and cost to carry out condition based maintenance is a major objective. This will be achieved by:

- use of live maintenance techniques
- optimum work packaging and scheduling
- use of on-line, remote monitoring where practical.

5.2.2.3 Emergency Corrective

Emergency corrective maintenance is the immediate work that must be performed to minimise the danger to personnel and equipment and to restore the system to service. The emergency work is typically initiated through Network Operations Group requesting that staff be immediately called out to rectify a situation.

5.2.2.4 Deferred Corrective

Deferred corrective maintenance is all work associated with rectifying an unacceptable plant condition to an acceptable condition, which is not emergency in nature. In addition to the actual “hands on” work to rectify a fault, this category of maintenance also includes the subsequent investigations and reports relating to plant failures.

5.2.2.5 Maintenance Support

Maintenance support tasks are those activities which are related to the ongoing maintenance and operations of the plant, but which do not specifically involve the plant itself. Examples include carrying out risk assessments, defect analysis and periodically reviewing the main substation plant item populations to consider changes in reliability performance. Maintenance tasks resulting from these investigations and reviews are documented as quality procedures and incorporated into the policies, procedures and secondary documentation for the different plant groups. Typically for substation plant, the defects are analysed and the results are used to modify maintenance and assist with selection of new plant.

The fault level and capacity of substation plant items are analysed annually and the recommendations are submitted where potential encroachments are noted.

Table 7 - Asset Maintenance Types

Maintenance Type		Activity	Frequency
Preventative Maintenance	Routine Preventative Maintenance	Routine Substation Maintenance	6 months
		Routine Civil Inspection	Annual
		CB Service	6/12 yearly
		CT/VT Oil Sampling	3 yearly
		Isolator/ES Service	6/12 yearly
		Power Transformer Service	6 yearly
		Tapchanger Service	6 yearly
		Power Transformer – Oil Sample	2 yearly
		Bushing Testing	6 yearly
		Power Transformer OTI/WTI Testing	6 yearly
		Earth Grid Injection Testing	10 yearly
		Infra-Red Test	2 yearly
		Oil Containment System Service	2 yearly
		Switching and Safety Equipment Testing	6 monthly
		Update of fault level signage	1 yearly
		Inspection of overhead hardware and earth wire attachments inside substation security fence	5 yearly
	Condition Based Maintenance	Investigation and/or repair of minor insulating fluid leaks (oil,SF_6)	As required, generally indicated by results of routine inspection or testing
		Corrosion treatment on structures and plant	
		Site infrastructure repair e.g. Erosion on roadways, painting of building	
		Substation signage and on site drawings update	As required, generally indicated by results of routine inspection or testing
Corrective Maintenance	Emergency	**Immediate** work that must be performed to prevent danger to personnel, equipment or system performance	Initiated through Control Centre requests
	Deferred	All work, including subsequent investigations and report, associated with rectifying an unacceptable plant condition to an acceptable state that is not emergency in nature.	

5.2.3 Refurbishment

Refurbishment of substation plant is triggered where plant does not function in accordance with the original design, identified through condition assessment, routine inspection, servicing or testing activities.

Refurbishment may also be required where plant, equipment or site infrastructure no longer complies with relevant legislation and statutory requirements or changed customer's expectations and/or requirements.

Typical refurbishment activities involve the replacement of specific items of plant or equipment forming part of a switching bay asset (e.g. instrument transformer due to poor physical condition or oil sampling results), work to repair main tank corrosion, oil leaks and other defects on power transformers, or work to upgrade or repair degraded infrastructure (e.g. erosion on roadways, poor drainage, corrosion on support structures), replacement of battery banks if they fail routine test, etc.

5.3 End of Life

Whilst nominally 40 years, the achieved economic or technical service life expectancy of substation plant assets is generally dependent upon their design, installation, environment, operating context, their performance and condition. It is Powerlink's strategy to manage its substation plant so that, where possible, each asset will achieve a full economic and technical service life as determined by network functionality. Wherever it is economic and practical to do so, service life will be ensured by the adoption of suitable measures such as corrective maintenance, refurbishment and life extension. In other cases, deteriorated condition or a requirement for increased rating or capability may make early replacement of an asset the most economic outcome.

Consequently, the appropriate time for disposal of a substation plant asset is determined by its performance, condition (as a leading indicator of future performance), ongoing maintenance and refurbishment costs versus the cost of asset reinvestment.

At the end of their service life substation assets have to be electrically disconnected from the network and clearly marked as such. In order to reduce the costs of removal, these can be left on site where economical and has small impact on stakeholders. If left on site then equipment needs to be made safe, measures taken to ensure insulating fluids do not contaminate the environment and appropriate substation security will have to be maintained. During this time ongoing maintenance is required to ensure structural soundness.

6. EMERGENCY RESPONSE AND NETWORK SECURITY

6.1 Emergency Response

Cyclones and natural disasters are a part of the Queensland climate. While substation assets have performed well during previous cyclones and natural disasters, specific measures are taken to improve resilience in these events such as:

- appropriate backup for substation AC supplies in cyclonic areas including increased fuel supply for diesel generators and increased number of portable diesel generators
- appropriate insurance spare levels
- arrangements to share spares with other Transmission Network Service Providers where applicable
- contingency plans in place where required
- flood monitoring measures.

6.2 Network Security

Substation security needs to take into account the different levels of threat posed to an asset of this type. The transmission network is part of National Critical Infrastructure and higher levels of security measures are required at major substations to meet minimum standards of overall security. Other levels of threat include theft and vandalism. Additionally, all substation security needs to meet a minimum standard to ensure public safety.

Substations have become a target for theft and vandalism due to the presence of attractive materials (e.g. prolific use of copper), remoteness and isolation, and low occupancy of Powerlink personnel.

Powerlink will continue to assess the requirements and accordingly invest in the security of our critical transmission assets with a focus on improving deterrent and detection measures at higher risk sites.

7. SUPPORTING ACTIVITIES

7.1 Risk Management

To successfully manage Powerlink's substation assets, it is necessary to identify and manage a range of risks, including those not directly related to the performance of the asset. These are analysed using the corporate risk framework. There is a range of risk mitigation and risk reduction measures employed such as condition based oil, SF_6 and water discharge samples, restricted access zones, increased frequency of inspection and services, innovative work methods such as live work, locating strategic spares, development of contingency plans, selective component replacement and similar.

7.2 Project Handovers

The construction of new substation assets, plant item replacement or life extension of assets involves the interaction of design, construction, project management, material acquisition maintenance service provider and strategies groups both within and external to Powerlink. The transition from the practical completion of a substation asset to its becoming an operational asset and the maintenance of that asset requires the recording and communication of critical information and related data about the asset.

The Project Handover process has been implemented to provide the conduit for transferring design and construction information between the Designers, Construction Contractor and the Maintenance Service Provider. It also provides an opportunity for liaison between the Strategy group, Construction Management, the project team and the Maintenance Service Provider to discuss the assets and the project handover process to ensure that opportunities for improvement are implemented.

7.3 Strategic Spares

An annual review of substation plant strategic spares is performed to ensure that:

- the quality, quantity and location of spares are adequate and appropriate
- the storage practices and facilities of spares are satisfactory to ensure component life span is not compromised as a result of incorrect or inadequate storage practices
- adequate spares have been supplied for new assets and component changes.

In addition, the maintenance of strategic spares is organised and conducted at appropriate intervals.

7.4 Technical Training

The O&FS Technical Network Services Group provides a strategy for the delivery of technical training to reinforce key concepts and strategies with service providers delivering across the asset lifecycle. Technical training is initially delivered by plant manufacturers or their agents.

Powerlink has an obligation to ensure that training is available for Maintenance Service Providers so that they are competent to perform work on all Powerlink assets, including those newly introduced.

7.5 Documentation

The HV Asset Strategy Team conveys asset management requirements through the Asset Management Plan and a number of asset management (AM) documents that are reviewed on a two yearly basis and promote the development of documentation and field guides to ensure substation plant strategies remain relevant and are in accordance with good industry practice.

7.6 Strategic Linkages

The HV Asset Strategy Team develops and maintains strategic linkages internally within Powerlink in order to ensure a seamless integration of network topography is maintained.

Alignment is maintained between Principal Maintenance Service Providers such as Ergon Energy and Operation Field Services, to ensure consistency in the provision of maintenance services.

Channels of active communication are maintained with other Transmission Network Service Providers to facilitate emergency restoration activities, provide discussion forums for work delivery protocols such as live work and share information on the implementation of new technology and major plant statistical data..

The active participation with various international power research institutes (such as EPRI and CEATI) as well as participation in various CIGRE bodies of work ensures the strategy can be kept up to date with technology developments.

8. ENVIRONMENT AND SAFETY

8.1 Safety Management

The design and implementation of substation plant maintenance strategies incorporate Powerlink's Safety Management System. This includes the use of risk management processes to ensure safety of workers, the safety of the public and the safety of plant and equipment.

8.2 Environmental Management

The design and implementation of substation plant maintenance strategies incorporates Powerlink's Environmental Policy. This includes the use of environmental risk assessment processes to identify and appropriately manage risks such as:

- containment of PCBs in older equipment
- containment of insulating oil in equipment such as transformers and circuit breakers
- management of operational noise from substation plant
- containment of SF_6 in switchgear and instrument transformers
- containment of hydrocarbon fuels such as diesel for generators
- containment of sulphuric acid in batteries; and
- management of vegetation inside and outside substations to reduce bushfire risk danger, allow appropriate access and prevent interaction with energised conductors.

9. FORWARD PLANNING

A ten year forward plan is prepared on per area basis, outlining the projects by type, location and expected completion date as well as scheduled condition assessments.

The work on various condition prediction tools is part of usual business process ensuring continuous improvement of the condition assessment process.

All routine maintenance plans are entered into SAP by outage group. These are combined with project outages and assessed 12 months in advance to minimise outages.

10. Distribution list

Internal	Contact details
☒ Finance and Business Performance	Group Manager (GM) Commercial and Legal Services
☒ Investment and Planning	GM Strategy and Planning, Manager High Voltage Asset Strategies, GM Projects and Business Management, Senior Substation Strategy Engineer, Substation Strategy Engineer
☒ Infrastructure Delivery & Technical Services	GM Infrastructure Delivery, GM Infrastructure Technical Services, GM Network Property
☒ Operations and Field Services	GM Operation Field Services, GM Technical and Network Services, GM Specialist Services, GM Network Operation Services
☒ Stakeholder Relations and Corporate Services	GM Environmental Strategies, GM Business Resilience