Guideline
Methodology for assessing economic value of loss management investments

Network Demand Management Consultation Working Group

1 Introduction

The Independent Pricing and Regulatory Tribunal of New South Wales (the Tribunal) currently regulates pricing for electricity distribution services in New South Wales under the National Electricity Code. On 11 June 2004, the Tribunal released a final report (the "report") and final determination (the "determination") in relation to network pricing over the period 1 July 2004 to 30 June 2009.

The report and determination set out actions and decisions designed to provide incentives for network demand management. These decisions include:

- establishing a working group to develop a methodology for assessing the economic prudence of energy loss management investment.

The report also re-affirmed the Tribunal's position that:

- prudent loss management investments will be rolled into the asset base
- economic loss management investment should not be optimised out of the regulatory asset base.

The report sets out the following overarching objective for the working group:

- "to ensure that the distribution network service providers (DNSPs) are able to follow a methodology for assessing the value of loss reduction investments that is consistent with the Tribunal's approach to assessing the prudence of these investments as part of the roll forward of the asset base."

The report notes that the purpose of this work is to provide the greatest amount of certainty for DNSPs faced with decisions to replace or augment loss management assets.

A number of specific issues are identified for consideration by the loss management working group. These are:

- "an appropriate methodological framework for calculating the amount of energy loss avoided as a result of the investment, including any relevant avoided losses occurring on the transmission network
- an appropriate methodology for calculating the per kWh value of energy loss based on an observable historic average of pool prices
- how DNSPs could incorporate the estimates of the value of loss reductions into their capital expenditure planning assessment processes and what implications, if any, this has for the regulatory test applied by the Tribunal for assessing the prudence of capital expenditure".

In October 2004, the Tribunal established a demand management consultation group to develop principles and guidelines on a number of matters, including the methodology for assessing the economic prudence of energy loss management investment.

2 Purpose and scope of guideline

This guideline has been prepared to provide clarity for DNSPs and associated service providers in respect of one aspect of the Tribunal's approach to assessing the prudence of loss reduction investments as part of its decision on the roll forward of the asset base. The loss management investments guideline will be applied by the Tribunal when making decisions about the prudence of capital expenditure to be rolled into the regulatory asset base. These decisions will be taken at the time of the next regulatory review.

The guideline is limited to the methodology for calculating the value of loss reduction investments in the context of the Tribunal's determination and decisions. The guideline does not consider wider issues or perspectives associated with the value of loss management investments or the incentives for loss management investments. Also, the guideline does not consider the costs of such investments.

This guideline is structured as follows:

Table 1 – Structure of guideline

Ref	Section	Details
3	**Context – Tribunal's final report**	**Provides information and extracts from the final report that significantly affect the methodology for calculating the value of loss management investments and this guideline**
4	**Issues considered in developing guideline**	**Summarises a number of points raised and issues considered in the course of developing the guideline**
5	**Principles and methodology**	**Sets out the principles on which the methodology for calculating the value of loss management investments is based**
6	**Examples**	**Provides worked examples to illustrate how the methodology could be applied to different loss management investments**

3 Context - Tribunal's final report

The Tribunal's determination and final report on NSW Electricity Distribution Pricing 2004/05 to 2008/09 sets out the Tribunal's decisions associated with providing incentives for network demand management.

Extracts of the final report of particular relevance to this guideline are set out in Table 2.

Table 2 – Final report references

Reference	Details
Section 8.1 Final decisions	The Tribunal has also decided to: … ▪ establish a working group to develop a methodology for assessing the economic prudence of energy loss management investment
8.3.7 A working group will be established to develop a method for assessing the	As electricity passes through an electricity network, a certain amount of energy is lost as a result of the resistance of the network components. As a result, customers need to purchase greater quantities of electricity than they actually consume at their

<table>
<tr><th>Reference</th><th>Details</th></tr>
<tr><td>value of loss management investments</td><td>
premises. Because customers rather than DNSPs bear these costs, the Tribunal has incorporated incentives in the regulatory framework for DNSPs to invest in loss management initiatives, by allowing them to roll into their prudent expenditure on loss management equipment into their regulatory asset base. This allows them to earn a return on and of these investments.
…
[The Tribunal] is concerned about maintaining incentives for investing in loss reducing assets in the future. The treatment of expenditures to replace or augment existing loss reduction assets has implications for the incentives that DNSPs have for investing in these assets.
…
The Tribunal now re-affirms this position:

prudent loss management investments will be rolled into the asset base
economic loss management investment should not be optimised out of the regulatory asset bases.

To assess the value of a loss management investment, the net present value of losses saved as a result of the investment need to be estimated. The Tribunal believes that, in principle, this value should be based on the Long Run Marginal Cost of generation. However, it recognises that this value is not directly observable in the market place and that a variety of estimates could emerge. A more pragmatic approach could be to value losses at an average of national electricity market pool prices for NSW. This could be an historical average based on observable data and would overcome the practical difficulties of deriving an estimate of Long Run Marginal Cost.
To help resolve this valuation issue, the Tribunal will establish a working group in 2004 to develop a methodology for assessing the economic value of loss management investment. This working group will seek to identify:

an appropriate methodological framework for calculating the amount of energy loss avoided as a result of the investment, including any relevant avoided losses occurring on the transmission network
an appropriate methodology for calculating the per kWh value of energy loss based on an observable historic average of pool prices
how DNSPs could incorporate the estimates of the value of loss reductions into their capital expenditure planning assessment processes and what implications, if any, this has for the regulatory test applied by the Tribunal for assessing the prudence of capital expenditure.

The overarching objective of this working group will be to ensure that the DNSPs are able to follow a methodology for assessing the value of loss reduction investments that is consistent with the Tribunal’s approach to assessing the prudence of these investments as part of the roll forward of the asset base. It is expected that the working group will finalise this methodology soon after the commencement of the 2004-09 determination period, to provide the greatest amount of certainty for DNSPs faced with decisions to replace or augment loss management assets. The Tribunal will publish the methodology as a guideline.
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4 Issues considered in developing guideline

In considering the issues associated with loss management investments and developing the methodology set out in this guideline, the demand management consultation group explicitly considered key contextual and other issues, including the following:

- background to the Tribunal's comments on loss management investments as set out in the report (section 3 above)
- relationship between economic value and prudency in relation to assessment of potential investments in network planning
- nature and types of expenditure which could be classified as loss management investments
- potential level of activity associated with loss management investment during the 2004-2009 regulatory period
- practical issues associated with determining the quantum of losses and calculating the effect of an investment on the quantum of losses
- practical options associated with determining the value of energy avoided as a result of a loss management investment
- regulatory principles such as proportionality and materiality, including the objective of ensuring that the costs associated with implementation do not outweigh potential benefits.

The following sections address these points.

4.1 Relationship between economic value and prudence

This guideline is concerned with the "economic value" of loss management investments in relation to the Tribunal's assessment of prudent investments and asset roll-forward.

In this context, it is assumed that one criterion for prudence is that the economic value of the loss management investment should exceed the cost. Therefore, this guideline addresses the calculation of the economic value or benefit of a loss management investment as input to this assessment test.

4.2 Nature of loss management investments

The Office of Gas and Electricity Markets (Ofgem) (the electricity regulator in Great Britain) has undertaken significant work on electricity distribution losses[1]. As part of this work, Ofgem considered the categories of losses and the types of actions that could be taken to manage these losses. Three main categories of losses were identified:

- Variable losses, often referred to as copper losses, occur mainly in lines and cables, but also in the copper parts of transformers and vary in the amount of electricity that is transmitted

[1] See, for example, http://www.ofgem.gov.uk/ofgem/work/index.jsp?section=/areasofwork/distributionlosses

through the equipment. For transformers, the variable losses are sometimes referred to as copper, or "series" losses.

- Fixed losses, or iron losses, occur mainly in the transformer cores and do not vary according to current. These are also sometimes termed "shunt" losses.
- Non-technical losses, such as theft.

The first two categories of losses are relevant to this guideline. Ofgem identified a range of measures and activities that could be undertaken to manage fixed and variable losses as set out in Table 3 below.

Table 3 – Loss management activities and investments

Category	**Potential loss management activities**
Variable losses	Utilisation of capacity - because of the proportionality between losses and the square of the current, the level of losses on a network will be affected by the utilisation of its capacity. By increasing the cross sectional area of lines and cables for a given load, losses will fall. Higher voltages - because at higher voltages a lower current is required to distribute the same amount of electricity, moving to higher voltages will reduce utilisation and therefore losses on the networks. Shorter or more direct lines - the configuration of the network may have an effect on losses in terms of the length of the wires. Similarly, the location of open points on a circuit can affect the distance electricity is transported. Balancing 3 phase loads - balancing 3-phase loads periodically throughout a network can reduce losses significantly.
Fixed losses	Quality of transformer core material - the level of fixed losses in a transformer is largely dependent on the quantity and quality of the raw material in the core. Transformers with more expensive core materials, such as special steel or amorphous iron cores, incur lower losses. Eliminating transformation levels - fixed losses can also be reduced by eliminating transformation levels. Switching off transformers - another method of reducing fixed losses is to switch off transformers in periods of low demand. If two transformers of a certain size are required at a substation during peak periods, only one might be required during times of low demand so that the other transformer might be switched off in order to reduce fixed losses. This will produce some offsetting increase in variable losses and might affect security and quality of supply as well as the operational condition of the transformer itself.

The demand management consultation group considered that the measures set out in Table 3 also apply to DNSPs' loss management activities in NSW.

Implication for this guideline – there are a wide range of investments that could be considered by DNSPs when assessing loss management in network planning. The type of project and investment affects the detailed calculation of energy losses avoided. The guideline needs to be sufficiently flexible to apply to this wide range of projects and should not be specific to a particular type of investment.

4.3 Level of activity in loss management investments

DNSP members of the working group noted that, in practice, it is unlikely that a significant number of investments will be undertaken by DNSPs within the 2004 –09 regulatory period with the sole objective of managing energy losses.

While investments will be undertaken which affect losses, these investments will generally be driven by demand growth or asset refurbishment and would be assessed accordingly i.e. any such by-products would be immaterial when assessing the benefits of a project.

Implication for guideline - it is unlikely that the guideline will be applied frequently, if at all, within the 2004-09 regulatory period.

4.4 Estimation of quantum of losses in planning

The formula and laws of physics associated with electrical losses are fundamental to electrical engineering and network design and therefore integrated with good industry practice.

In practice, while manual calculations may be used to determine losses on a single line with a simple configuration, the calculation of losses is an iterative process, usually undertaken using a load-flow program, because of the following factors:

- voltage drop along overhead lines and underground cables
- nature of the load, whether constant power (such as induction motor drives) or constant impedance (where power is proportional to V^2)
- requirement to maintain receiving end voltage within limits by use of voltage regulators or tap-changing transformers
- varying power factor of loads.

Implication for guideline – the detailed methodology and formula used to calculate losses are fundamental to engineering and industry practice and do not need to be specified in this guideline. Because, in practice, these calculations are usually performed using load flow programs, it is important that the guideline recognises this approach to calculating losses within network planning.

4.5 *Options for determining the value of energy avoided*

The Tribunal’s report specifies that the per kWh value of energy loss is to be based on an observable historic average of pool prices (refer section 3 above). The report suggests that one option would be to value losses at an average of national electricity market pool prices for NSW.

The demand management consultation group considered the options for energy value that would meet the criteria of being observable and based on a historic average of pool prices. The ongoing availability and accessibility of the information was also considered.

As a result, the working group considered that use of the National Electricity Market Management Company (NEMMCo) published average price data for NSW was an appropriate approach. This data is published with varying degrees of “granularity” – such as daily or monthly; this means that the DNSP is able to match the granularity of the loss calculation (kWh) with the granularity of the energy value ($/kWh) without changing the source of the data.

The demand management consultation group noted that the value of energy avoided depends on the perspective taken and the purpose and context for the analysis. The value utilised as part of a regulatory incentive scheme for loss reduction could differ from the approach taken in the Tribunal's report and in this guideline. For example, Ofgem considered a range of costs, including environmental costs, in designing the incentive scheme and determining a value for losses. It should be noted that loss management incentives schemes were outside the remit of the working group.

Implication for guideline – the value of energy avoided should be based on the NEMMCo published average price data for NSW.

4.6 *Pragmatism, materiality and workability*

The guideline should reflect the principles of good regulatory practice, including the need to recognise the materiality of decisions affected by the guideline.

The guideline should recognise the role and magnitude of loss management investments in network planning. The guidelines should also be pragmatic and workable from the perspective of the DNSPs and Tribunal.

5 Principles and methodology

5.1 Introduction

Taking account of the analysis of the issues summarised in section 4, the demand management consultation group considered that the methodology for assessment of the economic value of loss management investments should be expressed as a series of principles together with some guiding comments on the methodology rather than by specification of detailed formula. This approach reflects the way losses are assessed in network planning and provides flexibility to consider the wide range of activities that can be used to manage losses.

The high level principles are set out in section 5.2 below.

5.2 Principles for assessment of economic value of loss management investments

The DNSP's assessment of economic value of loss management investments should reflect the following principles:

1. The economic value of a loss management investment (V_{LMI}) occurs because the investment reduces the quantity of energy lost to which a value is attributed; the calculation of V_{LMIi} for a given year should separately identify the estimated quantity of losses avoided (Q_{LMIi}) in that year and the estimated unit value of energy loss (P_{LMIi}).

   For a given year, $V_{LMIi} = P_{LMIi} * Q_{LMIi}$

2 The economic value of the loss management investment (V_{LMI}) over the life of the asset is the present value of the forecast value of losses avoided (V_{LMIi}) for each year(i) [in the planning period]

$V_{LMI} = PV(V_{LMIi})$

3 The assessment of quantity of energy loss avoided (Q_{LMIi}) and estimated unit value (P_{LMIi}) should reflect the relationship between losses and equipment/line loading.

4 The reduction in the quantity of energy lost (Q_{LMIi}) as a result of the investment should be calculated consistent with good industry practice, including utilising appropriate electricity engineering planning methodologies and tools, such as load flow software where appropriate.

5 The estimates of Q_{LMIi} and P_{LMIi} should be calculated on a consistent basis and to the same level of disaggregation/granularity. For example, if a disaggregated value of energy loss is applied in the calculation, corresponding disaggregated quantity data should be calculated.

6 The relationship between the loss management investment and the estimated energy losses avoided should be clear.

7 The level of granularity (eg time period for analysis of energy value and amount of energy loss avoided) should be determined taking account of available data, the errors associated with the estimated value of the investment and the cost of undertaking the calculation. Increasing granularity is likely to increase the cost and complexity of the calculation. For the purposes of the Tribunal's assessment, in general, it will not be necessary to increase granularity; however, the DNSP may decide to do this.

8 If data other than NEMMCo's published average price data is used to calculate P_{LMIi}, the source of the energy value(s) data applied should be transparent and referenced to a third party or independent source.

6 Theoretical examples

The details of calculating the value of loss management investments will vary considerably between projects. The following theoretical examples have been developed to indicate the types of investment that may be considered by DNSPs for managing losses, and how the economic value of the investment could be estimated for a given year.

6.1 Example 1 - parallel transformer operation

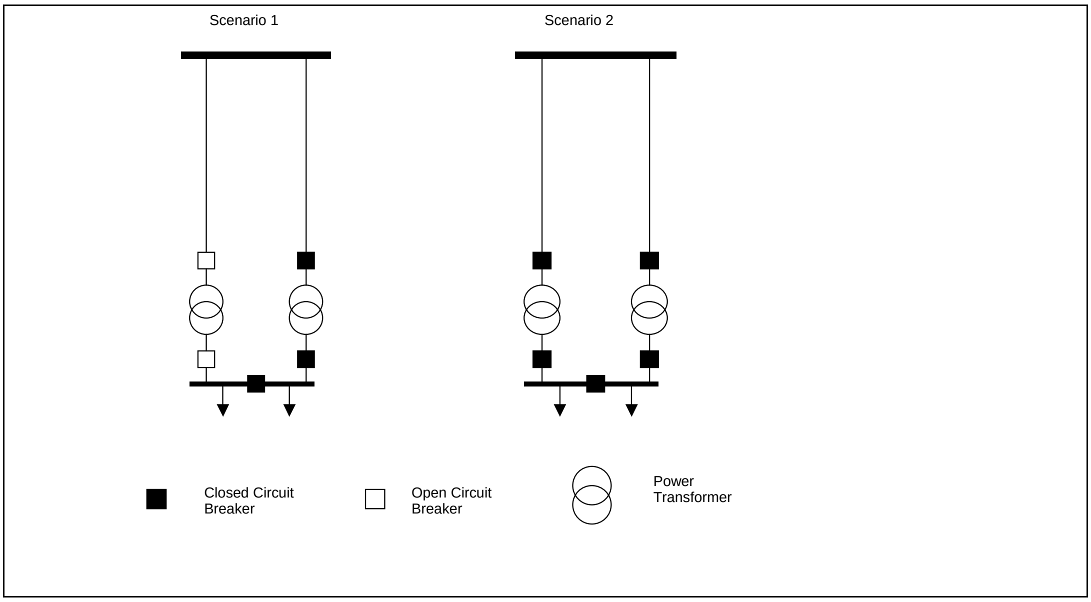
For a given network load, parallel operation transformers or supply lines reduces the loading of each individual line and transformer and there is an expectation that the loss profile may be minimised.

This example compares the loss profile between the "standby" and the "parallel" modes of operating a typical Zone Substation.

Two differing sets of scenarios have been studied.

Scenarios 1 and 2 – one on/one off versus parallel operation of transformers

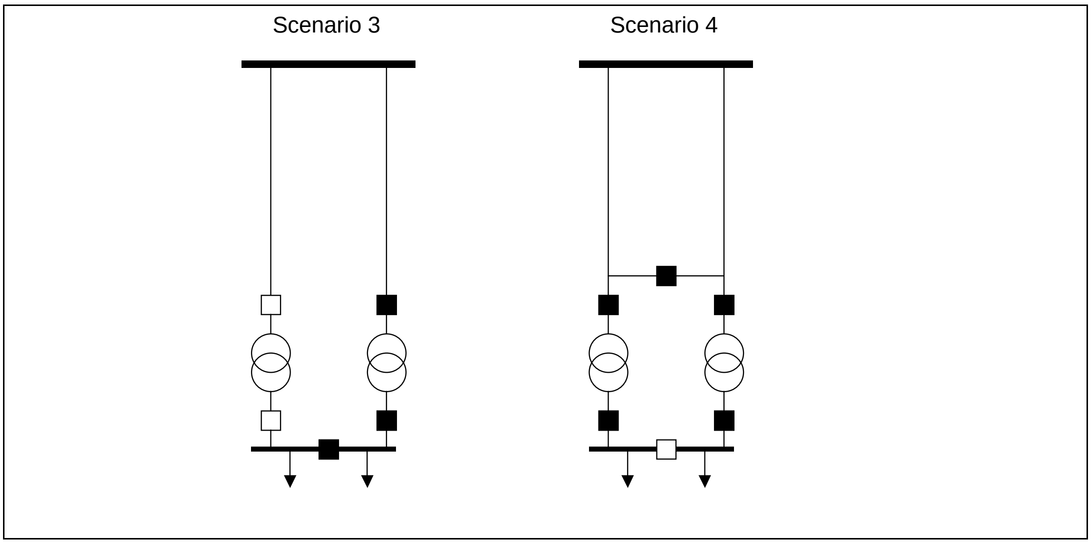
Two transformers are operated either in "one on/one off" (Scenario 1) or in parallel mode (Scenario 2) as shown below. It is assumed that there are no fault level issues with this operating mode.



To properly protect the arrangement shown in Scenario 2, it is normal to provide some form of pilot wire, or "intertripping", arrangement. This arrangement ensures that for a fault on an incoming line, only the faulty line is disconnected and no interruption of customer load occurs.

Scenarios 3 and 4 – one on/one off versus parallel operation of busbars in zone substation

The second set of scenarios compares the case where a zone substation, with a busbar on the high voltage side, is operated with a split busbar on the low voltage side. This is primarily due to the need to restrict the fault level at this busbar. Scenario 3 reflects "one on/one off" operating mode and Scenario 4 is the parallel operating mode.



The system losses under each scenario can be estimated and valued to derive a "cost" of system losses associated with each operating configuration. Table 4 below summarises the estimated losses and the annual cost of losses for the four scenarios

Table 4 – Loss profile comparison for standby/parallel operation of zone substations

Loss Estimation Calculation			
Assumed Pool Price =	40$/MWh	Loss Load Factor =	0.236
Scenario 1 (one one/one off)		**Scenario 2 (parallel mode)**	
Line Loss =	383.5kW	Line Loss =	268.8kW
Tx Shunt Loss	21.9kW	Tx Shunt Loss	32.7kW
Tx Series Loss =	192kW	Tx Series Loss =	161.9kW
Annual Cost of Losses	$55,264	**Annual Cost of Losses**	$47,075
Scenario 3 (one one/one off)		**Scenario 4 (parallel mode)**	
Line Loss =	224.7kW	Line Loss =	219.2kW
Tx Shunt Loss	21.7kW	Tx Shunt Loss	32.7kW
Tx Series Loss =	189.9kW	Tx Series Loss =	159.1kW
Annual Cost of Losses	$41,889	**Annual Cost of Losses**	$42,741

The table shows that parallel operating mode reduces the cost of losses in the case of the Scenario 1 and 2 configuration. In the case of the configuration for Scenarios 3 and 4, the parallel operating mode is estimated to increase losses.

Overall, the difference in kW losses between the parallel and one-on/one-off modes for each physical configuration is very small and translates to small difference between the estimated cost of the losses. The cost of providing the protection and control schemes required for parallel operating modes is likely to exceed the value associated with reducing losses.

6.2 Example 2 – increasing capacity of lines

An overhead line is to be constructed over a distance of 26km to a new industrial development in a rural area; the load requirement is 6.6 MW at a power factor of 0.9 lagging.

Initial design concludes that a three-phase 22 kV conductor is appropriate. However, where a load will increase to the maximum value over a medium to long time period, one option is to stage capital expenditure and achieve greater utilisation of the assets by constructing the overhead line for a higher operating voltage, say 66 kV, but operating it at a lower voltage, say 22 kV, until the voltage drop requires the additional infrastructure, such as a zone substation at each end.

The following analysis looks at the difference in line losses for this example for three different voltage and transformation options:

a) 22 kV using 37/3.00 AAAC – Nitrogen conductor

b) 66 kV using 37/3.00 AAAC - Nitrogen conductor

c) 66 kV using 6/4.75 + 7/1.60 ACSR/GZ - Cherry conductor.

For the purposes of this example, the Load Loss Factor (LLF) has been calculated empirically as:

$$LLF = 0.2 * LF + 0.8 * (LF)^2$$

Where LF is the Load Factor (= annual sales / (peak demand in kW * 8760)).

Line losses (L) = L peak * LLF * 8760

Where L peak is the losses in kW at the time of peak demand.

Table 5 below compares the energy losses for the three different voltage and transformation options[2]. It sets out the annual losses saved through installing the 66kV conductors relative to the 22 kV conductor and calculates the annual value of these saved losses assuming an energy value of $40/MWh.

Table 5 – 22 kV Nitrogen versus 66 kV Nitrogen/Cherry conductor

	LLF	Energy Sales	Calculated Losses			Loss Savings			
						(b) vs (a)		(c) vs (a)	
		MWh	MWh	MWh	MWh	MWh	$	MWh	$
Conductor			Nitrogen	Nitrogen	Cherry				
Voltage (kV)			22	66	66				
Ref			(a)	(b)	(c)				
Peak Losses (kW)			540.8	46	126				
Load factor									
0.5	0.300	28,908	1,421	121	331	1,300	$ 52,013	1,090	$ 43,604
0.6	0.408	34,690	1,933	164	450	1,768	$ 70,738	1,483	$ 59,301
0.7	0.532	40,471	2,520	214	587	2,306	$ 92,237	1,933	$ 77,324
0.8	0.672	46,253	3,184	271	742	2,913	$ 116,510	2,442	$ 97,672
0.9	0.828	52,034	3,923	334	914	3,589	$ 143,557	3,009	$ 120,346

[2] Losses in transformers have been ignored; it is assumed that either voltage regulating transformers or two-winding transformers would be required for either scenario.