westernpower

State of the Infrastructure Report

2014/15

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Introduction

Purpose

The primary purpose of Western Power's State of the Infrastructure Report ("the Report") is to provide stakeholders with information about the performance and state of the Western Power Network[1] ("the Network"). This supports improvements in the quality, transparency and alignment of decision-making by all stakeholders.

Western Power first published annual performance and asset data in this format for the year 2011/12, in response to one of the recommendations of the Parliamentary Standing Committee on Public Administration (Report 14 - Unassisted Failure) in January 2012. The Report is updated and published annually, maintaining a consistent and independently-verifiable approach to the manner in which performance data is sourced, analysed and reported.

Scope

The Report covers key transmission and distribution Network assets for the period 1 July 2014 to 30 June 2015 ("the reporting period") and provides:

- an overview of the performance of the Network with respect to public safety, the environment, supply reliability and power quality over the reporting period
- a forecast of the capacity of the Network to supply future demand
- a snapshot of the age profile, condition and risk of key Network assets as at 30 June 2015, with a comparison of the same data from previous years, where available.[2]

The Report does not present information on strategies, treatment plans or network investment programs; these are detailed in a range of other documents prepared by Western Power.

Context

Western Power's objective is to provide its customers with safe, reliable and affordable access to its electricity network. It focuses on providing agreed levels of service at the lowest practical cost, while minimising harm to the public, our workforce and the environment, and damage to property. Western Power has a robust asset management system in place to develop asset strategies and treatment plans to achieve this.

Western Power's Network investments are managed in the context of its regulatory environment, including:

- an economic regulation regime requiring investments to be demonstrably efficient in accordance with the relevant tests prescribed by the Electricity Network Access Code
- a safety regime requiring that the Network be operated as safely as is reasonably practical.

Western Power strives to maintain and operate its Network with as few incidents as is reasonably possible, given the inherent safety risks associated with operating an electricity network. Western Power's ability to address all Network risks in the short term is constrained by a range of factors, such as the volume and geographic dispersion of assets, funding and its works delivery capacity.

The risk-based prioritisation of network investment is therefore critical to optimising risk outcomes within these constraints. Western Power's approach to asset and risk management is maturing continuously to support transparent risk-based prioritisation that is more robust and defensible. It maintains a continuous dialogue with key external stakeholders to build understanding and confidence in the asset knowledge, tools and systems used to develop and support Western Power's investment decisions.

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[1] Western Power Network is a part of the network component of the South West Interconnected System (SWIS) – The SWIS is the entire interconnected system, including all the generators and small pockets of privately owned networks. (Reference Electricity Access code 2004 clause 1.3, page 31.)

[2] Historical values are reproduced from previous Reports.

1 Executive summary

The State of the Infrastructure Report focuses on five key areas:

1. public safety performance
2. environmental performance
3. reliability of supply and power quality performance
4. asset state (age and condition)
5. capacity of the Network to supply future demand.

Performance in 2014/15 in each of these areas (including overall asset state) was materially consistent with that reported for the previous year, in the context of normal year-on-year variability arising from external factors.

Western Power's public safety, environmental and reliability performance is influenced by factors such as:

- the condition of the Network
- the operating conditions and practices of the Network
- interaction with the Network by members of the public
- interaction with the Network by flora and fauna
- work practices and the actions undertaken by its workforce
- external environmental conditions.

While all asset classes were considered in preparing this Report, it presents information only on those assessed as presenting the highest levels of risk to:

- people and property due to injury or damage
- the environment
- customer reliability and quality of supply.

1.1 Public safety performance

Western Power reports on public safety performance using a range of measures agreed with its safety regulator Energy*Safety*, including the frequency of public safety incidents.

As summarised in Table 1, 229 public safety incidents were recorded during the reporting period, with no fatalities. This equates to a rolling 12-month average of 17.6 incidents per month, against an annual target of 9.5.

The increase in public safety related incidents was predominantly associated with an increase in the number of ground fires caused by third-party contact and vegetation interference with the Network.

Table 1: Public safety incidents by type

Public safety incident type	2012/13	2013/14	2014/15
Fire / damage caused by Western Power assets or inadvertent external contact with the electricity network	79	118	149
Vehicle, plant or equipment contact by public with the electricity network not resulting in fire, damage or injury	47	75	76
Injury (requiring medical treatment) or death to a person or animal from inadvertent contact with the electricity network	12	6	4
Injury (requiring medical treatment) or death to a person from electric shock where the shock was caused by the electricity network	3	0	0
Energy*Safety* order or reported defect	6	2	0
Total	**147**	**201**	**229**

1.2 Environmental performance

Western Power reports on environmental performance using a range of measures agreed with a number of environmental regulators.

These include the frequency of hydrocarbon leaks from Western Power's network assets and vehicle fleet, as summarised in Table 2. During the reporting period, 922 such incidents were recorded, 11 of which were reportable to the appropriate Regulator (three resulted from vandalism and one from a ground fire). Improvements in reporting and data capture processes have resulted in a large increase in the number of reported asset failure hydrocarbon leak incidents.

Table 2: Environmental hydrocarbon leak incidents by cause

	2012/13[3]	2013/14	2014/15
Network asset failure	N/A	459	798
Vehicle fleet	N/A	86	71
Human factors	N/A	27	20
Other (includes weather, fauna and third-party impacts)	N/A	46	33
Total	**N/A**	**618**	**922**

1.3 Reliability of supply performance

Western Power measures reliability of supply performance through:

1. corporate indicators of overall network performance
2. Service Standard Benchmarks defined by the AA3 regulatory contract
3. legislative benchmarks defined by the *Electricity Industry Act 2004 - Electricity Industry* (*Network Quality and Reliability of Supply) Code 2005* ("NQRS Code"), prescribing the metrics and performance levels expected of the distribution network.

1.3.1 Corporate indicators of overall network performance

Two measures measure the frequency and duration of power supply interruptions:

1. **Number of interruptions** (frequency) - the total number of customer interruptions lasting more than one minute on the Western Power Network after exclusions, divided by the total number of connected customers (averaged over the reporting period).
2. **Supply unavailability** (duration) - the annual sum of the duration of each customer interruption lasting more than one minute (customer minutes interrupted) on the Western Power Network after exclusions, divided by the total number of connected customers (averaged over the reporting period).

These are reported at the level of the entire Western Power Network and exclude interruptions that are:

- less than one minute in duration
- caused by generation outages and other third-party influences.

[3] Environmental performance reporting was introduced in the 2013/14 State of the Infrastructure Report and is not available for 2012/13.

Table 3 summarises the number of interruptions and minutes of supply unavailability recorded in this and the preceding two reporting periods.

Table 3: Power supply interruptions - frequency and duration

	2012/13	2013/14	2014/15
Number of interruptions	2.5	2.5	2.4
Minutes of supply unavailability	345	386	340

The largest impact on the reliability of supply was caused by lightning and bushfire events across the Metropolitan, Mid West, Wheatbelt and South West regions.

1.3.2 AA3 Service Standard Benchmarks

Under the AA3 regulatory contract, Western Power is required to:

1. maintain service levels consistent with historical averages of the three years up to 30 June 2012
2. improve service levels only where this is of value to the customer and can be done efficiently.

AA3 defines 14 Service Standard Benchmarks relating to the levels of service for distribution and transmission reliability of supply and security of supply. Of these, eight measure the frequency and duration of interruptions and minimum levels of service on the distribution network, in a manner consistent with national and international industry practice. These are based on the following metrics, categorised by area (CBD, urban or rural) and feeder length (for rural feeders):

1. **System Average Interruption Frequency Index** (SAIFI) - the average number of interruptions to a customer's supply in a year
2. **System Average Interruption Duration Index** (SAIDI) - the average total duration (in minutes) of interruptions to a customer's supply in a year.

The benchmarks exclude interruptions lasting less than one minute and those caused by generation and other third-party influences, planned interruptions, major event days and *force majeure* events.

As summarised in Table 4, all eight distribution network Service Standard Benchmarks were achieved during the reporting period, reflecting an improvement over previous years.

Table 4: Reliability performance - distribution network Service Standard Benchmarks

	2012/13	2013/14	2014/15
Distribution Service Standard Benchmarks achieved	7 of 8	7 of 8	8 of 8

The reliability performance of Western Power's transmission network is measured against the following national industry-standard benchmarks:

- **Circuit Availability** - the actual circuit hours available for transmission circuits, measured as a percentage of total possible circuit hours.
- **System Minutes Interrupted** - the summation of megawatt minutes of unserved energy resulting from interruptions caused by equipment failure at the substation which is connected to transmission network, divided by the system peak in megawatts. This is measured for:
  - the meshed transmission network
  - the radial transmission network
- **Loss of Supply Events** - the annual number of loss of supply events whose duration exceeded:
  - 0.1 system minute
  - 1.0 system minute
- **Average Outage Duration** - the annual average number of minutes of all unplanned transmission plant outages.

As summarised in Table 5, all six transmission Service Standard Benchmarks were achieved during the reporting period, with two showing marginal performance reductions compared to the previous year.

Table 5: Reliability performance - transmission network Service Standard Benchmarks

	2012/13	2013/14	2014/15
Transmission Service Standard Benchmarks achieved	6 of 6	6 of 6	6 of 6

1.3.3 NQRS Code performance metrics

The NQRS Code performance metrics measure the frequency and duration of all interruptions exceeding one minute in duration experienced by customers, regardless of cause, categorised by geographic area (CBD, urban and rural).

In accordance with the NQRS Code, Western Power reports the number of small-use customers experiencing interruptions exceeding 12 hours continuous duration, as shown in Table 6.

Table 6: Small-use customers experiencing outages exceeding 12 hours continuous duration

Measure	2012/13	2013/14	2014/15
Small-use customers experiencing at least one outage exceeding 12 hours continuous duration	38,820	43,750	37,280

This decrease is attributable to reduced storm activity and fewer pole-top fires in 2014/15.

Western Power also measures the number of small-use customers experiencing interruptions in excess of the maximum frequency permitted under the NQRS Code (9 interruptions in urban and CBD areas; 16 in all other areas), as summarised in Table 7.

Table 7: Small-use customers experiencing interruptions in excess of maximum frequency permitted

Measure	2012/13	2013/14	2014/15
Urban areas (including CBD) - small-use customers interrupted more than 9 times	8,702	12,326[4]	4,755
Other areas (including rural) - small-use customers interrupted more than 16 times	2,341	5,154	3,912
Total	**11,043**	**17,480**	**8,667**

The decrease in the number of customers impacted in urban areas was predominantly the result of fewer interruptions, both planned (to permit upgrade and maintenance activities) and unplanned (due to equipment failure). The decrease for rural customers is attributable to fewer unplanned interruptions due to overhead equipment failures.

[4] This value was reported incorrectly as 12,236 in the 2013/14 State of the Infrastructure Report. This was also reflected in the corresponding cumulative total in the Executive Summary (17,390 instead of 17,480).

1.4 Power quality performance

To ensure the correct and safe operation of network and customer equipment, Western Power monitors power quality parameters[5] on the low voltage (LV) distribution network.[6]

Table 8 summarises key power quality performance parameters.

Table 8: Power quality performance

	2012/13	2013/14	2014/15
Proportion of year in which customer voltage was potentially non-compliant	8%	8%	8%
Proportion of networks operating below 6 kV exceeding allowable range	11.7%	13.5%	13.1%

1.5 Asset state

The Network includes both overhead and underground construction and comprises millions of diverse individual assets, such as poles, towers, overhead wires, underground cables, switchgear, transformers, protection equipment and security fencing. These are of various ages and at different stages of their lifecycles, and subject to a broad range of environmental and operating conditions. A sound understanding of the state (or health) of an asset provides insight into its likelihood of failure in the future, permitting an assessment of the risk it poses. This, in turn, informs strategies and plans for maintenance and renewal activities.

Western Power classifies and reports the state of Network assets using a range of parameters, including age, condition, expected service life and risk.

While the state of assets varies significantly with type and location, the overall position at the Network level is materially unchanged from that reported in the 2013/14 State of the Infrastructure Report, as summarised in Table 9.

Table 9: Summary of asset class risk ratings

Risk area	Risk rating	Number of asset classes with rating		
		2012/13	2013/14	2014/15
Public safety	Extreme	1	0	0
	High	9	9	10
	Medium	4	4	6
	Low	6	6	6
Service	Extreme	0	0	0
	High	0	0	0
	Medium	9	9	9
	Low	6	6	7
Environmental	Extreme	0	0	0
	High	1	1	1
	Medium	0	1	1
	Low	0	0	0

A significant component of the Report is dedicated to providing an overview of the assessed state of the key classes of Network assets, as well as the associated high-level risk assessment.

5 The range of parameters monitored is in accordance with the requirements of the NQRS Code and the Technical Rules.

6 The *2014/15 Annual Reliability and Power Quality Report* presents further information on power quality performance during the reporting period.

1.6 Network capacity

The Network generally has sufficient capacity to meet short-term forecast load growth. A number of Network elements are currently experiencing capacity limitations or are projected to do so in 2015/16. Those capacity shortfalls that do not comply with planning standards will be addressed by projects planned during AA3.

Existing and emerging capacity constraints increase the likelihood of long duration customer supply interruptions following contingency events, such as the unplanned outage of a substation transformer or transmission line circuit, particularly when they coincide with adverse loading conditions, such as summer peak load days. These constraints do not represent an immediate inability to supply customers, due to the low probability of these circumstances occurring concurrently.

Table 10: Network elements forecast to exceed capacity targets (percent)

Network element	2014/15[7]	2015/16
Zone substations	5.4	3.9
Terminal substations	0.0	0.0
Metropolitan feeders	26.0	16.0
Rural feeders	2.4	2.0
Transmission lines	2.3	2.0
Distribution transformers	0.1	0.1

1.7 Year-on-year comparisons

Explanatory commentary is only provided where there is significant variance between the current year and previous years.

In comparing year-on-year performance, it is important to note that there can be significant variability for a number of reasons, including:

- the general state of assets, which influences failure rates and the frequency with which defects are found
- the geographic diversity of the Network, which influences whether a failure results in an incident
- year-on-year variability in environmental factors (e.g. the frequency and intensity of storms and lightning events, fuel loads and summer weather conditions) and public interference with the Network.

[7] These were the network elements forecast to exceed utilisation targets during 2014/15, as reported in the 2013/14 State of the Infrastructure Report.

2 Public safety performance

Western Power reports on public safety performance using a range of measures agreed with its safety regulator Energy*Safety*, including the frequency of public safety incidents.[8]

As summarised in Table 11, 229 public safety incidents were recorded during the reporting period, with no fatalities. This equates to a rolling 12-month average of 17.6 incidents per month, against an annual target of 9.5.

The increase in public safety related incidents was predominantly associated with an increase in the number of ground fires caused by third-party contact and vegetation interference with the Network.

Table 11: Public safety incidents by type

Public safety incident type	2012/13	2013/14	2014/15
Fire / damage caused by Western Power assets or inadvertent external contact with the electricity network	79	118	149
Vehicle, plant or equipment contact by public with the electricity network not resulting in fire, damage or injury	47	75	76
Injury (requiring medical treatment) or death to a person or animal from inadvertent contact with the electricity network	12	6	4
Injury (requiring medical treatment) or death to a person from electric shock where the shock was caused by the electricity network	3	0	0
Energy*Safety* order or reported defect	6	2	0
Total	**147**	**201**	**229**

Table 12 summarises public safety performance against other key indicators.

Table 12: Safety performance indicators

Safety performance indicator	2012/13	2013/14	2014/15
Notifiable incidents	61	43	28
Electric shocks that do not require medical treatment, relating to Western Power assets or activity	238	227	239
Unassisted wood pole failures (Distribution)	378	220	308
Unassisted wood pole failures (Transmission)	23	12	4
Unassisted mains conductor failures (Distribution)	383	643	264
Unassisted conductor failures (Transmission)	0	2	0
Ground fire incidents	80	118	145

Western Power reviews all reported electric shock and ground fire events and revises its asset strategies appropriately to reduce public safety risk.

Note:

From 1 July 2015, a new Public Impact performance indicator will replace the current Public Safety performance indicator. This new indicator will provide a more accurate reflection of the impact of the Western Power Network on members of the public, by reporting the public injury and public property damage incidents arising from:

1. defective Western Power Network assets
2. actions by Western Power's workforce
3. third-party actions in which substandard Western Power Network assets were a contributing factor.

[8] See Appendix A for safety reporting definitions.

3 Environmental performance

Western Power reports on environmental performance using a range of measures agreed with a number of environmental regulators.

These include the frequency of hydrocarbon leaks from Western Power's network assets and vehicle fleet, as summarised in Table 13. During the reporting period, 922 such incidents were recorded, 11 of which were reportable to the appropriate Regulator (three resulted from vandalism and one from a ground fire). Improvements in reporting and data capture processes have resulted in a large increase in the number of reported asset failure hydrocarbon leak incidents.

Table 13: Environmental hydrocarbon leak incidents by cause

	2012/13[9]	2013/14	2014/15
Network asset failure	N/A	459	798
Vehicle fleet	N/A	86	71
Human factors	N/A	27	20
Other (includes weather, fauna and third-party impacts)	N/A	46	33
Total	**N/A**	**618**	**922**

To minimise the risk of soil and ground water pollution from incidents, Western Power installs sealed bunds under transmission transformers. Table 14 summarises the status of transmission transformer bunds, which are progressively upgraded to the current standard to continually reduce the risk of a major incident. Changes reflect the installation of nine new bunds and upgrade of two existing bunds. The remaining changes are due to data validation.

Table 14: Status of transmission transformer bunds

	2012/13[9]	2013/14	2014/15[10]
Bund draining to a holding tank, polymer filter or interceptor	N/A	202	216
Containment bund draining to soil	N/A	141	136
No bund	N/A	11	14
Total	**N/A**	**354**	**366**

9 Environmental performance reporting was introduced in the 2013/14 State of the Infrastructure Report and is not available for 2012/13.

10 This value also reflects further data refinement since the publication of the 2013/14 State of the Infrastructure Report.

4 Reliability and power quality performance

4.1 Distribution network reliability performance

Reliability of supply is fundamentally important to our customers and is reflected as a key objective for Western Power.

Reliability is measured by customers' felt experience of the Western Power Network with regards to the number of sustained interruptions customers have experienced.[11] The number of interruptions and supply unavailability are both measured over a rolling 12-month period.

Western Power measures reliability of supply performance through:

1. corporate indicators of overall network performance
2. Service Standard Benchmarks defined by the AA3[12] regulatory contract
3. legislative benchmarks defined by the *Electricity Industry Act 2004 - Electricity Industry* (*Network Quality and Reliability of Supply) Code 2005* ("NQRS Code"), prescribing the metrics and performance levels expected of the distribution network.

4.1.1 Corporate indicators of overall network performance

Two measures measure the frequency and duration of power supply interruptions:[13]

1. **Number of interruptions** (frequency) - the total number of customer interruptions lasting more than one minute on the Western Power Network after exclusions, divided by the total number of connected customers (averaged over the reporting period).
2. **Supply unavailability** (duration) - the annual sum of the duration of each customer interruption lasting more than one minute (customer minutes interrupted) on the Western Power Network after exclusions, divided by the total number of connected customers (averaged over the reporting period).

These are reported at the level of the entire Western Power Network and exclude interruptions that are:

- less than one minute in duration
- caused by generation outages and other third-party influences.

Table 15 summarises the number of interruptions and minutes of supply unavailability recorded in this and the preceding two reporting periods.

Table 15: Power supply interruptions - frequency and duration

	2012/13	2013/14	2014/15
Number of interruptions	2.5	2.5	2.4
Minutes of supply unavailability	345	386	340

The largest impact on the reliability of supply was caused by lightning and bushfire events across the Metropolitan, Mid West, Wheatbelt and South West regions.

4.1.2 AA3 Service Standard Benchmarks

Under the AA3 regulatory contract, Western Power is required to:

11 Further information on reliability performance is published in the *2014/15 Annual Reliability and Power Quality Report*.

12 Western Power's current Access Arrangement (AA3) for 1 July 2012 to 30 June 2017.

13 These measures were introduced during the reporting period ending 30 June 2013.

1. maintain service levels consistent with historical averages of the three years up to 30 June 2012
2. improve service levels only where this is of value to the customer and can be done efficiently.

AA3 defines 14[14] Service Standard Benchmarks relating to the levels of service for distribution and transmission reliability of supply and security of supply. Of these, eight measure the frequency and duration of interruptions and minimum levels of service on the distribution network, in a manner consistent with national and international industry practice. These are based on the following metrics, categorised by area (CBD, urban or rural) and feeder length (for rural feeders[15]):

1. **System Average Interruption Frequency Index** (SAIFI) - the average number of interruptions to a customer's supply in a year
2. **System Average Interruption Duration Index** (SAIDI) - the average total duration (in minutes) of interruptions to a customer's supply in a year.

The benchmarks exclude interruptions lasting less than one minute and those caused by generation and other third-party influences, planned interruptions, major event days and *force majeure* events.

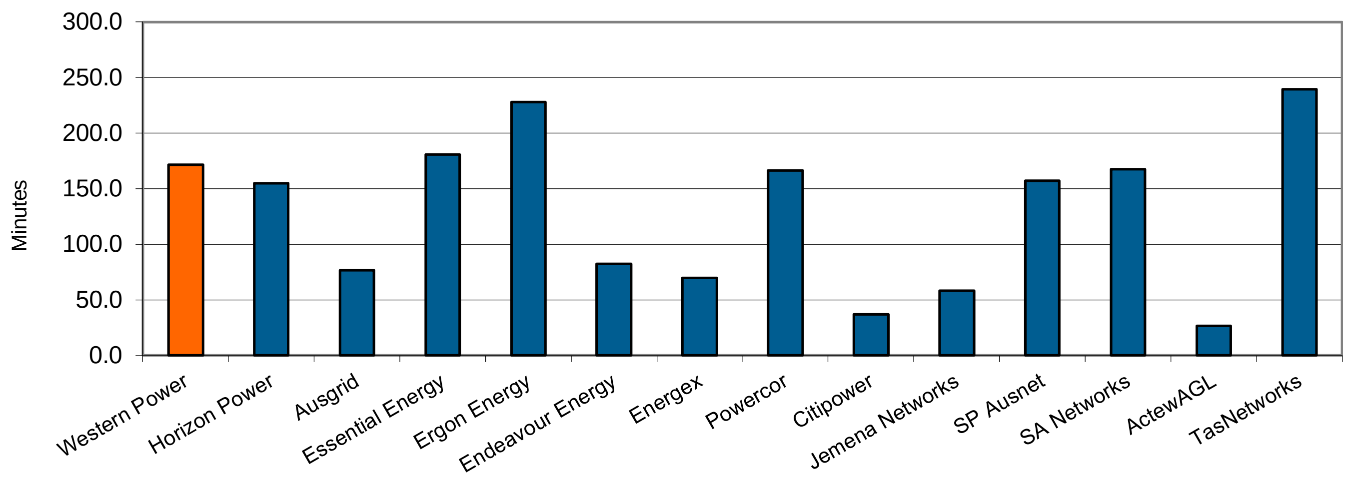
As summarised in Table 16, all eight distribution network Service Standard Benchmarks were achieved during the reporting period, reflecting an improvement over previous years.

Table 16: Reliability performance - distribution network Service Standard Benchmarks

	2012/13	2013/14	2014/15
Distribution Service Standard Benchmarks achieved	7 of 8	7 of 8	8 of 8

As these measures are similar to those used by all Australian distribution networks, they permit some degree of performance comparison, as shown in Figures 1 and 2. In doing so, it is essential to note that differences in a range of factors (such as network topology and topography and environmental influences) limit the validity and benefit of such national comparisons. Comparative statistics from other jurisdictions for the reporting period were not available at the time of compiling this report.

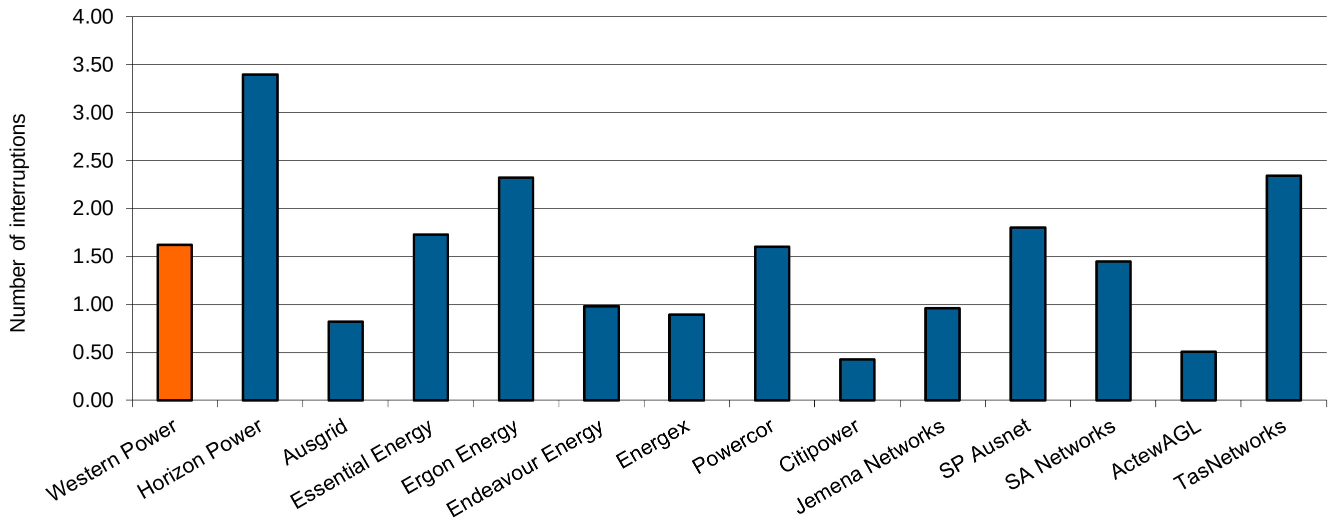
Figure 1: Reliability performance - Australian distribution networks (SAIDI, 2013/14)



14 A further three Service Standard Benchmarks report street lighting repair times (for metropolitan and regional areas) and call centre performance.

15 Rural feeders exceeding 200 km in length are defined as "Long".

Figure 2: Reliability performance - Australian distribution networks (SAIFI, 2013/14)



Figures 3 and 4 show actual performance of the CBD, Urban, Rural Short and Rural Long feeder categories against the Service Standard Benchmarks.

Figure 3: Reliability performance by feeder category (SAIDI)

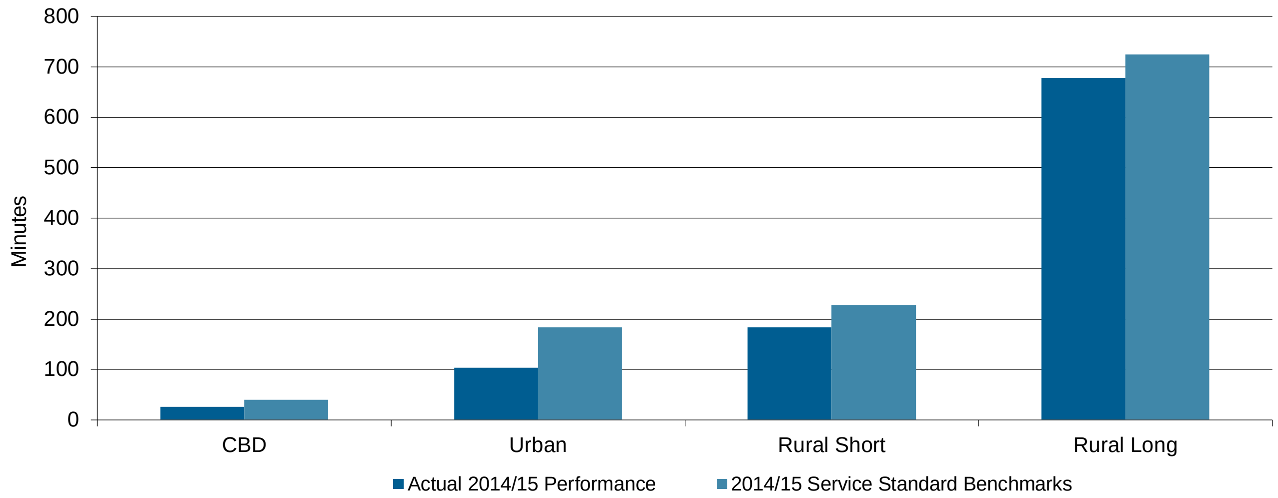
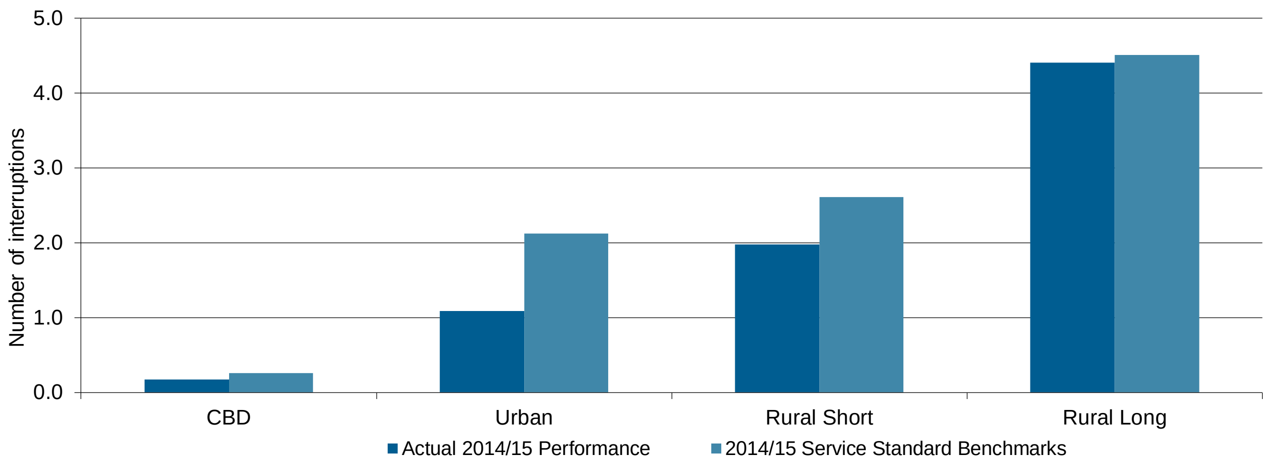


Figure 4: Reliability performance by feeder category (SAIFI)



4.1.3 NQRS Code performance metrics

The NQRS Code performance metrics measure the frequency and duration of all interruptions exceeding one minute in duration experienced by customers, regardless of cause, categorised by geographic area (CBD, urban and rural).

In accordance with the NQRS Code, Western Power reports the number of small-use[16] customers experiencing interruptions exceeding 12 hours continuous duration, as shown in Table 17.

Table 17: Small-use customers experiencing outages exceeding 12 hours continuous duration

Measure	2012/13	2013/14	2014/15
Small-use customers experiencing at least one outage exceeding 12 hours continuous duration	38,820	43,750	37,280

This decrease is attributable to reduced storm activity and fewer pole-top fires in 2014/15.

Western Power also measures the number of small-use customers experiencing interruptions in excess of the maximum frequency permitted under the NQRS Code (9 interruptions in urban and CBD areas; 16 in all other areas), as summarised in Table 18.

Table 18: Small-use customers experiencing interruptions in excess of maximum frequency permitted

Measure	2012/13	2013/14	2014/15
Urban areas (including CBD) - small-use customers interrupted more than 9 times	8,702	12,326[17]	4,755
Other areas (including rural) - small-use customers interrupted more than 16 times	2,341	5,154	3,912
Total	**11,043**	**17,480**	**8,667**

The decrease in the number of customers impacted in urban areas was predominantly the result of fewer interruptions, both planned (to permit upgrade and maintenance activities) and unplanned (due to equipment failure). The decrease for rural customers is attributable to fewer unplanned interruptions due to overhead equipment failures.

16 The NQRS Code defines small-use customers as those whose annual electricity consumption does not exceed 160 MWh.

17 This value was reported incorrectly as 12,236 in the 2013/14 State of the Infrastructure Report. This was also reflected in the corresponding cumulative total in the Executive Summary (17,390 instead of 17,480).

4.2 AA3 Transmission network reliability performance

The reliability performance of Western Power's transmission network is measured against the following national industry-standard benchmarks:

- **Circuit Availability** - the actual circuit hours available for transmission circuits, measured as a percentage of total possible circuit hours.
- **System Minutes Interrupted** - the summation of megawatt minutes of unserved energy resulting from interruptions caused by equipment failure at the substation which is connected to transmission network, divided by the system peak in megawatts. This is measured for:
  - the meshed transmission network
  - the radial transmission network
- **Loss of Supply Events** - the annual number of loss of supply events whose duration exceeded:
  - 0.1 system minute
  - 1.0 system minute[18]
- **Average Outage Duration** - the annual average number of minutes of all unplanned transmission plant outages.

As summarised in Table 19, all six transmission Service Standard Benchmarks were achieved during the reporting period, with two showing marginal performance reductions compared to the previous year.

Table 19: Reliability performance - transmission network Service Standard Benchmarks

	Benchmark	2012/13	2013/14	2014/15
Circuit Availability	≥ 97.7%	98.4%	98.3%	98.5%
System Minutes Interrupted				
Meshed network	≤ 12.50	4.50	4.82	6.9
Radial network	≤ 5.0	2.3	3.7	1.6
Loss of Supply Events				
> 0.1 system minute	≤ 33	13	20	27
> 1 system minute	≤ 4	2	1	0
Average Outage Duration	≤ 886	866	795	720

The following exclusions and assumptions apply to these benchmarks (as agreed with the ERA):

All: Interruptions caused by generation and other third-party influences, planned interruptions and *force majeure* events.

Circuit Availability: Interruptions involving non-transmission (below 66 kV) primary plant and equipment.

Assumes a maximum duration of 14 days for planned outages for major construction works (including periods in which availability is temporarily restored).

Loss of Supply Events, Average Outage Duration Interruptions less than one minute in duration.

Average Outage Duration Maximum duration of any contributing event is limited to 14 days.

[18] The > 0.1 system minutes volumes include > 1 system minute volumes.

4.3 Power quality performance

To ensure the correct and safe operation of network and customer equipment, Western Power monitors power quality parameters[19] on the low voltage (LV) distribution network.[20]

For those parts of the distribution network operating below 6 kV (nominally 240 V / 415 V), the steady-state voltage must remain within ±6% of nominal voltage under normal operating conditions. Present indicators show that the network voltage supplied to customers was potentially non-compliant for approximately 8% of the time. A voltage management program to progressively remedy this situation commenced in 2014 and is ongoing.

The nominal network voltage of 240 V (single-phase) has an operating range of 28 V (equivalent to ±6%). Of the 19,064 networks operating below 6 kV, around 2,500 (13.1%) exceed the 28 V allowable range. These occur predominantly in older, overhead network areas that have smaller size conductors. The smaller conductor size means that when the load shifts from low to full, the voltage change exceeds the allowable 28 V range.

Table 20 summarises key power quality performance parameters.

Table 20: Power quality performance

	2012/13	2013/14	2014/15
Proportion of year in which customer voltage was potentially non-compliant	8%	8%	8%
Proportion of networks operating below 6 kV exceeding allowable range	11.7%	13.5%	13.1%

19 The range of parameters monitored is in accordance with the requirements of the NQRS Code and the Technical Rules.

20 The *2014/15 Annual Reliability and Power Quality Report* presents further information on power quality performance during the reporting period.

5 State of Network assets

5.1 Introduction

The Network includes both overhead and underground construction and comprises millions of diverse individual assets, such as poles, towers, overhead wires, underground cables, switchgear, transformers, protection equipment and security fencing. These are of various ages and at different stages of their lifecycles, and subject to a broad range of environmental and operating conditions. A sound understanding of the state (or health) of an asset provides insight into its likelihood of failure in the future, permitting an assessment of the risk it poses. This, in turn, informs strategies and plans for maintenance and renewal activities.

Western Power classifies and reports the state of Network assets using a range of parameters, including age, condition, expected service life and risk.

While the state of assets varies significantly with type and location, the overall position at the Network level is materially unchanged from that reported in the 2013/14 State of the Infrastructure Report, as summarised in Table 21.

Table 21: Summary of asset class risk ratings

Risk area	Risk rating	Number of asset classes with rating		
		2012/13	2013/14	2014/15
Public safety	Extreme	1	0	0
	High	9	9	10
	Medium	4	4	6
	Low	6	6	6
Service	Extreme	0	0	0
	High	0	0	0
	Medium	9	9	9
	Low	6	6	7
Environmental	Extreme	0	0	0
	High	1	1	1
	Medium	0	1	1
	Low	0	0	0

A significant component of the Report is dedicated to providing an overview of the assessed state of the key classes of Network assets, as well as the associated high-level risk assessment.

5.1.1 Network elements

Western Power holds transmission and distribution licences for the construction, management and operation of the two distinct elements of the Network:

1. the **transmission network**, which transports electricity from generators to transmission terminal stations and then to zone substations
2. the **distribution network**, which transports electricity from zone substations to individual customers.

These elements are made up of many different types of assets. For the purposes of reporting the state of network assets, these are grouped into five broad classes:

1. structures
2. conductors
3. distribution plant and equipment
4. transmission plant and equipment
5. secondary systems.

5.1.2 Assessment of asset state

In the Report, assessment of the state of an asset is based upon:

1. **Condition** - defects, attributes and characteristics impacting the asset's serviceability.
2. **Age** - as an asset ages, the frequency and severity of defects tend to increase, progressively reducing its serviceability until intervention (repair or replacement) is required.
3. **Design life** - this is the asset's originally designed functional lifespan independent of condition. It reflects Western Power's engineering judgement, empirical evidence and data supplied by the manufacturer.
4. **Expected service life** - this is the period over which the asset is expected to serve its intended functional purpose safely, with an appropriate level of maintenance, repair or refurbishment (that is not disproportionate to the replacement cost). It takes into consideration the actual performance of the asset and the cumulative deterioration of the asset over time. The expected service life of an asset typically exceeds its design life. Exceeding expected service life does not mean an asset is likely to fail immediately, however the frequency and severity of defects and the likelihood of in-service failure are expected to increase.
5. **Risk** - risk assessment is based on the corporate risk framework and considers both consequence and likelihood of failure.

5.1.3 Data quality

The Network asset data used to support decisions has been collected over many decades. Although its quality and completeness varies across assets classes due to historical variability in type and method of collection, it is considered adequate for assessing risk and prioritising investment.

Western Power seeks to continually improve the quality and completeness of this data through improvements in technology and collection, storage and validation processes.

5.1.4 Risk management

As electricity is inherently hazardous, addressing the risk associated with the Network is a core focus of Western Power, particularly public safety risk.

Assessing the risks associated with Network assets is essential for their management, as well as informing asset management strategies and prioritising investment. This assessment considers both the likelihood and consequence of asset failures, which are influenced by factors such as:

- asset condition
- how assets are operated
- the number of customers they supply
- their proximity to the public
- the characteristics of its surrounding environment / location.

In managing public safety risk, the areas of particular focus are **electric shock**, **initiation of fires** and **injury / property damage**.

Western Power's ability to address all Network risks in the short term is constrained by a range of factors, such as the volume and geographic dispersion of assets, funding and its works delivery capacity. The risk-based prioritisation of network investment is therefore critical to optimising risk outcomes within these constraints.

Western Power's approach to asset and risk management is maturing continuously to support risk-based prioritisation that is more robust, defensible and transparent. It maintains a continuous dialogue with key external stakeholders to build understanding and confidence in the asset knowledge, tools and systems used to develop and support Western Power's investment decisions.

5.2 Structures

This asset class includes:

- poles
- towers
- dedicated streetlight metal poles[21]
- stays
- cross-arms
- foundations
- earthing related to poles and towers.

Of these assets, poles, towers, dedicated streetlight metal poles and cross-arms are identified as having the greatest potential to adversely impact public safety or reliability of the Network.

Note:

Communications structures are not discussed in this section. These structures do not carry live electrical conductors and are subject to a different asset management approach.

[21] This asset type was included within "other poles" in previous Reports, but is now reported separately due to its assessed risk level.

5.2.1 Poles and towers

Poles and towers support overhead lines and equipment in the transmission and distribution networks. Poles are categorised and managed according to their material type (wood, concrete or metal) and network type (transmission or distribution). Towers are only installed in the transmission network.

Asset conditions

Poles and towers are considered at risk of failure if they do not meet the requirements specified in AS/NZS7000:2010.

A range of conditions affect the expected service life of poles and towers:

- conditions affecting all structures:
  - fire damage
  - damage from cars and other objects
  - cracks
- conditions affecting wood poles:
  - splits
  - rot
  - insect damage (primarily termites)
- conditions affecting metal or concrete structures:
  - rust
  - metal fatigue
  - concrete cancer.

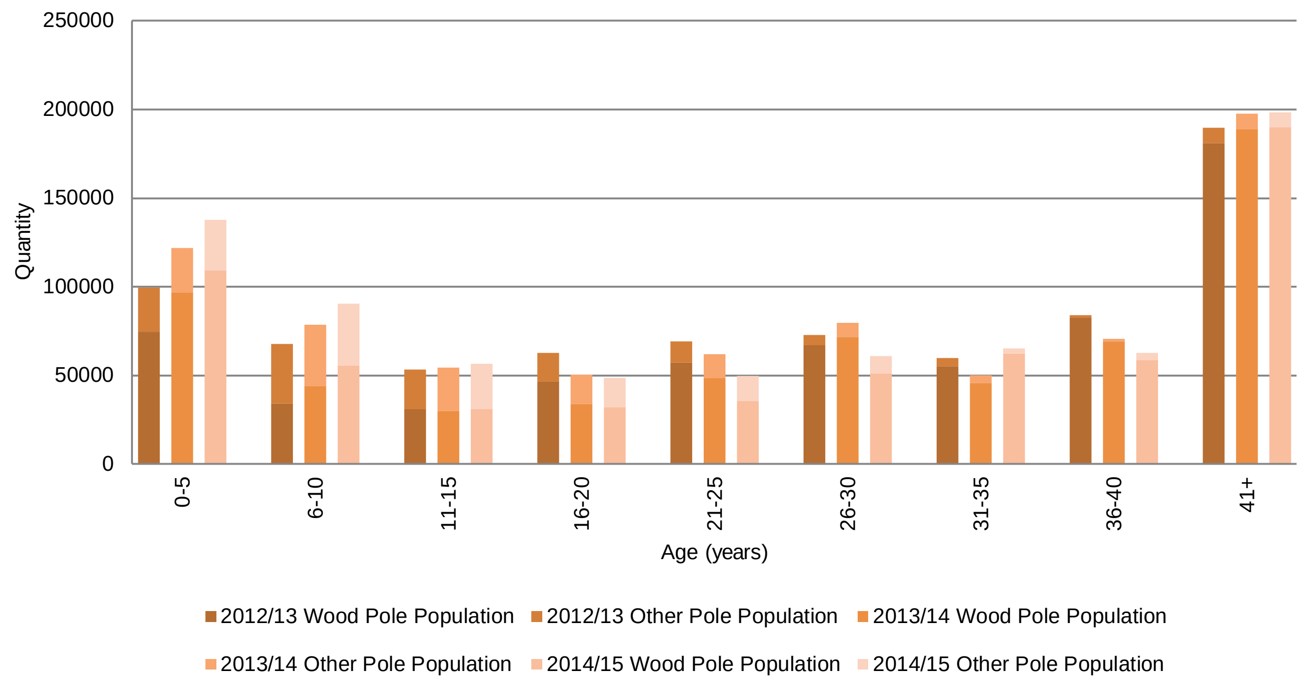
Poles and towers are regularly inspected to assess their condition. Where required, remedial actions are determined and prioritised for replacement based on risk.

Hardwood poles have an expected service life of 40 years and softwood poles have an expected service life of 50 years.

Asset age profile

The age profile of the Network's 770,535 distribution poles is shown in Figure 5. Of these, 625,654 were wood poles, of which 278,213 required treatment (removal, replacement, reinforcement or re-reinforcement), in accordance with Western Power's Wood Pole Strategy.

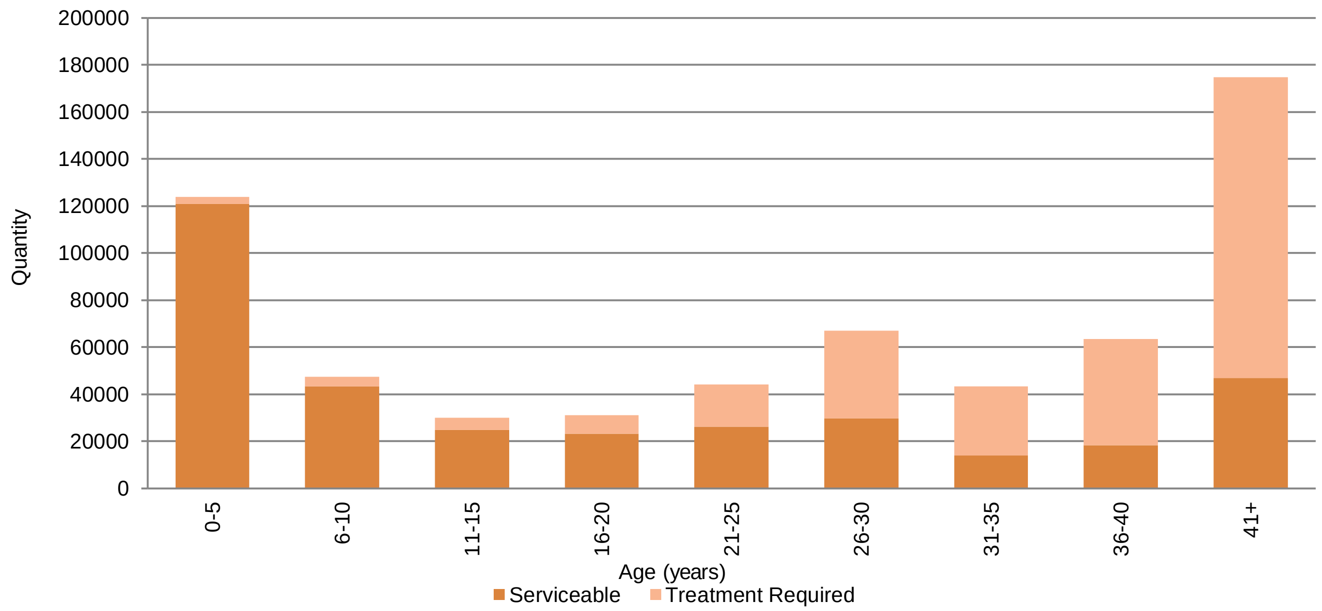
Figure 5: Age profile - distribution poles



In addition, 1352 metal poles and 47 concrete poles have been assessed as having conditions requiring replacement.

Figure 6 shows the volumes of distribution wood poles that do and do not require treatment. The decrease in the volume of distribution wood poles requiring treatment is due to increased reinforcement and replacement activity during the reporting period.

Figure 6: Treatment profile by age - distribution wood poles



Ongoing data clean-up and validation (both desktop and field-based) will introduce a degree of volatility in the volume of poles requiring treatment. Poles will only be treated once validation is carried out.

Key drivers of this volatility include:

- desktop recalculation of pole Serviceability Index, based on a new and less conservative algorithm
- validation of pole age attributes where inspection data does not match asset records
- re-inspection of poles for which there is conflicting inspection data.

Figure 7 shows the age profile of the total population of 41,238 transmission structures as at the end of the reporting period. 27,031are wood poles. Based on inspections performed from 2011/12 to 2014/15, it is estimated that 9,652 transmission wood poles require treatment (removal, replacement or reinforcement).

Figure 7: Age profile - transmission structures

Failure modes and consequences

The failure of a wood pole generally results in the pole breaking or snapping. The consequences of highest impact are:

- impact injury caused by a falling pole
- electric shocks resulting from contact with fallen conductors
- fire caused by fallen conductors touching other material
- network outages.

Towers and metal poles can also fail, particularly if corroded.

Table 22 summarises unassisted wood pole failures recorded in this and the preceding two reporting periods.

Table 22: Unassisted failures - wood poles (quantity, percentage of total population)

	2012/13		2013/14		2014/15	
	Qty	%	Qty	%	Qty	%
Unassisted failures - distribution wood poles	378	<0.1	220	<0.1	308	<0.1
Unassisted failures - transmission wood poles	23	<0.1	12	<0.1	4	<0.1

While the annual frequency of unassisted failures has declined since the start of AA3, the frequency of unassisted wood pole failures increased in 2014/15, despite the large volumes of pole reinforcements and replacements performed. This is primarily attributable to an increase in the incidence of split and decayed poles and reinforcement system failures.

Risk assessment

Table 23: Risk assessment - poles and towers

Risk area	Rating	Comment
Public safety	High	166,444 (27%) of distribution wood poles are situated in areas classified as Extreme or High bushfire risk zones; in these areas, asset failure increases the risk of fire. Distribution wood pole failures in densely populated areas also increase the likelihood of injury and damage due to physical impact and electric shock resulting from contact with fallen conductors. Distribution wood poles are assessed as presenting a High public safety risk because of the relatively large population requiring removal, replacement, reinforcement or re-reinforcement in accordance with Western Power's Wood Pole Asset Management Strategy.
Service	Low	The service impact of the failure of a distribution pole is generally limited to a relatively small number of customers. Failure of transmission structures is rare and the level of redundancy in the transmission system serves to limit the impact of their failure on reliability.

5.2.2 Dedicated streetlight metal poles

Dedicated streetlight metal poles provide structural support for luminaires and a conduit for conductors supplying the luminaire. They illuminate roads and public areas to enhance public safety and are generally present in areas with underground power.

Asset conditions

The key conditions affecting the expected service life of dedicated streetlight metal poles are:

- corrosion resulting from exposure to varying ground and weather conditions
- structural damage caused by physical impact (usually motor vehicle)
- deterioration of electrical components.

These assets are designed in accordance with the structural strength and frangibility[22] requirements of standards AS/NZS 4676 and AS/NZS 1158. The majority have "designed weakening" of the lower segment of the pole to disperse the energy of a collision impact, minimising injury risk to vehicle occupants. Such requirements limit the number of design measures that can be applied to minimise the impacts of corrosion.

Dedicated streetlight metal poles have an expected service life of 45 years.

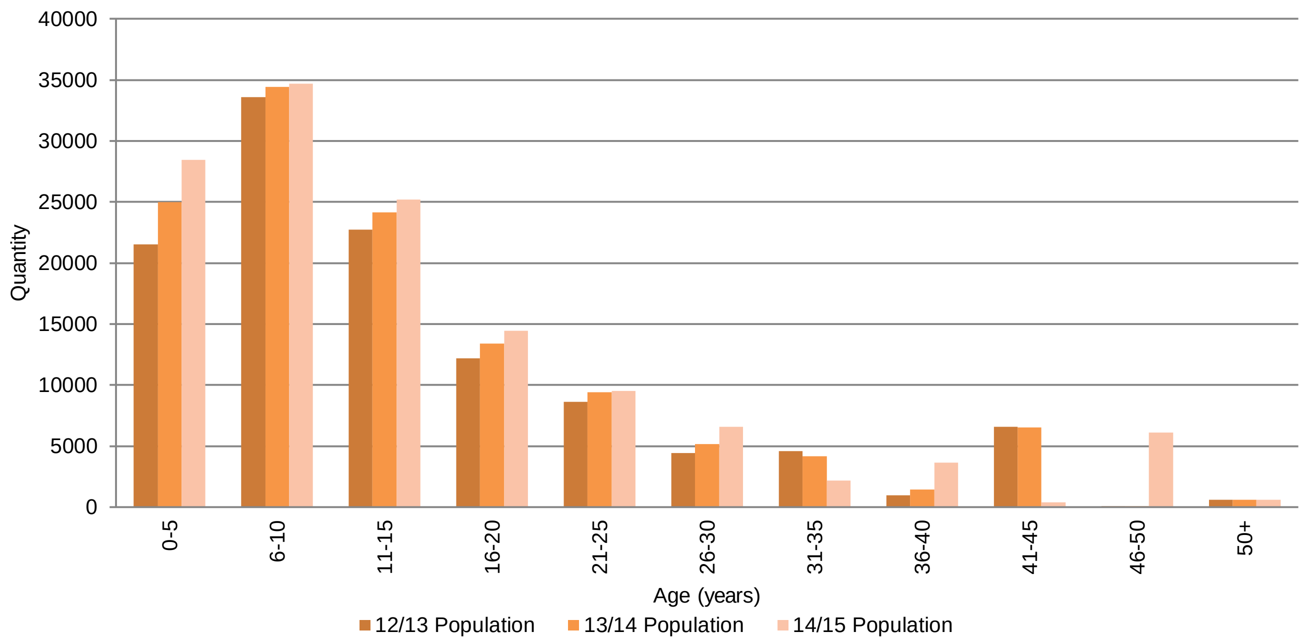
Asset profile

As shown in Figure 8, 5,654 of the network's total population of 131,774 dedicated streetlight metal poles have been identified as requiring treatment (removal, replacement or reinforcement[23]), in accordance with Western Power's strategy for managing assets of this type.

The network's population of these assets is increasing due to continued "gifting" of assets by Local Government Authority and developers and the replacement of overhead conductor (and the wood poles supporting them) under the State Underground Power Project.

Western Power replaces these assets based on condition or failure, with 1,689 replaced during 2014/15.

Figure 8: Age profile - dedicated streetlight metal poles



22 This refers to an object's propensity to break into fragments in the event of impact, rather than deforming elastically and retaining its integrity as a single object.

23 A trial for reinforcing these assets commenced in 2015 and is expected to conclude in 2015/16.

Failure modes and consequences

Most failures of dedicated streetlight metal poles are the result of structural failure (which is generally synonymous with the pole falling) or electrical failure, due to deterioration of the electrical components (such as wiring). The consequences of highest impact are:

- impact injury caused by a falling pole
- electric shocks resulting from contact with a fallen pole.

The main cause of unassisted pole failure is corrosion at the ground line.

Table 24 summarises unassisted failures recorded in this and the preceding two reporting periods.

Table 24: Unassisted failures - dedicated streetlight metal poles (quantity, percentage of total population)

	2012/13		2013/14		2014/15	
	Qty	%	Qty	%	Qty	%
Unassisted failures - dedicated streetlight metal poles	92	<0.1	63	<0.1	68	<0.1

Risk assessment

Table 25: Risk assessment - dedicated streetlight metal poles

Risk area	Rating	Comment
Public safety	High	Dedicated metal streetlight pole are assessed as presenting a High public safety risk, as they are located in populated areas, increasing the likelihood of injury and damage due to physical impact and electric shocks resulting from contact with fallen luminaires and conductive poles.

5.2.3 Distribution cross-arms

Distribution cross-arms support conductors, equipment and insulators on poles and maintain the safe separation between conductors.

Asset conditions

Cross-arms are susceptible to degradation from exposure to the weather and varying structural loads, potentially leading to failure.

A range of conditions affect the expected service life of wood cross-arms:

- splits and cracks
- fire damage
- rot.

A range of conditions affect the expected service life of steel cross-arms:

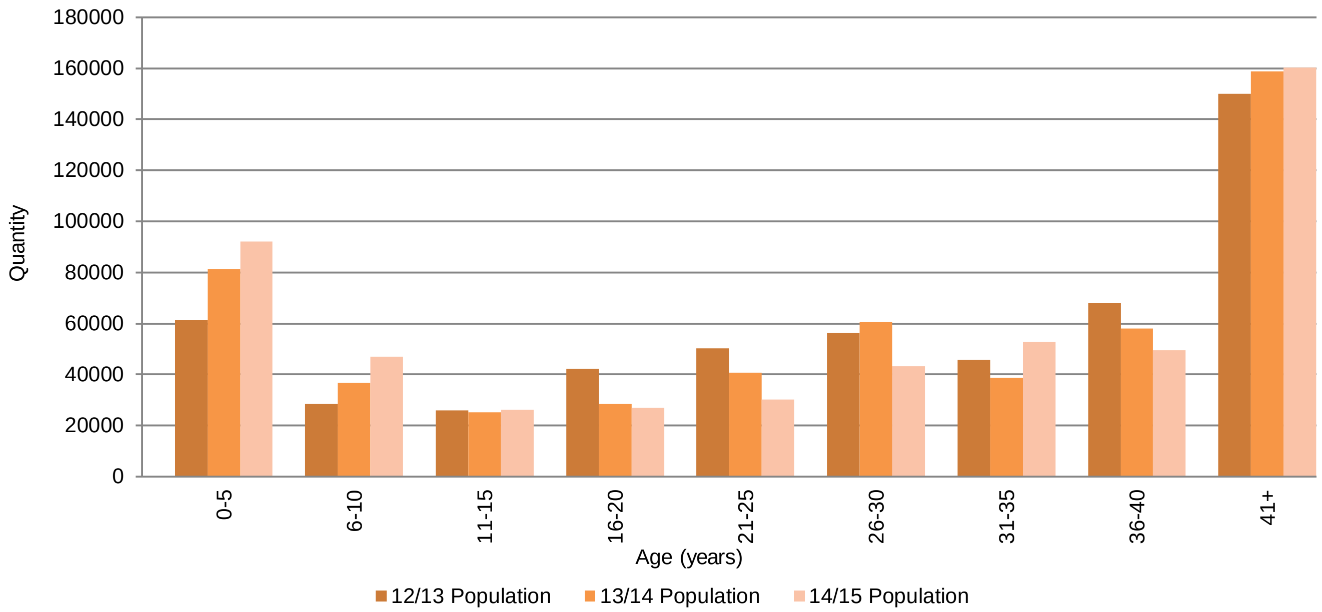
- cracked welds
- rust
- metal fatigue.

The cross-arms used in the network have expected service lives of 40 years (wood) and 50 years (steel).

Asset age profile

The age profile of the network's 528,000 distribution cross-arms is shown in Figure 9. Of these, approximately 425,000 are hardwood timber, 91,000 steel and 12,000 composite materials. The age of a cross-arm is derived from the age of the pole upon which it is mounted, as installation dates are not recorded.

Figure 9: Age profile - distribution cross-arms



The condition of cross-arms is assessed through routine inspection, with 14,024 cross-arms assessed as requiring replacement. The increase from 2013/14 is due to increased defect discovery through inspections, as a result of improved insight into failure causes.

Failure modes and consequences

The majority of failures occur in wood cross-arms and are most frequently caused by:

- breaks, rots or splits
- termite infestation
- loose hardware fasteners
- legacy wood species that are not adequate for the required duty
- dislodged insulators.

The failure consequences of greatest potential impact are:

- ground fires resulting from fallen cross-arms and conductors
- electric shock caused by contact with fallen conductors
- network outages.

Table 26 summarises unassisted failures recorded in this and the preceding two reporting periods.

Table 26: Unassisted failures - distribution cross-arms (quantity, percentage of total population)

	2012/13[24]		2013/14		2014/15	
	Qty	%	Qty	%	Qty	%
Unassisted failures - distribution cross-arms	N/A	N/A	581	0.1	417	<0.1

Risk assessment

Table 27: Risk assessment - distribution cross-arms

Risk area	Rating	Comment
Public safety	Medium	Approximately 25% of cross-arms are mounted on poles situated in areas classified as Extreme or High bushfire risk zones; in these areas, asset failure increases the risks of fire. Cross-arm failure in densely populated areas also increases the likelihood of electric shock as a result of contact with fallen conductors. Wood cross-arms are less susceptible to rot than wood poles. This asset class is assessed as presenting a Medium public safety risk.
Service	Low	The failure of a distribution cross-arm is unlikely to cause an extended outage to a large group of customers for more than one day.

[24] Separate classification of cross-arm failures commenced in 2013/14.

5.2.4 Pole-top fires

Pole-top fires occur as a result of electrical tracking between an energised conductor at the top of an insulator and an earth connection across an insulator surface. This electrical tracking can be caused by defective insulators or insulator surfaces being contaminated with pollution, in conjunction with surface moisture (from sources such as mist, dew or light rain). These pollution and weather conditions can vary significantly from year to year.

A range of conditions contributing to pole-top fires include:

- cracked or poor condition insulators
- loose hardware fasteners
- incorrect insulator type for the application
- contamination of the insulator surface.

Table 28 summarises unassisted distribution pole-top fires and resulting ground fires recorded in this and the preceding two reporting periods.

Table 28: Unassisted pole-top fires and resulting ground fires

	2012/13	2013/14	2014/15
Unassisted pole-top fires	242	435	214
Resulting ground fires	10	14	23

The reduction in pole-top fire frequency is attributed primarily to the increase in insulator silicon treatments performed during the reporting period, relative to previous years.

5.3 Conductors

This asset class includes overhead wires and underground cables and their associated accessories (such as joints, ties, luminaires and service connections) on both the transmission and distribution networks. Depending on their attributes, location and operation history, many conductors can operate safely well beyond 40 years.

5.3.1 Streetlight switchwire

The removal of all streetlight switchwire was completed in the previous reporting period (2013/14). This asset type is no longer reported.

5.3.2 Streetlight luminaires

A streetlight luminaire comprises the lamp fitting and associated wiring.

Asset conditions

Until 2006, streetlight luminaires were single-insulated in accordance with the standards in force at the time. Double insulation (Class II) wiring was implemented for streetlight assets in 2006, following revision of the relevant standard.[25]

Conditions on streetlight luminaires are identified through the Streetlight Fault Repair and Bulk Globe Replacement programs.

Streetlight luminaires have an expected service life of 20 years.

Asset profile

Of the network's population of approximately 252,702 streetlight luminaires, approximately 47,200 have reached or exceeded their expected service life.

Western Power replaces streetlight luminaires on condition or failure.

Failure modes and consequences

Deterioration of the insulation of a non-compliant single insulated luminaire can cause energisation of its metal components and the supporting pole, if constructed of metal or concrete.

The highest consequence of such an incident is electric shock resulting from contact with metal or concrete poles.

Table 29: Electric shocks resulting from streetlight luminaire failures

	2012/13	2013/14	2014/15
Electric shocks from streetlight luminaire failures	2	0	0

Risk assessment

Table 30: Risk assessment - streetlight luminaires

Risk area	Rating	Comment
Public safety	Medium	As streetlight luminaires are generally situated in populated areas, failure of insulation increases the likelihood of electric shock resulting from contact with conductive poles. The likelihood of insulation failure means that an event of this type is possible, presenting a medium risk.

[25] AS/NZS3000:2001 (Section 1.4.26).

5.3.3 Overhead distribution conductors

Overhead distribution conductors transport electricity from transmission zone substations to customers. This section relates mainly to bare (non-insulated) conductors, which have greater potential for impacting public safety than insulated conductors. Bare distribution conductors have an expected service life of 40 to 50 years.

Asset condition

A number of factors affect the expected service life of conductors:

- material
- gauge (wire diameter)
- environmental conditions
- operational loading.

The principal cause of conductor failure is reduction in strength due to corrosion and mechanical fatigue, particularly in salt-laden environments. This affects the following conductor types most seriously:

- steel conductors
- certain steel reinforced conductors
- small wire diameter, non-ferrous conductors (larger diameter non-ferrous conductors are expected to have a longer expected service life, even in adverse environmental conditions).

These attributes are used to identify conductors presenting a heightened likelihood of unassisted failure:

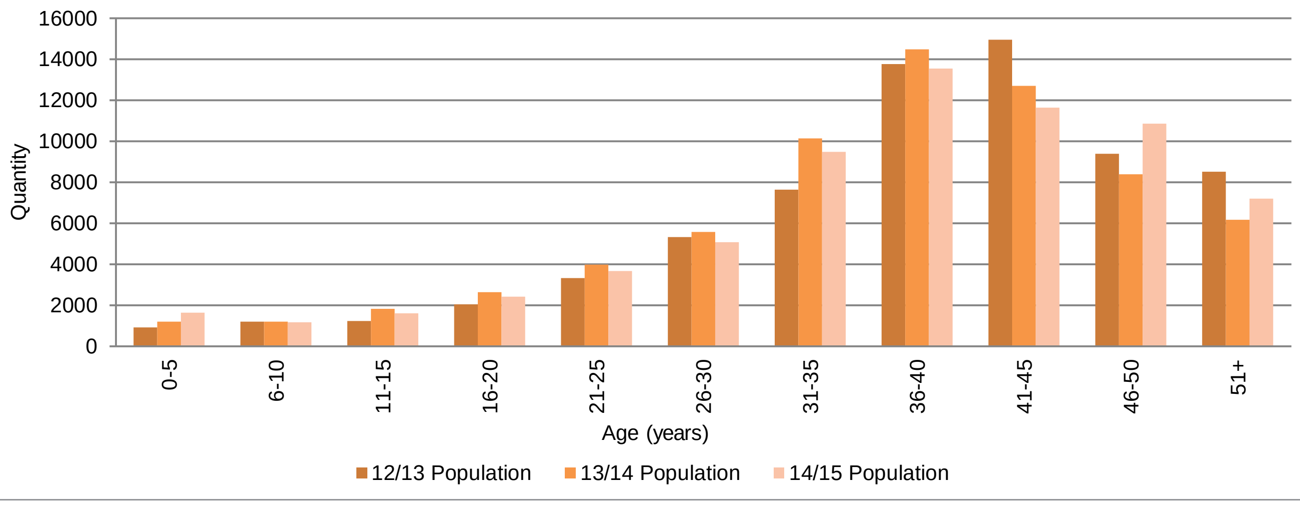
- small-gauge copper or steel (*Steel Conductor Aluminium Clad* or *Steel Coated Galvanized Zinc*) conductor more than 40 years old
- *Aluminium Conductor Steel Reinforced Conductor* with known performance issues
- *High Voltage Aerial-Bundled Conductor*
- *All Aluminium Conductor* that is more than 50 years old.

Of the network's population of 68,330 km of overhead distribution conductor (high voltage: 59,090 circuit km; low voltage: 9,240 circuit km), 26,509 km was assessed as presenting a higher likelihood of failure, with 6,858 km located in population centres or High or Extreme bushfire risk zones.

Asset age profile

As shown in Figure 10, approximately 40% of the Network's overhead distribution conductor population is more than 40 years old.

Figure 10: Age profile - overhead distribution conductors



All distribution overhead conductor age data is derived using estimation algorithms. Variations from the profile presented in the 2013/14 report are due to improved conductor age estimates.

Failure mode and consequences

The failure of overhead distribution conductors generally results in the conductor falling to the ground. The consequences of highest impact are:

- fire caused by live fallen conductors igniting other material
- electric shock resulting from contact with live fallen conductors.

Table 31 summarises unassisted distribution conductor failures recorded in this and the preceding two reporting periods.

Table 31: Unassisted failures - overhead distribution conductors (quantity)

	2012/13	2013/14	2014/15
Unassisted failures - overhead distribution conductors	383	643	264
Resulting ground fires	5	19	12

The decrease in unassisted mains conductor failures is attributable, in part, to:

- increases conductor replacement volumes in 2014/15
- year-on-year variability of weather-related events, such as storms and lightning
- improved evidence collection and investigation processes.

Risk assessment

Table 32: Risk assessment - overhead distribution conductors

Risk area	Rating	Comment
Public safety	High	Conductor failure in areas classified as Extreme or High bushfire risk zones increases the risk of fire. Failure in densely populated areas also increases the likelihood of serious electric shock accidents resulting from contact with fallen conductors.
Service	Medium	The service impact of a single distribution conductor failure is generally constrained to a relatively small number of customers.

5.3.4 Conductor clashing

Phase conductors have to maintain a minimum separation distance between each phase and earth conductor/s. Conductor clashing can occur if this separation distance is reduced sufficiently to permit electric current to travel along an unintended path between the conductors. Unassisted clashing typically results from environmental conditions (e.g. wind or ambient temperature) or fault conditions; while assisted clashing is usually caused by an external force, equipment failure, or interference with the Network. Conductor clashing occurs mainly on the distribution overhead network.

Asset conditions

A range of factors contribute to unassisted conductor clashing:

- the distance between adjacent poles ("bay" length)
- conductor tension
- conductor separation
- environmental conditions, such as orientation in relation to the direction of prevailing winds.

Asset profile

Western Power continues to investigate asset characteristics (such as "protection signatures") that correlate with increased likelihood of unassisted conductor clashing, permitting more effective prioritisation of treatment works.

Failure mode and consequences

Conductor clashing can result in conductor material sparking and the formation of droplets of molten conductor material. The highest consequences of impact are:

- fire caused by fallen droplets of molten metal
- loss of service to customers
- damage to the conductor.

Table 33 summarises unassisted clashing incidents recorded in this and the preceding two reporting period:

Table 33: Unassisted incidents and resulting ground fires - conductor clashing

	2012/13[26]	2013/14	2014/15
Unassisted conductor clashing incidents	254	155	88
Resulting ground fires	5	11	7

Risk assessment

Table 34: Risk assessment - conductor clashing

Risk area	Rating	Comment
Public safety	High	Conductor clashing in areas classified as Extreme or High bushfire risk zones increases the risk of fire. Conductor clashing is a recorded cause of ground fires.

[26] 2012/13 data includes both unassisted and assisted clashing incidents.

5.3.5 Conductor clearances

Overhead conductors crossing roadways and navigable waterways are required to provide a minimum clearance height to ensure safe passage beneath them.[27] Those that do not meet the requirements of the standards are identified by survey.

Asset profile

Of the Network's 233,368 conductor road crossings, 57,759 have been surveyed and 11,289 identified as non-compliant with current standards. Western Power has remediated all known navigable water crossings to comply with current standards.

Failure modes and consequences

Substandard conductor clearances generally result in accidental contact with conductors, the highest impact consequences of which are:

- electric shock resulting from contact with conductors
- fire caused by conductors touching other material
- conductor failure.

Risk assessment

Table 35: Risk assessment - conductor clearances

Risk	Rating	Comment
Public safety	High	Accidental contact with live conductors over road and river crossings can result in a fatality, but the likelihood is rare.

[27] These requirements are specified in AS/NZS7000:2010.

5.3.6 Overhead customer service connections

Overhead customer service connections connect individual customer properties to the low voltage overhead distribution network.[28]

Asset condition

The majority of older overhead customer service connections use preformed steel wire helical terminations with a known failure mode, as detailed below.

There is also evidence of other overhead customer service connection conditions with the potential to lead to electric shock, including substandard installation and repair practices. Western Power is investigating the prevalence of these issues and will commence their remediation once the extent of the potential hazard is better understood. Work practices have been changed to prevent future occurrences of these conditions.

Asset profile

As summarised in Table 36, the estimated population of overhead customer service connections was 373,612, of which 9,500 were of the older type that used preformed steel wire helical terminations.

Table 36: Asset population - overhead customer service connections

	2012/13	2013/14	2014/15
Overhead customer service connections	449,543	393,847	373,612
Connections with preformed steel wire helical terminations	34,865	53,012	9,500

The reduction in the reported population of overhead customer service connections is due to a combination of improved data accuracy and the progressive removal of these assets from the network through the undergrounding of these connections. The decrease in the number of older type overhead customer service connections is due to the replacement program[29] and improved data accuracy.

Failure modes and consequences

The most common cause of failure with the older connection types is degradation of insulation material. The highest consequence of impact is electric shock from contact with metal components energised as a result of the failure.

Table 37 summarises electric shocks recorded as a result of overhead customer service connection failures recorded in this and the preceding two reporting periods.

Table 37: Electric shocks - overhead customer service connections

	2012/13	2013/14	2014/15
Electric shocks from overhead customer service connection failures	166	168	135

Risk assessment

Table 38: Risk assessment - overhead customer service connections

Risk area	Rating	Comment
Public safety	High	Failure increases the likelihood of electric shock.

[28] Overhead customer service connections are a subset of customer service connections.

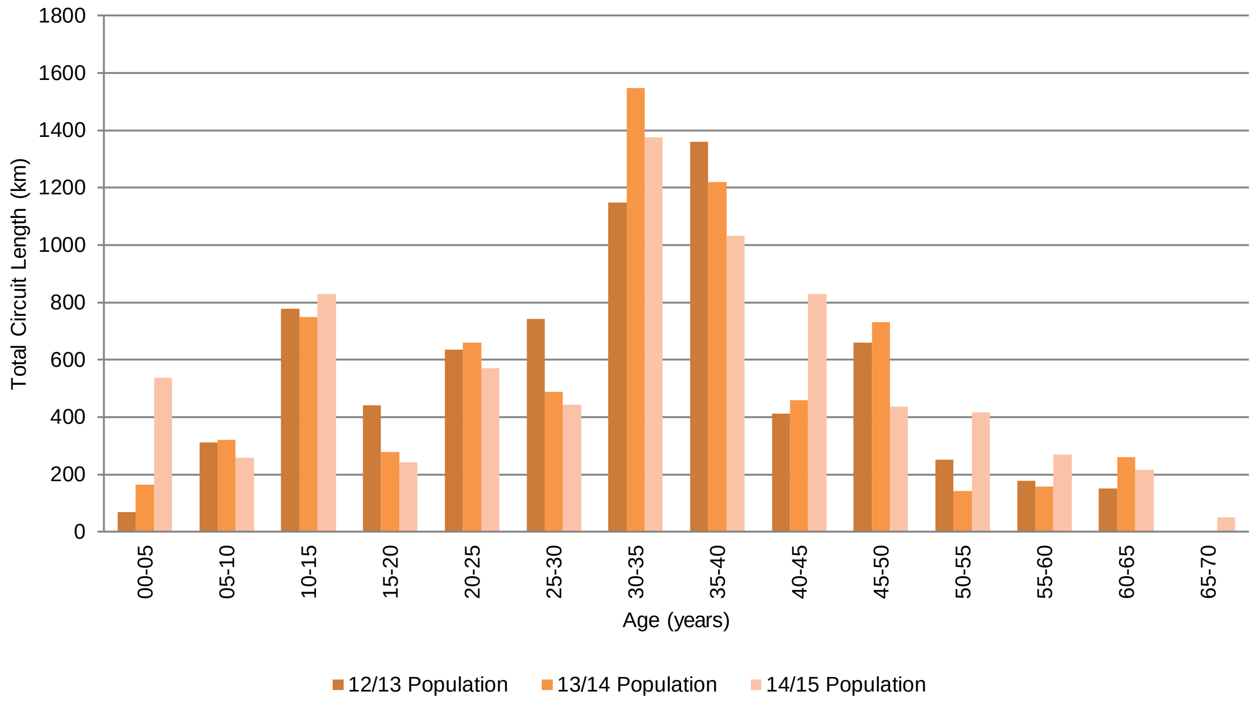
[29] In 2005, Western Power commenced a program to replace all overhead customer service connections known to have preformed steel wire helical terminations with a connection compliant with current standards (WA Electrical Requirements (WAER) July 2008 and AS/NZS 3000:2007). Replacement of the 9,500 known remaining connections of this type will be completed by 31 December 2015. Other service connections of this type may also be replaced under the State Underground Power Program or other maintenance programs.

5.3.7 Overhead transmission conductors

Overhead transmission conductors and accessories for overhead line circuits such as clamps, ties, vibration dampers and terminations, operate at voltages greater than 33 kV. The conductors enable the transfer of power from generator sources to transmission terminal substations.

The expected service life of transmission conductors is 60 years and the overall age profile of conductors by voltage is shown in Figure 11. Only a small percentage of the transmission conductor population has exceeded the expected service life.

Figure 11: Age profile - overhead transmission conductors



As summarised in Table 39, there were no unassisted conductor failures on the overhead transmission network, however there is an increasing volume of defects.

Table 39: Unassisted failures - overhead transmission conductors (quantity)

	2012/13	2013/14	2014/15
Unassisted failures - overhead transmission conductors	0	2	0

Table 40: Risk assessment - transmission overhead conductors

Risk area	Rating	Comment
Public safety	Medium	Conductor failure in areas classified as Extreme or High bushfire risk zones increases the risk of fire. Failure in densely populated areas also increases the likelihood of serious electric shock accidents resulting from contact with fallen conductors.
Service	Low	These overhead conductors generally present a low risk to supply due to the level of redundancy designed into the transmission network.

As the overall risk presented by transmission overhead conductors remains moderate, this asset type is not reported in detail.

5.3.8 Transmission underground cables

The underground transmission network comprises a range of high voltage (66 kV, 132 kV and 330 kV) cable types.[30] Some of these rely on a fluid insulation medium (typically oil) whose pressure is maintained by means of a reservoir and pressurisation equipment at each end of the cable.

Asset conditions

The likelihood of fluid leakage increases as this type of cable approaches the end of its expected service life of 40 years or as a result of physical damage.

Asset profile

As at the end of the reporting period, the Network's 52 km of transmission underground cable included 12 km containing fluid insulation medium, of which 10 km (83%) is nearing the end of its expected service life, or has exceeded it.

Failure modes and consequences

The most common failure mode for fluid filled cables is insulating fluid leakage, typically resulting from:

- cable joint failure
- mechanical fatigue causing cracks in cable sheaths
- damage to outer cable coverings causing corrosion of the metallic sheath
- extrusion damage during manufacture.

Table 41 summarises leaking fluid filled transmission cables recorded in this and the preceding two reporting periods.

Table 41: Leaking fluid-filled transmission cables

	2012/13	2013/14	2014/15
Unassisted cable sheath failures	2	2	2
Cables requiring additional top-ups	3	3	4
Volume of oil leaked (litres)	2,124	1,640	1,056

The fluid loss is attributed to two unassisted cable sheath failures that took an extended period to locate and repair and four cables requiring additional top-ups.

Risk assessment

Table 42: Risk assessment - underground transmission cable

Risk area	Rating	Comment
Environment	High	The leakage of insulating fluid presents a high environmental risk and incurs recurrent operating costs.
Public safety	Low	Underground cables present a low safety risk.
Service	Low	These cables generally present a low risk to supply due to the level of redundancy designed into the transmission network.

30 This excludes lower voltage cables within transmission zone and terminal substations.

5.4 Distribution plant and equipment

Distribution plant and equipment assets include all distribution network equipment other than structures, conductors and secondary systems. These assets are characterised by their high volumes and relatively low public safety and reliability impact of individual failures. On rare occasions, however, such failures can have significant impact, such as fire ignition.

Distribution plant and equipment consists of asset classes with similar life-cycle management characteristics. These asset classes include but not limited to:

- reclosers
- sectionalisers
- pole-top switch disconnectors
- ring main units
- dropout fuses
- distribution transformers
- substation enclosures
- voltage regulating transformers
- capacitor banks
- underground residential distribution pillars.

Improved data collection techniques and fault detection have provided an opportunity to assess higher volumes of distribution plant and equipment asset conditions. This condition information feeds into a range of qualitative and quantitative risk analysis tools and techniques. The resultant understanding of the risk profile of distribution plant and equipment assets informs the prioritisation of assets for replacement, based on risks to safety, customer supply and the environment ; i.e. when under taking replacement of distribution plant and equipment assets, priority is given to those located in close proximity to schools, hospitals, shopping malls, etc.

Western Power has further programs to address the safety and reliability impacts of distribution plant and equipment, including some that are typically addressed through routine maintenance activities such as:

- ground-mounted substation and switchgear security inspections
- updating switchgear labelling.

Typical failure modes of distribution plant and equipment assets are caused by:

- conditions, such as corrosion, oil leaks, overload and wear of operating mechanisms
- environmental factors, e.g. lightning strike, vegetation growth and fauna.

Failure of switchgear, namely pole-top switch disconnectors, reclosers and sectionalisers, expulsion dropout fuses and transformers present the greatest potential for impacting safety and reliability. These assets are discussed in detail in the following sections.

5.4.1 Pole-top switch disconnectors

A pole-top switch disconnector (PTSD) is a ganged (3-phase) manually-operated load break device, used to provide switching, isolation and bypass functionality on the high voltage overhead distribution network.

Asset conditions

A range of conditions affect the expected service life of pole-top switch disconnectors:

- poor contacts
- corrosion
- insulation degradation
- defective earthing
- defective or malfunctioning operating mechanism.

Table 43 summarises the population of this asset type requiring replacement due to assessed conditions.

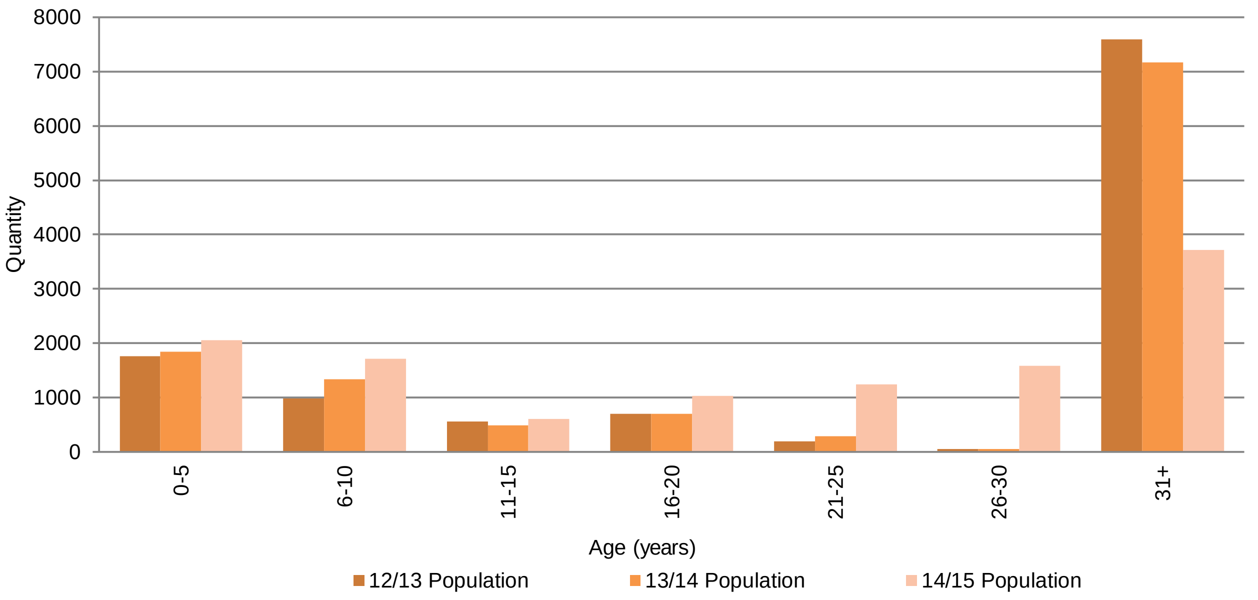
Table 43: Assets with conditions requiring replacement - pole-top switch disconnectors (quantity, percentage of total population)

	2012/13		2013/14		2014/15	
	Qty	%	Qty	%	Qty	%
Assets with conditions requiring replacement - pole-top switch disconnectors	353	3.0	290	2.4	281	2.4

Asset age profile

A significant proportion of pole-top switch disconnectors have exceeded their 30 year expected service life. Fewer assets of this type have been installed over the last 20 years, with reclosers and sectionalisers now preferred options for switchgear. Figure 12 shows the age profile of pole-top switch disconnectors.

Figure 12: Age profile - pole-top switch disconnectors



Failure modes and consequences

Pole-top switch disconnector failures are typically caused by component failure, preventing the operator from operating the switch. Depending on condition, failed units may remain in service, with reduced operational flexibility. The key consequence of failure is an increase in the number of customers affected by network outages.

Table 44 summarises pole-top switch disconnector failures recorded in this and the preceding two reporting periods.

Table 44: Failures - pole-top switch disconnectors

	2012/13		2013/14		2014/15	
	Qty	%	Qty	%	Qty	%
Pole-top switch disconnector failures	66	0.6	159	1.3	95	0.8

As pole-top switch disconnectors are static devices, failure is usually only identified when the individual asset is required to operate. The increased activity on the network, particularly due to the pole replacement program, requires larger numbers of pole-top switch disconnectors to be operated more frequently, leading to greater visibility of failure. Their failure rarely poses a public safety risk.

Risk assessment

Table 45: Risk assessment - pole-top switch disconnectors

Risk area	Rating	Comment
Public safety	Medium	The likelihood of fire ignition is assessed as unlikely.
Service	Medium	Failure may result in an increased number of customers being affected by network outages.

5.4.2 Reclosers

A recloser is an automatic protection / witching device installed on the high voltage overhead distribution network to detect and isolate faults on a line. It will automatically attempt to restore power i.e. reclose, after a predefined period, but if the fault is still present it will again trip. If the fault persists, the recloser it will 'lock-out" after up to four failed attempts to restore power. It will need to be operated manually, either locally or remotely, to restore power once the fault is cleared.

As part of Western Power's Bushfire Management Plan, reclosers in High bushfire risk zones are temporarily configured to a single reclose attempt during the bushfire season, to mitigate the risk of igniting a fire for multiple reclose attempts.

Reclosers installed on the network improve service continuity and minimises the number of customers impacted by network outages.

Asset conditions

A range of conditions affect the expected service life of reclosers:

- corrosion
- loose connections
- low gas level
- communication system faults.

Table 46 summarises the population of this asset type requiring replacement due to assessed conditions.

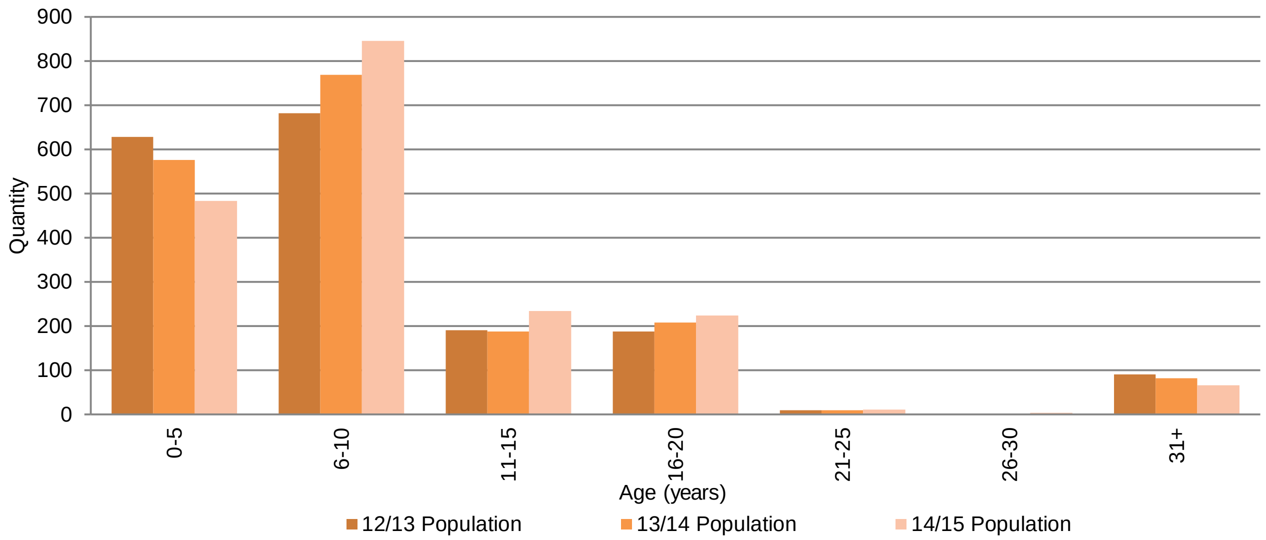
Table 46: Assets with conditions requiring replacement - reclosers (quantity, percentage of total population)

	2012/13		2013/14		2014/15	
	Qty	%	Qty	%	Qty	%
Assets with conditions requiring replacement - reclosers	163	9.1	143	7.8	126	6.8

Asset age profile

The majority of reclosers were installed in the last 20 years in preference to pole-top switch disconnectors, with a small number of reclosers having exceeded their expected service life of 25 years. Figure 13 shows the age profile of reclosers.

Figure 13: Age profile - reclosers



Failure modes and consequences

Recloser failures are typically caused by:

- corrosion of the tank
- deterioration of external connections
- low gas level
- electronic component failure.

Depending upon condition, failed units may remain in service with reduced operational flexibility, potentially affecting reliability. The key consequence of failure is an increase in the number of customers affected by network outages.

Table 47 summarises recloser failures recorded in this and the preceding two reporting periods.

Table 47: Failures - reclosers

	2012/13		2013/14		2014/15	
	Qty	%	Qty	%	Qty	%
Failures - reclosers	24	1.3	119	6.5	67	3.6

Risk assessment

Table 48: Risk assessment - reclosers

Risk area	Rating	Comment
Public safety	Low	The likelihood of fire ignition is assessed as rare.
Service	Medium	Failure may result in an increased number of customers being affected by network outages.

5.4.3 Sectionalisers

A sectionaliser is an automatic isolation device installed on the high voltage overhead distribution network usually used in conjunction with a recloser to isolate and help to identify the faulted section/s of line. Sectionalisers are not currently telemetered.

Asset conditions

A range of conditions affect the expected service life of sectionalisers:

- corrosion
- mechanical failure
- oil leaks
- insulation degradation.

Table 49 summarises the population of this asset type requiring replacement due to assessed conditions.

Table 49: Assets with conditions requiring replacement - sectionalisers (quantity, percentage of total population)

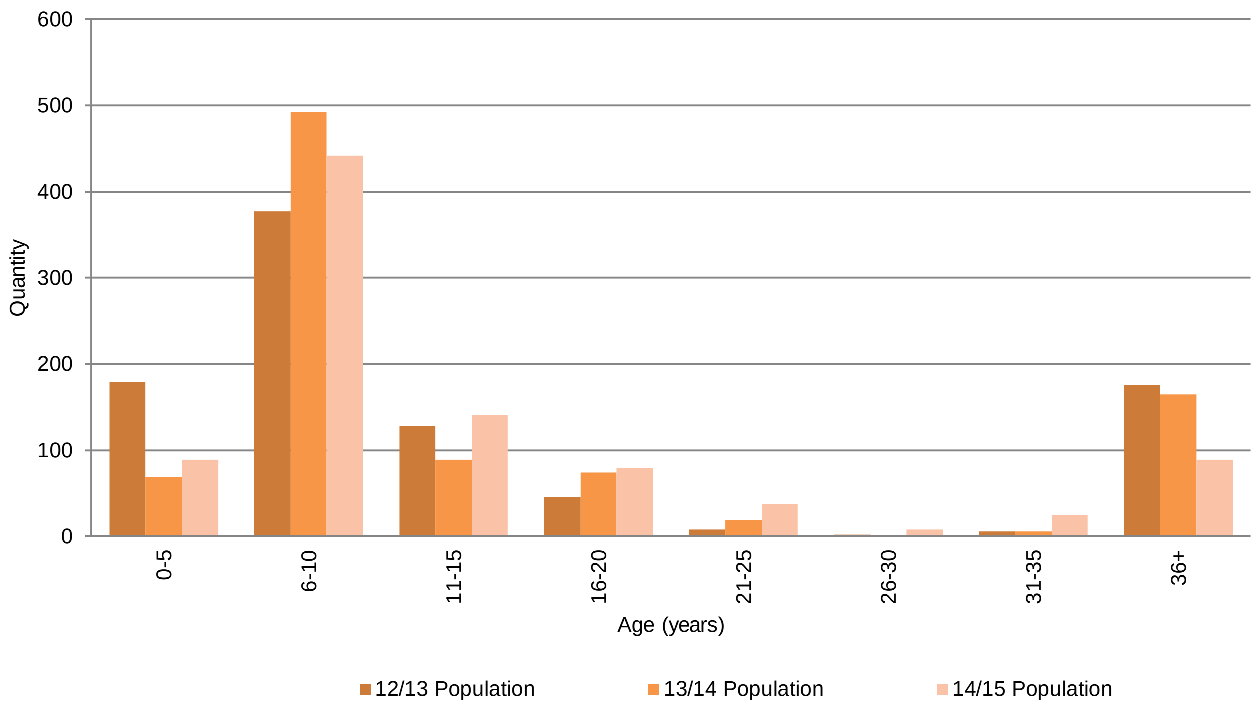
	2012/13		2013/14		2014/15	
	Qty	%	Qty	%	Qty	%
Assets with conditions requiring replacement - sectionalisers	114	12.4	73	8.0	91	10.0

The increase in this reporting period is attributable to the correction of defect data.

Asset age profile

The majority of sectionalisers have been installed over the last 20 years, with a small number having exceeded their expected service life of 35 years. Figure 14 shows the age profile of sectionalisers.

Figure 14: Age profile - sectionalisers



Failure modes and consequences

Sectionaliser failures are typically caused by:

- contacts failing to open to isolate the faulted section
- electronic component failure.

Depending upon condition, units that fail to operate may remain in service with reduced operational flexibility and potentially affect reliability. The key consequence of failure is an increase in the number of customers affected by network outages.

Table 50 summarises sectionaliser failures recorded in this and the preceding two reporting periods.

Table 50: Failures - sectionalisers

	2012/13		2013/14		2014/15	
	Qty	%	Qty	%	Qty	%
Failures - sectionalisers	8	0.9	2	0.2	26	2.9

Risk assessment

Table 51: Risk assessment - sectionalisers

Risk area	Rating	Comment
Public safety	Low	The likelihood of fire ignition is assessed as rare.
Service	Medium	Failure may result in an additional number of customers being affected by the network outage.

5.4.4 Distribution transformers (≥ 100 kVA)

Distribution transformers convert high voltages in the distribution network to the lower voltage levels required for customer connections.

This section considers only distribution transformers equal or larger than 100 kVA, as these generally supply multiple customers and have a greater service impact in the event of failure.

Asset conditions

A range of conditions affect the expected service life of distribution transformers:

- corrosion
- oil leaks
- bushing failures
- insulation degradation
- bushing / turret defects
- overloading.[31]

Distribution transformers rated 100 kVA and higher are managed assets. As a result of improved data collection techniques, network modelling and fault detection, distribution transformers are replaced proactively in the following situations:

1. a predicted transformer overload situation
2. a transformer being assessed as unserviceable or identified with type defects
3. opportunistic, aged-based replacement, when it is more economical to do so in conjunction with pole and conductor replacement.

Table 52 summarises the population of this asset type requiring replacement due to assessed conditions.

Table 52: Assets with conditions requiring replacement - distribution transformers (quantity, percentage of total population)

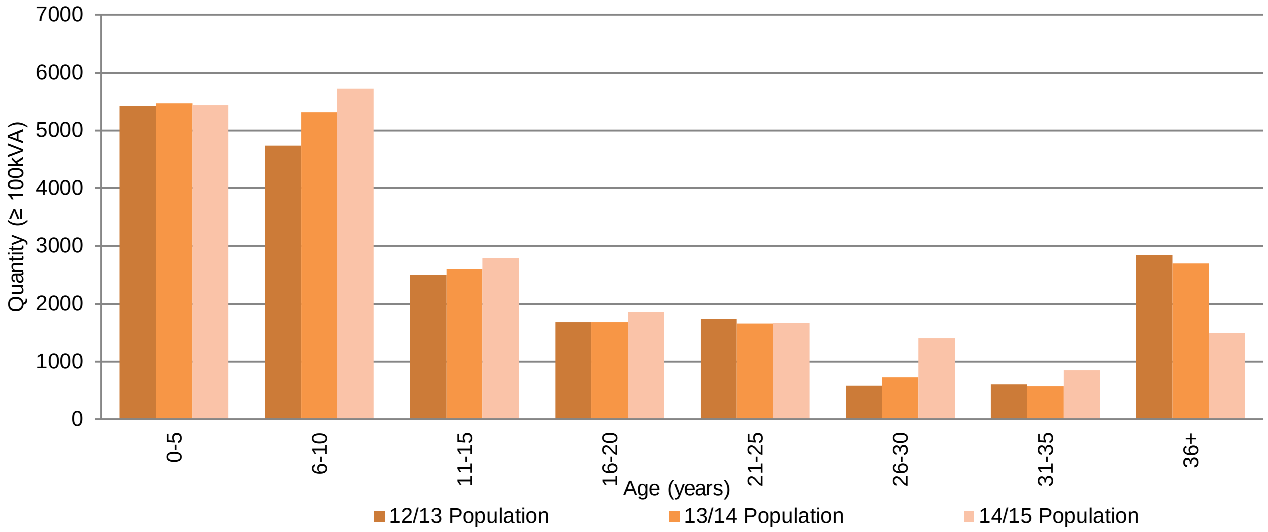
	2012/13		2013/14		2014/15	
	Qty	%	Qty	%	Qty	%
Assets with conditions requiring replacement - distribution transformers	343	1.7	321	1.5	331	1.6

[31] This factor is discussed in detail in Section 6 (Capacity).

Asset age profile

82% of the population is expected to provide reliable service for approximately another 10 years, while 7% of distribution transformers have exceeded the expected service life of 35 years. Figure 15 shows the age profile of distribution transformers.

Figure 15: Age profile - distribution transformers (≥ 100 kVA)



Failure modes and consequences

Distribution transformer failures are typically caused by:

- bushing / turret failure
- corrosion
- insulation failure
- oil leaks
- overload
- lightning strikes.

Failed units are replaced as an emergency response activity. The key consequence of failure is an increase in the number of customers affected by network outages.

Table 53 summarises distribution transformer failures recorded in this and the preceding two reporting periods.

Table 53: Failures - distribution transformers

	2012/13		2013/14		2014/15	
	Qty	%	Qty	%	Qty	%
Failures - distribution transformers	185	0.9	79	0.4	114	0.6

Risk assessment

Table 54: Risk assessment - distribution transformers (≥ 100 kVA)

Risk area	Rating	Comment
Public safety	Medium	It is possible for a distribution transformer failure to lead to a minor injury.
Service	Medium	Failure is likely to result in extended outages for about 80 to 200 customers.[32]
Environmental	Medium	It is possible for these assets to cause localised environmental damage with short-term effects.

[32] This is indicative, based on a 315 kVA transformer.

5.4.5 Dropout fuses

Dropout fuses protect distribution assets and distribution line segments by de-energising faulted portions of the network when subjected to a fault current.

In contrast with all other asset types reported, the key risk area associated with dropout fuses is a consequence of normal operation (in which a quantity of molten metal is expelled), rather than failure.

Asset conditions

A range of conditions affect the expected service life of dropout fuses:

- corrosion
- component deterioration.

Table 55 summarises the population of this asset type requiring replacement due to assessed conditions.

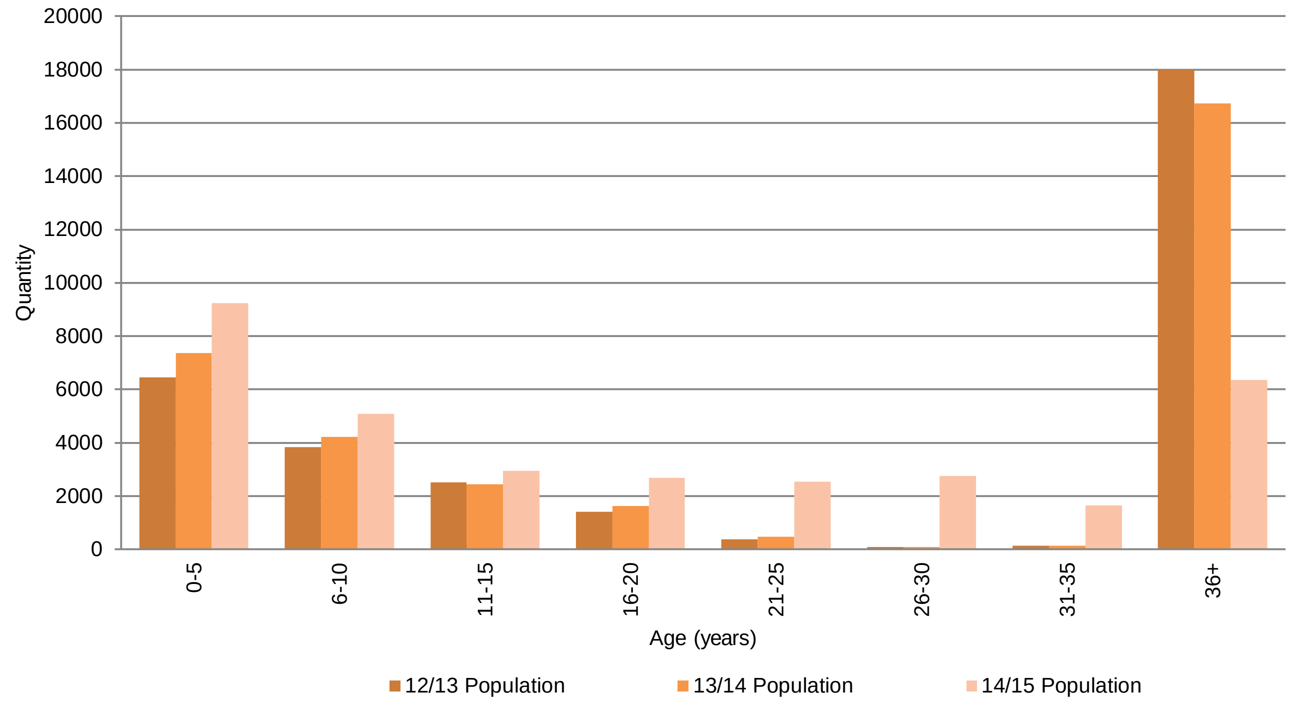
Table 55: Assets with conditions requiring replacement - dropout fuses (quantity, percentage of total population)

	2012/13		2013/14		2014/15	
	Qty	%	Qty	%	Qty	%
Assets with conditions requiring replacement - dropout fuses	4,636	14.1	4,563	13.8	4,187	12.6

Asset age profile

A large proportion of dropout fuses have exceeded their 35 year expected service life but continue to provide reliable service. Figure 16 shows the age profile of dropout fuses.

Figure 16: Age profile - dropout fuses



Failure modes and consequence

Dropout fuse failures are typically caused by component deterioration resulting in either:

1. the fuse failing to release (hang-up) under fault conditions or
2. releasing prematurely and falling to the ground, even when no fault current is present due to weak spring tension in the contacts that hold the fuse barrels.

Depending upon conditions, failed units are replaced as an emergency response activity.

The key consequence of failure is an increase in the number of customers affected by network outages. It is important to recognise that normal operation of this asset increases the likelihood of fire, due to the expulsion of droplets of molten metal. New fire-safe fuses are used in most areas to reduce the risk of fire ignition by expulsion of molten metal.

Table 56 summarises dropout fuse failures recorded in this and the preceding two reporting periods.

Table 56: Failures - dropout fuses

	2012/13		2013/14		2014/15	
	Qty	%	Qty	%	Qty	%
Dropout fuse failures	159	0.5	349	1.0	378	1.1

Risk assessment

Table 57: Risk assessment - dropout fuses

Risk area	Rating	Comment
Public safety	High	The operation of a expulsion dropout fuse in areas classified as Extreme or High bushfire risk zones increases the risk of fire.
	Low	The operation of a fire-safe fuse in any area has low risk of igniting a fire.
Service	Medium	Failure may result in an increased number of customers being affected by network outages.

5.5 Transmission plant and equipment

Transmission plant and equipment includes the equipment used in terminal stations and zone substations to:

- convert higher voltages to lower voltages
- allow switching of the transmission network.

The following transmission plant and equipment asset types are identified as having the greatest potential to adversely impact safety and reliability:

- power transformers
- circuit breakers
- instrument transformers
- disconnectors and earth switches
- surge arrestors
- substation security fencing
- substation earthing.

Other transmission plant and equipment includes reactors, capacitors and static VAR compensators, which help control system voltage. As the failure of these assets is unlikely to have a significant safety or reliability impact, they are not included in this Report. It should be recognised that failure of reactive plant can have a significant impact on generation dispatch.

Important note on risk assessment for this asset class

In any network, the most extreme failure of energised substation equipment can result in explosion, with the potential to cause injury or death to anyone in close proximity.

In assessing the risks associated with assets of this type, it must be emphasised that:

- failures of this type are rare
- this type of equipment is generally located in unmanned sites and operated remotely
- in the majority of cases, protection systems isolate these assets from the Network to minimise further damage to other assets.

Substation equipment is contained within a fenced perimeter, minimising public safety risk. The significant residual safety risk to Western Power employees and contractors is mitigated by appropriate work practices and training.

5.5.1 Power transformers

Power transformers are major substation assets that convert voltage levels on the transmission network. They are often fitted with an On Load Tap Changer to maintain voltage levels within the required limits.

Asset conditions

A range of conditions affect the expected service life of power transformers:

- degradation of cellulose in the paper insulation of the windings
- deterioration of external components (such as cooling equipment, load tap changers, bushings) due to operational activity.

Condition of power transformers is assessed by a range of methods, including:

- high voltage testing
- oil analysis
- testing of individual components (e.g. bushings, tap changers)
- periodic inspections
- known type defects (e.g. a high failure rate of a particular type of tap changer).

Table 58 summarises the population of this asset type requiring replacement due to assessed conditions.

Table 58: Assets with conditions requiring replacement - power transformers (quantity, percentage of total population)

	2012/13		2013/14		2014/15	
	Qty	%	Qty	%	Qty	%
Assets with conditions requiring replacement - power transformers	32	9.4	28	8.1	33	9.6

Asset age profile

Figure 17 shows the age profile of power transformers.

Figure 17: Age profile - power transformers

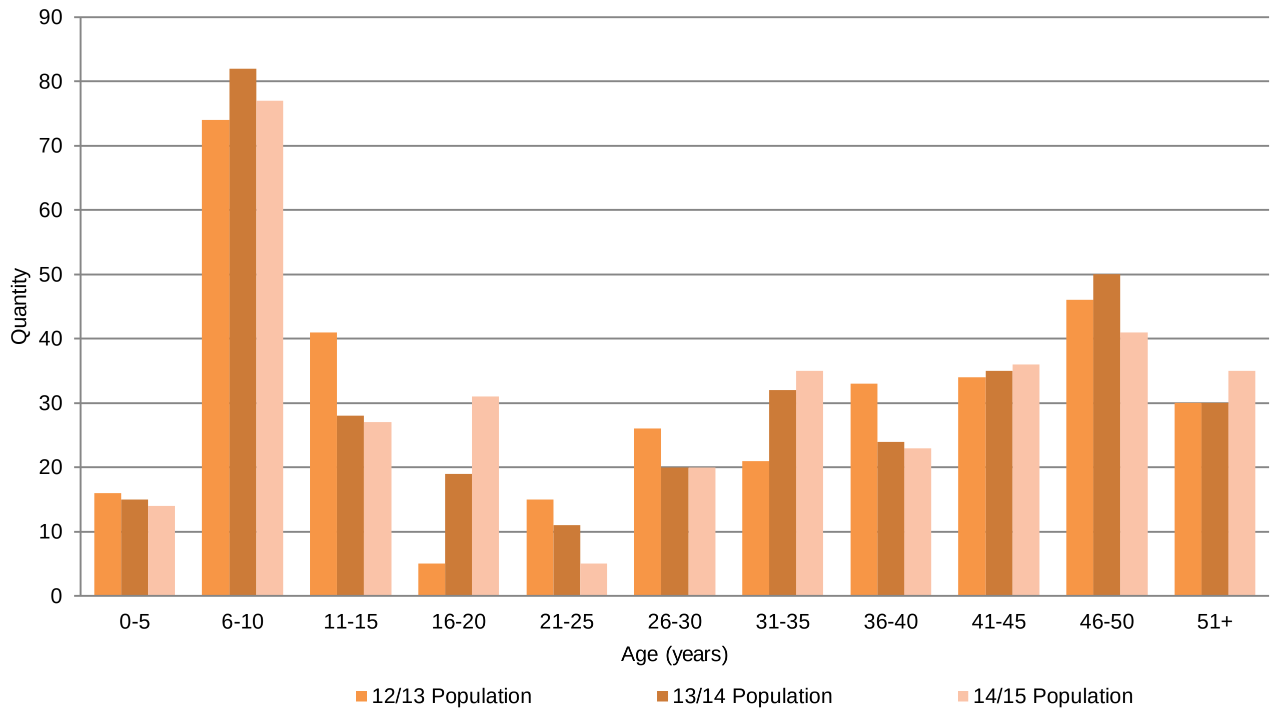


Table 59 summarises the proportion of the population that has exceeded this asset type's expected service life of 40 years.

Table 59: Assets exceeding expected service life - power transformers

	2012/13		2013/14		2014/15	
	Qty	%	Qty	%	Qty	%
Assets exceeding expected service life - power transformers	96	28.2	115	33.2	112	32.6

Failure modes and consequences

The most common failure modes are:

- failure of equipment connected to the transformer, such as instrument transformers or load tap changers
- breakdown of the paper in the transformer, resulting in loss of insulation.

The consequences of greatest impact are:

- injury or death resulting from close proximity to an extreme failure
- network outages.

Table 60 summarises power transformer failures recorded in this and the preceding two reporting periods.

Table 60: Failures - power transformers

	2012/13		2013/14		2014/15	
	Qty	%	Qty	%	Qty	%
Failures - power transformers	1	0.3	1	0.3	1	0.3

Risk assessment

Table 61: Risk assessment - power transformers

Risk area	Rating	Comment
Public safety	High	Explosive failures can cause serious injuries, however the likelihood of these events are rare.
Service	Medium	Failures can result in outages affecting large numbers of customers, however the likelihood of these failures are rare.

5.5.2 Circuit breakers and switchboards

Circuit breakers are installed at terminal stations, switching stations and zone substations to interrupt supply to specific network sections when abnormal conditions are detected. This maintains system security and allows switching operations to be performed, in addition to protecting other network assets from damage and ensuring the safety of personnel.

Circuit breakers are categorised according to installation, namely indoor or outdoor, and insulation and interrupting medium, namely vacuum, gas or oil. These assets are used on networks that operate at between 6.6 kV and 330 kV.

A switchboard is a collection of indoor circuit breakers that is typically installed and maintained as a single unit. Western Power's standard switchboard comprises eight indoor circuit breakers.

Asset conditions

A range of conditions affect the expected service life of circuit breakers and switchboards:

- number of operations, especially under fault conditions
- oil or gas leaks
- wear of moving parts
- breakdown of insulating medium
- defective operating mechanisms.

Condition of circuit breakers and switchboards is assessed by a range of methods, including:

- high voltage testing (contact resistance, timing and travel, insulation)
- gas or oil analysis
- periodic inspections
- mechanical tests (timing and travel).

Table 62 summarises the population of this asset type requiring replacement due to assessed conditions.

Table 62: Assets with conditions requiring replacement - circuit breakers (quantity, percentage of total population)

	2012/13		2013/14		2014/15	
	Qty	%	Qty	%	Qty	%
Assets with conditions requiring replacement - circuit breakers	369	13.9	356	13.0	502	18.1

Asset age profile

Figure 18 shows the age profile of circuit breakers, grouped by interrupting medium. Oil-filled breakers present a greater danger of fire and explosion than breakers using other interrupting media.

Figure 18: Age profile - circuit breakers (grouped by interrupting medium)

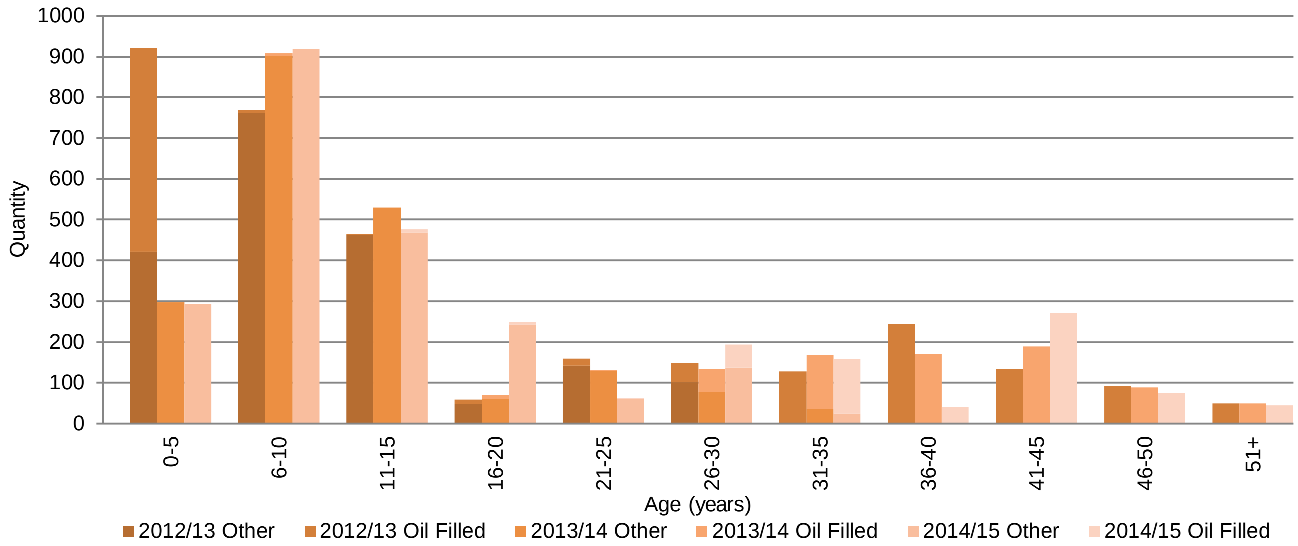


Table 63 summarises the proportion of the population that has exceeded this asset type's expected service life of 45 years.

Table 63: Assets exceeding expected service life - circuit breakers

	2012/13		2013/14		2014/15	
	Qty	%	Qty	%	Qty	%
Assets exceeding expected service life - circuit breakers	142	5.4	137	5.0	115	4.1

Failure modes and consequences

Circuit breaker failures are typically caused by:

- leaking or contamination
- breakdown of the oil, gas or vacuum insulating medium
- high contact resistance
- wear of mechanical parts
- issues with the breaker's secondary circuit.

The consequences of greatest impact are:

- injury of death resulting from close proximity to an extreme failure
- network outages.

Table 64 summarises circuit breaker failures recorded in this and the preceding two reporting periods.

Table 64: Failures - circuit breakers

	2012/13		2013/14		2014/15	
	Qty	%	Qty	%	Qty	%
Failures - circuit breakers	2	0.1	1	<0.1	1	0.1

Risk assessment

Table 65: Risk assessment - circuit breakers and switchboards

Risk area	Rating	Comment
Public safety	High	Indoor circuit breakers present a higher safety risk than outdoor units due to the close proximity of personnel to the energised bus and working in a confined space.
Service	Medium	Failure can result in outages to a large number of customers, however the likelihood of this event is rare. Indoor units also present a higher reliability risk than outdoor units due to the likelihood of failure of one circuit breaker affecting adjacent circuit breakers and impacting a large number of customers.

5.5.3 Instrument transformers

Instrument transformers measure network voltage or current at specific locations for protection, control and operational purposes. Instrument transformers include current transformers (CT), voltage transformers (VT), capacitive voltage transformers (CVT) and combined units.

Asset conditions

A range of conditions affect the expected service life of instrument transformers:

- environmental conditions such as pollution and humidity
- oil leaks.

Condition of instrument transformers is assessed by a range of methods including:

- high voltage testing (insulation, accuracy, resistance)
- periodic inspections.

Table 66 summarises the population of this asset type requiring replacement due to assessed conditions.

Table 66: Assets with conditions requiring replacement - instrument transformers (quantity, percentage of total population)

	2012/13		2013/14		2014/15	
	Qty	%	Qty	%	Qty	%
Assets with conditions requiring replacement - instrument transformers	272	4.3	269	4.1	157	2.4

Asset age profile

Figure 19 shows the age profile of instrument transformers.

Figure 19: Age profile - instrument transformers

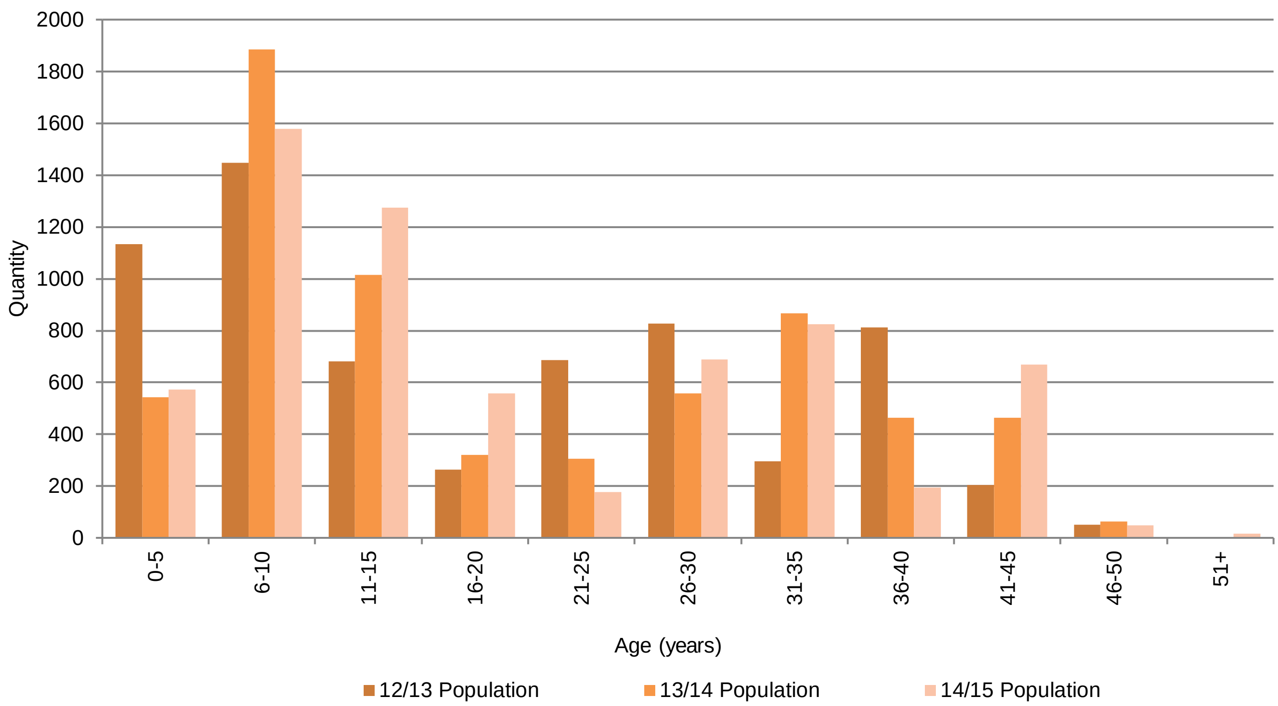


Table 67 summarises the proportion of the population that has exceeded this asset type's expected service life of 40 years.

Table 67: Assets exceeding expected service life - instrument transformers

	2012/13		2013/14		2014/15	
	Qty	%	Qty	%	Qty	%
Assets exceeding expected service life - instrument transformers	256	4.0	531	8.2	736	11.1

Failure modes and consequences

Instrument transformer failures are typically caused by breakdown of the insulating medium.

The consequences of greatest impact are:

- injury or death resulting from close proximity to an extreme failure
- deactivation of some metering and protection schemes

Table 68 summarises instrument transformer failures recorded in this and the preceding two reporting periods.

Table 68: Failures - instrument transformers

	2012/13		2013/14		2014/15	
	Qty	%	Qty	%	Qty	%
Failures - instrument transformers	4	<0.1	5	<0.1	2	<0.1

Risk assessment

Table 69: Risk assessment - instrument transformers

Risk area	Rating	Comment
Public safety	Medium	Explosive failures are rare but can cause serious injuries.
Service	Low	Failure of instrument transformers on substation circuits can affect many customers with a typical restoration time of less than 12 hours.

5.5.4 Disconnectors and earth switches

Disconnectors and earth switches[33] safely isolate and earth sections of the Network. They also control the flow of power in terminal stations and zone substations.

Asset conditions

A range of conditions affect the expected service life of disconnectors and earth switches:

- seizure of linkages and other moving parts
- wear causing inadequate contact on live parts of the switch
- lack of spare parts.

The main method of assessing the condition of disconnectors and earth switches is periodic inspections, including the use of thermographic techniques.

Table 70 summarises the population of this asset type requiring replacement due to assessed conditions.

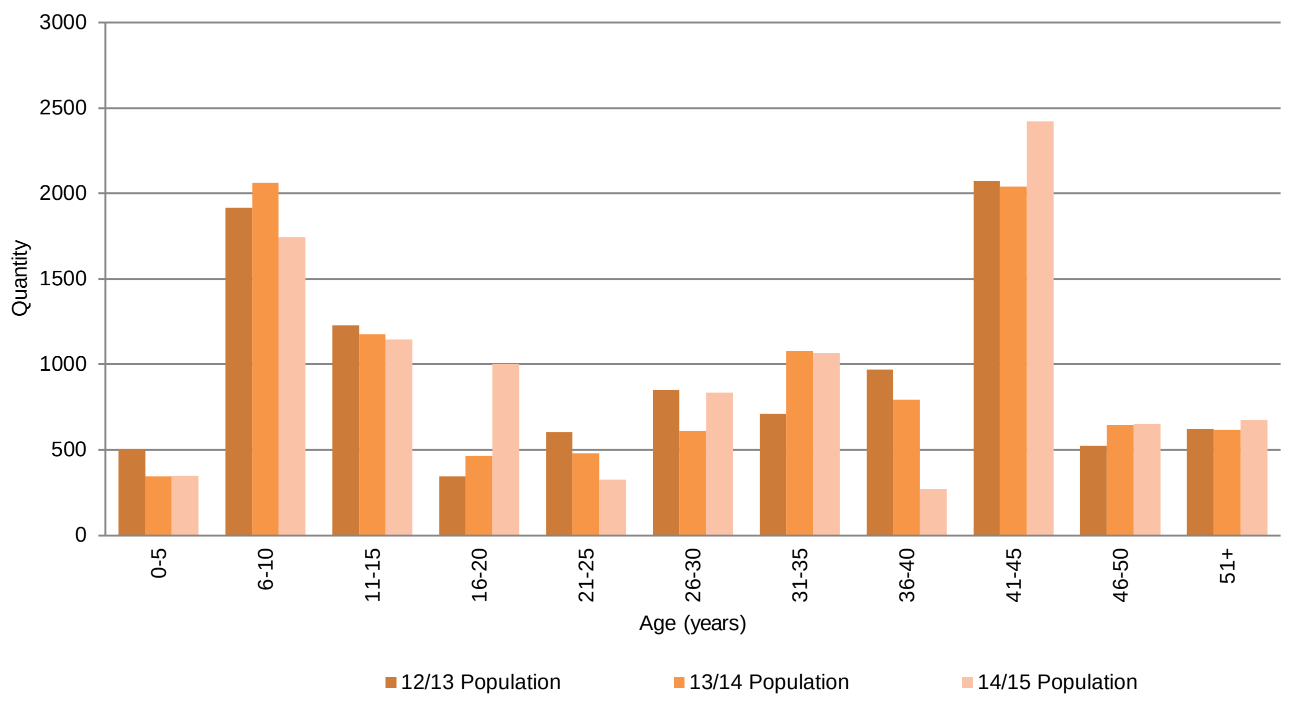
Table 70: Assets with conditions requiring replacement - disconnectors and earth switches (quantity, percentage of total population)

	2012/13		2013/14		2014/15	
	Qty	%	Qty	%	Qty	%
Assets with conditions requiring replacement - disconnectors and earth switches	639	6.2	530	5.1	522	5.0

Asset age profile

Figure 20 shows the age profile of disconnectors and earth switches.

Figure 20: Age profile - disconnectors and earth switches



33 Earth switches are generally an integral part of disconnectors.

Table 71 summarises the proportion of the population that has exceeded this asset type's expected service life of 50 years.

Table 71: Assets exceeding expected service life - disconnectors and earth switches

	2012/13		2013/14		2014/15	
	Qty	%	Qty	%	Qty	%
Assets exceeding expected service life - disconnectors and earth switches	621	6.0	619	6.0	675	6.4

Failure modes and consequences

Disconnector and earth switch failures are typically caused by:

- the switch seizing in the closed position
- the switch breaking when operated
- wear of moving and stationary contacts resulting in partial contact of the current-carrying path and excessive heating.

The consequences of greatest impact are:

- injury or death resulting from close proximity to an extreme failure
- outage of the respective circuit for an extended period.

Table 72 summarises disconnector and earth switch failures recorded in this and the preceding two reporting periods.

Table 72: Failures - disconnectors and earth switches

	2012/13		2013/14		2014/15	
	Qty	%	Qty	%	Qty	%
Failures - disconnectors and earth switches	0	0.0	0	0.0	0	0.0

Risk assessment

Table 73: Risk assessment - disconnectors and earth switches

Risk area	Rating	Comment
Public safety	Low	Failure may result in the break-up of components or sparking during switching operations.
Service	Low	Failure may result in slightly longer switching times.

5.5.5 Surge arrestors

Surge arrestors limit voltage surges caused by lightning, preventing serious damage to primary plant and explosive failures. They are installed at terminal stations and zone substations, as well as on poles throughout the transmission network.

Asset conditions

A range of conditions affect the expected service life of surge arrestors:

- number of surge operations
- moisture ingress into the semi-conductive metal oxide plates
- known type defects (e.g. gap type arrestors).

These are assessed by a range of methods, including:

- electrical testing (watts loss, leakage current, insulation DC resistance)
- 2-monthly periodic inspections
- 6-monthly thermographic survey.

Table 74 summarises the population of this asset type requiring replacement due to assessed conditions.

Table 74: Assets with conditions requiring replacement - surge arrestors (quantity, percentage of total population)

	2012/13		2013/14		2014/15	
	Qty	%	Qty	%	Qty	%
Assets with conditions requiring replacement - surge arrestors	4	0.2	2	<0.1	3	0.1

Asset age profile

Figure 21 shows the age profile of surge arrestors.

Figure 21: Age profile - surge arrestors

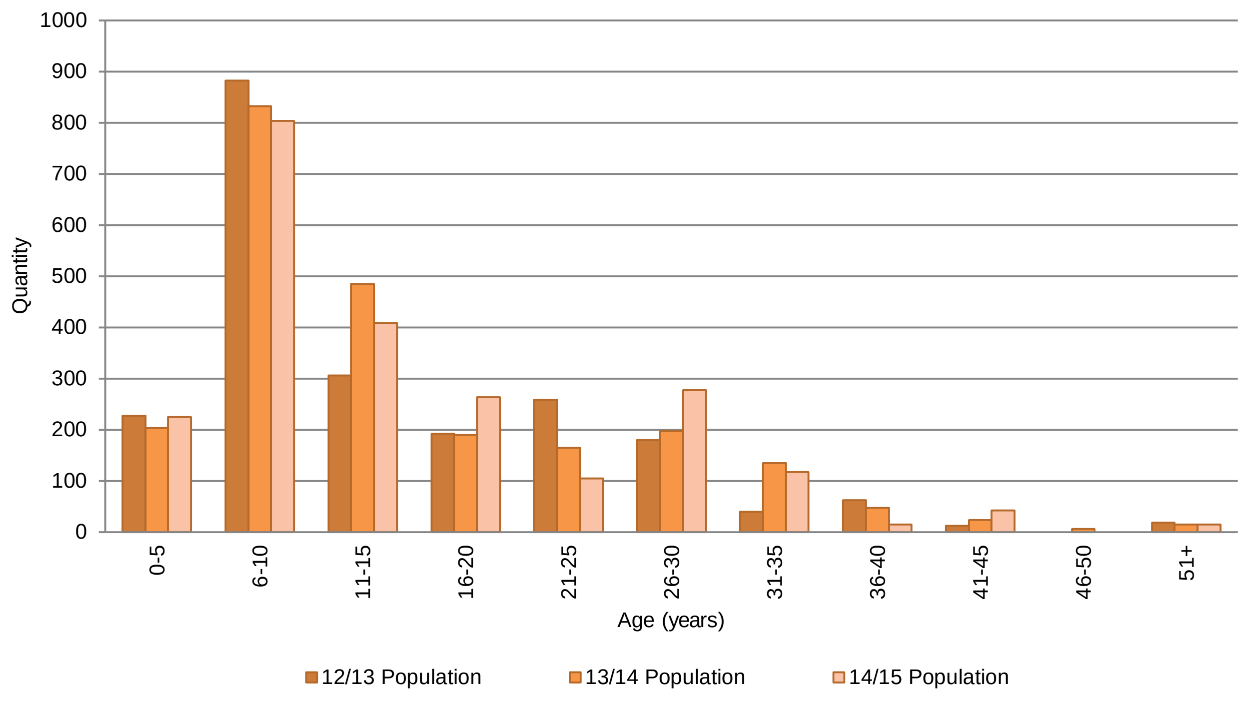


Table 75 summarises the proportion of the population that has exceeded this asset type's expected service life of 40 years.

Table 75: Assets exceeding expected service life - surge arrestors

	2012/13		2013/14		2014/15	
	Qty	%	Qty	%	Qty	%
Assets exceeding expected service life - surge arrestors	31	1.4	45	2.0	57	2.5

Failure modes and consequences

Surge arrestor failures are typically caused by:

- breakdown of the semi-conductive medium resulting in higher than rated current through the arrestor
- breakdown of insulation due to the arrestor absorbing moisture after periods of high humidity.

The consequence of greatest impact is injury or death resulting from close proximity to an extreme failure.

Table 76 summarises surge arrestor failures recorded in this and the preceding two reporting periods.

Table 76: Failures - surge arrestors

	2012/13		2013/14		2014/15	
	Qty	%	Qty	%	Qty	%
Failures - surge arrestors	1	<0.1	1	<0.1	0	0.0

Risk assessment

Table 77: Risk assessment - surge arrestors

Risk area	Rating	Comment
Public safety	Low	Explosive failure causing injury is rare. Ejection of material is less likely with polymer arrestors than those constructed of porcelain.
Service	Low	Service interruptions are brief as arrestors can be removed and the busbar returned to service.

5.5.6 Substation security fencing

Each of Western Power's 155 substation sites is enclosed by fencing intended to prevent unauthorised entry.

Asset condition

Most of Western Power's substation security fencing is constructed of chain mesh that was compliant with the standards in force at the time of their construction. A range of new materials (such as palisade, weldmesh, concrete and masonry) have been used in more recent security fence constructions.

Asset profile

Following revisions to the relevant standard[34] in 2006 and independent advice, chain mesh fencing is no longer regarded as sufficient for the purpose of preventing unauthorised access. A survey of substation sites identified that chain mesh fencing is still present at 119 sites.

Failure modes and consequences

Failure modes include:

- unauthorised access with or without the aid of poles and vegetation
- damage to or degradation of fencing.

The consequence of greatest impact is injury or death as a result of unauthorised access and inadvertent contact with live electrical equipment.

Table 78 summarises unauthorised entries into substation sites recorded in this and the preceding two reporting periods.

Table 78: Unauthorised entries - substation sites

	2012/13	2013/14	2014/15
Unauthorised entries - substation sites	35	27	30

Substation security fencing failure and defects are corrected promptly through operational response.

Risk assessment

Table 79: Risk assessment - substation security fences

Risk area	Rating	Comment
Public safety	High	Possibility of electric shock to intruders resulting from inadvertent contact with live electrical equipment.
Service	Medium	Potential for compromising protection systems or causing protection to operate, interrupting supply to customers.

[34] National Guidelines for Prevention of Unauthorised Access to Electricity Infrastructure (ENA DOC 015-2006).

5.5.7 Substation earthing

All terminal and zone substations are equipped with an earthing system that is essential for mitigating step and touch potential during transmission system earth faults. It also ensures fast short circuit protection relay operations to protect and isolate substation primary plant during short circuit to earth faults.

An earthing system consists of:

- earth grid
- operator earth mats
- grading rings
- earth electrodes
- earth straps
- earth braids
- portable earths.

Asset condition

Each substation's earthing system was designed to manage a particular fault level, with a considerable design safety margin. Due to the significant increase in fault current resulting from network infrastructure and generating capacity, it is prudent to review substation earthing to ensure its continued adequacy.

Further research at substation sites has provided Western Power with greater insight for managing this risk. The development of a substation earthing strategy has progressed and is continuing.

5.6 Secondary systems

Secondary systems are critical for maintaining safety and reliability, as well as protecting equipment. They consist of the following asset sub-classes:

- protection systems monitor the condition of the Network to detect faults (e.g. short circuits) and trigger action to segregate the fault from the healthy Network
- Supervisory Control and Data Acquisition (SCADA) provide the capability to monitor and control Network elements remotely.
- communication networks carry signals between the disparate elements of protection and SCADA systems and also provide telephony and voice radio communications services
- auxiliary power supplies for circuit breaker operation, protection systems and SCADA / communications assets.

Much of the equipment in these sub-classes is highly dependent on electronic computer and communications technologies. The short product lifecycles and accelerated obsolescence characteristic of these technologies present a continuing asset management challenge.

Conditions of secondary systems are assessed through on-line monitoring and routine inspections.

The consequences of failure of a single asset are mostly low due to design redundancy and monitoring. A proportion of the population is identified as obsolete or having known type defects; this is mitigated through operational response and asset replacement programs.

6 Capacity

As required by the *Electricity Networks Access Code 2004*, Western Power publishes Technical Rules (approved by the ERA) specifying the criteria for Western Power's network capacity planning. In addition, Western Power has developed Planning Guidelines for the transmission and distribution networks to provide a consistent interpretation of the planning criteria in the Technical Rules.

The Network generally has sufficient capacity to meet short-term forecast load growth. A number of Network elements are currently experiencing capacity limitations or are projected to do so in 2015/16. Those capacity shortfalls that do not comply with planning standards will be addressed by projects planned during AA3.[35]

Existing and emerging capacity constraints increase the likelihood of long duration customer supply interruptions following contingency events, such as the unplanned outage of a substation transformer or transmission line circuit, particularly when they coincide with adverse loading conditions, such as summer peak load days. These constraints do not represent an immediate inability to supply customers, due to the low probability of these circumstances occurring concurrently.

Table 80 summarises the proportions of those network elements forecast to exceed capacity (as defined by planning criteria) during summer 2015/16.

Table 80: Network elements forecast to exceed capacity targets (percent)

Network element	2014/15[36]	2015/16
Zone substations	5.4	3.9
Terminal substations	0.0	0.0
Metropolitan feeders	26.0	16.0
Rural feeders	2.4	2.0
Transmission lines	2.3	2.0
Distribution transformers	0.1	0.1

This improvement is due to a combination of reduced demand forecasts and reinforcement works that have increased the capacity of the network.

35 Further information on these projects and the issues they address is published in Western Power's Annual Planning Report.

36 These were the network elements forecast to exceed utilisation targets during 2014/15, as reported in the 2013/14 State of the Infrastructure Report.

6.1 Constrained zone and terminal substations

Western Power produces annual electricity demand forecasts for each zone substation, with the aggregate forecast published internally in the Summer Central Load Trends Report. The demand forecast for each zone substation allows Western Power to assess the adequacy of supply against substation capacity, as defined by the relevant planning criteria.

Based on a one-in-ten year high demand scenario, five zone substations (3.9% of the population) are forecast to exceed their capacity by 2015/16, should worst-case network plant contingencies occur at the same time.

Table 81 provides additional information on the capacity constraints for each substation forecast in 2014 to exceed capacity in 2015/16, listing:

- the estimated number of customers at risk of supply loss (beyond that permitted by the Technical Rules) as a result of exceeding capacity by more than 0.5 MVA
- the applicable planning criteria.

Table 81: Forecast substation capacity constraints (based on 2014 10% Probability of Exceedance[37] forecast)

Substation	Zone / Terminal	Customers at risk[38]	Planning criteria[39]
Busselton	Zone	759	N-1
Bunbury harbour	Zone	1308	N-1
Mandurah	Zone	4960	NCR
Meadow Springs	Zone	4207	NCR
University	Zone	159	NCR

Metropolitan substations are planned to the NCR criterion and have facilities for connection of a rapid response transportable transformer in the event of unplanned transformer contingency events, typically within 12 hours.

The Mandurah and Meadow Springs zone substations have the largest numbers of customers at risk in the event of an unplanned outage of a substation supply circuit during 2015/16 peak demand conditions, should the peak be extreme (a one-in-ten year summer). Though this coincidence of circumstances is considered unlikely, it has the potential to result in an extended interruption for customers supplied from the Mandurah and Meadow Springs zone substations. Western Power is presently assessing options to address these issues.

Geographic information on the Network is published in the Annual Planning Report and is also available through the Network Capacity Mapping Tool on Western Power's website. There may be minor variations from the information presented in Table 81 to that published in the Annual Planning Report, reflecting:

- ongoing activity to transfer load away from capacity constrained substation sites to neighbouring substations to mitigate risk
- load forecast updates.

[37] A 10% Probability of Exceedance ("PoE") corresponds to a one-in-ten-year event.

[38] The number of customers at risk is estimated based on the average customer density (kVA/customer) in each substation during peak demand. Western Power has projects under way to address the constraints for the listed substations.

[39] The Technical Rules require an N-1 substation to have sufficient capacity to supply all forecast loads during an outage of one element in the substation's supply circuits. The Normal Cyclic Rating (NCR) substation criterion enables a substation to be loaded higher than its N-1 capacity and permits the disconnection of a limited number of customers for a target period of 12 hours. NCR substations are restricted to the Perth metropolitan area due to the practical limitations in deploying a rapid response spare transformer within the 12 hour target period.

6.2 Transmission network constraints

Western Power routinely assesses the ability of its transmission network to supply existing and future demand growth in accordance with the levels of supply reliability and system security specified by the Technical Rules. Western Power's routine assessments identify existing and future transmission constraints, which are typically associated with:

- insufficient thermal rating of transmission lines
- fault levels approaching maximum equipment specifications
- insufficient voltage support in areas of the Network.

The following subsections list the existing and emerging network constraints that are:

- due to the thermal rating on transmission lines, fault levels and voltage support respectively
- identified in the course of routine power system analysis investigations, based on the:
  - 2014 load forecasts for the year 2015/16 under a 10% Probability of Exceedance forecast load demand scenario, i.e. a one-in-ten year summer
  - most likely generation forecast dispatch, as identified in Section 4 of the 2014/15 Annual Planning Report.

A number of operational measures[40] can be taken to manage these constraints, with load shedding used only as a last resort. Western Power's System Management and Network Operations continuously monitor the Network to identify potential contingencies that could lead to an unsatisfactory operating state[41] requiring an operational response.

Given the range of measures available, the number of customers at risk of supply loss because of these constraints cannot be calculated precisely. Failure to address these constraints in conjunction with growing demand will make the power system less secure and more vulnerable to widespread power outages.

6.2.1 Transmission network thermal constraints

The following transmission circuit and lines are forecast to exceed their nominal ratings in 2015/16 in the event of worst-case contingencies, even after the operation of generator runback schemes, load or network tripping schemes, or the dispatch of generation under third-party support contracts:[42]

- Three Springs zone substation bus bar 132 kV
- Kojonup to Wagin 66 kV
- Kwinana to Cockburn Cement / Medina 132 kV
- Pinjarra to Alcoa Pinjarra 132 kV
- Mandurah to Pinjarra 132 kV
- Pinjarra to Meadow Springs / Cannington 132 kV.

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40 These include re-dispatch of generation, reconfiguration of the network, arming post-contingent load shedding schemes or triggering pre-contingent load shedding as a last resort.

41 This would be characterised by network elements being overloaded or the power system being operated beyond acceptable voltage or frequency ranges.

42 There are numerous credible generation dispatch scenarios, each of which potentially leads to different loading on transmission lines. Further transmission line overloads can occur under less favourable, but less likely, generation dispatch conditions.

These represent 2.0% of the transmission lines in the Western Power transmission network.[43] This means that a fault on a key transmission line under extreme demand conditions may result in power flows on these lines exceeding their thermal ratings. Should this occur, System Management and Network Operations would reduce the power flow on overloaded lines by re-dispatching generation, network switching and, as a last resort, shedding load.

The transmission network thermal constraints that existed in the North Country region between Pinjar and Mungarra under certain operating conditions are no longer present, due to the decreasing load forecast. Based on the 2014 load forecast and historical wind generation outputs (i.e. credible load and generation scenarios), the transmission network north of Three Springs is currently sufficient to meet the demand in the area.

Muja Terminal was operating in a reduced security state, following the unrelated failures of two of its three high-capacity bus tie transformers over the past two years. These outages caused a number of network thermal constraints, including:

- Picton to Marriott Road 132 kV overload
- Kemerton to Marriott Road 132 kV overload
- reduced transfer limit to Eastern Goldfields.

The majority of these constraints have been relieved through emergency network projects, including:

- the construction of a 132 kV line from Kemerton Terminal to the Picton-Pinjarra-Busselton 132 kV teed line
- the replacement of one of the high capacity bus tie transformers at Muja Terminal with a new transformer
- the relocation of a Merredin Terminal transformer to Muja Terminal.

There is still a reduced transfer limit to the Eastern Goldfields, which is currently mitigated by a network control scheme and operational measures.[44]

6.2.2 Transmission network fault level constraints

The following transmission network locations are forecast as exceeding maximum fault level limitations by 2015/16:

- Kwinana Terminal 132 kV
- Southern Terminal 132 kV
- Cannington Terminal 66 kV Network
- Western Terminal 132 kV
- Western Terminal 66 kV Network
- South Fremantle 66 kV Network
- East Perth 132 kV Network.

Fault level limitations are typically managed by network reconfiguration and limiting the connection of any new generation in an area. If this is not feasible, plant must be upgraded to above-forecast fault levels, or the network augmented to allow alternative reconfiguration options. While network augmentations are currently being planned to alleviate fault level limitations, connection of generation that would add to fault levels at these locations may not be permitted until these are complete.

[43] The number of transmission lines is based on the 2014/15 Western Power Network model used in network capacity planning studies.

[44] These include re-dispatch of generation and network switching.

6.2.3 Transmission network voltage stability limitations

The following areas of the transmission network are forecast to approach or exceed voltage stability limitations in 2015/16, even after the operation of generator runback schemes, load or network tripping schemes, or the dispatch of generation under third-party support contracts:

- Muja 66 kV network
- Albany area
- Busselton/Picton 132 / 66 kV network.

A number of transmission network voltage stability limitations also exist in the Eastern Goldfields[45] areas under certain operating conditions. These are currently managed by System Management through Dispatch Support Contracts. Voltage issues in the Geraldton area have been improved with the new 330 kV network, which was built as part of the Mid West Energy Project (Southern Section).

Undervoltage load shedding schemes are enabled across the Network to mitigate the risk of widespread voltage collapse. These schemes are generally designed to operate only following multiple contingencies. If the Network has been planned to meet the Technical Rules' planning criteria, these schemes should not operate in the event of a single credible network contingency.

This is not the case in the Muja 66 kV, Busselton / Picton and Albany areas, where a critical single contingency in adverse demand and generation conditions could trigger undervoltage load shedding.

6.3 Constraints impacting block loads

New block loads[46] can add significantly to the utilisation of the transmission network and affect its transfer capability. The ability of the Network to accommodate increased utilisation depends on many factors, usually requiring detailed studies. These studies are undertaken by Western Power on request as part of processing applications to connect, in accordance with the Applications and Queuing Policy (AQP).[47]

Where network capacity is available, loads can be connected on an unconstrained non competing basis. In other areas which are capacity constrained, Western Power applies criteria to assess if the load is eligible for an unconstrained connection, or otherwise must fund network upgrades to provide unconstrained supply. In some cases, in order to avoid costs associated with network upgrades or augmentation, customers may request a curtailable supply that limits their demand under some system conditions. The criteria are referred to as the *Competing Application Thresholds Test* and are defined by the following criteria:

1. the total load must not exceed 1.5 MVA for its National Metering Identifier
2. the load application must be eligible for network tariffs RT1 to RT6.

The following parts of the transmission network are currently capacity constrained and the connection of loads which do not satisfy the Competing Application Thresholds' test are subject to curtailability requirements unless funding network upgrades to relieve the constraints. Network upgrades may either be funded solely by the applicant, or shared as part of a Competing Applications Group[47] solution.

[45] The transfer constraints to the Eastern Goldfields are due to both voltage and generation rotor angle instability limitations.

[46] This term refers to large energy requirements (typically industrial) that are not represented within "underlying load growth" forecasts that account for factors such as historical trends and expected population growth.

[47] Refer to http://www.westernpower.com.au/aboutus/accessArrangement/accessArrangement.html.

6.3.1 North Country (Mid West)

This region is supplied by the transmission network north of Pinjar Substation. Transmission line capacity and network voltage stability issues exist on the 132 kV network supplying the majority of the substations in this region.

The transmission network thermal constraints which existed in the North Country region between Pinjar and Mungarra under certain operating conditions are no longer present, due to the decreasing load forecast and completion of Mid West Energy Project Southern Section. Based on the 2014 load forecast and historical wind generation outputs (i.e. credible load and generation scenarios), the transmission network north of Three Springs is currently sufficient to meet the demand in the area. Therefore, Network Control Services in the area may not be required for the next five years.

Western Power will review the Network Control Services requirements annually and report upon them in the Annual Planning Report.

Considering the unpredictability of wind generation outputs, future customer loads that are greater than 1.5 MVA connecting to the Western Power Network north of Three Springs will continue to be subject to additional eligibility criteria and may trigger the requirement for Network Control Services to be funded by those customers.

As a result, the above has been sufficient to address the projected transmission constraints during the 2015/16 peak demand periods using the 2014 10% PoE forecast load demand scenario. For this reason, the majority of transmission line limitations in the North Country are not listed in Section 6.2.

6.3.2 Great Southern (Albany)

This region is subject to a voltage constraint at Albany substation. This constraint is listed in Section 6.2, as there is no dispatch support contract in place for this region to mitigate it.

6.3.3 Eastern Goldfields

The region is connected to the main South West Interconnected System via a 220 kV line approximately 650 km from Muja, and is stepped down to 132 kV at West Kalgoorlie Terminal to supply the substations in the area. Due to its relative remoteness, there are engineering challenges associated with the integration of additional block loads. New load connections are subject to technical considerations including:

- equipment thermal ratings
- voltage recovery limitations
- transient overvoltage limitations
- synchronous stability constraints
- power system load rejection
- spinning reserve requirements.

Supply to existing Western Power customers is maintained through the use of Dispatch Support Contracts in the event of a network plant contingency. This has been sufficient to meet the existing demand in Eastern Goldfields.

6.4 Constraints impacting generation

New generation can add significantly to the Network's utilisation and transfer capability. The ability of the Network to accommodate additional generation depends on many factors, usually requiring detailed studies. In accordance with the AQP, Western Power performs these studies on request as part of processing applications to connect.

The Access Code requires Western Power to provide new generation proposals with offers to connect on an unconstrained basis. This means that Western Power must design connections on the basis of allowing the worst case credible dispatch from all existing generation and the new generating unit(s).

In some locations, the level of generation already connected means that new generation cannot be connected on an unconstrained basis without network reinforcement. Generators need to consider the cost implications of funding these reinforcements. In the Mid West region, for example, current constraints require augmentations to the shared network to allow new generation to connect on an unconstrained basis. Fault level limitations at various sites also constrain the ability for new generation to connect. Existing fault level limitations impacting new generation connections are listed in Section 6.2.2.

To reduce connection costs, some generators have agreed to be constrained by runback schemes that automatically restrict their output to maintain system security.

Through the AQP, Western Power is currently preparing offers for connection of generators to the Network on a constrained basis. Through the Competing Applications Group, applicants can share the costs of network developments and / or implementation of control schemes to manage their output under some conditions.

6.5 Constrained distribution feeders

6.5.1 Thermal constraints

In accordance with the Technical Rules,[48] Western Power's Distribution Network Planning Guidelines stipulate a maximum urban feeder exit cable utilisation of 80%. In the event of a fault occurring on a feeder, this target ensures that the affected load can be supplied by other feeders without exceeding their ratings. This enables prompt reconnection of the majority of affected customers (other than those near the faulted part of the Network) by means of network switching through an alternative supply path.

Of the total population of 730 metropolitan distribution feeders, utilisation exceeds 80% in 115 (15.7%). Of these, 28 (3.8%) are projected to be overloaded during the 2015/16 summer peak without operational intervention or network reinforcement. Operational interventions to avoid feeder overloads include:

- network switching to temporarily move load to adjacent feeders
- running small relocatable generators to reduce feeder loading.

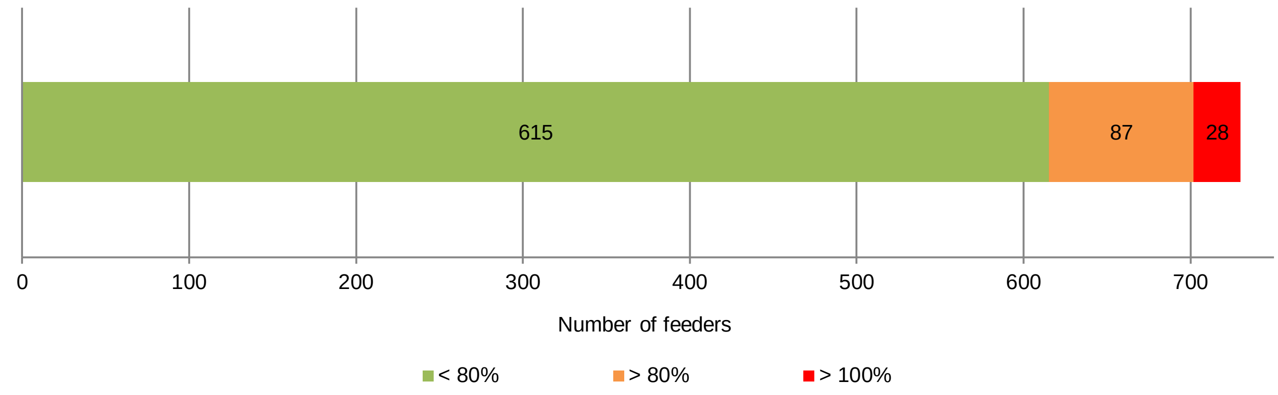
While these interventions prevent consequent reduction in asset life and increased risk of failure, they incur additional operating expenditure.

Reinforcement options (such as upgrading feeder conductors and installing additional feeders to permit load balancing) offer a longer term solution.

[48] Technical Rules - clause 2.5.5.3(b)2(A).

Figure 22 shows the targeted feeder utilisation level performance, including those projected to be overloaded without operational intervention, i.e. exceeding 100% utilisation. Over-utilised feeders are assessed as presenting a high service risk to customers, due to the reduced ability to reroute supplies in the event of a feeder fault.

Figure 22: Forecast feeder utilisation (2015/16)



If an over-utilised feeder surrounded by other interconnected feeders is subject to an unplanned outage during the summer peak, it may take longer than normal, in excess of two to three hours, to restore supply completely. This is because the entire lost customer base cannot be transferred on to the adjacent interconnected feeders, due to a lack of distribution transfer capacity and over-utilisation of existing feeders.

In the 2014/15 summer period, more than 500 fault events were recorded on metropolitan distribution feeders. For each event, the average number of customers losing supply was 517 and the average outage duration 248 minutes. This exceeds the average interruption duration expected if utilisation was below the 80% target on all feeders (in excess of three hours).

Without augmentation, growing customer demand means that the number of feeders exceeding the target utilisation will increase, exposing more customers to an increased likelihood of long duration outages.[49] This would also increase the requirement for operational intervention to avoid forecast overloads, resulting in increased operating expenditure.

The number of over-utilised feeders was 65 lower than that reported in 2013/14. This is attributable to factors such as completion of capacity reinforcement projects, temporary or permanent offloads to adjacent feeders and lower forecasts in some areas.

49 Without sufficient spare capacity on adjacent feeders, customers may remain unsupplied until the fault is repaired, which could take up to 12 hours for an underground cable fault.

6.5.2 Voltage constraints

The Technical Rules[50] stipulate that the minimum steady state voltage of a distribution system operating at voltages of 6 kV and above must be maintained within ±10% of nominal voltage, except as a consequence of a non-credible contingency. For those parts of the distribution network operating below 6 kV, the steady state voltage during normal operating state must remain within ±6% of nominal voltage.

Four long rural feeders supplying approximately 9,400 customers are forecast to be voltage constrained over the 2015/16 summer peak. This means that 2% of the 209 rural feeders in the Network are forecast to be voltage constrained by 2015/16.

Customers supplied from voltage constrained feeders are likely to experience voltages outside the range stipulated in the Technical Rules. This can damage connected equipment or cause it to malfunction, as well as leading to supply interruptions through inadvertent operation of protection due to unbalanced voltages.

This is assessed as a high service risk, due to the impact of breaching the planning obligations in the Technical Rules.

As these feeders tend to be long radial feeders, there is limited ability to shift load to adjacent feeders and therefore a narrow range of operational options for managing voltage fluctuations. A variety of solutions exist for addressing feeder voltage constraints in the long term, including:

- installing isolation transformers to supply single phase sections
- replacing single phase feeders with three phase feeders
- installing voltage regulators and/or capacitor banks
- installing static compensators
- edge-of-grid non-network solutions
- upgrading existing feeders
- constructing new feeders.

6.5.3 Under fault rated conductor

Portions of the high voltage distribution network have been identified as under fault rated, which means they have insufficient rating to safely carry currents likely to flow in worst case fault conditions. A fault close to an under fault rated section of the network may cause the conductor to sag and breach safe clearance requirements or break. Conductor failures have the potential to cause power outages, bushfires or injury to the public and Western Power personnel.

This constraint occurs primarily in the country distribution network, where there is very limited interconnection between feeders. For this reason, it is not possible to reconfigure the network to prevent fault currents exceeding feeder ratings without a significant degradation of reliability. Work is planned throughout the AA3 period to address substations with a high risk rating, with the remainder to be addressed in AA4.

Table 82 summarises the proportion of under fault rated conductor for this and the preceding two reporting periods.

Table 82: Population - under fault rated conductor (circuit km, percentage of total population)

	2012/13		2013/14		2014/15	
	Circuit km	%	Circuit km	%	Circuit km	%
Population - under fault rated conductor	1,270	2.1	1,027	1.7	1,027	1.7

50 Clause 2.2.2(a).

6.6 Constrained distribution transformers

The Network has a population of 67,554 distribution transformers.

For large units with a capacity of 100 kVA or greater, the risk of distribution transformer becoming overloaded increases significantly in heatwave conditions,[51] where load can increase by two to three times due to domestic air conditioning usage.

The lower capacity transformers are less likely to be overloaded as they are sized to supply the maximum load to each of the customers it serves, which typically are single customers whereas for the larger units, sizing is based on allowing for diversity (After Diversity Maximum Demand) and not on the maximum demand of individual customers.

The incidence of transformer failures has been reduced significantly by the Overloaded Transformer Program. Since its introduction in 2005, overloading failures have averaged at fewer than five transformers, compared to 52 in a single high load day in 2004.

Each year, a load analysis is conducted on all distribution transformers in the Network, assessing parameters such as:

- customer consumption data
- summer peak feeder loads
- transformer capacity and the number of customers connected.

The analysis prioritises the replacement of overloaded transformers, based on risk. A distribution transformer is considered to be at risk of failure when its:

- calculated peak load exceeds the nameplate continuous rating[52] by 35%
- Transformer Utilisation Factor[53] (TUF) exceeds 0.5.

Table 83 summarises the volume of assets forecast as being at risk of failure and scheduled for replacement under this program in the coming year, for this and preceding two reporting periods.

Table 83: Distribution transformers forecast at risk of failure (quantity, percentage of total population)

	2012/13		2013/14		2014/15	
	Qty	%	Qty	%	Qty	%
Distribution transformers forecast at risk of failure	92	0.1	31	<0.1	45	<0.1

The increase from 2014/15 is attributed to organic load growth in the network and some replacements being carried over from the previous year.

[51] In this discussion, a heatwave is defined a period of three or more consecutive days in which daytime temperatures exceed 40°C and remain at 26°C or higher at night.

[52] Transformers can be operated safely beyond their nameplate continuous rating for short periods without adversely affecting asset life. The combination of the peak load and utilisation factor criteria account for this.

[53] This is an internally developed measure of the relationship between actual energy delivered by a transformer and its capacity. Empirically, using TUF in conjunction with the degree of overload has been demonstrated to be a reliable predictor of failure risk.

Appendix A Safety reporting definitions

Public safety incidents

Public safety incidents include:

- a ground fire or property damage caused by Western Power assets. This does not include fire or property damage caused by vehicles that collide with Western Power poles, but does include those caused by:
  - the explosion of cable joints or transformers (for example, following a current surge)
  - pole-top fires
  - dropout fuse operation or conductor failure
  - a bird or other animal coming in contact the electricity network
  - a tree branch falling onto the electricity network
- contact with Western Power's overhead or underground network by a vehicle, plant or equipment.
- injury (requiring medical treatment) or death to a person or animal from inadvertent contact with the electricity network
- injury (requiring medical treatment) or death to a person from electric shock where the shock was caused by the electricity network
- any Energy*Safety* Order or reported defect received by Western Power.

Notifiable incidents

A notifiable incident is an incident, event, or other occurrence of which the Director [Energy*Safety*] must be notified under Regulation 35 of the *Electricity (Supply Standards and System Safety) Regulations 2001,*[54] which states:

> *(1) A network operator must notify the Director of any incident or event that is caused, or significantly contributed to, by electricity and that results in -*
>
> *(a) serious injury*
>
> *(b) serious damage*

Regulation 34 of the *Electricity (Supply Standards and System Safety) Regulations 2001* (in part) defines the following relevant terms:

serious damage means -

> *(a) damage to private property if the value of the damage is likely to exceed $5 000 in total*
>
> *(b) damage to a facility of a network, or to property belonging to the network operator or a contractor or subcontractor to the network operator, if -*
>
> > *(i) the damage was caused by a fire or explosion and fire or other emergency services attended the scene of the fire or explosion*
> >
> > *(ii) the value of the damage is likely to exceed $50 000 in total;*

serious injury means an injury that is fatal or requires the victim to be admitted to hospital whether for assessment, monitoring or treatment.

[54] Government of Western Australia, Electricity (Supply Standards and System Safety) Regulations 2001, State Law Publisher.

Electric shock incidents

An incident [involving contact with electricity] which does not require medical or first aid treatment. An incident where NO injuries are sustained, but precautionary medical treatment is sought, is regarded as an electric shock.

Note:
An electric accident is defined as an incident that requires medical or first aid treatment including fatalities and is reported as a notifiable incident.[55]

Unassisted pole failures

Unassisted pole failure is any breaking of a pole, except where the pole:

- was subjected to a force exceeding that equivalent to the design wind load specifications of AS/NZS 7000:2010
- was struck by lightning
- was compromised by vandalism
- failed as a result of fire.

Poles that fail as a result of fire shall be recorded as a separate category.

Unassisted conductor failures

Unassisted conductor failure is defined as a failure due to conductor deterioration (such as corrosion) and breakage. The broken conductor does not have to fall to the ground to be included in this measure. It includes any number of conductor failures or broken conductors, but specifically excludes customer service wires, stay wires and unserviceable wires that:

- was subjected to a force exceeding the conductor failure limit set out in AS/NZS 7000:2010
- was struck by lightning
- was compromised by vandalism
- failed as a result of a fire.

Conductors failing as a result of fire are recorded in a separate category.

Note:

Prior to January 2013, unassisted conductor failure was defined (and reported) as a failure due to conductor deterioration (such as corrosion) and breakage. The broken conductor does not have to fall to the ground to be included in this measure. It includes any number of conductor failures or broken conductors, but specifically excludes customer service wires, stay wires and unserviceable wires. Energy*Safety* agreed that the definition be applied from January 2013.

Ground fires

A ground fire is any ground fire that:

- starts in, or originates from, the electricity Network
- is started by any tree, or part of a tree, falling upon or coming into contact with the electricity Network
- is started by any person, bird, reptile, or other animal in, or on, the electricity Network
- is started by lightning striking the electricity network or part of the electricity Network
- is started by any other thing forming part of, or coming into contact with, the electricity Network
- is otherwise started by the electricity Network.

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[55] Energy*Safety, Reporting accidents and incidents,* Department of Commerce, 22 September 2010 (extracted 10 July 2012) www.commerce.wa.gov.au/energysafety/Content/Services/Reporting_accidents.html.

Appendix B List of abbreviations

AA3 / AA4	Third / Fourth Access Arrangement
AQP	Applications and Queuing Policy
AS/NZS	Australian and New Zealand Standard
CBD	Central Business District
CT	Current transformer
CVT	Capacitive voltage transformer
DC	Direct current
ERA	Economic Regulation Authority
kVA	Kilovolt Ampere
LV	Low voltage
MVA	Megavolt Ampere
NCR	Normal Cyclic Rating
NQRS	Network Quality and Reliability of Supply
NSP	Network Service Provider
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SCADA	Supervisory Control and Data Acquisition
SWIS	South West Interconnected System
TUF	Transformer Utilisation Factor
VAR	Volt-Ampere Reactive
VT	Voltage Transformer