AMS – Victorian Electricity Transmission Network

Asset Replacement and Refurbishment

SP AusNet
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Contact

This document is the responsibility of Network Development Division, SP AusNet.

Please contact the indicated owner of the document with any inquiries.

Derek Postlethwaite

SP AusNet

Level 31, 2 Southbank Boulevard

Melbourne Victoria 3006

Ph: (03) 9695 6000

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1 Introduction

This document outlines the asset replacement and refurbishment strategies that underpin the management of assets in the Victorian electricity transmission network. In the context of this document the term 'renewal' is used to mean refurbishment or replacement.

1.1 Refurbishment

This strategy involves refurbishing plant to extend its reliable service life. This is often the lowest capital cost option. However, in many cases it is reliant on spare equipment being available while deteriorated plant is being refurbished and the economics of this option are predicated on the probability that known technical issues can be addressed.

In general, refurbishment addresses specific, known problems that would, if no remedial action were taken, lead to failure and foreshorten the service life of the asset. Generally, refurbishment improves the declining reliability of the plant but does not extend its useful service life. In most cases, refurbishment has only a minor impact on maintenance costs because refurbishment tends to stabilise rising future costs rather than dramatically reducing costs below historic levels.

This strategy requires careful case-by-case analysis as benefits are unique to each refurbishment and are highly dependent on stabilizing or reducing a rising failure rate, with a secondary benefit of a small extension in reliable service life.

1.2 Replacement

This strategy involves replacing plant to ensure continued service. While this strategy often has the highest up-front costs it also tends to lead to the largest reductions in failure risk and maintenance costs. Replacement also presents an opportunity to modernise plant which can avoid costs associated with obsolete equipment and improve the level of service.

Replacement is often the preferred option when the reliability of an asset is critical, when asset outages and spares are not available for refurbishment, or when refurbishment is simply an ineffective means for addressing unreliability.

A primary requirement for asset replacement planning is knowledge of asset condition and other factors that will affect the remaining technical life of the assets. This technical life assessment is undertaken in accordance with the Asset Life Evaluation Strategy (AMS 10-101) and further information may be obtained by referring directly to this policy.

Plans for asset replacement look for efficiencies over the entire planning period. For example, by integrating the augmentation needs of the Australian Energy Market operator and those of distribution network service providers with SP AusNet's replacement plans for a variety of co-located assets. This approach optimises engineering and construction resourcing and minimises project risks and network outages for construction purposes.

2 Objectives

The objective of asset renewal is to achieve sustainable outcomes in:

- Safety of customers, the community and workers
- Quality, reliability and security of supply of electricity transmission services
- Compliance with codes, licences, contracts, industry standards and obligations
- Quality, reliability and security of supply performance risks
- Minimising total life cycle costs through the consideration of capital costs, maintenance costs and operational risk costs
- Minimising the volatility of renewal works and associated material, skill and revenue requirements.
- Minimising project delivery risks and the potential impact of renewal works on network availability, market participants and connected parties

3 Criteria

3.1 Compliance

SP AusNet's network and asset management practice must comply with all relevant electricity transmission codes, licences, contracts and prescribed industry standards to ensure that the rights and benefits of other National Electricity Market (NEM) participants are not compromised. Currently, these obligations include 22 regulatory instruments involving some 350 mandatory obligations and 260 event driven obligations relevant to the Victorian electricity transmission network.

Of particular significance are several legislative obligations relating to worker safety. Under the Occupational Health and Safety Act SP AusNet is required to: as far as is reasonably practicable, maintain for employees a working environment that is safe and without risks to health.

The Electricity Safety Act requires SP AusNet to: operate its electricity transmission network to minimise, as far as is practicable, hazards to the safety of any person.

These Acts require SP AusNet to have regard to the likelihood and harm and what is known or should be known about safety hazards. SP AusNet must also consider the availability and suitability of ways to eliminate or mitigate safety hazards. SP AusNet is then further obliged to have regard to the cost of removing or mitigating the safety hazard or risk.

3.2 Network Performance

If equipment performance trends indicate that contractual performance requirements (relating to the respective codes and licences) will not be met, or will be unreasonably compromised, planned (pro-active) renewal is investigated.

Maintenance, refurbishment and replacement plans are developed using an underlying strategy of condition-based remediation. This strategy uses risk management principles that take into account criticality, reliability and the prudence of adopting a particular course of action.

The risk and consequence of plant failure, including unserved load and reduced network performance are assessed as part of each asset management decision. Asset management is also balanced with a longer-term perspective on capital and network access requirements and indicators such as the Weighted Average Remaining Life (WARL) of the assets.

While assets are generally managed as a discrete ‘fleet’, each decision to replace or refurbish items of plant is taken on a case-by-case basis.

When assets are unable to operate at their full rating, this tends to place operational restrictions on network configuration and capability and can result in poor utilisation of associated major plant (for example, power transformers). To address this, planned replacement of minor plant items (for example, disconnectors) is often combined with other plans to optimise network capability.

The operations and assets of direct connected customers, such as steel and aluminium producers, and generators are often damaged by outages, interruptions or availability constraints. For example, generators who are unexpectedly constrained from the market are exposed to financial losses against which they are currently unable to insure.

3.3 Asset Condition

Asset condition is a key driver of renewal activities. As equipment condition deteriorates its design safety margins and performance can gradually decline below network operating requirements. Assets require a margin which allows them to operate during foreseeable abnormal operating conditions, caused by network faults, surges, outages, and high ambient temperatures. This margin determines network reliability and security.

Failure Modes Effect Analysis (FMEA) is the principle technique used to gain knowledge about the modes and rates of deterioration of each asset type. Benchmarking with other transmission network service providers and liaison through industry associations such as CIGRE brings additional data, experience and insight. Using this knowledge, condition is assessed through a wide range of activities including online condition monitoring, regular inspections, planned maintenance and issue-focussed testing.

Condition profiles for a fleet of assets, aid comprehension of the extent and the rate of deterioration. They also provide input to asset risk models used to contrast future risk forecasts with historical and current risk positions.

Condition ranking each asset within a fleet of its peers, identifies individual assets having the greatest probability of failure and targets intensive inspection, testing and potentially, renewal activities.

3.4 Asset Criticality

The consequence of plant failures, including loss of service is established for each major asset and combined with the probability of such events to enable the evaluation of risk costs for individual assets. Comparative assessments of asset fleet risk, based on individual asset probabilities and consequences of failure, are a valuable tool in determining the volume and timing of economic renewal activities.

3.5 Life Cycle Costs

3.5.1 Asset Life Evaluation

The expected asset life is evaluated and assigned to each asset type or meaningful asset cohort. These lives take into account engineering, regulatory and commercial factors. The expected lives are reviewed regularly and updated as part of each revenue-reset. The Asset Life Evaluation Strategy (AMS 10:101) provides asset life evaluation criteria for various asset categories.

3.5.2 Weighted Average Remaining Life (WARL)

WARL is a high-level indicator designed to indicate the risk of systemic failures in asset types due to age related problems. By monitoring the WARL of various asset groups, asset risk management decisions can be informed.

Declining WARL in stable technologies (e.g. for towers, isolators and power transformers) indicates increasing economic and performance risks. However, declining WARL in rapidly advancing technologies such as digital relays and communication systems is not necessarily of concern as replacement equipment is superior from both cost and functionality perspectives.

3.6 Future Customer Requirements

Network service providers coordinate their planning efforts through the Victorian industry network planning forums.

A ten-year asset renewal plan is prepared and published annually for the electricity transmission network as part of the Australian Energy Market's (AEMO's) Victorian Annual planning Report. These renewal plans are integrated with the network augmentation plans developed by AEMO for the shared network assets and by distribution network service providers for the connection assets to minimise their network impact and to optimise economic benefits.

3.7 Spares and Technical Support

A contingency strategy is developed when a manufacturer no longer offers technical support and spare parts for key assets. Depending on the level of technical support and spares available from within SP AusNet, plant criticality to the network and NEM constraints, this strategy may involve the replacement of one asset to generate spares for the maintenance of other assets in less critical areas of the network. This strategy generally results in an improvement in asset restoration time during a failure, but not to the overall network reliability and availability.

4 Optimisation (of Renewal Scope)

4.1 Prudence (Integration and Pro-activity)

Renewal plans are integrated to provide cost efficiencies and to optimise resource utilisation, thereby minimising volatility in material, skill and revenue requirements. Asset management decisions consider health and safety, environment, network security, security of supply, value of unserved energy and NEM constraints. The asset management process assesses each renewal decision on a case-by-case basis to ensure prudence.

4.2 Risk Based Renewal

Asset renewal planning considers pro-active (planned) renewal of assets where the following conditions apply:

- Existing equipment cannot economically meet emerging functional requirements.
- Existing equipment cannot economically meet emerging legislative requirements
- The equipment will present an uneconomic risk in terms of safe and reliable operation during the asset renewal-planning period
- The predicted costs associated with keeping the equipment in service over the asset renewal planning period present a lower net present value than an asset renewal option

4.3 Integrated Renewal

Integrated renewal involves replacing many of the assets on a site in a single project. A typical integrated project would replace a terminal station transformer, circuit breakers, disconnectors, instrument transformers and associated protection, monitoring and control equipment in a single project.

The alternative to integrated renewal is to replace assets on a component or sub-system basis. The main contributing reason as to why utilities have continued for some time to replace assets on a component or sub-system basis is that it can be a cost efficient technique for the management of risk due to plant failure. However, an integrated approach may have other far-reaching benefits in terms of network performance and reliability.

The integrated strategy also offers the opportunity to simplify engineering, and reduce 'whole of life' costs. There is a meaningful risk reduction, which flows through to avoidance of availability penalties. Often, new functionality will enable data and information gathering for operational and asset management purposes.

Integrated renewal can provide the following benefits:

- Lower lifecycle costs as common project costs including design, project management and mobilisation are distributed across the cost of all assets replaced
- Reduced impact on the energy market through fewer outages to replace assets

- More simply and cost effectively integrate new technologies such as protection and monitoring systems onto the site
- Improve the capability of the site to meet future needs i.e. develop a site layout or space required to meet future augmentation needs

5 Options for Renewal

There are four fundamental options upon which specific renewal strategies can be based:

- Do Nothing
- Renew on Failure
- Renew on Performance or Condition
- Renew on Risk

'Do Nothing' and 'Renew on Failure' are principally reactive strategies and 'Renew on Performance or Condition' and 'Renew on Risk' are predictive strategies. While the reactive strategies are often inconsistent with SP AusNet's obligations under the National Electricity Rules and the Electricity Safety Act they are included in case-by-case evaluations to establish relevant benchmarks, such as the value of continuing service from the asset and the economic timing for renewal actions.

Within the predictive strategies, a wide range of delivery tactics are considered in order to establish the most economic option for renewal.

5.1 Do Nothing

In many cases the "Do Nothing" option is inconsistent with SP AusNet's obligations under the National Electricity Rules and the Electricity Safety Act. Nevertheless, diligent evaluation of this strategy provides useful information on:

- The need for continuing service from the asset, and
- The quantum and rate of change of performance and business risks.

5.2 Renew on Failure

This strategy can be used where asset failure has a low impact on health and safety, the environment and on network performance. Another requirement for this strategy to be economic is a short procurement and re-establishment lead-time. It is therefore not generally adopted for major network assets such as circuit breakers or transformers. Examples of assets where this strategy has been employed include switchyard lighting and other auxiliary systems where duplicated facilities exist.

This strategy is also frequently inconsistent with SP AusNet's obligations under the National Electricity Rules and the Electricity Safety Act.

5.3 Renewal on Performance or Condition

Planned asset renewal, based upon declining performance or condition, aims to optimise the life cycle costs of an asset or group of assets by predicting when operating and risk costs will exceed the cost of funding remedial works. This strategy assumes that performance and asset condition monitoring systems are able to predict pending in-service failures with enough time to renew assets before they fail. When this strategy is applied to a group of assets, the strategy further assumes that operating costs and the consequence of failure are similar across the group. This allows the economic timing of replacement activities to be directed by performance and condition alone. This type of strategy can be used to prioritise renewal on a like-for-like basis or to determine the scheduling of a bay-by-bay delivery strategy where design and delivery variations can be minimised. For this strategy to be economically adopted the following is required:

- Detailed knowledge of the plant and equipment condition and trending in that condition
- Operations and maintenance costs and renewal cost data from previous inspection, maintenance and renewal activities
- Sufficient flexibility in the planning window and delivery resources availability to vary renewal programmes in response to changing plant condition
- Sufficient flexibility in network access to allow multiple outages of circuits

5.4 Renewal on Risk

Renewal-on-risk is a predictive strategy which aims to renew major assets before they fail in-service.

This strategy requires a forecast of asset failure probabilities, the consequences of failure and operating and capital costs associated with a variety of renewal tactics to select and accurately schedule remedial actions and finally to minimise project delivery risks. Each renewal tactic is economically compared with the base economics of the Do Nothing and the Renew-on-Failure options.

Tactics within the Renewal-on-Risk strategy, which may also be adopted for the Renewal-on-Performance-or-Condition strategy, include renewal:

- On a like-for-like basis,
- By asset class,
- By specific scope of works,
- On a bay-by-bay basis,
- On a brownfield which re-establishes most assets on an existing site, and
- On a greenfield which replaces an entire installation with new equipment at a new location.

An important variation on each of these delivery tactics is the deferred renewal option whereby the optimal timing of the most economic option is established.

5.4.1 Like for Like renewal

Like-for-like renewal is most frequently deployed when no additional functionality is required from the new asset and little engineering is required for its re-establishment. This tactic is also used when network availability is constrained or the market impact of circuit outages is high and in circumstances when renewal must be completed within a finite time frame determined by other connected parties. Like for like renewal is also useful for isolated renewals of specific high-risk assets within an installation containing low-risk assets.

Like-for-like renewal is most economic when a class of assets is strongly generic such as line insulators or bare conductors. It is frequently economic when skilled labour and specialised tools are a significant proportion of total capital costs and economic efficiency is thus determined by productive completion of a large number of similar actions.

5.4.2 Renewal by Asset Class

Renewal-by-Asset Class is favoured when it is clear that a cohort of assets has fundamentally different life-cycle costs.

Usually driven by clear differences in the average failure frequency of an entire class of assets or significantly higher historic operating and maintenance costs; Renewal-by-asset class can sometimes indicate that condition monitoring has failed to identify an emerging risk sufficiently early to allow for deployment of a more economic renewal tactic, such as renewal-on-condition or renewal-on risk.

Generally, this approach is preferred only when a class of asset has a failure rate that is clearly higher than acceptable or when it exhibits a higher deterioration rate than its peers.

Often, when problems are detected in one piece of equipment it suggests a fleet-wide problem and there is a need to investigate. In some cases, fleet-wide refurbishment or replacement decisions are necessary to ensure that safety, reliability and availability levels are maintained.

This approach avoids the rapid deterioration of network performance due to multiple, class or type-related failures. Typically, this tactic will involve a program of replacement for an asset type (e.g. 220 kV Brown Boveri DCFQ/DCVFQ circuit breakers) either within a specific station or across the network. To support this tactic the following is required:

- Multiple outages as each asset within a class is progressively refurbished/replaced
- Planned renewal preparations, thus minimising health, safety and environment impacts, the risk of customer impact and adverse network performance
- Planned engineering and design preparations, thereby realising efficiency benefits over the replacement-on-failure approach
- Multiples of engineering, design and construction activities required for each asset replacement

This strategy is not particularly suited to situations where all of the assets within an installation are of a similar service age and condition. In addition, adoption of this strategy may result in some deterioration in the overall performance of the network due to the prolonged period involved in renewal by asset class across multiple sites.

5.4.3 Selective Scope of Works

In this tactic a series of economic studies are undertaken to identify the optimum renewal schedule for each significant asset or group of assets within a particular installation. The scope of work is then determined by scheduling the renewal of those assets which have the highest risk or drive a rapid change in risk. Lower failure risk assets and those responsible for slow changes in the risk profile are then deferred to latter stages of a staged delivery program. Selective-scope-of-works is the most economic delivery tactic within the general strategy of renewal based on risk.

Selective-scope-of-works often results in a staged delivery program as it frequently proves uneconomic to address all deteriorating assets in a single project at a single point in time.

Sound information on failure probabilities and the consequences of failure are necessary to differentiate how the risks of failure change over time for each asset. Particular care is necessary to incorporate estimates of the engineering and project delivery costs associated with a single large project versus multiple smaller projects in order to optimise the scope and timing of stages.

Some pragmatic decisions must also be made around the multiple outages required of network circuits to undertake large scale projects in a concise schedule compared with those required for a multi-staged project over an extended time frame.

5.4.4 Renewal on a Bay-by-Bay (or Scheme/Network) Basis

This strategy involves the renewal of all primary plant and equipment within a specific bay of a station. This is of particular advantage when the ‘standard bay design’ can be applied to multiple bays, thus minimising engineering costs and allowing similar efficiencies to be incorporated into procurement and construction works.

This strategy is often adopted for large terminal station refurbishments. It should be noted that not all facilities are arranged on a bay basis and consideration must also be given to the appropriate renewal strategy for assets which serve the entire installation, for example DC power supply systems, control systems and some protection systems.

Another advantage of this approach is that where risks within a station are clearly related to the outgoing circuits associated with specific bays, it allows capital expenditure to be targeted for maximum performance advantage. Characteristics of this strategy are:

- Single outages can be achieved for each bay, but multiple outages are required for a complete station refurbishment
- Application of a standard design can realise benefits in terms of engineering, design and procurement costs

The advantages of this approach are largely negated where:

- A standard bay design is not applicable
- Much of the station equipment is of similar age and condition
- There are not clearly defined risk differences associated with outgoing circuits
- The layout of the switchyard impinges on the construction works between adjacent bays (i.e. clearance issues)

5.4.5 Replacement of a Whole Station in an Existing Location (Brownfield)

Under this replacement strategy all assets are replaced as part of a single, coordinated project within the existing station or location. Such a project is subject to a range of constraints associated with performing such works in an in-service station or location, such as:

- Minimising circuit outages
- The need to maintain supplies to customers
- Electrical access considerations such as outages and physical clearances
- Physical limitations on the use and movement of mobile plant
- Coordination with other outage related works on the network
- Health and Safety issues associated with works within 'live' switchyards

Efficiencies of this strategy are gained through optimising:

- A single, consolidated design and planning process
- A single procurement process for plant and equipment
- Single workforce mobilisation
- Minimal opportunity, depending upon timing, for unplanned outages and supply disruptions due to defects
- More structured, planned and efficient operational activities

5.4.6 Replacement of a Whole Station in a New Location (Greenfield)

This replacement strategy involves the construction of a replacement station on a new site. It is inherently more expensive than works within an existing station, primarily due to the need to procure new land and establish key infrastructure such as civil works and fencing. Interconnection with existing incoming and outgoing circuits is a significant cost factor in Greenfield decisions.

This strategy is usually only economic when the existing infrastructure is clearly inadequate in terms of function and condition and the existing site is confined to the extent that replacement works cannot be undertaken without sustained disruption to supplies.

This option offers higher construction efficiencies compared with undertaking works without the constraints of nearby "live" circuits in a "Brownfield" environment.

6 Renewal Strategy Selection Methodology

Discounted cash flow techniques (consistent with the regulatory test) are applied to the quantitative criteria (outlined above) for all major projects where costs can reasonably be accounted or estimated.

However, qualitative or less tangible criteria (e.g. industry good practice, alignment with Transmission Vision philosophy, manufacturing support) must also be considered. Where intangibles relate to real economic costs and benefits an estimate of the value is made and included in economic options analysis.

The following approach is integral to the development of the asset replacement plan:

- Assign a technical life to each generic asset group based on the principles set down in AMS 10-101 Asset Life Evaluation
- Use asset condition to determine remaining useful lives of assets within an asset group
- Determine the effects (consequences) of asset failure and value the effects
- Model the asset group to identify the assets within the group that present the highest level of risk
- Model the forecast remaining useful lives, effects (consequences) and expenditure over a 20 year period
- Carry out a bottom-up analysis of the assets that present the highest level of risk. This is to more accurately determine their performance, condition, expected remaining life and to consider replacement options and timing
- Ensure the bottom-up analysis considers all operational risks, performance, compliance, life cycle costs and synergy benefits that may be achieved with network augmentation, switching configuration and fault level management
- Integrate asset renewals within existing or planned augmentation projects so that efficient delivery will achieve the required benefits
- Perform economic evaluations (that are consistent with the relevant regulatory tests) for all major asset renewal projects
- Develop replacement plans for a 10 to 20 year period based on the generic lives and the detailed analysis of projects within the first 10 years
- Develop firm replacement plans for a five-year period

7 Strategies

- Broaden and enhance the use of on-line-condition-monitoring tools and techniques to uniformly gather, analyse and rank condition assessment data for major assets including power transformers, transmission lines and circuit breakers
- Broaden and enhance the use of asset risk models to optimise the volume and timing of asset renewal programs
- Use asset risk models to determine the optimal asset management strategies for different asset classes, specifically supporting decisions around the adoption of “replace on failure” or “risk based replacement” strategies
- Refine the process used to manage ongoing changes to the selected portfolio to ensure that the business is continually resourcing the most optimal set of capital projects.

- Quantify the economics of each technically feasible remedial option and select the most economic option subject to pragmatic decisions on project risk (likelihood that selected option can be delivered as specified)