STATE OF THE INFRASTRUCTURE REPORT 2012/13

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FOREWORD

The Western Power Network supplies power to more than one million customers across an area larger than the United Kingdom. Its diverse asset base includes more than 800,000 poles and almost 100,000 circuit kilometres of power lines. Many of the network's assets have been in service for more than 40 years.

The State of the Infrastructure Report 2012/13 ("the Report") presents a high level snapshot of the performance of the Western Power Network (as at 30 June 2013) in relation to safety, asset condition, capacity, reliability and power quality. This report addresses only the performance of the network. Information regarding strategies, treatment plans and network investment programs in response to the performance are detailed in the Network Management Plan and other relevant reports published by Western Power.

The methods used to prepare and verify the information in this report are consistent with those established for the inaugural State of the Infrastructure Report in 2011/12. This allows performance to be compared from year to year and will, in time, help identify long term trends. The information in this report has changed in some areas compared to the 2011/12 Report.

The Report shows steady or improved performance in most the following areas compared to 2011/12:

- Unassisted failures of poles and conductors, electric shocks due to overhead customer service connections and fires caused by conductor clashing were less frequent in 2012/13.
- On average, customers experienced a more reliable supply, with fewer than three power interruptions and less than six hours without power over the course of the reporting period.

Performance decreased in several areas, including the frequencies of public safety incidents, streetlight switchwire incidents and conductor clashing incidents.

Western Power is committed to the targeted investment of $7 billion over the five years of the third Access Arrangement period (ending 30 June 2017) in the asset categories covered by the Report. This investment will be prioritised on the basis of remediating safety-critical assets, including more than 100,000 pole replacements and 260,000 pole reinforcements.

The investment programs specifically addressing public safety risks include:

- *Streetlight Switchwire Removal Program*
  This program removed 3,066 km of this type of conductor from the network in 2012/13, with removal of the remainder to be complete by 30 June 2014.
- *Wood Pole Management Program*
  Western Power has made significant changes to the way it operates in order to meet community expectations and the challenges that have arisen because of decades of underinvestment in maintaining and replacing network assets, particularly its 650,000 wood poles. Over the past year, wood pole replacements increased by 12% to 17,432 and wood pole reinforcements increased 96% to a total of 48,479.
- *Overhead Conductor Replacement Programs*
  These programs systematically address asset performance issues based on risk. For example, half of all conductor replacements planned to the end of 2016/17 will be undertaken in extreme and high fire risk zones and the frequency of clashing conductor incidents will be reduced by a range of targeted remediation programs.

Delivering the standard of network performance expected by customers and stakeholders will require multi-billion dollar investment above levels in the State Budget and for a period well beyond AA3.

Andre Botha
Chief Operating Officer

Dave Fyfe
Executive Manager

PURPOSE, SCOPE AND CONTEXT

PURPOSE

Western Power's State of the Infrastructure Report ("the Report") is updated and published annually to provide visibility to stakeholders on:

1. the state of the Western Power Network ("the Network") infrastructure and assets
2. the Network's safety and reliability performance.

Its primary objective is to allow stakeholders to form a view of the state and performance of the Network.

It employs a consistent approach that can be verified independently.

SCOPE

The key elements of this Report for the year ending 30 June 2013 (the reporting period) are:

1. assessments of safety, reliability and power quality performance
2. a forecast of network capacity constraints and security
3. a snapshot of the condition of network assets and a comparison of the same data from the previous year (where available)
4. age profiles for key assets.

Note:
Asset data in the Report is as at 30 June 2013.

The following section lists additional publications reporting on these and other related matters.

CONTEXT

To improve the way we plan, build and operate the Network, Western Power must maintain a balance between safety, reliability and affordability.

Engagement with a broad range of external stakeholders is crucial to the effective planning of investments in the Network. Western Power publishes a suite of reports annually (including this Report) in support of this engagement.

Western Power recommends this Report be considered in conjunction with the following documents, which present extensive information on Western Power's network management approach and strategies and network investment programs:

- Network Management Plan
- Annual Planning Report
- Annual Reliability and Power Quality Report
- Service Standard Performance Report
- AA3 (Third Access Arrangement) submissions and responses.[1]

These documents are available from Western Power's website.

[1] The Third Access Arrangement commenced on 1 July 2012 and ends on 30 June 2017.

1 EXECUTIVE SUMMARY

This Report is focused on four key areas of performance:

- public safety
- asset state
- capacity of the Network to supply future demand
- reliability of supply and power quality.

1.1 PUBLIC SAFETY

The supply of electricity carries an inherent level of risk. Network service providers (NSPs) worldwide must manage the fundamental dangers of electricity. Australian NSPs face the additional challenge of operating overhead powerlines in areas prone to bushfires.

Western Power's safety outcomes are directly impacted by:

- the condition and performance of network infrastructure
- the standards employed in design and construction activities
- the materials and equipment in use
- interaction with the Network by members of the public
- work practices and the actions undertaken by its workforce.

Public safety is assessed against a number of measures, including the frequency of public safety incidents. During the reporting period, Western Power recorded 147 public safety incidents, equating to an average of 12.3 incidents per month as shown in Table 1.

TABLE 1: FREQUENCY OF PUBLIC SAFETY INCIDENTS BY TYPE

Public safety incident type	Result
Fire or explosion caused by Western Power assets	79
Vehicle, plant or equipment contact with the Western Power Network	47
Injury (requiring medical treatment) or death[2] to people and animals from inadvertent contact with the Western Power Network	12
Injury (requiring medical treatment) or death[2] from electric shock within a customer's premises if caused by the Western Power Network	3
Energy*Safety* Order or reported defect[3]	6
Total	**147**

[2] There were no human fatalities in 2012/13.

[3] This category was not reported in 2011/12 as there were no incidents.

1.2 ASSET STATE

The cycle of investment in the Network spans a number of decades. Many network assets are operating beyond their expected functional lifespan, or "design life" (which accounts for factors such as industry norms, empirical evidence and manufacturers' data). Exceeding design life does not mean an asset is likely to fail immediately, however the frequency and severity of defects can be expected to increase.

Public safety risk relating to an asset is influenced by a range of factors, including its condition, proximity to the general public and the assessed fire risk of its location, particularly for wood poles and overhead powerlines.

All asset classes were considered in preparing this report. It discusses in detail only those assessed as presenting the highest levels of risk to:

- safety due to electric shock and the initiation of fires
- reliability and quality of supply.

Electric shock

No fatalities due to electric shock were recorded in the reporting period and reducing the incidence of non-fatal electric shocks continues to be of paramount importance. A significant proportion of electric shocks were attributable to a particular type of overhead customer service connection configuration. Since 2005, Western Power has replaced more than two thirds of these connections. By June 2015, this program will be completed, removing this particular source of risk.

This Report also acknowledges the risk of electric shock associated with conductor failure, primarily as a result of it falling to the ground and the consequent dangers. This risk applies to a number of different conductor types, each of which is subject to a remediation program. Streetlight switchwire (the conductor type assessed as presenting the highest level of risk) is being removed progressively and will no longer be present in the Network by 30 June 2014.

Initiation of fires

The Network covers an area of 254,920 square kilometres, much of which is isolated and unpopulated. The Report identifies improved management of Western Power's poles and cross-arms as imperative in reducing the risk of fires resulting from the failure of these assets.

Risk-based prioritisation of remediation works and accelerated remediation programs are reducing this risk by increasing delivery volumes. The improvement of asset management strategies, research into new techniques and technologies, improved reporting and engagement with other utilities are expected to yield additional opportunities for further risk reduction. By June 2017, approximately 85% of all wood poles assessed as requiring remediation will have been replaced or reinforced.

Other reported risks with potential to initiate ground fires include:

- direct contact between live conductors ("clashing")
- conductor failures
- pole-top fires caused by pole-top asset defects and environmental conditions.

Mitigation actions are prioritised on the basis of risk to public safety.

Sustained investment will be required to address the safety risks posed by wood poles and conductors. It should be noted that other asset classes presenting lower levels of risk also require remedial works.

1.3 NETWORK CAPACITY

An assessment of network capacity underscores the need for sustained network expansion to accommodate growing customer demand. With the capacity expansions that are planned to the end of 2016/17, the Network will be able to meet forecast load growth and requests to connect new customers. Some maximum utilisation targets are likely to be exceeded during summer 2013/14, as summarised in Table 2.

TABLE 2: NETWORK ELEMENTS FORECAST TO EXCEED UTILISATION TARGETS

Network element	% forecast to exceed utilisation targets
Zone substations	7.8%
Terminal substations	7.7%
Metropolitan feeders	31.0%
Rural feeders	2.8%
Transmission lines	3.1%
Distribution transformers	**0.14%**

A number of less significant capacity constraints are not included in the Report.

1.4 RELIABILITY OF SUPPLY AND POWER QUALITY

Reliability of supply is measured against two key metrics that allow Western Power to quantify the impact of interruptions on customers and influence network investments:

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

These measures are reported at the level of the entire Network and separately for CBD, urban and rural areas. The reliability of the Network has met most targets with some customers in rural areas not receiving adequate supply reliability.

Power quality is measured against the requirements specified in the *Electricity Act 1945*, the *Network Quality and Reliability of Supply Code 2005* ("NQRS Code") and the Technical Rules to enable customer equipment to function correctly and operate safely and without damage.

Western Power monitors power quality parameters such as harmonic distortion and voltage unbalance on the low voltage (LV) distribution network and these are reported annually to the Economic Regulation Authority (ERA). These parameters comply with requirements of either the NQRS Code or the Technical Rules.

1.5 YEAR-ON-YEAR COMPARISONS

Explanatory commentary is only provided where there is significant variance to the current year.

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

- the generally degraded state of many assets (leading to failure rate and defect "find" rate volatility)
- 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 prevalence and intensity of storms or lightning events).

2 PUBLIC SAFETY

Western Power's safety outcomes are directly impacted by:

- the condition and performance of network infrastructure
- the standards employed for design and construction activities
- the materials and equipment in use
- interaction with the Network by members of the public
- work practices and the actions of its workforce.

Public safety is assessed against a number of measures including the frequency of public safety incidents (as defined in Appendix A). During the reporting period,[4] Western Power recorded 147 public safety incidents, equating to an average of 12.3 incidents per month. The breakdown of public safety incidents is shown in Table 3.

TABLE 3: FREQUENCY OF PUBLIC SAFETY INCIDENTS BY TYPE

Public safety incident type	Result
Fire or explosion caused by Western Power assets	79
Vehicle, plant or equipment contact with the Western Power Network	47
Injury (requiring medical treatment) or death[5] to people and animals from inadvertent contact with the Western Power Network	12
Injury (requiring medical treatment) or death[5] from electric shock within a customer's premises if caused by the Western Power Network	3
Energy*Safety* Order or reported defect[6]	6
Total	**147**

Western Power also reports on key public safety performance measures as agreed with its safety regulator Energy*Safety* (definitions of these measures appear in Appendix A). Results against these measures are shown in Table 4.

TABLE 4: SAFETY PERFORMANCE INDICATORS

Incident type	Number
Notifiable incidents	61
Electric shocks relating to Western Power assets or activity (not requiring medical treatment)	238
Unassisted wood pole failures (distribution)	378
Unassisted wood pole failures (transmission)	23
Unassisted conductor failures (distribution)	383
Unassisted conductor failures (transmission)	0
Ground fire incidents	80

[4] The reporting of notifiable incidents and electric shocks is based on the date notified (or profiled), rather than the date on which they occurred.

[5] There were no human fatalities in 2012/13.

[6] This category was not reported in 2011/12, as no such incidents were reported.

2.1 ELECTRIC SHOCKS AND GROUND FIRES

Western Power considers that there is no such thing as an "insignificant electric shock". All circumstances giving rise to electric shocks can lead to electrocution; fortunately, such events are very rare.

Any ground fire initiated by Western Power assets has the potential to threaten life and property. Fortunately, few ground fires result in bushfires and fewer still result in the loss of human life.

Western Power reviews all electric shock and ground fire events and revises its investment strategies appropriately to reduce the overall risk of both as rapidly as possible.

2.2 CROSS-JURISDICTIONAL SAFETY REPORTING

Western Power's safety performance is measured using criteria developed in conjunction with Energy*Safety* (listed in Appendix A).

Meaningful safety benchmarking across Australian NSPs is currently difficult because of the varying safety regulation regimes across jurisdictions and lack of harmonisation of safety performance criteria. Western Power engages with other electricity NSPs to improve its understanding of issues and solutions that have the potential to impact public safety performance.

3 STATE OF NETWORK ASSETS

3.1 INTRODUCTION

3.1.1 Network elements

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

- The **transmission network** transports electricity from generators to transmission terminal stations and then to zone substations.
- The **distribution network** 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:

- structures
- conductors
- distribution plant and equipment
- transmission plant and equipment
- secondary systems.

3.1.2 Assessment of asset state

The assessment of the state of an asset is based upon a number of factors, including:

- **Condition** - defects impacting the asset's serviceability.
- **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.
- **Design life** - this estimates the asset's expected functional lifespan independent of condition. It reflects Western Power's engineering judgement, empirical evidence and data supplied by the manufacturer. Exceeding design life does not mean an asset is likely to fail immediately, however the frequency and severity of defects can be expected to increase.
- **Service life** - this is the period over which the asset will continue to serve its intended purpose safely, without the need for maintenance or repair whose cost is disproportionate to that of its replacement. It recognises that cumulative deterioration of the asset over time will occur, due to wear and tear or environmental effects. Service life typically exceeds design life.

3.1.3 Risk assessment methodology

Evaluating the risk associated with network assets is essential for informing asset management strategies and requires an assessment of both the likelihood and consequence of asset failure. The approach to performing these assessments is in accordance with Western Power's Corporate Risk Framework, focussing on the following risk areas:

Public safety: Risk to the safety of the general public.

Personnel safety: Risk to the safety of Western Power and contractor personnel.

Service: Risk of the loss of network connection and loss of electricity supply.

This approach helps focus Western Power's investment on reducing risk as rapidly as possible by prioritising work on the assets presenting the highest risk.

Note:
A number of the assets reported in this section cite "electric shock" as a possible failure consequence. In all such references, use of this term is consistent with the intentions of the Safety Reporting Definitions agreed with Energy*Safety* (these definitions appear in full in Appendix A).

Bushfire risk zones

For some assets, the assessment of public safety and personnel safety risk is influenced by the "fire risk zone" classification, which considers:

- likelihood factors (e.g. worst weather conditions, prospects of escape, landscape profile, vegetation and land use)
- consequence factors (e.g. impact on public and personnel safety, damage to property and environmental impact).

Western Power's Bushfire Risk Assessment methodology has been endorsed by the Department of Fire and Emergency Services and the Western Australian Department of Environment and Conservation (DEC).

3.1.4 Legacy data

The quality and completeness of network asset data are adequate for prioritising investment. There are ongoing opportunities to refine the data pool due to its scale, scope and the variability with which it has been collected over many decades.

Improvements to Western Power's data and data collection methods have increased the accuracy of asset information; maintaining this focus will ensure it has the necessary information upon which to base its decisions.

Note:
During the electronic conversion of paper-based records, assets without a known installation date were assigned default installation dates of 1 January 1970 or 1 January 1901. To minimise distortion of age profiles, this report aggregates the years most impacted by this issue for affected asset types.

3.2 STRUCTURES

This asset class includes:

- poles
- towers
- stays
- cross-arms
- foundations
- earthing related to poles and towers.

Of these assets, poles, towers and cross-arms are identified as having the greatest potential to adversely impact public safety or reliability of the Network. These assets are discussed in detail in this section.

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

3.2.1 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 condition

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.

Structures are regularly inspected and remedial actions determined and implemented based on the asset condition, with the objective of reducing the risk of failure.

Metal and concrete structures are inspected to detect relevant conditions that can lead to failure. Treatment options are considered and implemented to reduce the risk of asset failure.

Western Power's Wood Pole Strategy is based on the following key elements:

- All unreinforced hardwood poles more than 25 years old are considered to be at risk of unassisted failure and will be reinforced, replaced or removed.[7]
- All poles will be reinforced, replaced or removed where condition assessment indicates risk of unassisted failure.
- All poles with legacy reinforcement systems that do not comply with AS/NZS7000:2010 are considered to be at risk of unassisted failure and will be re-reinforced, replaced or removed.
- All poles with stay systems that do not comply with AS/NZS7000:2010 are considered to be at risk of unassisted failure and the stay systems will be remediated to comply with AS/NZS7000:2010.

Notes:

1. There are 327,000 reinforced transmission and distribution poles, many of which have legacy reinforcements that do not comply with AS/NZS 7000:2010. These poles will be replaced or re-reinforced progressively.
2. Due to the large volume of poles requiring treatment, Western Power prioritises this work based on risk.

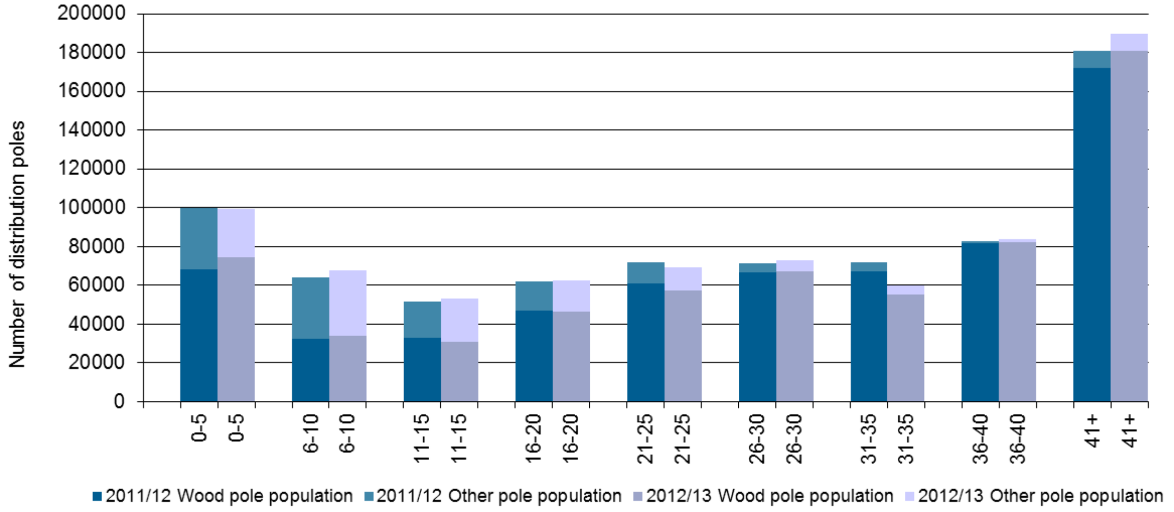
Western Power is continuing to refine its processes to achieve the most effective and efficient pole treatment approach possible.

Asset age profile

The age profile of the 758,947 distribution poles in the network is shown in Figure 1. Of these, 629,492 are wood poles, of which 440,000 require removal, replacement, reinforcement or re-reinforcement in accordance with Western Power's strategy.

Western Power is aware that the 0-5 age bracket does not reflect all of the 16,930 distribution wood poles replaced during the reporting period. This is due to data conversion issues with the recent implementation of new asset information systems and documentation received for a number of pole replacements. The issue is well understood and Western Power has taken steps to address it.

FIGURE 1: AGE PROFILE - DISTRIBUTION POLES



7 Based on AS/NZS:1720.2.

A total of 65,939 wood poles have been assessed as having conditions (such as rot) requiring replacement or removal in accordance with Western Power's current strategy, a 29% increase from 2011/12. This is due primarily to enhanced inspection processes and the introduction of more conservative serviceability assessment criteria to identify and treat unserviceable poles before they fail in service.

In addition, 2,045 metal poles and 49 concrete poles have been assessed as having conditions (such as rust, metal fatigue and concrete cancer) requiring replacement or removal.

Figure 2 shows the volumes of distribution wood poles with and without conditions.

FIGURE 2: CONDITION PROFILE BY AGE - DISTRIBUTION WOOD POLES

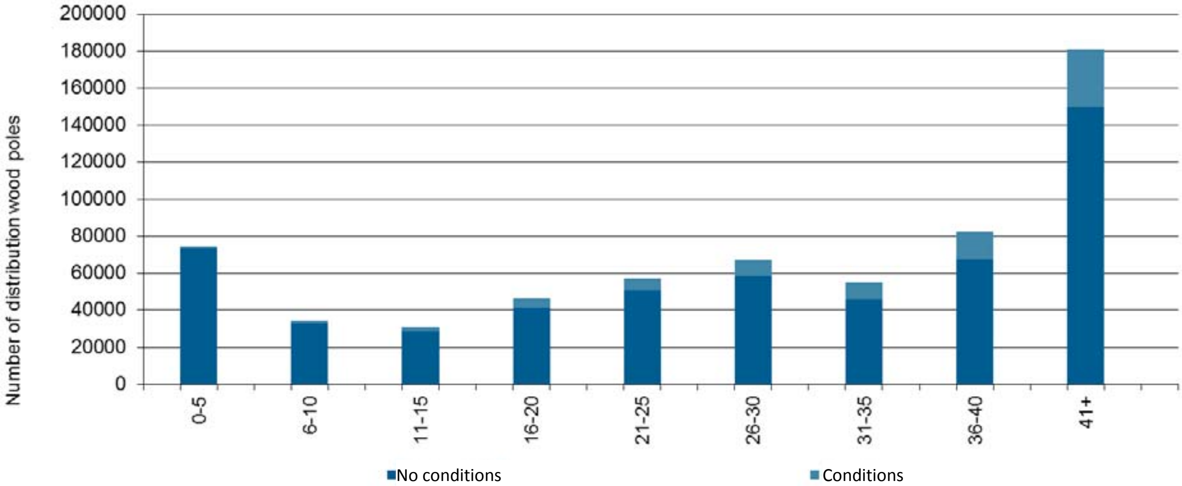
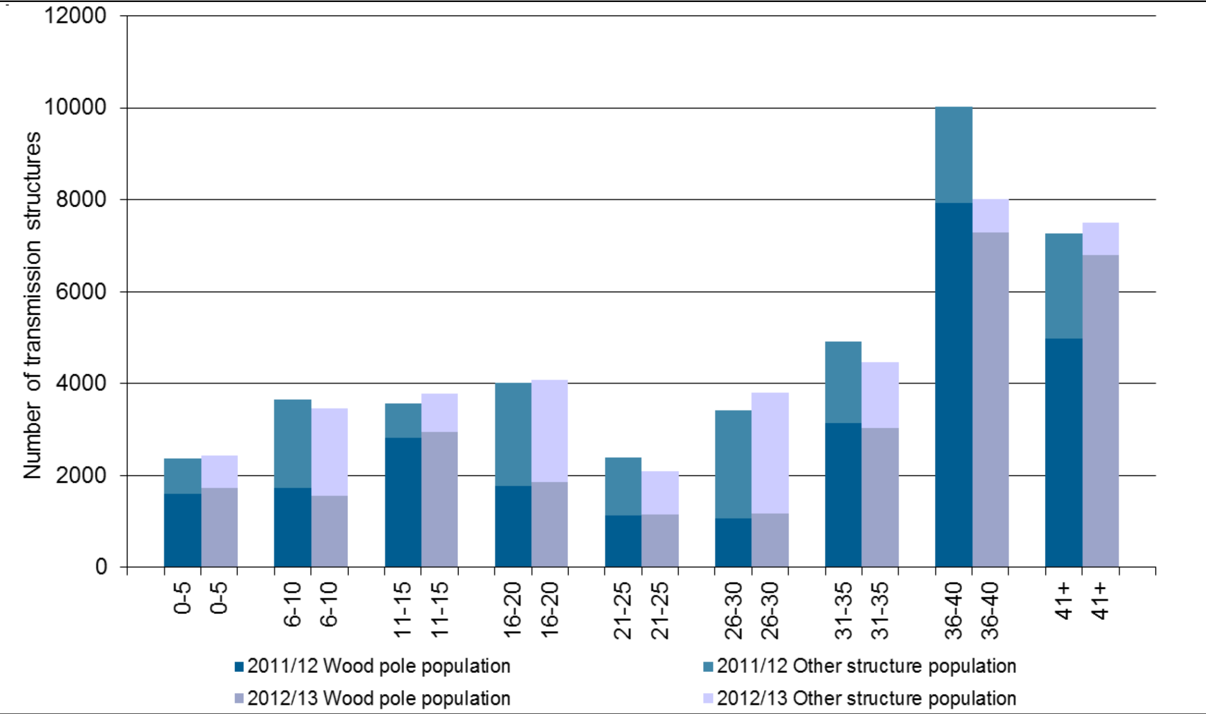


Figure 3 shows the age profile of the total population of 40,365 transmission structures. 27,500 are wood poles, of which 10,500 require replacement, reinforcement or re-reinforcement in accordance with Western Power's current strategy. This represents an increase of 52% from 2011/12. As with distribution poles, this increase is due primarily to enhanced inspection processes and the introduction of more conservative serviceability assessment criteria to identify and treat unserviceable poles before they fail in service.

FIGURE 3: 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:

- injury caused by the falling pole
- serious electric shock accidents resulting from contact with fallen conductors
- fire caused by the fallen conductors touching other material
- network outages.

The large volume of distribution wood poles exceeding design life means that these assets have a higher likelihood of failure. Towers and metal poles can also fail, particularly if exposed to winds exceeding design limits.

Wood pole failures recorded during the reporting period were:

- Distribution: 378 (0.06% of the population) *(2011/12: 0.06%)*
- Transmission: 23 (0.08% of the population) *(2011/12: 0.08%)*

This represents reductions of 2% and 34% (distribution and transmission respectively) from 2011/12. To some extent, these reductions are due to year-on-year variability. However, the improved inspection regime and increased pole replacement/reinforcement program have also contributed to the improved performance.

Risk assessment

TABLE 5: RISK ASSESSMENT - POLES AND TOWERS

Risk area	Rating	Comment
Public safety	High	169,960 (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 electric shock resulting from contact with fallen conductors. This asset class is 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 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.

The quantity of poles requiring reinforcement or replacement (440,000) means that the remediation works will take a number of years to complete. Western Power continues to prioritise activities that will expedite the reduction of the safety risk associated with aged wood poles, through initiatives such as:

- pole inspections to ensure accurate data regarding asset condition
- replacements and reinforcements targeting the highest risk poles (i.e. the worst condition poles in extreme and high fire risk or public safety zones).

In addition, the Serviceability Assessment Methodology (defined by the Wood Pole Asset Management Strategy) will enable network-wide, risk-based prioritisation of remedial work by creating a Risk Score for every pole.

Western Power plans to replace or reinforce at least 364,000 distribution wood poles in AA3. This volume is limited by Western Power's current assessment of its capacity to perform the work. Western Power also plans to replace or reinforce at least 6,700 transmission wood poles over the same period.

The Wood Pole Asset Management Plan and the Network Management Plan detail the full suite of strategies employed to address risks posed by aged wood poles.

3.2.2 Distribution cross-arms

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

The population of distribution cross-arms is approximately 528,000, of which approximately 466,500 are hardwood timber and 60,000 steel, with the balance made up of composite materials presently being trialled.

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.

The service life of steel cross-arms is affected by these conditions:

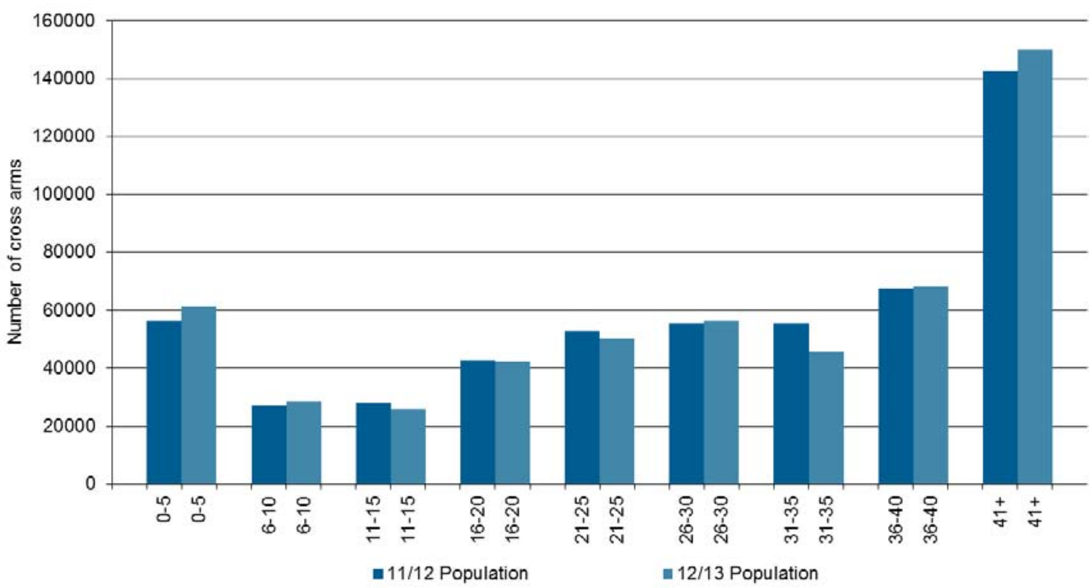
- cracked welds
- rust
- metal fatigue.

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

Asset age profile

Figure 4 shows the age profile for distribution cross-arms.[8] The age of some of this population is derived from the age of the pole upon which the cross-arm is mounted, as data is incomplete for this asset.

FIGURE 4: AGE PROFILE - CROSS-ARMS



[8] The 2011/12 cross-arms age profile published in the 2011/12 State of the Infrastructure Report also included streetlight pole volumes.

The condition of cross-arms is assessed through routine inspection. As at the end of the reporting period, 11,133 cross-arms were assessed as requiring replacement, an increase of 110% from 2011/12. This is due primarily to enhanced inspection processes to identify and replace unserviceable cross-arms before they fail in service.

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
- pole-top fires resulting from insulation breakdown
- 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
- pole-top fire due to insulation breakdown
- network outages.

Failure of cross-arms and pole-top equipment can initiate pole-top fires 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).

Defects 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.

242 distribution pole-top fires were reported for the reporting period *(2011/12: 359)*, a reduction of 33% from 2011/12. To some extent, this is due to year-on-year variability. However, continuation of the pole replacement, cross-arm replacement and siliconing programs have also contributed to improved performance.

These pole-top fires resulted in 10 ground fires *(2011/12: 12)*.

Risk assessment

TABLE 6: RISK ASSESSMENT - DISTRIBUTION CROSS-ARMS

Risk area	Rating	Comment
Public safety	Medium	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. As wooden cross-arms are less susceptible to ground-borne 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.

The main strategy for mitigating pole-top fires is the application of silicone coating to the insulators. Other strategies include:

- replacement of porcelain insulators
- replacement of wood cross-arms with steel cross-arms
- tightening bolts on installations
- replacement of the entire pole-top assembly (i.e. cross-arms and insulators).

Pole-top fire mitigation programs are prioritised on the basis of:

- likelihood and consequence of pole-top fires (e.g. extreme and high fire risk zones)
- history of previous pole-top fires
- exposure to environmental pollutants.

A large quantity of wood cross-arms is being replaced or removed in conjunction with other programs, including the State Underground Power Program and the Wood Pole Replacement Program, which also involves the installation of new insulators that are less susceptible to pole-top fires.

3.3 CONDUCTORS

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

3.3.1 Streetlight switchwire

Streetlight switchwire is a separate and dedicated overhead conductor component that supplies power to streetlight luminaires, enabling them to be switched on and off in groups. Switchwires are energised either by clocks or photoelectric cells within streetlight control boxes.

New and upgraded streetlights are connected directly to the low voltage street mains and switched individually, eliminating the need for a switchwire.

Asset condition

Streetlight switchwire typically uses older, small-gauge copper conductors that are prone to deterioration, reduced service life and failure, particularly in salt-laden coastal environments.

Records are unreliable for the age of streetlight switchwire, however Western Power has prioritised its removal as it presents the highest safety risk of all conductor asset types.

Asset profile

Western Power removed a total of 3,066 route km[9] of streetlight switchwire during the reporting period. Removal of the remaining 1,166 route km will be complete by 30 June 2014.

Failure modes and consequences

The failure of this asset type generally results in the switchwire falling to the ground.

The consequence of highest impact is electrocution from contact with a fallen streetlight switchwire.

32 fallen streetlight switchwire incidents were recorded for the reporting period (*2011/12: 28*).

Risk assessment

TABLE 7: RISK ASSESSMENT - STREETLIGHT SWITCHWIRE

Risk area	Rating	Comment
Public safety	Extreme	As streetlight switchwires are generally situated in populated areas, failure increases the likelihood of electrocution resulting from contact with fallen conductors. The remaining volume of streetlight switchwire means that an event of this type is possible, presenting an extreme risk.

9 Streetlight switchwire length is measured in route km, which refers to the physical distance traversed by a section of the network. All other conductor lengths are measured in circuit km, which is the total length of all the conductor elements used in a section of the network.

3.3.2 Streetlight luminaires[10]

A streetlight luminaire comprises the lamp fitting, metal outreach and wiring to provide the physical connection to the pole, as well as the electrical connection to either an overhead or underground supply.

Asset condition

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 Australian Standard.[11]

The condition of these assets is determined through inspections performed by programs such as Streetlight Fault Repair and Bulk Globe Replacement. Assets assessed as being in poor condition may be replaced through these programs.

Asset profile

The Network contains approximately 237,674 streetlight luminaires, which have an expected life of 20 years. Approximately 53,000 have reached or exceeded their expected life.

Western Power replaces streetlight luminaires on failure through a number of programs. 7,540 luminaires were replaced in 2012/13 and a further 7,200 are forecast to be replaced in 2013/14.

Failure modes and consequences

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

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

Two electric shocks due to streetlight luminaire failures were recorded during the reporting period *(2011/12: 0)*.

Risk assessment

TABLE 8: 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.

[10] This discussion includes PowerWatch security lighting.

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

3.3.3 Overhead distribution conductors

Bare or covered (insulated) overhead distribution conductors transport electricity from transmission zone substations to customers. This discussion relates mainly to bare conductor, which has the greater impact on public safety.

Asset condition

A number of factors affect the service life of conductors:

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

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

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

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

- small gauge copper or steel (SC/AC[12] or SC/GZ[13]) conductor more than 40 years old
- ungreased ACSR[14] conductor more than 20 years old
- High Voltage Aerial Bundled Conductors (HV ABC).

Of the 68,503 km of overhead distribution conductors in the Network, 22,998 km is assessed with the above attributes, with 5,913 km located in population centres or extreme and high fire risk zones. This subpopulation will be surveyed to assess the conductor condition and prioritise replacement programs.

The Conductor Replacement Program replaced 278 km in 2012/13, with a further 422 km planned for replacement in 2013/14.

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12 Steel Conductor Aluminium Clad.

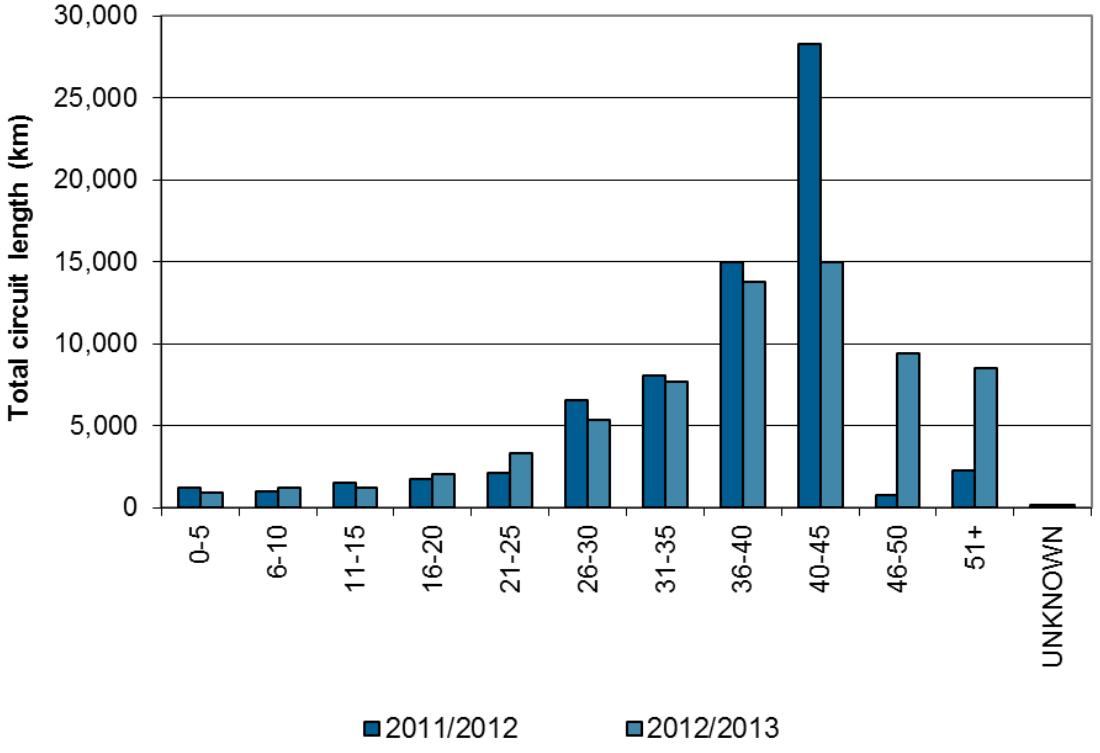
13 Steel Coated Galvanized Zinc.

14 Aluminium Conductor Steel Reinforced.

Asset age profile

As shown in Figure 5, a large proportion of the overhead distribution conductor in the Network is more than 40 years old.

FIGURE 5: AGE PROFILE - OVERHEAD DISTRIBUTION CONDUCTORS



All distribution overhead conductor age data is derived using estimation algorithms, which are subject to ongoing revision to improve the accuracy of conductor age estimates.

Failure mode and consequences

The failure of this asset type generally results in the conductor falling to the ground. The consequences of highest impact are:

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

383 unassisted conductor failures were recorded for the reporting period *(2011/12: 393)*, which resulted in five ground fires *(2011/12: 9)*.

Without works to address the deterioration of the conductor population, the number of fires and electric shocks due to conductor failure is expected to increase. Condition assessment surveys of the subpopulation of highest potential risk will drive replacement programs.

Risk assessment

TABLE 9: 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.

3.3.4 Conductor clashing

Conductor clashing occurs when bare live overhead conductors come into contact with one other.

Asset conditions

A range of factors contribute to this issue:

- bay length
- conductor tensioning
- conductor separation.

Asset profile

The Network has an estimated 11,863 high voltage and 12,446 low voltage bays with higher risk of conductor clashing due to bay length. These bays are the focus of current remediation programs.

Failure mode and consequences

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

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

254 conductor clashing incidents were recorded for the reporting period *(2011/12: 196)*, resulting in two ground fires *(2011/12: 4)*, an increase of 30% of 2011/12. This is due primarily to year-on-year variability, predominantly from a high number of unseasonable extreme environmental events, such as lightning, high winds and storms. Improvements in identification and reporting of incidents also contributed to the increase.

Risk assessment

TABLE 10: 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.

Western Power is transitioning to a new approach of assessing the risk of conductor clashing using an engineering risk management model. This approach will more effectively identify bays presenting a heightened public safety risk due to clashing.

Western Power continues to prioritise activities that will expedite reduction of the safety risk associated with conductor clashing.

3.3.5 Conductor clearances

Overhead conductors crossing roadways and navigable waterways are required to provide a minimum clearance height to ensure safe passage beneath them.[15]

Asset profile

Conductor clearances over roadway and navigable water crossings that do not meet Australian Standards are identified by survey. Of a total 32,580 conductor crossings determined to present a high public safety risk, 29,139 have been surveyed.

In 2012/13, 173 road crossings and four river crossings with substandard clearances were remediated. A further 236 road crossings with substandard clearances are planned for remediation in 2013/14.

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.

During the reporting period, two incidents were recorded of vehicles striking conductors with substandard clearance across roads *(2011/12: 3)*, neither of which resulted in notifiable incidents or injury.

Risk assessment

TABLE 11: 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.

Conductors with substandard clearance are being rectified progressively, prioritising those with the lowest clearance heights in the highest traffic areas.

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

3.3.6 Overhead customer service connections

Overhead customer service connections connect individual customer properties to the low voltage overhead distribution network.[16]

Asset condition

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

There is also evidence of other overhead customer service connection conditions (including substandard installation and repair practices) having the potential to lead to electric shock. 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

The estimated population of overhead customer service connections is 449,543, of which approximately 34,865 are of the older type that use preformed steel wire helical terminations.

Failure modes and consequences

The most common cause of failure with the older connection type is degradation of insulation material.

The consequence of highest impact is electric shock from contact with metal components energised as a result of the failure.

166 electric shocks attributable to connections of this type were recorded for the reporting period *(2011/12: 197)*.

Risk assessment

TABLE 12: RISK ASSESSMENT - OVERHEAD CUSTOMER SERVICE CONNECTIONS

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

In 2005, Western Power commenced a program to replace all of the estimated 300,000 older overhead helical termination customer service connections with one of the following:

- an overhead customer service connection compliant with current standards[17] or
- an underground customer service connection as part of the State Underground Power Program.

265,135 overhead customer service connections of this type had been replaced by the end of the reporting period *(2011/12: 205,600)*. Replacement of the remaining 34,865 will be completed by 30 June 2015.

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16 Overhead customer service connections are a subset of customer service connections.

17 WA Electrical Requirements (WAER) July 2008 and AS/NZS 3000:2007.

3.3.7 Transmission underground cable

The underground transmission network comprises a range of high voltage (66 kV, 132 kV and 330 kV) cable types.[18] 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 condition

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

Asset profile

The Network's 52 km of transmission underground cable includes 12 km containing fluid insulation medium, of which 10 km (83.3%) 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.

A leaked fluid volume of 2,124 litres from five cables was recorded for the reporting period *(2011/12: 1,574)*. The increase from 2011/12 is attributable to two unassisted cable sheath conductor failures that took an extended period to locate and repair.

Risk assessment

TABLE 13: 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.

Western Power assesses the condition of fluid filled cables by inspecting fluid levels weekly, monitoring alarms and performing a range of non-destructive tests. Upon detection of a leak that exceeds safe levels, the location of the leak is determined and repairs are performed to prevent cable failure.

The planned replacement of two cables with high leakage rates in 2013/14 was deferred following successful maintenance works.

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

3.4 DISTRIBUTION PLANT AND EQUIPMENT

Distribution plant and equipment assets include all distribution network equipment other than poles, conductors and secondary systems (SCADA and communications equipment). These assets are characterised by their high volumes and relatively low impact of individual failure on network safety and reliability.

Distribution plant and equipment consists of asset classes with similar life-cycle management characteristics. These asset classes include:

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

Consistent with industry practice, many of the distribution plant and equipment asset classes were previously categorised as "Run-to-Fail" (RTF), with minimal maintenance undertaken. Improved data collection techniques and fault detection have provided an opportunity to assess higher volumes of distribution plant and equipment asset conditions. In conjunction with this assessment, Western Power's corporate risk model and location consequence rating make it more prudent for some distribution plant and equipment assets to be categorised as "Non-Run-to-Fail", meaning they are maintained or replaced proactively prior to failure.

A cumulative risk score derived from the corporate risk matrix and location consequence is used to prioritise the replacement of distribution plant and equipment assets. Other Western Power programs address the safety and reliability of impacts of distribution plant and equipment, including some typically addressed through routine maintenance activities. These include:

- 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).

Failure of switchgear (pole-top switch disconnectors, reclosers and sectionalisers) and transformers presents the greatest potential for impacting safety and reliability. These assets are discussed in detail in the following sections.

Note:

The Network Management Plan provides information on current investment programs addressing the risks associated with failure of plant and equipment assets.

3.4.1 Pole-top switch disconnectors

A pole-top switch disconnector (PTSD) permits simultaneous manual isolation of high voltage three-phase sections of the distribution network.

Asset conditions

Conditions affecting the service life of these assets include:

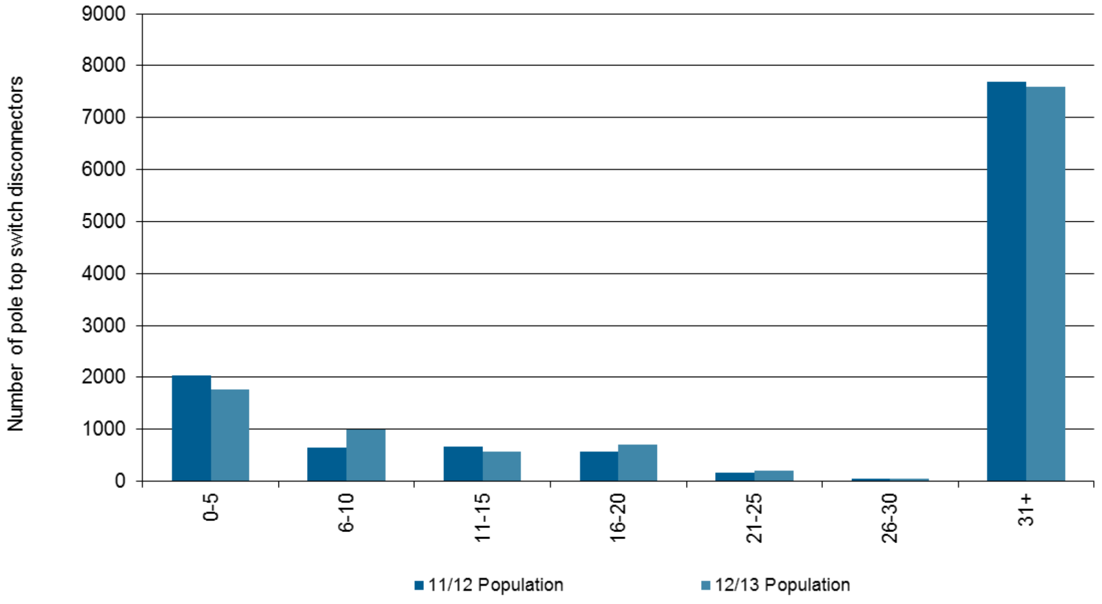
- corrosion
- insulation degradation
- defective earthing
- defective or malfunctioning operating mechanism.

353 PTSDs (2.97% of the population) have been assessed with conditions requiring replacement, a reduction of 84% from 2011/12. This has resulted from the introduction of a new work practice requiring all switching operators to carry a portable earth mat for use when operating PTSDs. This mitigates the safety risk to operators from PTSDs with defective earth mats, which would otherwise require the replacement of the PTSD before it could be safely operated.

Asset age profile

A significant proportion of PTSDs have exceeded their 30 year design life. Fewer of these assets have been installed over the last 20 years, with reclosers and sectionalisers now preferred options for switchgear. Figure 6 shows the age profile of PTSDs.

FIGURE 6: AGE PROFILE - POLE-TOP SWITCH DISCONNECTORS



Failure modes and consequences

Asset 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 reduced reliability.

66 PTSD failures (0.55% of the population) were recorded during the reporting period *(2011/12: 0.1%)*, an increase of 450% from 2011/12. As these assets are static devices, failure is usually only identified when they are required to operate. The increased activity on the network, particularly due to the pole replacement program, requires larger numbers of these devices to be operated more frequently, leading to greater visibility of failure. Failure of these assets typically does not pose a public safety risk.

Risk assessment

TABLE 14: RISK ASSESSMENT - POLE-TOP SWITCH DISCONNECTORS

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.

3.4.2 Reclosers

A recloser is an automatic switching device installed on the high voltage overhead distribution network to detect and interrupt momentary faults. It improves service continuity and minimises the number of customers impacted by network outages by restoring power automatically once the fault is cleared.

Asset conditions

Conditions affecting the service life of these assets include:

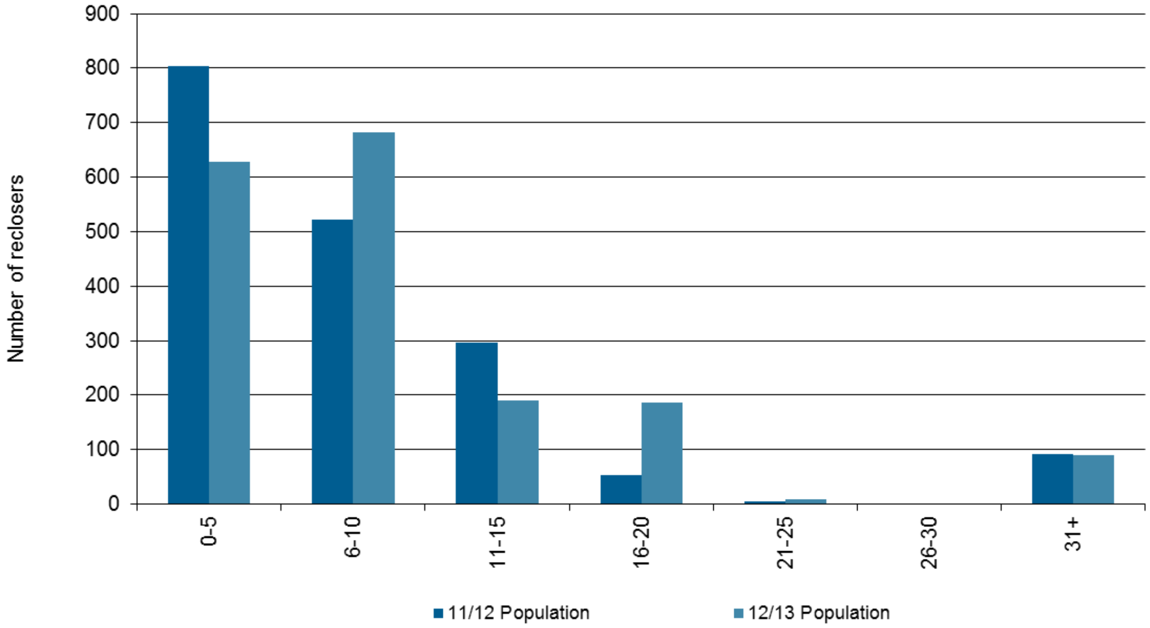
- corrosion
- mechanical failure
- insulation degradation
- low gas level
- communication system faults.

163 reclosers (9.12% of the population) have been assessed with conditions requiring replacement, a reduction of 25% from 2011/12. This has resulted from the successful implementation of a maintenance program to identify conditions in a timely manner and maintain existing assets, rather than replace them.

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 having exceeded their design life of 25 years. Figure 7 shows the age profile of reclosers.

FIGURE 7: AGE PROFILE - RECLOSERS



Failure modes and consequences

Asset failures are typically caused by the following conditions:

- insulation breakdown
- mechanical failure due to corrosion of components
- 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.

24 recloser failures (1.34% of the population) were recorded during the reporting period *(2011/12: 0.22%)*, a 500% increase from 2011/12. This is due mainly to extreme environmental events (lightning) and a failure rate higher than anticipated for aged hydraulic type reclosers. The asset strategy for reclosers is under review to address this increasing failure rate.

Risk assessment

TABLE 15: 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.

3.4.3 Sectionalisers

A sectionaliser is an automatic switching device installed on the high voltage overhead distribution network usually used in conjunction with a recloser to isolate the faulted section/s. These assets generally have telemetry capability.

Asset conditions

Conditions affecting the service life of these assets include:

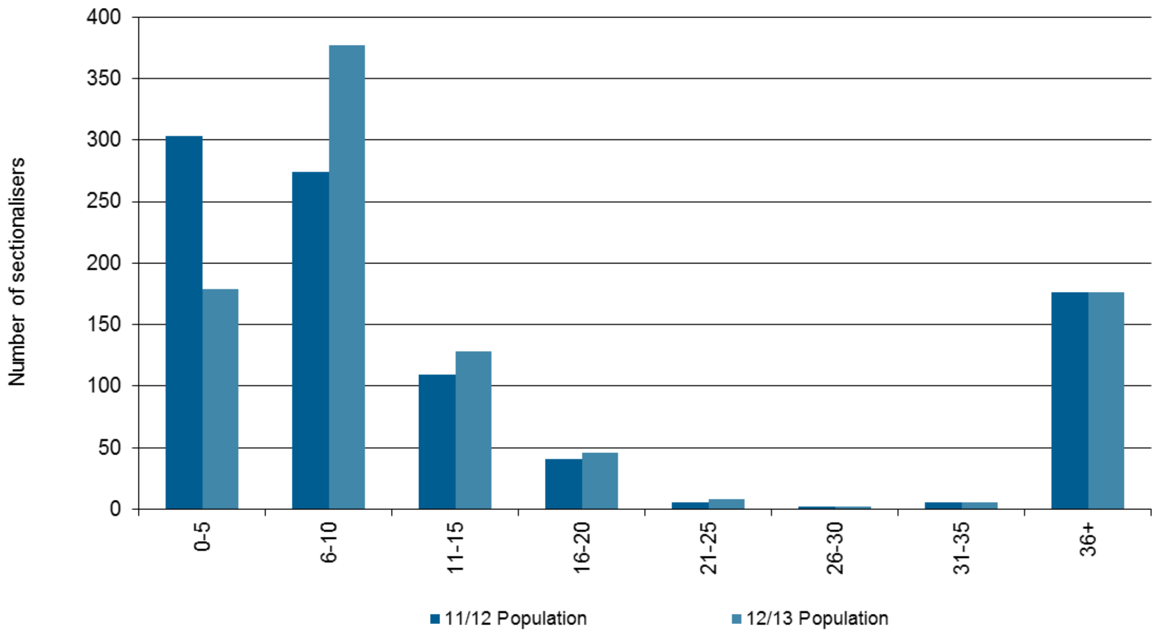
- corrosion
- mechanical failure
- oil leaks
- insulation degradation
- communication system faults.

114 sectionalisers (12.36% of the population) have been assessed with conditions requiring their replacement, an increase of 217% from 2011/12. This is due to the asset deterioration rate exceeding the rate at which they are being replaced.

Asset age profile

The majority of sectionalisers have been installed over the last 20 years, with a small number having exceeded their design life of 35 years. Figure 8 shows the age profile of sectionalisers.

FIGURE 8: AGE PROFILE - SECTIONALISERS



Failure modes and consequences

Asset failures are typically caused by:

- contacts failing to open to trip the faulted section
- 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.

Eight sectionaliser failures (0.86% of the population) were recorded during the reporting period *(2011/12: 0.1%)*. The increasing number of sectionaliser failures is a direct result of the growing volume of sectionalisers identified as requiring replacement.

Risk assessment

TABLE 16: 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.

3.4.4 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 units larger than 100 kVA, as these generally supply multiple customers and have a greater service impact in the event of failure.

Asset conditions

Conditions affecting the service life of these assets include:

- corrosion
- oil leaks
- bushing failures
- insulation degradation
- turret defects
- overloading.[19]

Consistent with common industry practice, distribution transformers have previously typically been managed as run-to-fail assets with minimal maintenance undertaken, unless located in an extreme or high fire risk zone or in an environmentally sensitive area. A more comprehensive condition monitoring and inspection program has now been implemented, with improved data collection techniques and fault detection. As a result, more distribution transformers in poor condition are now identified and replaced proactively based on the following:

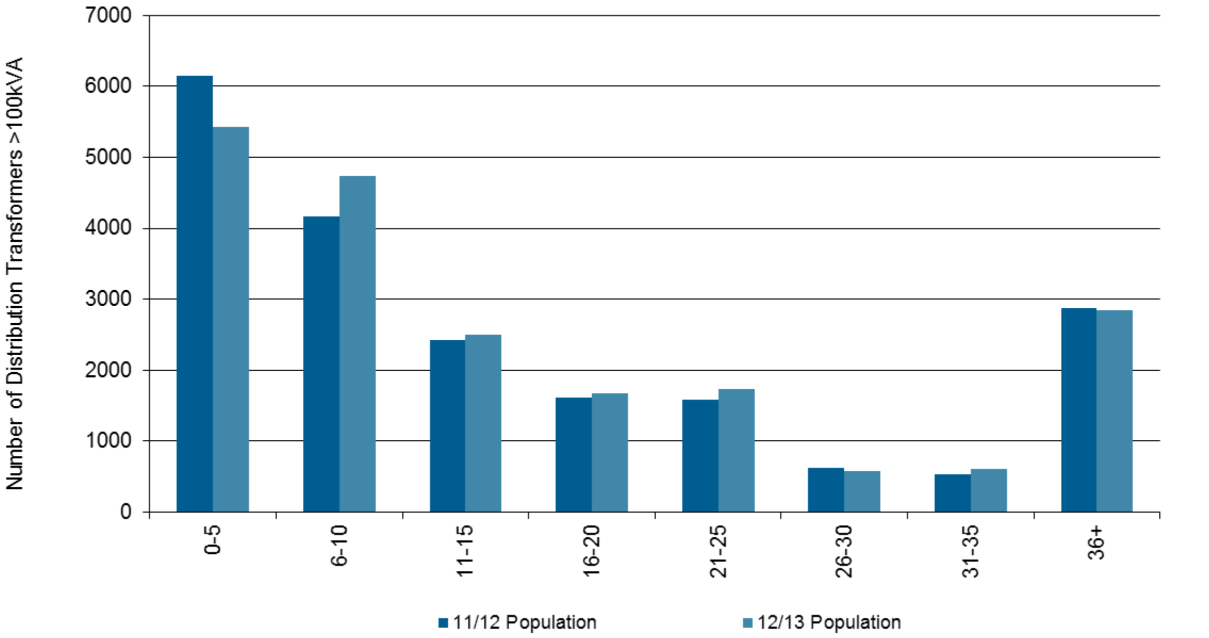
- a predicted transformer overload situation[19]
- an asset's condition is assessed as unserviceable.

Asset age profile

A small proportion of these assets exceed their design life of 35 years, with most expected to continue to provide reliable service for approximately another 10 years. Figure 9 shows the age profile of distribution transformers.

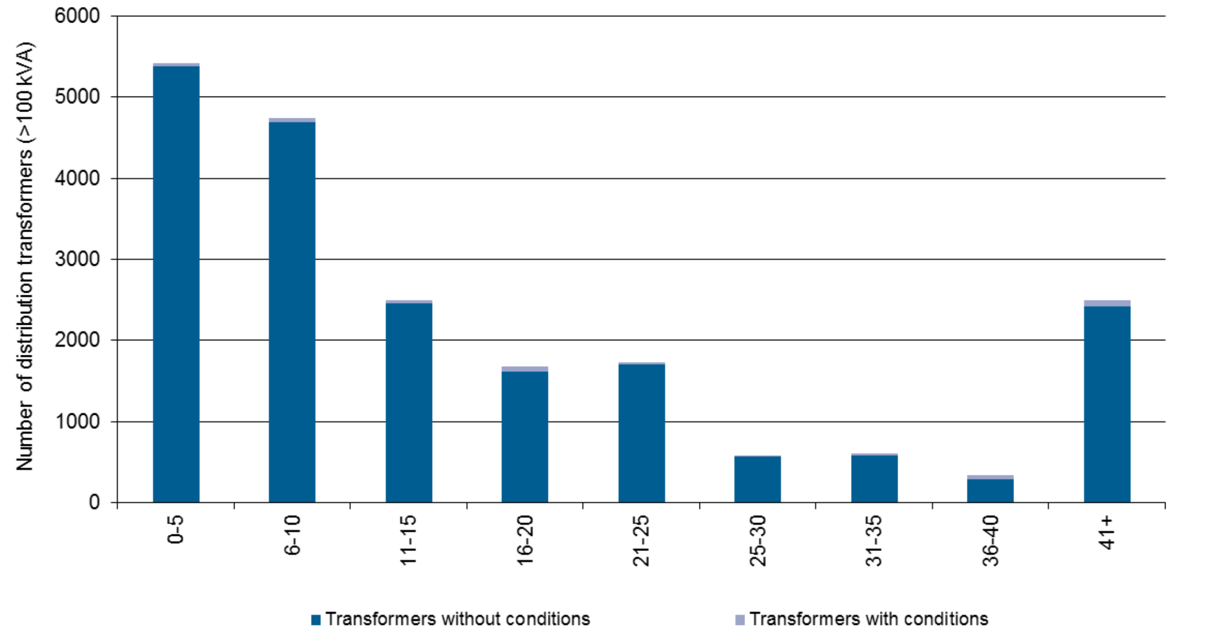
[19] This factor is discussed in detail in Section 4 (Capacity).

FIGURE 9: AGE PROFILE - DISTRIBUTION TRANSFORMERS (> 100 KVA)



343 distribution transformers (1.7% of the population) have been assessed with conditions requiring their replacement, an increase of 23% from 2011/12. Better and more widespread implementation of the inspection program has increased the defect find rate, with more distribution transformers being identified for replacement during the inspection process and fewer in-service failures. Figure 10 shows the condition profile of distribution transformers.

FIGURE 10: CONDITION PROFILE - DISTRIBUTION TRANSFORMERS (> 100 KVA)



Failure modes and consequences

Asset failures are typically caused by:

- bushing failure
- overload
- lightning strikes.

Failed units are generally replaced as an emergency response activity. The key consequence of failure is loss of supply to multiple customers.

185 distribution transformer failures (0.92% of the population) were recorded during the reporting period *(2011/12: 1.1%)*.

Risk assessment

TABLE 17: 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 100 customers.[20]

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

3.4.5 Dropout fuses

Dropout fuses protect distribution transformers and distribution network segments by de-energising faulted portions of the network within milliseconds of being subjected to a fault current.

In contrast to all other asset types reported, the key risk area associated with dropout fuses is a consequence of normal operation, rather than failure.

Asset conditions

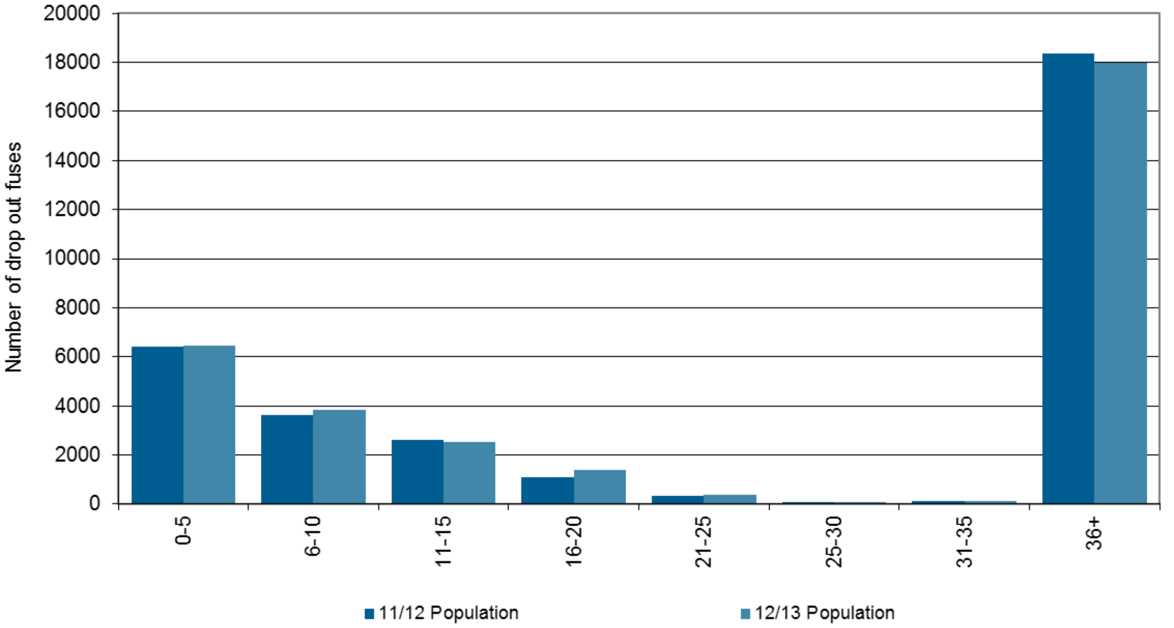
Conditions affecting the service life of these assets include:

- corrosion
- component deterioration.

Asset age profile

A large proportion of dropout fuse assets that have exceeded their 35 year design life and continue to provide reliable service. Figure 11 shows the age profile of dropout fuses.

FIGURE 11: AGE PROFILE - DROPOUT FUSES



4,636 dropout fuses (14.12% of the population) have been assessed with conditions requiring their replacement, an increase of 47% from 2011/12. A review of the dropout fuse asset strategy resulted in the identification of new failure modes. More dropout fuses are therefore being identified for replacement during the inspection process, reducing in-service failures.

Failure modes and consequence

Asset failures are typically caused from component deterioration resulting in the fuse failing to operate or from loose contacts tripping and falling to the ground. Depending upon conditions, failed units are generally 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 extreme and high fire risk zones to reduce the risk of fire caused by expulsion of molten metal.

159 dropout fuse failures (0.48% of the population) were recorded during the reporting period *(2011/12: 0.4%)*, an increase of 30% from 2011/12. This is due largely to year-on-year variability, predominantly from a high number of unseasonable extreme environmental events, particularly lightning.

Risk assessment

TABLE 18: RISK ASSESSMENT - DROPOUT FUSES

Risk area	Rating	Comment
Public safety	High	Asset failure in areas classified as extreme or high bushfire risk zones increases the risk of fire.
Service	Medium	Failure may result in an increased number of customers being affected by network outages.

3.5 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 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.

Note:

The Network Management Plan provides information on current investment programs addressing the risks associated with failure of plant and equipment assets.

3.5.1 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 standards.

Asset conditions

Conditions affecting the service life of these assets include:

- 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.

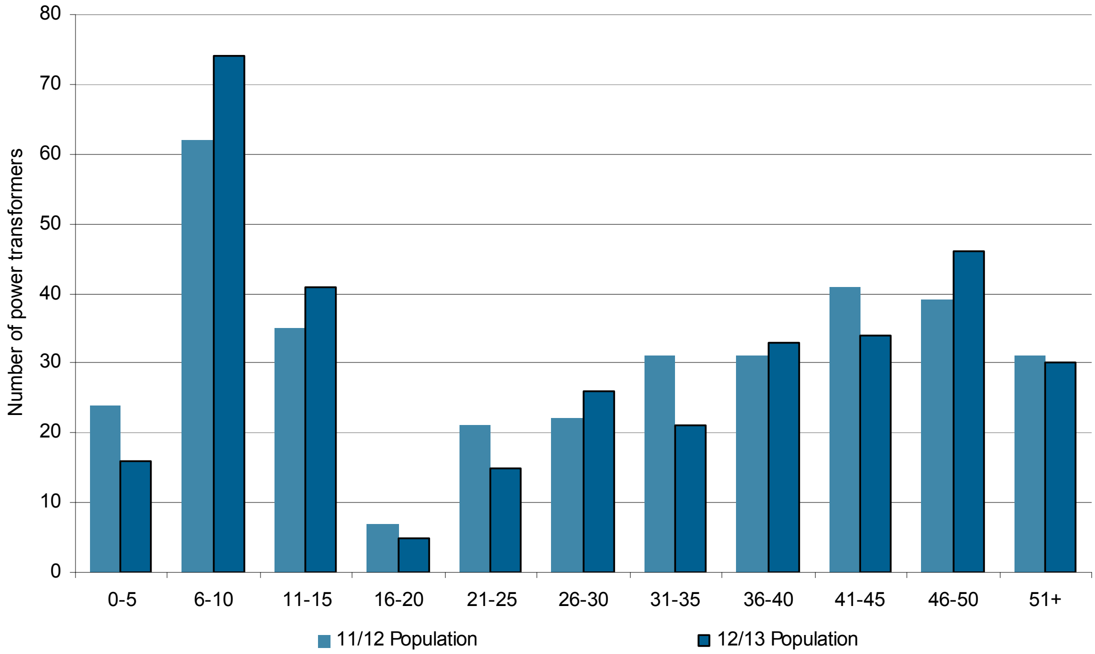
Condition of these assets is assessed by a range of methods, including:

- 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).

Asset age profile

Figure 12 shows the age profile of power transformers.

FIGURE 12: AGE PROFILE - POWER TRANSFORMERS



96 power transformers (28.2% of the population) have exceeded their design life of 40 or 50 years (depending on transformer size) and 32 (9.4%) require mitigation independent of their age, due to assessed conditions such as insulation degradation, lack of spare parts and component issues.

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.

One power transformer failure (0.3% of the population) was recorded during the reporting period *(2011/12: 0%)*.

Risk assessment

TABLE 19: RISK ASSESSMENT - POWER TRANSFORMERS

Risk area	Rating	Comment
Public safety	High	Explosive failures are rare and can cause serious injuries.
Service	Medium	Failure can result in outages affecting large numbers of customers.

3.5.2 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 (indoor or outdoor) and insulation and interrupting medium (vacuum, gas or oil). These assets 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

Conditions affecting the service life of these assets include:

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

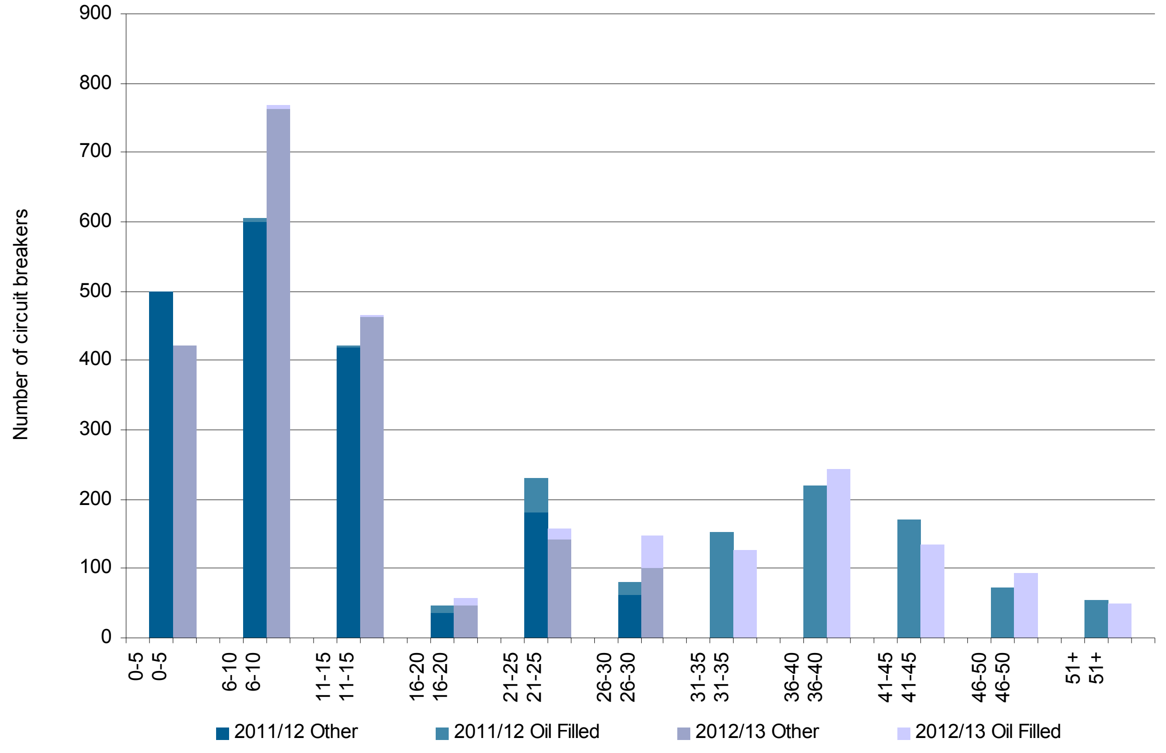
Condition of these assets is assessed by a range of methods, including:

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

Asset age profile

Figure 13 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 13: AGE PROFILE - CIRCUIT BREAKERS AND SWITCHBOARDS (GROUPED BY INTERRUPTING MEDIUM)



142 of these assets (5.4% of the population) have exceeded their design life of 45 years and 369 (13.9%) require mitigation, due to assessed conditions such as mechanical degradation, lack of spare parts or component issues.

Failure modes and consequences

Asset failures are typically caused by:

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

The consequences of greatest impact are:

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

Two failures of these assets (0.08% of the population) were recorded during the reporting period *(2011/12: 0.2%)*.

Risk assessment

TABLE 20: RISK ASSESSMENT - CIRCUIT BREAKERS AND SWITCHBOARDS

Risk area	Rating	Comment
Public safety	High	Explosive failures are rare and can cause serious injuries. Indoor circuit breakers present a higher safety risk than outdoor units due to the close proximity of personnel to the energised bus.
Service	Medium	Failure can result in outages to a large number of customers. 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.

3.5.3 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

Conditions affecting the service life of these assets include:

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

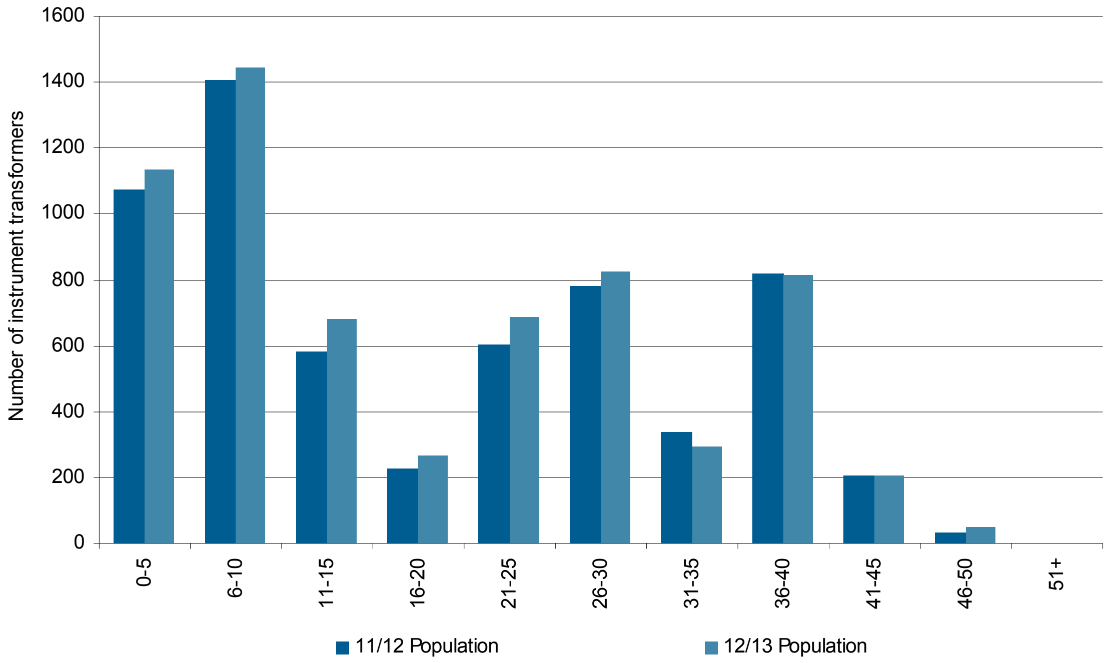
Condition of these assets is assessed by a range of methods including:

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

Asset age profile

Figure 14 shows the age profile of instrument transformers.

FIGURE 14: AGE PROFILE - INSTRUMENT TRANSFORMERS



256 (4.0% of the population) have exceeded their design life of 40 years and 272 (4.3%) require mitigation, due to assessed conditions such as insulation degradation, lack of spare parts or component issues.

Failure modes and consequences

Asset 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

Four instrument transformer failures (0.06% of the population) were recorded during the reporting period *(2011/12: 0.02%)*.

Risk assessment

TABLE 21: RISK ASSESSMENT - INSTRUMENT TRANSFORMERS

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

3.5.4 Disconnectors and earth switches

Disconnectors and disconnector/earth switches[21] safely isolate and earth sections of the Network. They also control the flow of power in terminal stations and zone substations.

Asset conditions

Conditions affecting the service life of these assets include:

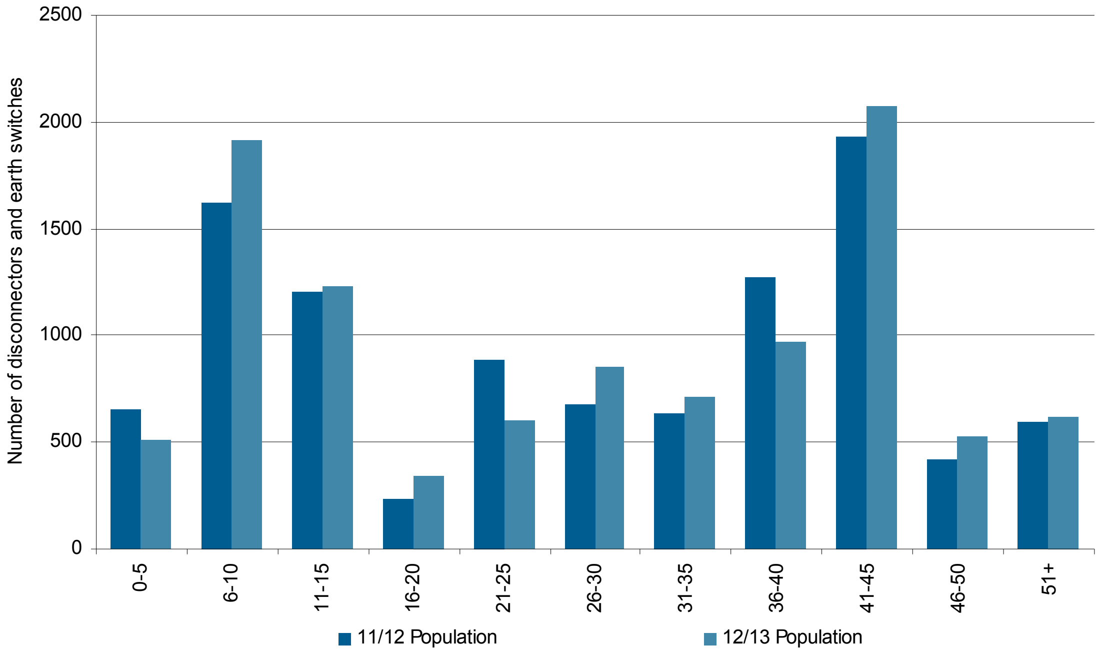
- seizure of linkages and other moving parts
- wear causing improper contact on live parts of the switch
- lack of spare parts.

The main method of assessing the condition of these assets is periodic inspections (including thermo-graphic techniques).

Asset age profile

Figure 15 shows the age profile of disconnectors and disconnector/earth switches.

FIGURE 15: AGE PROFILE - DISCONNECTORS AND EARTH SWITCHES



621 disconnectors and earth switches (6.0% of the population) have exceeded their design life of 50 years and 639 (6.2%) require mitigation independent of age, due to assessed conditions such as mechanical degradation, lack of spare parts or component issues.

[21] Earth switches are generally an integral part of disconnectors.

Failure modes and consequences

Asset 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 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.

No disconnectors or earth switch failures were recorded during the reporting period *(2011/12: 0.01%)*.

Risk assessment

TABLE 22: 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.

3.5.5 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 or on poles throughout the transmission network.

Asset conditions

Conditions affecting the service life of these assets include:

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

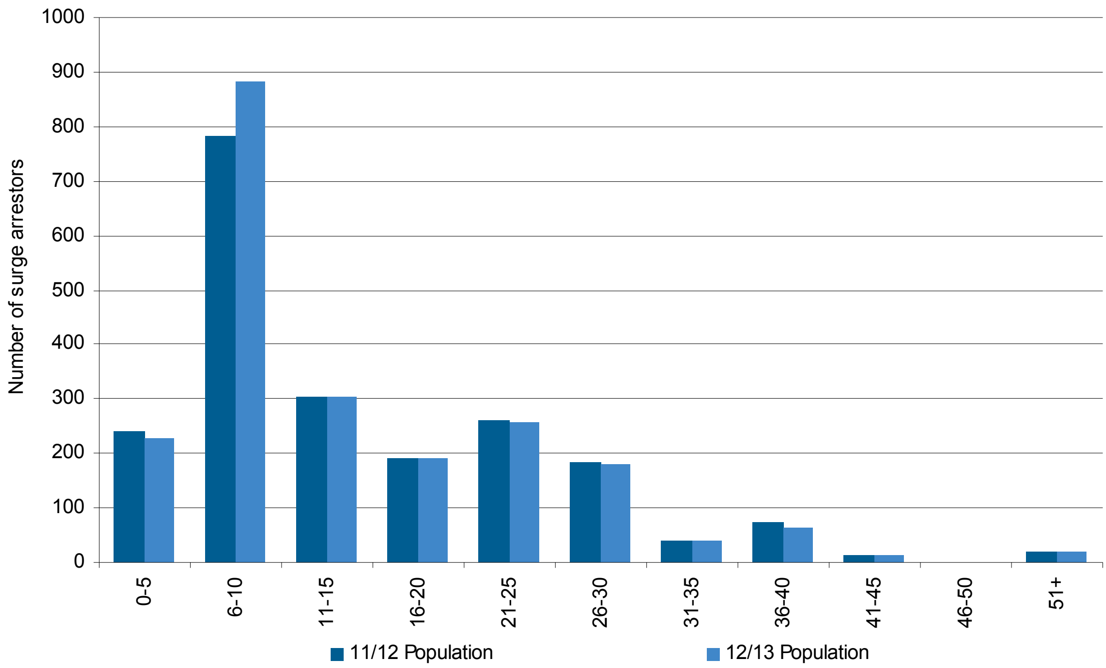
Condition for these assets is assessed by a range of methods, including:

- high voltage testing (watts loss, leakage current)
- periodic inspections.

Asset age profile

Figure 16 shows the age profile of surge arrestors.

FIGURE 16: AGE PROFILE - SURGE ARRESTORS



31 surge arrestors (1.4% of the population) have exceeded their design life of 40 years and 149 (6.8%) require mitigation, due to assessed conditions such as insulation degradation, lack of spare parts or component issues.

Failure modes and consequences

Asset 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.

One surge arrestor failure (0.05% of the population) was recorded during the reporting period *(2011/12: 0.0%)*.

Risk assessment

TABLE 23: 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.

3.5.6 Substation security fencing

Each of Western Power's 154 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[22] 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 120 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.

35 unauthorised entries into substation sites were recorded during the reporting period *(2011/12: 21)*. This is directly related to the level of construction activity in substations, which provides increased motivation for theft from sites.

Asset failure and defects are corrected promptly through operational response.

Risk assessment

TABLE 24: 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.

Western Power conducts daily security patrols at metropolitan substations. Five substations have electronic security systems installed and are monitored on a 24/7 basis.

Western Power is progressively upgrading all fences that do not comply with the current standard, prioritising those substation fences assessed as presenting the highest risk. In the interim, Western Power routinely inspects for holes and other means of facilitating unauthorised access, which are addressed through operational response.

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

3.5.7 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 is nearing completion.

3.6 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 these assets 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.

4 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 elements are currently experiencing capacity limitations or are projected to do so in 2013/14. Those capacity shortfalls that do not comply with planning standards will be addressed by projects planned during AA3. (Further information on these projects and the issues they address is available in the Annual Planning Report, the Network Development Plan and Western Power's AA3 submission to the ERA.)

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

Table 25 summarises the proportions of those network elements forecast to exceed capacity (as defined by planning criteria) during summer 2013/14.

TABLE 25: NETWORK ELEMENTS FORECAST TO EXCEED UTILISATION TARGETS DURING 2013/14

Network element	% forecast to exceed utilisation targets	2011/12[23]
Zone substations	7.8%	13.1%
Terminal substations	7.7%	8.0%
Metropolitan feeders	31.0%	38.0%
Rural feeders	2.8%	5.7%
Transmission lines	3.1%	1.6%
Distribution transformers	0.14%	0.25%

The reduction in utilisation (with the exception of transmission lines) is due to a combination of reduced demand forecasts and reinforcement works that have increased the capacity of the network. The increase in the utilisation for transmission lines is due to an increase in load in the Mandurah area.

[23] These were the percentages reported in the 2011/12 State of the Infrastructure Report and relate to elements forecast to exceed utilisation targets during 2012/13.

4.1 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, 10 zone substations (7.8% of the population) and 2 terminal stations (7.7%) are forecast to exceed their capacity by 2013/14.

Table 26 provides additional information on the capacity constraints for each substation forecast (in 2012) to exceed capacity in 2013/14, listing:

- the estimated number of customers at risk of supply loss[24] as a result of exceeding capacity
- the applicable planning criteria.

TABLE 26: FORECAST SUBSTATION CAPACITY CONSTRAINTS (2012 10% POE FORECAST)

Substation	Zone / terminal	Customers at risk[25]	Planning criteria[26]
Bunbury Harbour	Zone	3485	N-1
Capel	Zone	566	N-1
Geraldton	Terminal	1467	N-1
Joondalup	Zone	72	NCR
Mandurah	Zone	2209	NCR
Meadow Springs	Zone	785	NCR
Merredin	Terminal	1047	N-1
Moora	Zone	362	N-1
Nedlands	Zone	333	NCR
Osborne Park	Zone	987	NCR
Padbury	Zone	2131	NCR
University	Zone	730	NCR

The Bunbury Harbour zone substation has the largest number of customers at risk in the event of an unplanned outage of a substation supply circuit during 2013/14 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 up to 3485 customers. Rotational load shedding would reduce the impact on individual customers, with outages potentially continuing for several weeks until a replacement transformer is deployed.

[24] In excess of the number permitted by the Technical Rules.

[25] The number of customers at risk is estimated based on an average usage of 3.75 kVA per customer at time of peak demand and is based on the 2012 10% PoE forecast.

[26] 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 up to 12 hours. NCR substations are restricted to the Perth metropolitan area due to the practical limitations in deploying a rapid response spare transformer within 12 hours.

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

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 26 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.

4.2 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 that are based on:
  - the 2012 load forecasts for the year 2013/14 under a 10% Probability of Exceedence forecast load demand scenario (a one-in-ten year summer)
  - the most likely generation forecast dispatch (as identified in Section 5 of the 2012 Annual Planning Report).

A number of operational measures[27] 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[28] 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.

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

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

4.2.1 Transmission network thermal constraints

The following transmission lines are forecast to exceed their nominal ratings in 2013/14 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:[29]

- Three Springs Zone Substation busbar 132 kV
- Kojonup to Albany 132 kV
- Muja to Kojonup 132 kV
- Pinjarra to Alcoa Pinjarra 132 kV
- Mandurah to Pinjarra 132 kV
- Pinjarra to Meadow Springs / Cannington 132 kV
- Pinjar to Yanchep 132 kV
- Joondalup to Wanneroo 132 kV

These represent 3.1% of the transmission lines in the Western Power transmission network.[30] 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. In this situation, System Management would reduce the power flow on overloaded lines by redispatching generation, network switching and, as a last resort, shedding load.

A number of transmission network thermal constraints also exist in the north country region between Pinjar and Mungarra under certain operating conditions. These are currently managed by System Management through a Dispatch Support Contract.

4.2.2 Transmission network fault level constraints

The following transmission network locations are forecast as exceeding maximum fault level limitations by 2013/14:

- Kwinana 132 kV Network
- Southern Terminal 132 kV Network
- South Fremantle 66 kV Network
- Western Terminal 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. Network augmentations are currently being planned to alleviate fault level limitations. Until these are complete, connection of generation that would add to fault levels at these locations may not be permitted.

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29 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.

30 The number of transmission lines is identified based on the 2012/13 Western Power Network model used in network capacity planning studies.

4.2.3 Transmission network voltage stability limitations

The following areas of the transmission network are forecast to approach or exceed voltage stability limitations in 2013/14, 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 Geraldton and Eastern Goldfields[31] areas under certain operating conditions. These are currently managed by System Management through the use of Dispatch Support Contracts.

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 credible contingencies. If the Network has been planned to meet the planning criteria in the Technical Rules, 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.

4.3 CONSTRAINTS IMPACTING BLOCK LOADS

New block loads[32] 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).[33]

As a result of demand growth, all available capacity has been allocated in three areas of the Western Power Network. To preserve the ability to meet underlying demand growth, restrictions have been applied to the connection of new block loads and expansions of existing loads that exceed the thresholds defined for each of these areas. In accordance with the AQP, applications below these thresholds are treated as non-competing and are allowed to connect. Applications exceeding the thresholds are managed through the AQP, either as an Applicant Specific Solution or as part of a Competing Applications Group (CAG).

To maintain system security and the transmission system's compliance with the Technical Rules, connection of applications exceeding these thresholds is conditional on their loads being curtailed if required.

This approach allows new block loads to access spare capacity when available without impacting other customers. This results in lower connection costs and defers costly network augmentations until there is greater certainty regarding future demand.

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

32 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.

33 Refer to http://www.westernpower.com.au/aboutus/accessArrangement/accessArrangement.html.

In accordance with the Contributions Policy[34] and AQP, new loads will only be able to avoid the curtailment requirement by providing their own Network Control Service (NCS) arrangement or making an equitable contribution to either NCS or future augmentations implemented by Western Power. This may require customers to apply to participate in future CAG solutions or an Applicant Specific Solution.

From 1 February 2013, block load curtailment applies in the following regions:

North Country (Mid West)

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

Until these constraints are relieved by NCS or augmentations, the following curtailability thresholds apply to new loads and load increases in this area:

- South of Three Springs substation 3.3 MVA
- North of Three Springs substation 1.5 MVA

These are currently managed by System Management through the use of Dispatch Support Contracts. This has been sufficient to address the projected transmission constraints during the 2012/13 and 2013/14 peak demand periods using the 2012 10% PoE forecast load demand scenario, excluding the additional load presented by new block loads that are required to be curtailable. For this reason, the majority of transmission line limitations in the North Country are not listed in Section 4.2.

Great Southern (Albany)

Transmission line capacity issues exist on the 132 kV lines supplying Kojunup, Albany and Mount Barker substations.

Until these constraints are relieved by NCS or augmentations, a curtailability threshold of 1.5 MVA applies to new loads and load increases in this area.

These constraints are listed in Section 4.2, as there is no dispatch support contract in place for this region to mitigate them.

Eastern Goldfields

The region is supplied by a radial 220 kV transmission line, which is stepped down to 132 kV at West Kalgoorlie Terminal to supply the substations in the area. The major constraint on the Eastern Goldfields network is the transfer capacity of the existing 220 kV transmission line from Muja to Kalgoorlie.

Until these constraints are relieved by NCS or augmentations, a curtailability threshold of 3.3 MVA applies to new loads and load increases in this area.

This is currently managed by System Management through the use of Dispatch Support Contracts.

[34] Refer to http://www.westernpower.com.au/documents/aboutus/accessarrangement/2012/Contributions_policy.pdf.

4.4 CONSTRAINTS IMPACTING GENERATION

New generation can add significantly to the utilisation of the Network and affect the transfer capability of the Network. 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 4.2.2.

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

Through the AQP, Western Power is currently offering CAG solutions to generation applicants for connection to the Network on a constrained basis. The CAG solutions provide an opportunity for competing applicants and Western Power to share costs for network augmentations to remove or reduce the impeding network constraints.

4.5 CONSTRAINED DISTRIBUTION FEEDERS

4.5.1 Thermal constraints

In accordance with the Technical Rules,[35] Western Power's Distribution Network Planning Guidelines stipulate a maximum 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 683 metropolitan distribution feeders, utilisation exceeds 80% in 215 (31%). Of these, 81 (12%) are projected to be overloaded during the 2013/14 summer peak without operational intervention or network reinforcement. Operational interventions are taken to avoid feeder overloads and include:

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

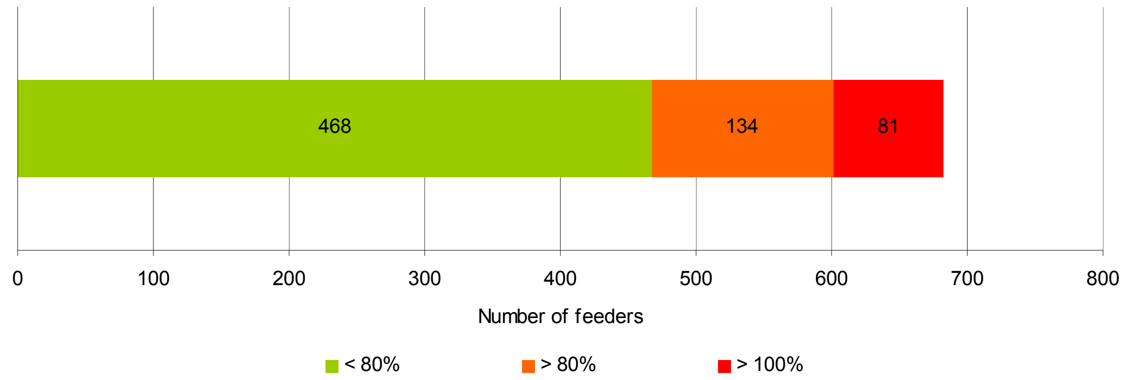
These prevent feeders being overloaded and subsequent reduction in asset life and increased risk of destruction. These necessary interventions incur additional operating expenditure.

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

[35] Clause 2.5.5.3(b)2(A).

Figure 17 shows the targeted feeder utilisation level performance, including those projected to be overloaded without operational intervention (i.e. exceeding 100% utilisation). Overutilised feeders are assessed as presenting a high service risk to customers, due to the impact of breaching the planning obligations in the Technical Rules.

FIGURE 17: FORECAST FEEDER UTILISATION (2013/14)



If an overutilised 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 overutilisation of existing feeders.

In summer 2012/13, more than 480 fault events were recorded on metropolitan distribution feeders. The average number of customers losing supply was 651 per event, with an average outage duration of 204 minutes. This is longer that the average interruption duration (in excess of three hours) that would be expected if utilisation was below the 80% target on all feeders.

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.[36] This would also increase the requirement for operational intervention to avoid forecast overloads, resulting in increased operating expenditure.

The number of overutilised feeders has decreased by 34 in the 12 months to 30 June 2013. This is due to reasons such as completion of capacity reinforcement projects, temporary or permanent offloads to adjacent feeders and milder summer compared to previous year (in some areas).

36 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.

4.5.2 Voltage constraints

The Technical Rules 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).[37] 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.

Six feeders (predominantly long rural feeders) supplying approximately 8540 customers are forecast to be voltage constrained over the 2013/14 summer peak. This means that 2.8% of the 209 rural feeders in the Network are forecast to be voltage constrained by 2013/14.

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.

4.5.3 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 (breaching 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.

Of the 59,218 circuit km of overhead high voltage conductors in the Network, an estimated 1,270 circuit km (2.14% of the total population) is under fault rated *(2011/12: 0.8%)*.[38]

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[37] Clause 2.2.2(a).

[38] The total reported in 2011/12 included only under fault rated conductor in high and extreme bushfire risk zones.

4.6 CONSTRAINED DISTRIBUTION TRANSFORMERS

The Network includes a fleet of 65,828 distribution transformers.

For large units (capacity of 100 kVA or greater), the risk of distribution transformer overload increases significantly in heatwave conditions,[39] when load increases of 200% - 300% are common. At the time of a transformer's installation, there is usually no information available on the number of customers it will service or the load to which it will be subjected.

As transformers of lower capacity usually service single customers and are normally sized for the maximum load of that customer, they are less likely to be overloaded.

Historical data indicates that approximately 5% of the larger capacity transformers identified as being at risk of overloading will fail if not replaced before the next heatwave, possibly exploding. Such failures are assessed as presenting a high public safety risk, due to the possibility of their initiating a fire. This failure rate increases significantly for overloaded transformers that are subjected to a second heatwave period.

The risk of transformer failures has been reduced significantly by the Overloaded Transformer Program. Since its introduction in 2005, fewer than five (on average) transformers have failed each year as result of overloading, compared to 52 transformer failures 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 overloading when its:

- calculated peak load exceeds the nameplate continuous rating[40] by 35%
- Transformer Utilisation Factor[41] (TUF) exceeds 0.5.

Through this program, 92 transformers (0.14% of the population) are forecast as being at risk of overloading and are scheduled for replacement during 2013/14. This reduction of 44% from 2011/12 is attributed to the effectiveness of the asset strategy for managing overloaded distribution transformers and its implementation.

Distribution transformers with capacities below 100 kVA are managed through the asset replacement program using a "run-to-fail" strategy. Their condition is, however, routinely monitored during the four year pole inspection cycle and any with physical evidence of deterioration (such as significant oil leaks) are addressed before they fail in service.

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39 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.

40 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.

41 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.

5 RELIABILITY OF SUPPLY

5.1 DISTRIBUTION NETWORK RELIABILITY

Because of Western Power's unique role in the electricity supply chain in Western Australia, the reliability of supply is a subject of interest in the broad customer community. This is likely to increase with the population of rooftop photovoltaic cells supplying the Network.

Reliability of supply is measured against two key metrics that allow Western Power to quantify the impact of interruptions on customers and influence network investments to support improvement.

These metrics used by Western Power are consistent with national and international industry practice:

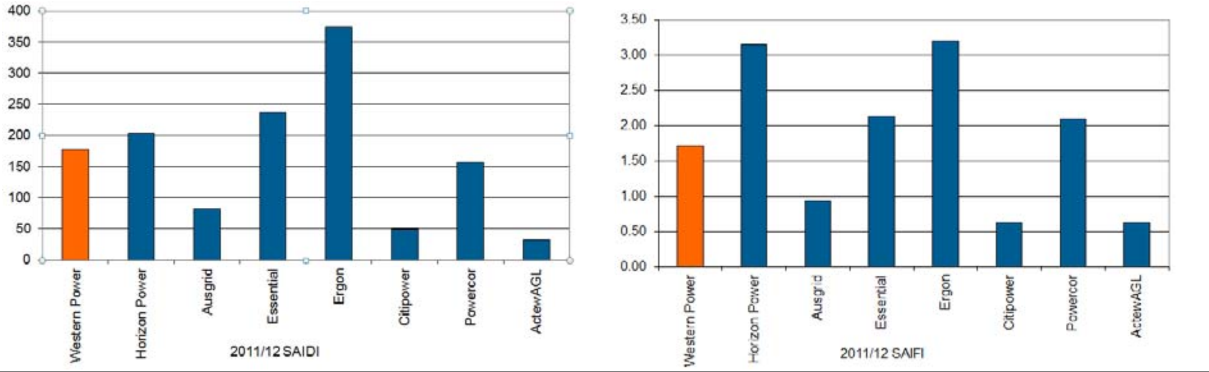
- **System Average Interruption Frequency Index** (SAIFI) - the average number of interruptions to a customer's supply in a year.
- **System Average Interruption Duration Index** (SAIDI) - the average duration (in minutes) of interruptions to a customer's supply in a year.

These measures are reported at the level of the entire Network and also separately for CBD, urban and rural areas. The distribution network within these areas is defined and categorised by feeder category:

- CBD
- Urban
- Rural Short
- Rural Long.

As these particular measures are similar to those used by all Australian Distribution NSPs, they permit some degree of performance comparison, as shown in Figure 18.[42] In doing so, it is essential to note that differences in factors such as network topography and environmental influences limit the validity and benefit of such national comparisons.

FIGURE 18: 2011/12 RELIABILITY PERFORMANCE OF AUSTRALIAN DISTRIBUTION NETWORKS



42 Extracted from the websites and annual reports of the Australian Energy Regulator and individual networks. Not all comparative performance measures are available for all Australian distribution businesses. Comparison data for 2012/13 was not available at the time of publication of this report.

The CBD, urban and rural measures focus on understanding the levels of reliability performance against the topography of network infrastructure and the requirements and expectations of customers specific to each area. The Rural area is further divided into Rural Short and Rural Long feeder categories, primarily reflecting the length of feeder required to supply more remote rural locations. Figures 19 and 20 show actual performance of the CBD, Urban, Rural Short and Rural Long feeder categories against the 2012/13 Service Standard Benchmarks agreed with the ERA.

FIGURE 19: SAIDI PERFORMANCE BY FEEDER CATEGORY

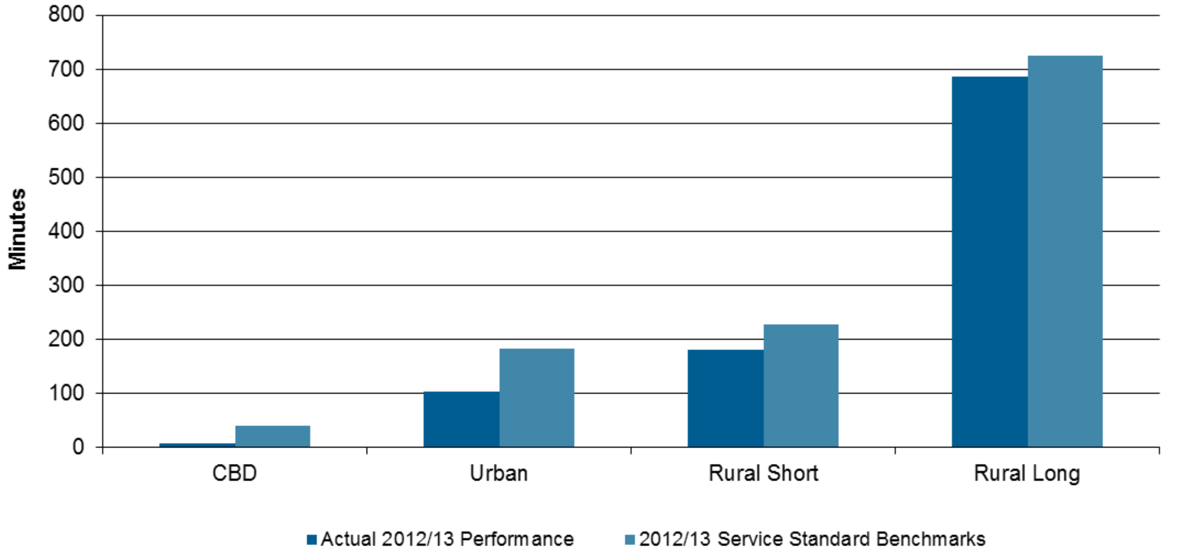
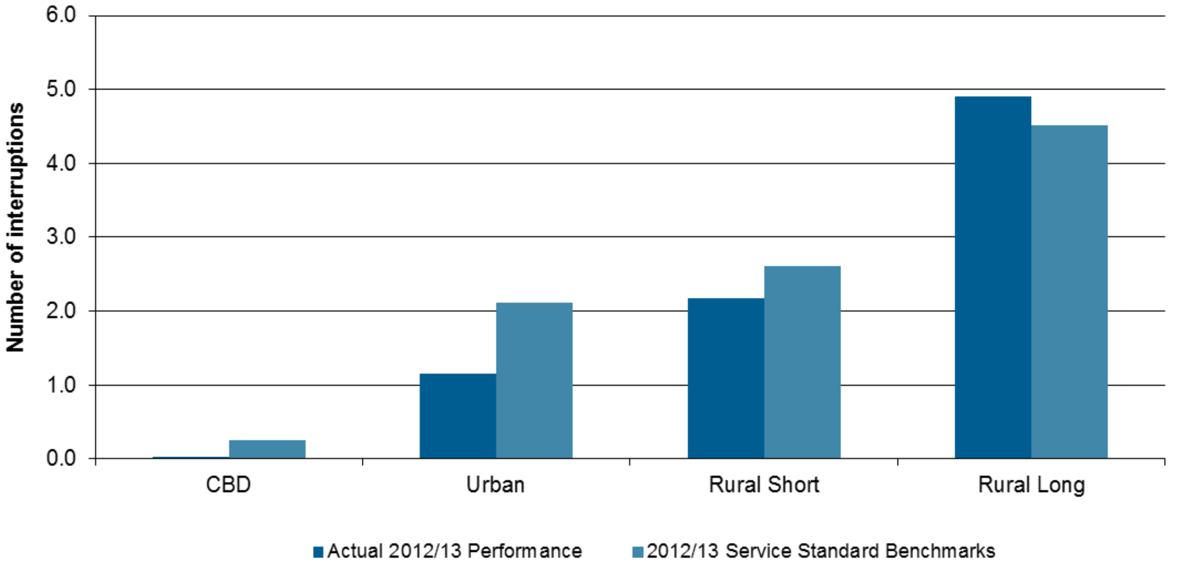


FIGURE 20: SAIFI PERFORMANCE BY FEEDER CATEGORY



In accordance with the *NQRS Code*, Western Power measures the number of all interruptions experienced by small-use customers that exceed a 12 hour continuous duration throughout the reporting period, as shown in Table 27.

TABLE 27: CONTINUOUS OUTAGES EXCEEDING 12 HOURS - SMALL-USE CUSTOMERS

Measure	Number
Small-use customers experiencing one outage exceeding a continuous 12 hours	38,820
Small-use customers experiencing more than one outage exceeding a continuous 12 hours	3,043

Western Power also measures the number of times an individual small-use customer has experienced any interruption within the reporting period against the prescribed targets of 9 (urban and CBD areas) and 16 (all other areas), as shown in Table 28.

TABLE 28: FREQUENCY OF INTERRUPTION - SMALL-USE CUSTOMERS

Measure	Number
Urban area (including Perth CBD) small-use customers interrupted more than nine times	8,702
Other area (including rural area) small-use customers interrupted more than 16 times	2,341

5.2 TRANSMISSION NETWORK RELIABILITY

The performance reliability of Western Power's transmission network is measured against national industry standard regulatory reporting measures.

The key transmission reliability measures are:

- **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.
- **Loss of Supply -** the annual number of events where the loss of supply was:
  - between 0.1 - 1.0 system minutes
  - greater than 1.0 system minute
- **Average Outage Duration -** the annual average number of minutes of all unplanned outages.

The performance of Western Power's transmission network against these measures is shown in Table 29.

TABLE 29: TRANSMISSION NETWORK RELIABILITY

			AA3 benchmark	**2011/12**	**2012/13**	
Transmission reliability	Circuit availability		≥ 97.7%	98.5%	98.4%	✓
	System Minutes Interrupted	Meshed network	≤ 12.50	3.98	4.50	✓
		Radial network	≤ 5.0	2.5	2.3	✓
	Loss of Supply Events	> 0.1 system minute	≤ 33	19[43]	13	✓
		> 1 system minute	≤ 4	1	2	✓
	Average outage duration		≤ 886	844	866	✓

[43] In 2011/12 this was reported as 18 under the definition applicable at the time (Second Access Arrangement - AA2).

The following cases are excluded from calculations of Circuit Availability, System Minutes Interrupted, Loss of Supply and Average Outage Duration:

- unregulated transmission assets
- outages shown to be caused by a fault or other event on a third-party system (e.g. intertrip signal, generator outage, customer installation)
- force majeure events.

The following additional exclusions apply to Circuit Availability, as agreed with the ERA:

- non-transmission primary equipment (primary equipment operating at voltages less than 66 kV, including zone substation power transformers)
- duration of planned outages for major construction work, including periods where availability is temporarily restored, is to be capped at 14 days in calculating transmission line availability.

Interruptions lasting less than one minute are excluded from the Loss of Supply Events and Average Interruption Duration.

Any event contributing to Average Outage Duration is capped at 14 days, as agreed with the ERA.

5.3 POWER QUALITY

The Electricity Distribution Licence requires Western Power to meet power quality requirements as specified in the Electricity Act 1945, NQRS Code and the Technical Rules to enable customer equipment to function correctly and operate safely and without damage.

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 the network voltage supplied to customers is potentially non-compliant for approximately 8% of the time and a voltage management program is proposed in AA3 to progressively remedy this situation.

The nominal network voltage of 240 V (single-phase) has an operating range of 28 V (equivalent to ± 6%). Of the 17,875 networks operating below 6 kV, 2,200 (11.7%) 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.

Note:

The current Australian Standard defines a nominal supply voltage of 230 V +10%/-6%, rather than 240 V ± 6%. Should Western Power adopt this standard, a number of presently non-compliant LV networks will become compliant. Western Power is prioritising remediation of networks that would not be compliant under the new standards.

Western Power monitors power quality parameters such as harmonic distortion and voltage unbalance on the LV distribution network and these are reported annually to the ERA. These parameters comply with requirements of either the Code or the Technical Rules.

APPENDIX A: SAFETY REPORTING DEFINITIONS

PUBLIC SAFETY INCIDENTS

Public safety incidents include:

- A public fire or explosion caused by Western Power assets. This does not include fires or explosions caused by vehicles that collide with 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 mal-operation or conductor failure
  - a bird or other animal coming in contact with a live conductor
  - a tree branch falling onto a conductor
- Contact with Western Power's overhead or underground network by a vehicle, plant or equipment. This does not include incidents in which a vehicle collides with a pole or other plant and equipment, resulting in contact with a live conductor.
- Injury (requiring medical treatment) or death to a person or animal from inadvertent contact with Western Power infrastructure.
- Injury (requiring medical treatment) or death to a person from electric shock where the shock was caused by the Western Power 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,*[44] 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*[6] (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.

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[44] 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.[45]

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/NZS7000:2010
- 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 July 2012, unassisted conductor failure was 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.

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[45] 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.

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.

Note:

Prior to July 2012, the number of recorded ground fires did not include those primarily caused by a third party action such as a car contacting a pole.

APPENDIX B: LIST OF ABBREVIATIONS

AA2/3/4	Second / Third / Fourth Access Arrangement
ABC	Aerial Bundled Conductor
ACSR	Aluminium Conductor Steel Reinforced (type of conductor)
AQP	Applications and Queuing Policy
AS/NZS	Australian and New Zealand Standard
CAG	Competing Applications Groups
CBD	Central Business District
CT	Current transformer
CVT	Capacitive voltage transformer
DEC	WA Department of Environment and Conservation
ERA	Economic Regulation Authority
FESA	Fire and Emergency Services Authority of Western Australia
HV	High voltage
IMO	Independent Market Operator
kVA	Kilovolt Ampere
LV	Low voltage
MVA	Megavolt Ampere
NCR	Normal Cyclic Rating
NCS	Network Control Services
NQRS	Network Quality and Reliability of Supply
NSP	Network Service Provider
PTSD	Pole-top switch disconnector
PV	Photovoltaic (cell)
RTF	Run-to-Fail
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SC/AC	Steel Conductor Aluminium Clad (type of conductor)
SC/GZ	Steel Coated Galvanized Zinc (type of conductor)
SCADA	Supervisory Control and Data Acquisition
TUF	Transformer Utilisation Factor
VAR	Volt-Ampere Reactive
VT	Voltage transformer