Asset Management Plan

DC Distribution System

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Authorisations

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Review cycle	2.5 Years	

Responsibilities

This document is the responsibility of the Asset Strategy Team, Tasmanian Networks Pty Ltd, ABN 24 167 357 299 (hereafter referred to as "TasNetworks").

The approval of this document is the responsibility of the General Manager, Strategic Asset Management.

Please contact the Asset Strategy Leader with any queries or suggestions.

- Implementation All TasNetworks staff and contractors.
- Compliance All group managers.

Record of revisions

Section number	Details
All sections	*Re-write from Transend format into TasNetworks format and update of data.*

Table of Contents

1 Purpose

The purpose of this asset management plan is to define the management strategy relating specifically to DC distribution systems and related assets for a ten year rolling planning period. The plan provides:

- TasNetworks' approach to asset management, as reflected through its legislative and regulatory obligations and strategic plans;
- The key projects and programs underpinning its activities; and
- Forecast CAPEX and OPEX, including the basis upon which these forecasts are derived.

2 Scope

This document covers all 125 V DC distribution systems installed within TasNetworks' substations, used to supply substation primary plant and its associated protection and control schemes. The objective of this plan is to maintain and minimise business risk to acceptable levels by achieving reliable asset performance at minimal life-cycle cost.

Other battery banks and DC systems used to supply communication assets and services are excluded from this document.

3 Strategic Alignment and Objectives

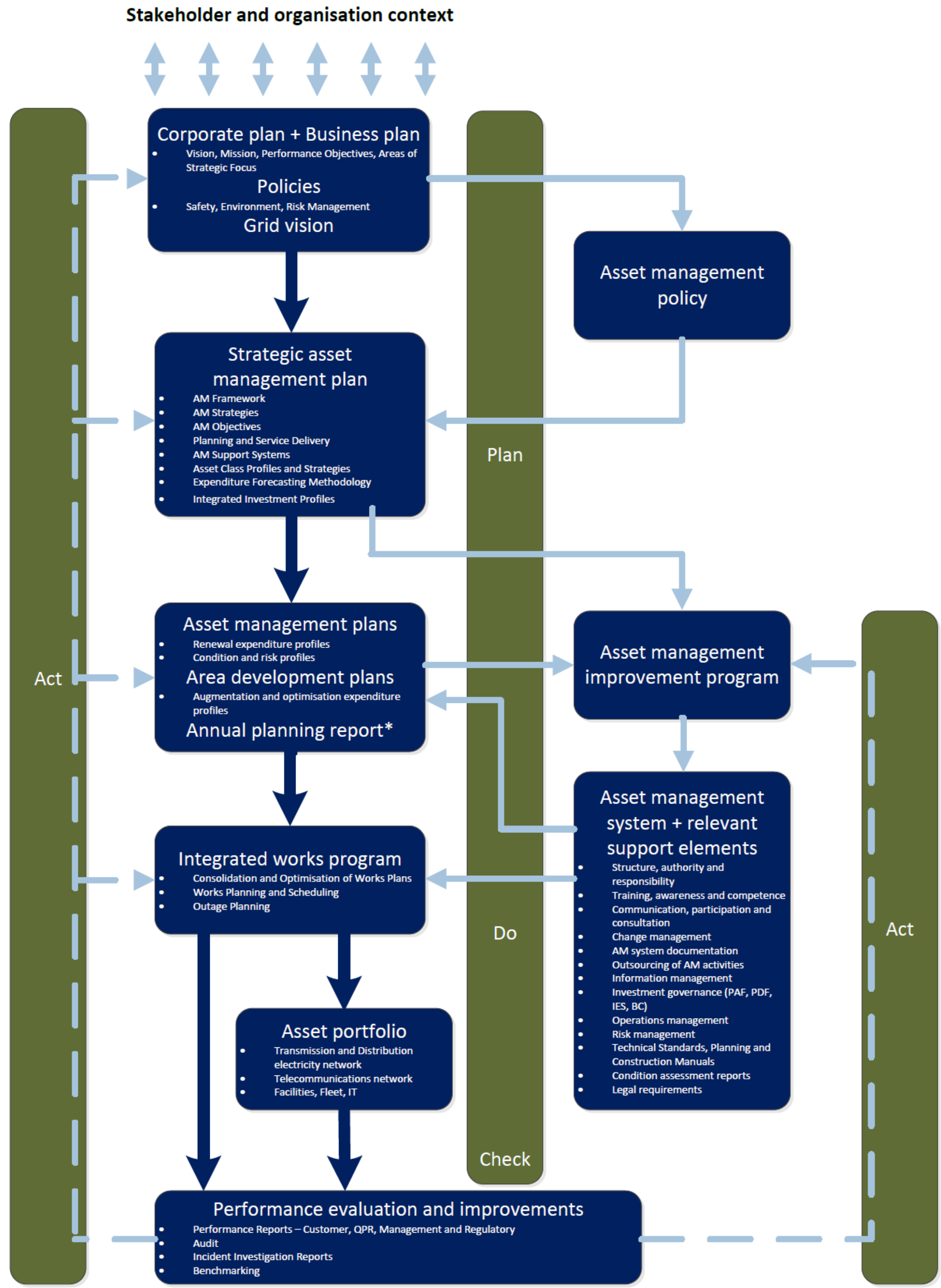
This asset management plan has been developed to align with both TasNetworks' Asset Management Policy and Strategic Objectives. This management plan describes the asset management strategies and programs developed to manage the DC distribution system assets, with the aim of achieving these objectives.

For these assets the management strategy focuses on the following objectives:

- Safety will continue to be our top priority and we will continue to ensure that our safety performance continues to improve
- Service performance will be maintained at current overall network service levels, whilst service to poorly performing reliability communities will be improved to meet regulatory requirements
- Cost performance will be improved through prioritisation and efficiency improvements that enable us provide predictable and lowest sustainable pricing to our customers
- Customer engagement will be improved to ensure that we understand customer needs, and incorporate these into our decision making to maximise value to them
- Our program of work will be developed and delivered on time and within budget

The asset management policy and strategic objectives are outlined within the Strategic Asset Management Plan. Figure 1, from the Strategic Asset Management Plan, represents TasNetworks documents that support the asset management framework. The diagram highlights the existence of, and interdependence between the, Plan, Do, Check, Act components of good asset management practice.

Figure 1: TasNetworks asset management documentation framework



* The Annual Planning Report (APR) is a requirement of sections 5.12.2 and 5.13.2 of the National Electricity Rules (NER) and also satisfies a licence obligation to publish a Tasmanian Annual Planning Statement (TAPS). The APR is a compilation of information from the Area Development Plans and the Asset Management Plans.

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4 Asset Information Systems

4.1 Systems

TasNetworks maintains an Asset Management Information System (AMIS) that contains detailed information relating to the DC systems population. AMIS is a combination of people, processes and technology applied to provide the essential outputs for effective asset management, such as:

- Reduced risk;
- Enhanced transmission system performance;
- Enhanced compliance, effective knowledge management;
- Effective resource management; and
- Optimum infrastructure investment.

It is a tool that interlinks asset management processes through the entire asset lifecycle and provides a robust platform for extraction of relevant asset information.

Asset defects are recorded directly against the asset registered in the asset management information system (WASP).

The defect information is readily accessible through TasNetworks' business intelligence reporting system

4.2 Asset Information

The following AMIS standards provide additional information relevant to DC distribution systems:

- R17113 WASP Asset Register – Data Integrity Standard – Battery; and
- R17036 WASP Asset Register – Data Integrity Standard – Battery charger

4.2.1 AM8 Condition Data

An initiative within the Asset Performance and Strategy team was completed in 2016 to review key asset condition and maintenance regimes to assess their capability for asset condition being the basis for setting spending priorities. This initiative was referred to as AM8.

Condition based assessments provide a quantitative means to assess asset condition, their risk and failure probabilities and a basis to justify mitigation measures. Condition assessments are used to produce risk indices for assets and / or asset classes and provide a basis for asset expenditures.

Condition data is gathered through asset inspection and maintenance activities and is used along with defect, failure and performance data to formulate asset management strategies. Condition assessment relies on asset knowledge capable of being modelled using numerical analysis.

A number of observations were concluded as part of the review including the need to obtain condition data consistently across all asset types and in electronic form. The need for storage and collection would align with other business initiatives such as the AJILIS project.

5 Description of the Assets

DC distribution systems are installed in all substations, the purpose of which is to provide a reliable source of stored DC power to supply the critical supervision, control, protection and metering functions which include the following functional requirements for:

- Protection circuits;
- Switchgear trip and close circuits;
- Indication, alarms and Supervisory Control And Data Acquisition (SCADA) circuits;
- Auxiliary and emergency lighting;
- Switchgear spring charge motor circuits and motorised disconnectors;
- Security and fire detection systems; and
- Other applications as required.

To facilitate the above, each DC distribution system typically comprises of:

- A battery;
- A battery charger;
- A fuse switchboard;
- A DC distribution board; and
- Associated interconnections.

The following sections provide high-level asset information relating to TasNetworks' DC distribution systems.

5.1 DC Distribution System Types

TasNetworks has 50 DC distribution systems currently in service. The DC distribution systems comprise 95 battery banks distributed between seven manufacturers and 99 battery chargers distributed between four manufacturers.

TasNetworks is systematically rationalising the battery charger and battery bank populations to reduce the number of manufacturers to mitigate the issues associated with managing a diverse population group of assets. Issues such as condition monitoring, trend analysis, physical design and construction characteristics, contingency planning and spares management are considered when battery chargers and/or batteries are to be procured for new or replacement of existing installations.

TasNetworks' battery and battery charger population is summarised by manufacturer in Figure 2 and Figure 3.

Figure 2: Battery banks by manufacturer (as at October 2017)

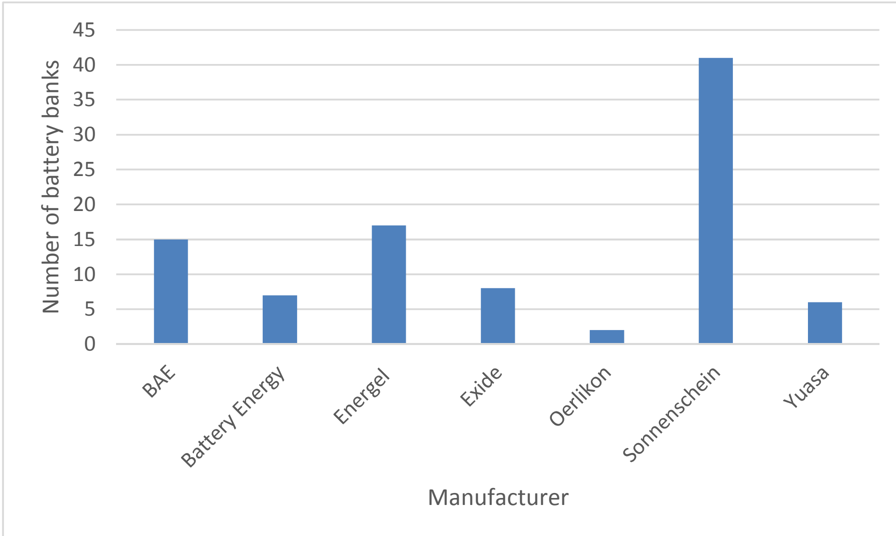
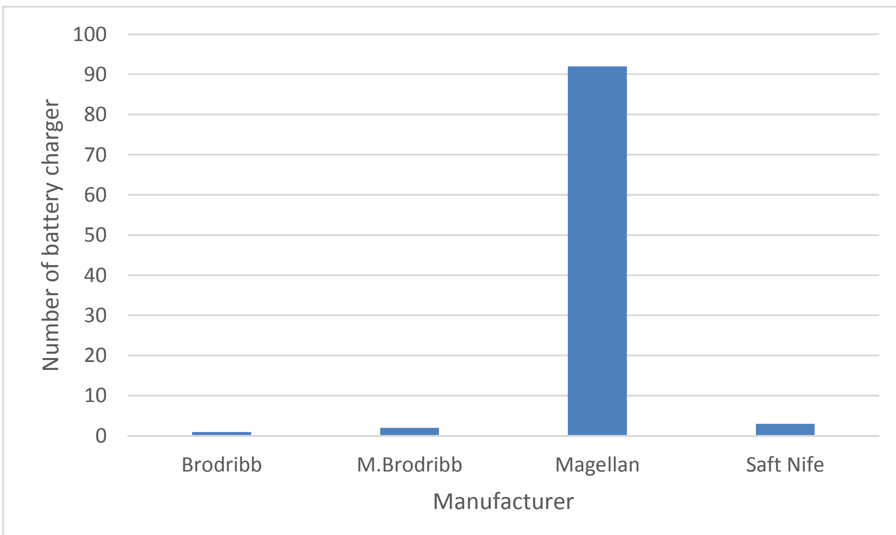


Figure 3: Battery chargers by manufacturer (as at October 2017)



TasNetworks' DC distribution systems are also identified and managed based on substations with singular DC distribution systems and substations with duplicate DC distribution systems. These categories include:

- Seven substations with single battery and DC supply systems; and
- Forty three substations with duplicate batteries and DC supply systems.

Included in the above totals is one substation that has more than two battery banks.

TasNetworks battery population comprises only valve regulated sealed lead acid technology.

5.1.1 Batteries

From around 2000, TasNetworks has standardised on the use of lead acid type batteries of various forms. Sealed and gel types installed in the early 2000s have now being replaced by valve regulated.

Valve regulated lead acid batteries have a high sustainability derived from proven performance and high recyclability of components. Vented batteries have been progressively replaced with sealed gel type batteries which are less maintenance intensive and the safety risk associated with vented hydrogen gas (lead acid) produced during charging is also mitigated.

Each battery bank is sized to provide a minimum of eight hours supply to the station to ensure sufficient capacity in the event of an emergency and loss of AC supply. The eight hours ensures that remote control capability of the station is maintained even in the event of major system outages.

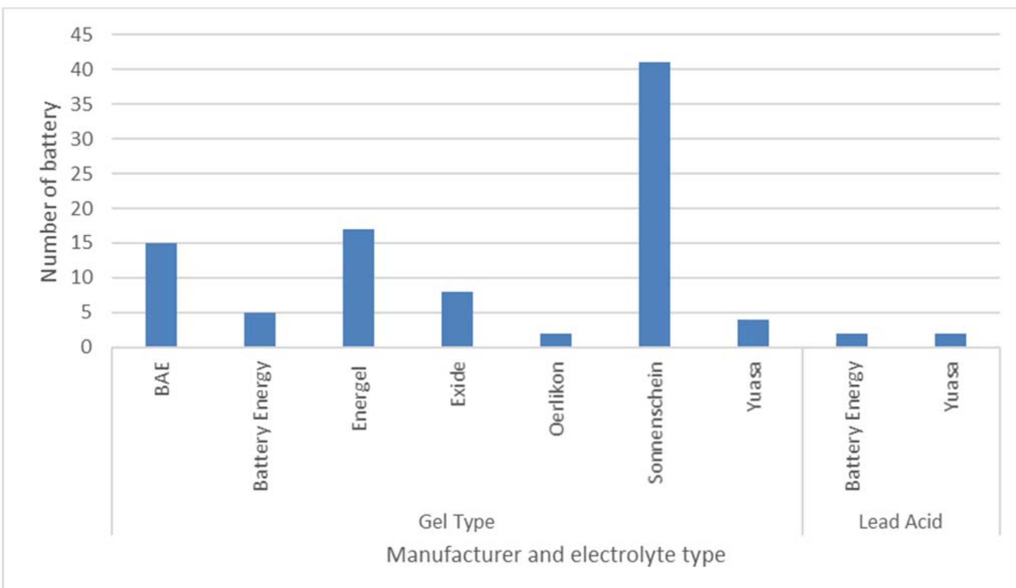
Each new battery bank has a nominal voltage of 125 V DC with the exception of a 48 VDC bank at Castle Forbes Bay Tee.

5.1.1.1 Battery Types

The batteries used in substations can be broken down further by considering both the electrolyte and manufacturer.

Most battery installations are gel types. Of the gel type units, the Sonnenschein units were installed between 2008 and 2011 whilst the Battery Energy and Energel gel type units, which have displayed poor performance, were installed between 2000 and 2008.

Figure 4: Battery installations showing electrolyte type and manufacturer



5.1.2 Battery Chargers

TasNetworks has standardised on the use of one manufacturer for battery chargers. The standard design uses readily available components which are easily replaced. The design also includes numerous alarm and data outputs which are remotely monitored through the substation supervisory, control and data acquisition (SCADA) system.

The chargers are permanently on and connected to maintain the float charge on the batteries.

5.1.3 Fuse Boards

The fuse boards are used to provide both electrical protection via fuses of the batteries. The fuse board also contains diode based circuits to allow parallel connections between two batteries and chargers.

5.1.4 Distribution Boards

Each substation has at least two DC distribution boards. The distribution boards house the miniature circuit breakers that actually supply protection and control devices. Protection and control devices are typically duplicated into an ‘A’ and ‘B’ system. TasNetworks policy is to install all ‘A’ protection devices to the ‘A’ DC distribution board, and similarly for the ‘B’ system. This connection arrangement ensures that any fault within the distribution board itself does not cause interrupt supply to all connected devices.

The distribution boards also provide limited alarms to SCADA.

5.2 Age Profile

DC distribution systems have been classified as short life assets through an independent assessment, where 15 years life expectancy for DC systems reflects accepted business practice and is considered appropriate when compared to other utilities short life assets. The average age of TasNetworks’ batteries population is 6.7 years, and battery chargers are 9.3 years as at October 2017.

The age profile for TasNetworks’ DC distribution system population is shown in Figure 5 and Figure 6.

Figure 5: Age profile of batteries (as at October 2017)

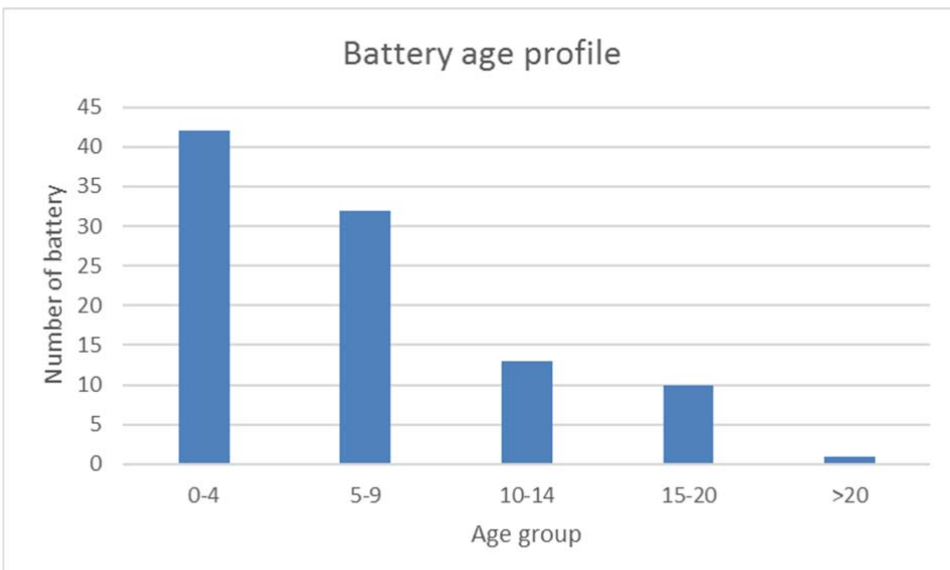
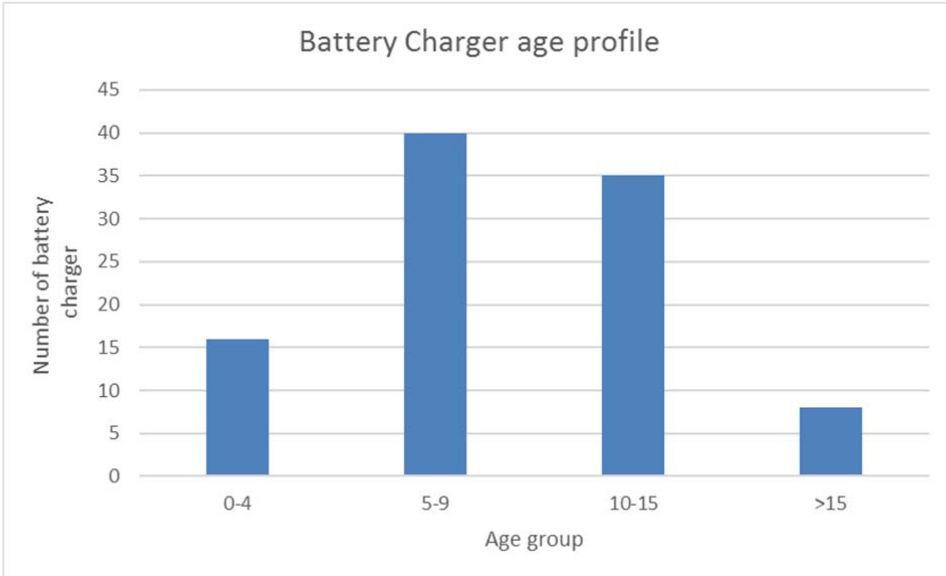


Figure 6: Age profile of battery chargers (as at October 2017)



6 Standard of Service

6.1 Technical Standards

TasNetworks has developed prescriptive technical specifications and a suite of drawings to standardise DC supply systems. The design has been developed over a number of years and undergoes review when improvements are identified.

6.2 Performance Objectives

To mitigate the risk of inadequate quality control during manufacturing, TasNetworks requires routine tests to be performed on each component of the DC distribution system to prove the quality of manufacture prior to dispatch from the manufacturer's works.

6.3 Key Performance Indicators

TasNetworks undertakes two broad classes of performance monitoring, namely internal and external performance monitoring.

6.3.1 Internal Performance Monitoring

TasNetworks monitors DC distribution system performance for major failures through its incident reporting process. The process involves the creation of a fault incident record in the event of a major DC distribution system failure that has an impact on, or has the potential to impact on the transmission system. The fault incident is then subjected to a detailed investigation that establishes the root cause of the failure and recommends remedial strategies to reduce the likelihood of reoccurrence of the failure mode within the DC distribution system population. Reference to individual fault investigation reports can be found in TasNetworks' reliability incident management system (RIMSys).

For DC distribution system failures that do not initiate a transmission system event, such as minor failure or defects, TasNetworks maintains a defect management system that enables internal performance monitoring of DC distribution system related faults and defects.

The DC distribution systems performance impacts on TasNetworks' overall network service obligations, which include specific performance requirements for both prescribed and non-prescribed transmission assets

TasNetworks' service target and performance incentive (STPIs) scheme, which has been produced in accordance with the Australian Energy Regulator's (AER's) Service Standards Guideline, is based on plant and supply availability. The PI scheme includes the following specific measures:

- Plant availability:
  - Transmission line circuit availability (critical and non-critical); and
  - Transformer circuit availability.
- Supply availability:
  - Number of events in which loss of supply exceeds 0.1 system minute; and
  - Number of events in which loss of supply exceeds 1.0 system minute.

Details of the STPIS scheme and performance targets can be found in TasNetworks' Strategic Asset Management Plan (SAMP).

The availability of AC distribution systems has an impact on the performance measures reported regularly to the AER and directly impacts on TasNetworks' performance incentive scheme.

TasNetworks has evaluated its DC distribution systems performance against external benchmarks, such as International Transmission Operations & Maintenance Study (ITOMS), and the various performance incentive schemes which measure availability and loss of supply events.

6.3.2 External Performance Monitoring

TasNetworks participates in various formal benchmarking forums with the aim to benchmark asset management practices against international and national transmission companies. Key benchmarking forums include:

- International Transmission Operations & Maintenance Study (ITOMS); and
- Transmission survey, which provides information to the Electricity Supply Association of Australia (ESAA) for its annual Electricity Gas Australia report.

In addition, TasNetworks works closely with transmission companies in other key industry forums, such as CIGRE (International Council on Large Electric Systems), to compare asset management practices and performance.

6.3.2.1 ITOMS Benchmarking

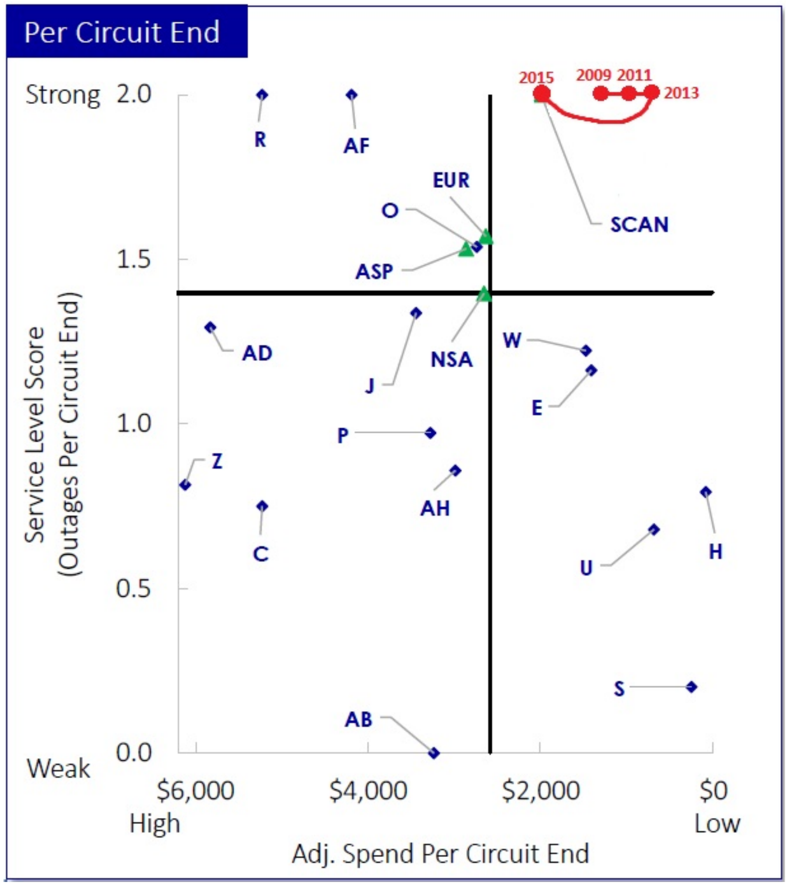
The industry benchmarking of DC distribution system assets are not covered as a specific category measure in ITOMS activities but they are covered within the auxiliary systems assets combining both AC and DC systems collectively called auxiliary plant equipment. Further discussions relating to the ITOMS studies are presented in relevant ITOMS reports which are held by TasNetworks Network Performance and Asset Strategy group.

The ITOMS results are typically presented in a scatter plot which enables comparison between participant utilities. The international benchmarked averages (cost & service) are shown as the centre crosshairs, with diamond shapes representative of surveyed participant utilities and regional averages shown as triangles marked NA (North America), EUR (Europe), ASP (Australia South Pacific), and SCAN (Scandinavia). The optimal performance location on the scatter plot is located in the upper right hand quadrant because, in this quadrant, service level is at its highest at the least cost. For AC distribution system assets, TasNetworks have been consistently in this upper right hand quadrant and this has continued for 2015. The chart does demonstrate that the average spend has increased with service level score remaining at the maximum high level.

Figure 7 illustrates that the performance, in terms of maintenance expenditure and fault outages of TasNetworks' auxiliary equipment, has maintained low service costs and high service performance consistently across years 2009 to 2015 when compared to other transmission companies in the study.

The external benchmarking activities demonstrate that the performance of TasNetworks' auxiliary systems is favourably aligned to that of other participants in the ITOMS study, as shown in Figure 7. For auxiliary plant equipment, TasNetworks is consistently in the upper right hand quadrant as shown in figure 7 as red circles. Maintenance costs are being maintained at relatively low levels for a correspondingly high service level. The present maintenance strategies should be continued in order to maintain high levels of reliability and performance. The replacement of obsolete AC distribution systems where failing condition and safety issues are some of the drivers that contributes to poor performance statistics. Further improvements are expected through a proactive approach of failure prevention, key performance indicators and on-line monitoring.

Figure 7: ITOMS Auxiliary Plant benchmarked performance chart



6.3.2.2 ESAA Benchmarking

TasNetworks' reporting to the ESAA covers transmission network data of system minutes unsupplied, energy delivered and transmission circuit availability. For ESAA benchmarking, network data is limited to transmission circuits.

6.3.2.3 Failure Types

The main risks associated with the DC system population include:

- Major asset failure;
- Safety risks; and
- Environmental risks

7 Associated Risk

7.1 Risk Management Framework

TasNetworks has developed a Risk Management Framework for the purposes of assessing and managing its business risks, and for ensuring a consistent and structured approach for the management of risk is applied.

The Risk Management Framework requires that each risk event is assessed against all of the following consequence categories:

- Safety and People
- Financial
- Customer
- Regulatory Compliance
- Network Performance
- Reputation
- Environment and Community

An assessment of the risks associated with the DC distribution systems has been undertaken in accordance with the Risk Management Framework. For each asset in this class the assessments have been made based on:

- Condition of DC distribution systems in service across the network
- Criticality of DC distribution systems and associated assets
- Probability of failure (not meeting business requirement)
- Consequence of failure
- Performance
- Safety risk
- Environmental risk
- Customer

Due to the level of risk identified in some of the assessment criteria a requirement to actively manage these risks has been identified.

7.1.1 Condition

The condition assessment and maintenance practices for DC distribution systems have been revised where appropriate to sustain or improve DC distribution systems reliability. Such maintenance practices together with industry benchmarking activities are aimed at reinforcing and implementing a regime of continual improvement, innovation and learning. The adoption of contemporary asset management techniques are aimed at reducing the DC distribution system annual preventive maintenance expenditure, without compromising performance.

The condition of DC distribution systems, especially the older systems which are largely identified by DC distribution systems that incorporate lead acid or alkaline type batteries are characterised by the following:

- Cracks in battery casings, cell dry-out, post terminal seal leaks, stuck valves, plate sulfation, dendritic shorts, cracked plates or separators and failing plate welds;
- Internal warping of the battery plates (batteries still show full voltage);

- Wiring protective covering degradation due to prolonged operation and exposure leading to battery earth faults;
- Electronic component failure increase as the equipment is subject to various operating requirements over its life;
- Optimum frequent cycling not able to be automatically performed by the older battery chargers;
- Inappropriate float charge and equalization settings resulting in overcharging and the subsequent loss of electrolyte and possible explosion;
- Excessive overcharging resulting in the gassing of batteries and the potential of fire, especially in confined spaces; and
- Environmental factors, especially inadequate temperature control.

Any deterioration in condition can be further aggravated where DC distribution systems are not remotely monitored and status alarm signals are not able to be remotely interrogated. The undetected failure status of a DC distribution system not being able to be monitored and thereby going undetected has a potential to cause considerable interruption to electricity supplies, major plant damage and may adversely impact on security of the transmission system.

TasNetworks will consider the systematic replacement of DC distribution systems based on various factors which include performance, reliability and economic considerations especially where safety and a declining trend in condition are evident.

At several sites integrated with, or adjacent to, customer or generator facilities, TasNetworks relies on the third party for its DC supply requirements. The high level of secondary asset integration at these sites increases the operational and business risks associated with the management of the assets as the boundaries of responsibilities are complex and difficult to manage and maintain. Any lack of or inappropriate maintenance being applied to these DC supply systems has the potential to impact the reliability and availability of TasNetworks' transmission system.

TasNetworks is investigating strategies to manage third party maintenance of DC distribution that can impact on TasNetworks system security and will systematically segregate assets where practicably possible in conjunction with other capital or augmentation works.

7.1.2 Probability of Failure

The predominant causes of a major DC distribution system failure include:

- The undetected loss of DC supplies (no alarms on older DC distribution systems), especially single DC distribution systems;
- Batteries not being able to maintain their designed nameplate Ah rating;
- Maintenance inadequacies where there is a third party ownership of DC distribution systems;
- Inadequate quality control during manufacture which can affect random units or batches of batteries; and
- The deterioration of asset condition as described in Section 7.1.1.

The 125V DC Systems Condition Assessment Report, D11/2420, has provided sufficient information for TasNetworks to calculate a failure for Battery Energy/Energel batteries. An annual failure rate of 5% has been used based on 10 cells in a 50 cell battery failing every four years.

For other systems, TasNetworks has calculated an annual failure rate of 1.33% which equates to 20% of the cells failing over a fifteen year life.

7.1.3 Consequence of Failure

A major failure of a DC distribution system has been identified as a significant risk area as it has the potential to impact on safety and transmission system performance in the event of loss of DC supply.

The loss of DC supply to a substation means that all protection and control functionality is lost. Whilst primary electricity may not necessarily be lost in this case, if a fault does occur on the transmission network, the protection system will be unable to operate at this site, resulting in remotely connected substations being used to isolate the fault.

As a result, all supply at the affected station will be lost, and all interconnecting transmission circuits will also be out of service, which may further constrain other connected substations and transmission circuits.

7.1.4 Environmental Risk

TasNetworks' main environmental risks associated with batteries relate to possible contact and exposure to toxic chemicals such as lead, antimony, arsenic, mercury, nickel, selenium, silver, and zinc, and reactive chemicals, such as sulphuric acid, solvents, acids, caustic chemicals, and electrolytes.

Lead-acid batteries contain aqueous electrolyte and are capable of producing and releasing hydrogen gas during charging. Hydrogen production, thermal runaway and possible explosion/fire is possible. Proper ventilation of the battery area and wash facilities are provided to mitigate safety risks associated with lead acid batteries. It is noted that TasNetworks has replaced all "wet-cell" batteries with valve regulated lead acid batteries which has removed the need for wash stations and the need to have batteries located in separate dedicated battery rooms.

Disposal of toxic chemicals is undertaken in accordance with the relevant standards and procedures.

7.2 Special Operation and Design Issues

7.2.1 Operational Issues

The capacity of TasNetworks' DC distribution systems are determined by the Ampere hour (Ah) rating of the battery banks and, mostly range between 100 Ah to 400 Ah. Risdon Substation, a gas insulated switchgear (GIS) installation, employs the largest rating battery banks at 625 Ah. Battery chargers charging rates are matched to the battery banks. There are currently no specific capacity issues with the DC distribution systems apart from older installations where the DC distribution boards do not offer the flexibility and expansion capabilities for additional DC power and control circuits. These installations will be addressed on a site-by-site basis in conjunction with other replacement or refurbishment drivers

7.2.2 Design Issues

DC distribution systems design and compliance issues are key elements in developing an asset management strategy for the population. Design considerations are separated into two areas namely; specific design issues and regulatory compliance with the National Electricity Rules.

7.2.2.1 Specific design issues

DC distribution systems design issues relate mainly to the inability of older DC distribution systems not being able to satisfactorily meet the demands placed on a modern electrical utility by its customer base. The design issues that are or have previously been common across TasNetworks' DC distribution system population include:

- Obsolete lead acid and alkaline battery technology;
- Obsolete distribution boards and fuses that present safety and reliability concerns and do not conform to current best-practice and industry standards;
- The inability for manufacturer and the industry to technically support obsolete charger designs and battery technology;
- The lack of sufficient spares to adequately maintain expected service and performance levels;
- The inability of older DC distribution systems to support SCADA functionality; and
- Charging rates of the older battery chargers are not compatible with new gel batteries.

7.3 Summary of Risk

TasNetworks' experience with DC distribution system defects and failures have mainly been associated with the loss of AC supply to battery chargers, battery charger function failures, DC distribution system earth faults and defects and failures associated with deteriorating battery condition. The potential for failure and the detrimental transmission system impact a failure of this nature can have, as highlighted in the recent failure at Sheffield Substation in 2006 that occurred during a lightning storm, is that the battery voltage may drop sufficiently low to prevent the protection relays from recording fault data. In this instance the situation could have been far worse if the batteries were unable to maintain the DC supplies to the various loads and protection relays for their designed duration (generally eight hours) and thus preventing the protection schemes from detecting and issuing tripping signals to substation primary equipment elements to remove the fault from the system.

The 125V DC Systems Condition Assessment Report, D11/2420, provides more details on actual performance.

The major issues identified in the earlier review of the DC distribution systems which have generally been corrected with recent new technology are:

- Poor condition of Battery Energy/Energel batteries;
- Safety:
    - Batteries generating toxic gas;
    - Thermal runaway due to high charging rates; and
    - Fire risk.
- Design issues:
    - Poor manufacturing and quality control; and
    - Obsolete battery and charger technology.
- Duplication:
    - Issues and needs associated with single or duplicated DC distribution systems.
- Standardisation:
    - The inability of manufacturers to support now obsolete DC distribution systems; and
    - The availability of suitable spares to maintain a diverse population of DC distribution systems

8 Management Plan

8.1 Historical

Historically, management of DC distribution systems has been undertaken based primarily on condition and condition assessments. This will be continued into the future through inclusion of a Condition Based Risk Management (CBRM) program.

8.2 Strategy

The management strategies adopted to mitigate the risks associated with DC distribution systems are monitored on an ongoing basis to ensure they are effective and relevant to achieving TasNetworks' risk management objectives. Practices are reviewed on a regular basis taking into account:

- Past performance;
- Manufacturer's recommendations;
- Industry practice (derived from participation in technical forums, benchmarking exercises and discussions with other transmission companies); and
- Availability of new technology.

Failures within DC distribution systems may cause serious or catastrophic damage to the assets, so allowing failures to occur represents a real risk to the surrounding infrastructure.

To reduce the risk of an DC distribution systems failure, TasNetworks has adopted the following specific strategies to address the predominant causes and consequences of failure.

8.2.1 Routine Maintenance

There is a fundamental requirement for TasNetworks to periodically inspect the assets to ensure their physical state and condition does not represent a hazard to the public. Other than visiting the assets, there is no other economic solution to satisfy this requirement.

8.2.2 Routine Maintenance versus Non Routine Maintenance

Failures within DC distribution systems may cause serious or catastrophic damage to the asset. These assets are located in critical network points, so allowing failures to occur represents a real risk to the stability of the electrical system. These assets also have a high unit value, so a preventative corrective maintenance program represents a cost effective alternative to a reactive corrective maintenance program.

8.2.3 Refurbishment

Where DC distribution systems are removed from the network in good operating condition by activities such as capacity and power quality drivers, these assets are assessed for redeployment back into the network where such refurbishment is deemed to be an economic proposition.

8.2.4 Planned Asset Replacement versus Reactive Asset Replacement

Replacement is generally only preferred when this is a more economic proposition compared to ongoing maintenance costs over the estimated remaining service life of the asset. These are identified from the maintenance and inspections activities and feed into the list of proposed capital expenditure projects for prioritisation. Typically individual cells are replaced in a battery as required, until a whole battery replacement becomes preferred. Battery charger, fuse boards and other component defects are normally minor and easily rectified and are performed as required.

8.2.5 Non Network Solutions

The role of the DC distribution systems generally cannot be cost effectively substituted via upgrading other infrastructure on the network.

8.2.6 Network Augmentation Impacts

TasNetworks' requirements for developing the power transmission system are principally driven by five elements:

1. Demand forecasts;
2. New customer connection requests;
3. New generation requests;
4. Network performance requirements; and
5. National electricity rules (NER) compliance.

Details of planned network augmentation works can be found in TasNetworks Annual planning Report (APR), which is updated on an annual basis.

Proposed network augmentation projects identified in the Annual Planning Report will have minimal impact on the DC distribution systems population from an asset management perspective. Additional costs associated with new DC distribution system installed as part of network augmentation projects will impact on the ten-year projected operational expenditure, since maintenance and testing needs to be performed as detailed in the maintenance plan. As the number of DC systems associated with new developments is not finalised, they have not been included in these projections.

8.3 Routine Maintenance

The performance of batteries is sustained by the implementation of regular condition monitoring and preventive maintenance activities. Maintenance practices are reviewed on a regular basis taking into account:

- Past performance;
- Manufacturer's recommendations;
- Industry practice (derived from participation in technical forums, benchmarking exercises and discussions with other transmission companies); and
- The availability of new technology.

The requirement for operating expenditure is a function of the defined periodic condition monitoring regimes defined preventive maintenance requirements and corrective works. Condition assessment and preventive maintenance practices include:

- Routine asset inspection;
- Various condition monitoring techniques; and
- Identification, repair and recording of faulty DC distribution systems.

The revised condition assessment and maintenance practices for DC distribution systems are presented in Table 1. Based on condition monitoring data, the frequency of maintenance intervals may increase towards the end of a DC distribution systems life. In the event that increased maintenance levels are required, the decision to replace a DC distribution system or component thereof may be justified depending on the impact on preventive maintenance expenditure and transmission system performance.

Visual inspection, condition/performance test (impedance testing and conductive battery discharge test) are performed regularly to ensure that the batteries are healthy.

The battery impedance tests are used to identify the condition of the batteries. Changes in impedance indicate that the electrical performance of individual cells or connections have changed, indicating a decline in condition.

Battery discharge tests are undertaken to confirm the actual ampere hour rating of the battery. The results are then compared with the station needs. The decision to replace individual cells or the entire battery bank is then made based on the size of the battery capacity shortfall.

Modern DC distribution systems also allow for remote monitoring of various battery and charger functions through the integration with TasNetworks SCADA system. Such modern technology systems lead to a reduction in equipment inspections and maintenance practices and allow for improvements in a proactive DC distribution system monitoring.

Table 1: Condition monitoring and preventive maintenance practices

Task	**Frequency**
Visual inspections and routine condition monitoring	Quarterly
Impedance test	Annually-Coordinated with other site inspections
Discharge test	At two years and ten years of age, then every two years on all batteries
Thermal imaging	Annually- Coordinated with substation thermal imaging program

8.4 Non Routine Maintenance

Minor and major asset defects that are specifically identified during asset inspections and routine maintenance or through other ad-hoc site visits are prioritised and rectified as per the recommendations set out in TasNetworks condition assessment report and general asset defects management process.

The methodology used to develop and manage non routine maintenance is adjusted to meet the option analysis completed specific for the defect to meet the performance criteria set out in TasNetworks' risk framework, with the objective to return to service and prevent asset failure.

8.5 Reliability and Quality Maintained

8.5.1 Standardisation

To mitigate the risk of a major failure of a DC distribution system, TasNetworks has standardised the requirements and specifications for DC distribution systems installations in TasNetworks' DC Distribution Systems Standard.

The specification requires that TasNetworks' new DC distribution systems, as a minimum, conform to the design requirements and type-tests as stipulated in Australian and international standards.

8.6 Regulatory Obligations

DC distribution system performance impacts on TasNetworks' overall network service obligations, which include specific performance requirements for both regulated and connection transmission assets.

The National Electricity Rules (NER) states "If the fault clearance time of a primary protection system for a two phase-to-ground short circuit fault is less than 10 seconds, the primary protection system must have sufficient redundancy to ensure that it can clear short circuit faults of any fault type within the relevant fault clearance time with any single protection element (including any communications facility upon which the protection system depends) out-of-service."

A protection system is defined as "A system, which includes equipment, used to protect a Registered Participant's facilities from damage due to an electrical or mechanical fault or due to certain conditions of the power system."

Since virtually all of TasNetworks' protection schemes operate faster than 10 seconds, it can be assumed that all protection systems must be duplicated. The NER also requires that substations have secure electricity supplies for dedicated plant performing communications, monitoring, control, and protection functions.

Whilst DC systems are not specifically mentioned as part of the protection system, TasNetworks has implemented a policy of installing DC distribution systems with some duplication to eliminate common points of failure.

Duplicate trip coils and independent high speed protection systems are supplied via two independent systems (system 'A' and system 'B'). The system may be supplied by either single or duplicated batteries or chargers.

8.6.1 Service Obligations for Network Assets

TasNetworks' service target performance incentive scheme (STPIS), which has been produced in accordance with the Australian Energy Regulator's (AER's) Electricity TNSPs STPIS publication, is based on plant and supply availability. The STPIS includes the following specific measures relevant to transmission network assets:

a. Plant availability:
   i. Transmission line circuit availability (critical and non-critical); and
   ii. Transformer circuit availability.
b. Supply availability:
   i. Number of events in which loss of supply exceeds 0.1 system minute; and
   ii. Number of events in which loss of supply exceeds 1.0 system minutes.

Details of the STPIS scheme and performance targets can be found in TasNetworks' TSMP.

There are currently no specific service level obligations for DC distribution systems.

8.6.2 Service Obligations for Non-regulated assets

8.6.2.1 Hydro Tasmania

TasNetworks has a Performance Incentive (PI) scheme in place with Hydro Tasmania under its Connection and Network Service Agreement (CANS 2) for connection assets between the two companies. The PI scheme includes connection asset availability which can be impacted by

TasNetworks HV switchgear assets. An overview of Hydro Tasmania PI scheme and performance targets can be found in the Connection Agreement.

8.6.2.2 Tamar Valley Power Station (TVPS)

TasNetworks has a PI scheme in place with Tamar Valley Power Station (TVPS) under its Generator Connection Agreement for connection assets between the two companies. The PI scheme includes the connection asset availability measure. An overview of TVPS PI scheme and performance targets can be found in the Connection Agreement.

8.6.2.3 Major Industrial Direct Customer Connections

TasNetworks have a number of direct connections to major industrial customers through EHV and HV substations. The following sites have asset category assets providing these direct connections:

- Boyer Substation (6.6 kV);
- George Town Substation (220 kV & 110 kV);
- Hampshire Substation (110 kV);
- Huon River Substation (11 kV);
- Newton Substation (22 kV);
- Port Latta Substation (22 kV);
- Que Substation (22 kV);
- Queenstown Substation (11 kV);
- Risdon Substation (11 kV);
- Rosebery Substation (44 kV); and
- Savage River Substation (22 kV).

The individual connection agreements describe the level of service and performance obligations required from the associated connection assets.

8.7 Replacement

8.7.1 Replacement Strategies

The decision to replace or decommission DC distribution systems is not driven specifically by age but rather considers a combination of other criteria in the decision process, such as obsolete design, spares availability and manufacturer support. Degradation of DC battery systems, particularly deteriorated wiring at some sites is factored into replacement and refurbishment programs, as appropriate. DC distribution system functionality, reliability and integration with other electrical system needs to keep abreast of technological advances in order to satisfy system and customer requirements. It is thus incumbent upon TasNetworks to ensure that such factors are accounted for in strategy development.

Where specific design issues and/or duplication is not satisfactory, TasNetworks will progressively replace, or where possible refurbish, DC distribution systems in order to maintain or improve transmission performance and reliability. The strategy is based on lifecycle cost analysis and is consistent with industry practice.

The replacement program of works will, where possible, be coordinated with other capital programs as identified in the Regional Development Plans and/or APR, taking into consideration various drivers which include the cost benefits of integration with other capital investment programs and the mitigation of risks associated with the population of DC distribution systems.

8.7.2 Replacement Program

To address design, condition and performance risks associated with the DC distribution system population, continuation of the DC distribution system replacement program is recommended. The prioritisation of replacement will be based on the following considerations:

- Unreliable and DC distribution systems that are in a poor condition or present a safety risk shall be replaced as a priority;
- DC distribution systems will be installed at sites where TasNetworks is co-sited with a generator and/or customers and where TasNetworks does not presently own the DC distribution systems; and
- Battery chargers and other critical DC distribution system components that are obsolete and do not have adequate manufacturer/spare parts support will be replaced.

Where practicable, substation DC distribution system replacements and/or duplication will be coordinated with substation capital works.

8.8 Program Delivery

The needs assessment and options analysis for undertaking an asset management activity is documented in the Investment Evaluation Summary for that activity.

The delivery of these activities follows TasNetworks' end to end (E2E) works delivery process.

8.9 Spares Management

TasNetworks maintains spares for DC distribution systems in accordance with TasNetworks System Spares Policy.

TasNetworks has two trailer mounted batteries to facilitate rapid deployment to sites for maintenance or to allow system repairs in the event of a failure at site.

8.10 Redundancy Analysis

TasNetworks has previously undertaken an analysis for DC supply systems to determine an optimum level of redundancy. The analysis considered the time to respond and provide emergency back-up AC or DC supply, the overall DC load at the station and the potential load or system minutes that could be lost if the DC systems failed.

The analysis is performed in two basic steps:

- Calculate the site urgency by identifying how quickly a mobile supply can be connected to the site, and use the size of the site (ie number of connected DC loads) to determine the extent of potential drain on site batteries; and
- Derive if duplication is required by comparing the urgency against the potential impact of an event measured by system minutes (One system minute (sys min) is approximately 31.5 megawatt hours (MWhrs)).

The following two tables define the urgency and duplication needs for site DC System needs.

Table 2: Calculation of site urgency

	Station Size		
Time to reinstate (hrs)	**Small**	**Medium**	**Large**
0-1.5	Non urgent	Non urgent	Average

1.5-3	Non urgent	Average	Urgent
>3	Average	Urgent	Urgent

Table 3: Derivation of DC system duplication

	Sys min lost		
Urgency	**0-0.1**	**0.1-1.0**	**>1.0**
Non urgent	Single	Single	Duplicate
Average	Single	Duplicate	Duplicate
Urgent	Duplicate	Duplicate	Duplicate

Appendix B –DC system Duplication Analysis Results contains the outcomes of the DC duplication analysis for each site. The analysis has identified that the following sites could change the level of battery redundancy installed. The changes could be made when the batteries fall due for replacement.

Table 4: Potential Battery duplication change actions

Location	**Action**
Huon River	Downgrade to a single battery
Kermandie	Downgrade to a single battery
Liapootah	Downgrade to a single battery
North Hobart	Upgrade to dual batteries
Newton	Downgrade to a single battery
Port Latta	Downgrade to a single battery
Scottsdale	Downgrade to a single battery
Triabunna	Downgrade to a single battery
Tungatinah	Downgrade to a single battery
Wesley Vale	Downgrade to a single battery

8.11 Technical Support

Other operational costs which are not able to be classified under the above categories are allocated to technical support. These tasks include:

- System fault analysis and investigation;
- Preparation of asset management plans;
- Standards management;
- Management of the service providers;
- Training;
- Group management; and
- General technical advice.

8.12 Disposal Plan

Disposal of DC distribution systems will be undertaken in accordance with relevant standards and procedures.

8.13 Summary of Programs

Tables 5 and 6 provide a summary of all of the programs/projects described in this management plan.

Table 5: Summary of DC distribution system OPEX programs

Work Program	Work Category	Work Category	Project/Program
Routine Maintenance	CMDCS	Corrective maintenance	S001-SUBS-Corrective-DC Supplies
	PMDCS	Preventative maintenance	S159-SUBS -Battery Impedance Test
	PMDCS	Preventative maintenance	S158-SUBS -Battery Discharge Test

Table 6: Summary of DC distribution system CAPEX programs / projects

Work Program	Work Category	Project title	Project/Program details
Capital	RENSB	DC Supply renewal	The following substations have been identified as having batteries which will exceed 10 years of service life during the 2019-24 period and are targeted for battery replacement. a. George Town A & B in 2021, C& D in 2023 b. Huon River A & B in 2020 c. Kingston A & B in 2023 d. Knights Road A & B in 2024 e. Mornington A & B in 2023 f. New Norfolk A & B in 2023 g. Queenstown A & B in 2019 (they are 15 and 13 years old now) h. Rokeby A & B in 2023 i. Scottsdale A & B in 2019 j. Sheffield A & B in 2024 k. St Leonards A & B in 2024 l. St Marys A & B in 2023 m. Sorell A & B in 2023 n. Savage River B in 2019 (assuming data in WASP is accurate, confirm if battery done in last couple of years) o. Triabunna A & B in 2019 (assuming data in WASP is accurate, confirm if battery done in last couple of years) p. Trevallyn A & B in 2019 (assuming data in WASP is accurate, confirm if battery done in last couple of years) q. Tungatinah A & B in 2024 r. Ulverstone A & B in 2019 (assuming data in WASP is accurate, confirm if battery done in last couple of years) s. Waddamana C & D in 2023 t. Wesley vale B in 2019 Also several substations potentially have battery chargers that may require replacement due to condition. These battery chargers will need to be reviewed to ascertain their remaining

Work Program	Work Category	Project title	Project/Program details
			life. Dates listed indicates their installed date: a. Burnie A & B in 2003 b. Derby A & B in 2005 c. Emu Bay A & B in 1998 d. Hadspen A & B in 1998 e. New Norfolk A in 1987 f. Trevallyn A & B in 1998

9 Financial Summary

9.1 Proposed OPEX Expenditure Plan

Requirements for operating expenditure are a function of the defined periodic condition monitoring regimes, defined maintenance requirements and expected minor and major post insulator works.

9.2 Proposed CAPEX Expenditure Plan

The capital programs and expenditure identified in this management plan are necessary to manage operational and safety risks and maintain network reliably at an acceptable level. All capital expenditure is prioritised expenditure based on current condition data, field failure rates and prudent risk management.

A comprehensive capital investment strategy has been developed to address the design and performance issues associated with the DC distribution systems. This plan recommends that batteries and other system components at 24 substations be replaced. The upgrade program is aimed at mitigating the business risks presented by poor asset condition and to increase the reliability and availability of secondary equipment. In addition, the program will rationalise the type of DC distribution systems through equipment standardisation, enabling improved use of condition monitoring practices, a reduction in spares inventory and simplified contingency planning and fault response processes.

9.3 CAPEX – OPEX trade offs

The operating expenditure programs are essential for identifying assets that require replacement for condition-based reasons. There is a positive relationship between these two categories in that regular inspection programs gather continuous condition information of the assets to better target asset replacements and identify any asset trends. Maintenance and repair activities also defer the requirement for capital expenditure and increase the likelihood of the asset operating for as long as possible within the network.

10 Related Standards and Documentation

The following documents have been used either in the development of this management plan, or provide supporting information to it:

TasNetworks documents:

1. WASP Asset Register – Data Integrity Standard – Battery R17113
2. WASP Asset Register – Data Integrity Standard – Battery charger R17036
3. TasNetworks' Annual Planning Report, 2017 R689487
4. Strategic Asset Management Plan R248812
5. AM8 Asset Condition Review – project report June16 FINAL R503361
6. Engineering and Asset Services operational expenditure planning methodology, D11/102320.
7. 125V DC Systems Condition Assessment Report, D11/2420

Technical requirements for new DC Distribution systems are detailed in the following standards/specifications:

8. DC Distribution System Standard - R522693

Other standards and documents:

9. Australian Standard AS 4360 Risk Management, Standards Australia, 2004
10. Sinclair Knight Mertz report, Assessment of proposed regulatory asset lives, August 2013 R192773
11. National Electricity Rules

11 Appendix A – Summary of Programs and Risk

Description	Work Category	Risk Level	Driver	Expenditure Type	Residual Risk
S001-SUBS-Corrective-DC Supplies	CMDCS	Medium	Customer Financial Regulatory Compliance Reputation Safety	Opex	Low
S159-SUBS -Battery Impedance Test	PMDCS	Medium	Customer Financial Regulatory Compliance Reputation Safety	Opex	Low
S158-SUBS -Battery Discharge Test	PMDCS	Medium	Customer Financial Regulatory Compliance Reputation Safety	Opex	Low
DC Supply renewal	RENSB	Medium	Customer Financial Regulatory Compliance Reputation Safety	CAPEX	Low

12 Appendix B –DC system Duplication Analysis Results

The following table was originally created for the previous AMP release. It has been retained to provide some guidance for any future review of the needs for DC system enhancements.

Table 7: DC system duplication analysis results

Location	Batteries	Time to reinstate DC supply (hrs)	Station Size (ie DC loading)	Urgency	Sys mins lost	Derived duplication status
Arthurs Lake	Single	2.9	Small	Non Urgent	0.01	Single
Avoca	Duplicate[1]	2.5	Small	Non Urgent	0.5	Single
Boyer	Duplicate	1.5	Medium	Non Urgent	4.8	Duplicate
Bridgewater	Duplicate	1.5	Small	Non Urgent	1.7	Duplicate
Burnie	Duplicate	1.5	Large	Average	3.1	Duplicate
Castle Forbes Bay[2]	Single	2.5	Small	Non Urgent	0	Single
Chapel Street	Duplicate	2	Large	Urgent	2.5	Duplicate
Creek Road	Duplicate	1.8	Large	Urgent	6.3	Duplicate
Derby	Duplicate[3]	2.5	Small	Non Urgent	0.2	Single
Derwent Bridge	Single	2.9	Small	Non Urgent	0.01	Single
Devonport	Duplicate	1.5	Medium	Non Urgent	3.2	Duplicate
Electrona	Duplicate	1.75	Medium	Average	1.2	Duplicate
Emu Bay	Duplicate[4]	1.5	Medium	Non Urgent	0.5	Single
Farrell	Duplicate	2.6	Large	Urgent	0	Duplicate
George Town 110kV George Town 220 kV	Duplicate Duplicate	1.8	Large	Urgent	27	Duplicate
Hadspen	Duplicate	1.75	Large	Urgent	3.2	Duplicate
Huon River	Duplicate	2.9	Small	Non Urgent	0.2	Single
Kermandie	Duplicate	2.25	Medium	Average	0.5	Single
Kingston	Duplicate	1.75	Medium	Average	2.3	Duplicate
Knights Road	Duplicate	2	Medium	Average	1.2	Duplicate
Liapootah	Duplicate	2.1	Medium	Average	0	Single
Lindisfarne	Duplicate	1.5	Large	Urgent	3.0	Duplicate
Meadowbank	Single	1.6	Medium	Average	0.2	Single

[1] Upgraded from single in 2014
[2] 48 VDC installed for supply to motorised disconnector 2016
[3] Upgraded from single in 2016
[4] Upgraded from Single in 2016

Mornington	Duplicate	1.6	Medium	Average	1.4	Duplicate
Mowbray	Duplicate	1.5	Medium	Non Urgent	1.7	Duplicate
New Norfolk	Single	1.5	Medium	Non Urgent	0.8	Single
Newton	Duplicate	3.1	Small	Average	0.9	Single
North Hobart	Single	1.5	Medium	Non Urgent	2.8	Duplicate
Norwood	Duplicate	1.6	Medium	Average	1.5	Duplicate
Palmerston	Duplicate	2.25	Large	Urgent	0.4	Duplicate
Port Latta	Duplicate	2	Medium	Average	0.9	Single
Que	Single	2.1	Small	Non Urgent	0.02	Single
Queenstown	Duplicate	3.6	Medium	Urgent	2.3	Duplicate
Railton	Duplicate	1.6	Medium	Average	2.5	Duplicate
Risdon	Duplicate	1.5	Large	Urgent	10.6	Duplicate
Rokeby	Duplicate	1.5	Small	Non Urgent	1.3	Duplicate
Rosebery	Duplicate	3.1	Medium	Urgent	3.5	Duplicate
Savage River	Duplicate	2.5	Small	Non Urgent	1.5	Duplicate
Scottsdale	Duplicate	2.1	Small	Non Urgent	0.8	Single
Sheffield	Duplicate	1.75	Large	Urgent	0	Duplicate
Smithton	Duplicate	2	Medium	Average	1.7	Duplicate
Sorell	Duplicate	1.5	Medium	Non Urgent	1.6	Duplicate
St Leonards	Duplicate	1.5	Medium	Non Urgent	2.2	Duplicate
St Marys	Duplicate	2.9	Small	Non Urgent	1.6	Duplicate
Trevallyn	Duplicate	1.5	Medium	Non Urgent	3.0	Duplicate
Triabunna	Duplicate	2.25	Medium	Average	0.6	Single
Tungatinah	Duplicate	2.25	Medium	Average	0.09	Single
Ulverstone	Duplicate	1.5	Medium	Non Urgent	1.7	Duplicate
Waddamana	Duplicate	2.6	Large	Urgent	0.07	Duplicate
Wesley Vale	Duplicate	1.5	Medium	Non Urgent	0.08	Single

14 Appendix C – External DC connection point

Table 13 includes details of emergency DC connection points at all substations. These connection points enable connection of TasNetworks trailer mounted DC battery system for emergency connection or support discharge testing at single battery stations.

Table 8: Battery external connection point

Location	DC connection (battery trailer) Y/N	General Comments
Arthurs Lake	Yes	
Avoca	Yes	
Boyer	Yes	
Bridgewater	Yes	
Burnie	No	
Castle Forbes bay Tee	No	
Chapel Street	Yes	
Creek Road	Yes	
Derby	No	
Derwent Bridge	Yes	
Devonport	No	
Electrona	No	
Emu Bay	No	
Farrell	Yes	
George Town	Yes [220kV]	
Gordon	?	
Hadspen	No	
Huon River	No	
Kermandie	No	
Kingston	Yes	
Knights Road	Yes	
Liapootah	Yes	Older design DC connection-Internal
Lindisfarne	Yes	
Meadowbank	Yes	
Mornington	Yes	
Mowbray	No	
New Norfolk	Yes	Single Batt Bank
Newton	Yes	

North Hobart	Yes	Single Batt Bank
Norwood	No	
Palmerston	No	Older DC design
Port Latta	No	
Que	No	
Queenstown	No	Older DC design
Railton	No	Older DC design
Risdon	No*	
Rokeby	Yes	
Rosebery	No	
Savage River		
Scottsdale	No	
Sheffield	?	
Smithton	?	Battery Trailer connection in Switchboard
Sorell	Yes	
St Leonards	Yes	
St Marys	No	
Trevallyn	No	
Triabunna	No	
Tungatinah	Yes	
Ulverstone	No	
Waddamana	Yes [110kV]	
Wesley Vale	No	