UTILITIES COMMISSION
OF THE NORTHERN TERRITORY

Northern Territory Power System Performance Review

2017-18

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Disclaimer

The Northern Territory Power System Performance Review (NTPSPR) is prepared using information sourced from participants of the electricity supply industry, Northern Territory Government agencies, consultant reports and publicly available information. The NTPSPR is in respect of the financial year ending 30 June 2018. The commission understands the information received to be current as at December 2018.

The NTPSPR contains analysis and statements based on both the commission's and, on behalf of the commission, Entura's interpretation of data provided by Territory electricity industry participants. Where possible, to enable comparison with other jurisdictions, the commission has sought to align its reporting of the data with the other Australian jurisdictions. However, there are some differences and any comparisons should only be considered indicative.

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Any questions regarding this report should be directed to the Utilities Commission, utilities.commission@nt.gov.au or by phone 08 8999 5480.

About this report

Since 2001, the commission has published an annual Power System Review (PSR) as a single document providing a review of past and current generation, network and retail performance, forecasts of system demand and supply reliability, and an assessment of the adequacy of the fuel supply.

Following publication of the 2016-17 Power System Review, the commission undertook a stakeholder survey to gauge the usability and usefulness of the report. Accordingly, to improve the commission's annual reporting, the PSR will be split into three separate reports, namely:

- Northern Territory Electricity Retail Review
- Northern Territory Electricity Outlook Report
- Northern Territory Power System Performance Review (NTPSPR, this report).

The NTPSPR focuses on the 2017-18 generation and network performance of the regulated power systems. Where possible, it compares 2017-18 performance to historical data to identify trends.

The report's main purpose is to inform the Treasurer (as regulatory minister), government, licence holders and stakeholders on the 2017-18 generation and network performance of the Territory's regulated power systems, and highlight any areas of concern.

Regular reporting on the electricity supply industry should help with understanding and increase transparency of issues and, consequently, improve planning, investment, understanding of value for money (price compared to level of service) and general performance by holding electricity businesses accountable for their performance and impacts on customers.

The content of this report was largely produced by Entura on behalf and with the assistance of the Utilities Commission. Accordingly, the commission supports the analysis, conclusions and recommendations made on its behalf by Entura.

The 2017-18 NTPSPR is prepared in accordance with section 45 of the *Electricity Reform Act 2000*. The report is restricted to the Northern Territory's regulated power systems, namely Darwin-Katherine, Alice Springs and Tennant Creek.

Key findings and recommendations

Overall performance

Overall the review found the performance of the Territory's power systems in 2017-18 to be satisfactory, and in general the standards of service and adequacy of the network and generating units are being maintained. However, performance is inconsistent across the power systems and there are warning signs that are concerning, particularly in Alice Springs and Tennant Creek where observed generation and network performance, respectively, was poor.

This overall performance in 2017-18 was in the context of a year of transition and other challenges. This includes upgrades and testing of new generation in Alice Springs and Tennant Creek, a tropical cyclone in the north and increasing behind-the-meter solar photovoltaic (PV) generation across the Territory.

While there are differences across the three systems, in terms of the generation plant (number of units, size, fuel type and location), network (poles, wires, substations, transformers, monitoring and signalling equipment), customer demand and weather, through this review the commission has identified some common trends and issues. These include issues related to the robustness of the power systems (ability to recover quickly when conditions change) and incorrect operations. For example, there have been several incidents as a result of incorrect assumptions regarding the status of redundant systems and network incidents that could have been contained, but due to secondary system failures, resulted in generator trips that cascaded into serious system incidents, including system blacks.

Given the generation upgrades in Alice Springs and Tennant Creek continued into 2018-19, and the rapid changes to demand and supply expected in all three systems in the near term as government implements its plan to achieve 50 per cent renewable generation by 2030, the ability for the systems to be agile to enable continued secure and safe operation is vital.

Accordingly, to address the risks, the commission considers the need for overall:

- improvements to the performance and condition monitoring of existing generators
- better administrative procedures in terms of coordination and cooperation between licence holders
- better planning, including modelling of system changes and associated operations, by Power and Water Corporation (PWC) Power Services in consultation with System Control and licensees.

The commission acknowledges there are challenges in operating the Territory's smaller power systems. The scale and isolation of the systems impact their ability to withstand sudden changes in balancing energy demand and supply. While the significant changes must be managed in a careful way, there is also an opportunity to review policies, such as the minimum spinning reserve and under frequency load shedding (UFLS) policies to ensure the scale and frequency of customer interruptions are reduced as low as reasonably possible while considering cost impacts.

This recommended review of policies, which would need to be undertaken by PWC's System Control, is important in Alice Springs and to a lesser extent Tennant Creek with the commissioning of new generation expected in 2018-19. The radical changes in the

Alice Springs network in terms of the decommissioning of the Ron Goodin power station will also require serious consideration of operating protocols across the range of power system operation. The addition of significant large-scale solar PV generation to the Darwin-Katherine network must be managed in a similarly careful way.

While 2017-18 saw the commencement of significant changes and challenges to the Territory's power systems, the commission expects the changes and challenges will continue through 2018-19 and beyond. Accordingly, consistent with its primary objective of protecting the long-term interests of Territory consumers of services provided by regulated industries with respect to price, reliability and quality, the commission will continue to monitor the performance of the power systems, hold associated licensees accountable for their obligations, provide advice where appropriate and follow up on recommendations and commitments made within this report.

Darwin-Katherine

A review of generation and network performance in the Darwin-Katherine power system in 2017-18 found satisfactory performance, however there are warning signs that indicate performance is deteriorating, as summarised in Table i.

Detail on the performance of the Darwin-Katherine power system in 2017-18, including comparisons to historical data and comprehensive discussion in relation to the identified issues and concerns, and positives is provided in Chapter 1 of this report.

Table i: Generation and network performance in the Darwin-Katherine power system in 2017-18

	Performance	Trend	Issue/concern	Positives
Overall customer impact	Satisfactory	Flat	• Impact on Katherine customers is bordering on unacceptable	• Response to Tropical Cyclone Marcus
Generation	Satisfactory	Flat – deteriorating	• Weddell and Pine Creek power station generator performance • Single unit reliability • Low level and variability of reliability • Over-reliance on Channel Island • Advanced age of generation fleet • Incidents impacting customers that occurred in notified non-reliable periods that are the result of an identified risk • Single points of failure leading to multiple generation incidents • Network issues being managed by generator constraints	• Shorter less frequent incidents affecting customers • No UFLS (when electricity is essentially 'turned off' in an area to address a mismatch between demand and available generation) incidents as a result of single generator trips • Channel Island reliability • Strong reporting culture for non-reliable notices • No Darwin-Katherine system blacks
Network	Satisfactory	Flat – deteriorating	• High level of transmission interruptions • High frequency of incidents in Katherine • Secondary systems coordination and commissioning	• Few distribution incidents in Darwin • Network adequacy managed well • Small increase in complaints despite impacts from Tropical Cyclone Marcus

Alice Springs

A review of generation and network performance in the Alice Springs power system in 2017-18 found network performance is satisfactory, however the generating units are not performing adequately, as summarised in Table ii.

The commission expects that once the commissioning of Territory Generation's new Jenbacher generators at the Owen Springs power station is complete and this project is bedded down, the performance of the generators and the system as a whole will improve.

Detail on the performance of the Alice Springs power system in 2017-18, including comparisons to historical data and comprehensive discussion in relation to the identified issues and concerns, and positives is provided in Chapter 2 of this report.

Table ii: Generation and network performance in the Alice Springs power system in 2017-18

	Performance	Trend	Issue/concern	Positives
Overall customer impact	Poor	Deteriorating	• An increase in the frequency and severity of incidents has led to outages with a greater impact on customers.	
Generation	Poor	Deteriorating	• An increase in the frequency of incidents, including an increase of single generator unit trips, and forced outages • Reliability and availability of Owen Springs power station • Availability of Ron Goodin power station • Generator response to frequency deviation • Indications that the coordination of generation design with regard to network requirements has been lacking	• A reduction in the number of UFLS incidents (when electricity is essentially 'turned off' in an area to address a mismatch between demand and available generation) as a result of single generator trips
Network	Satisfactory	Stable	• Performance of short rural feeders is showing signs of decreasing with the duration and frequency of outages increasing • There has been an increase in the share of outage complaints. • Change in, and relocation of, generation to one power station needs to be considered and modelled to ensure customers are not exposed to additional risk of loss of supply	• No major network incidents in 2017-18 • No major incidents caused by the transmission network over the last four years • All feeder types are within the target for the duration of interruptions set for the combination of performance in the three regulated systems

Tennant Creek

A review of generation and network performance in the Tennant Creek power system in 2017-18 found generation is performing well. However, the network continues to show poor resilience to faults.

Details on the performance of the Tennant Creek power system in 2017-18, including comparisons to historical data and comprehensive discussion in relation to the identified issues and concerns, and positives is provided in Chapter 3 of this report.

Table iii: Generation and network performance in the Tennant Creek power system in 2017-18

	Performance	Trend	Issue/concern	Positives
Overall customer impact	Poor	Deteriorating	• Increase in frequency and duration of incidents impacting customers	
Generation	Good	Flat – improving	• Commissioning of new generation is slower than planned	• Low level of unplanned outages and high availability • Generator performance has reduced impact on customers
Network	Poor	Deteriorating	• Poor system average interruption duration index result for short rural feeders • Large increase in incident duration • More complaints regarding loss of power	• Rural long feeders within global performance targets

Contents

1 | Darwin-Katherine power system

This chapter focuses on the 2017-18 generation and network performance of the Darwin-Katherine power system. Where possible, it compares 2017-18 performance to historical data to identify trends. Specifically this chapter considers:

- overall customer impact
- generator performance, observed under frequency load shedding (UFLS) and single generator trips, generation availability, generation adequacy, non-reliable periods, major generation incidents, generation constraints, and generation planned and recent enhancements
- transmission and distribution network performance, network utilisation, network adequacy, major network incidents, network constraints, network planned and recent enhancements, and network power quality notifications.

Power system description

The Darwin-Katherine power system is the largest of the three regulated power systems in the Northern Territory. It supplies Darwin city, Palmerston, suburbs and surrounding areas of Darwin, the township of Katherine and its surrounding rural areas.

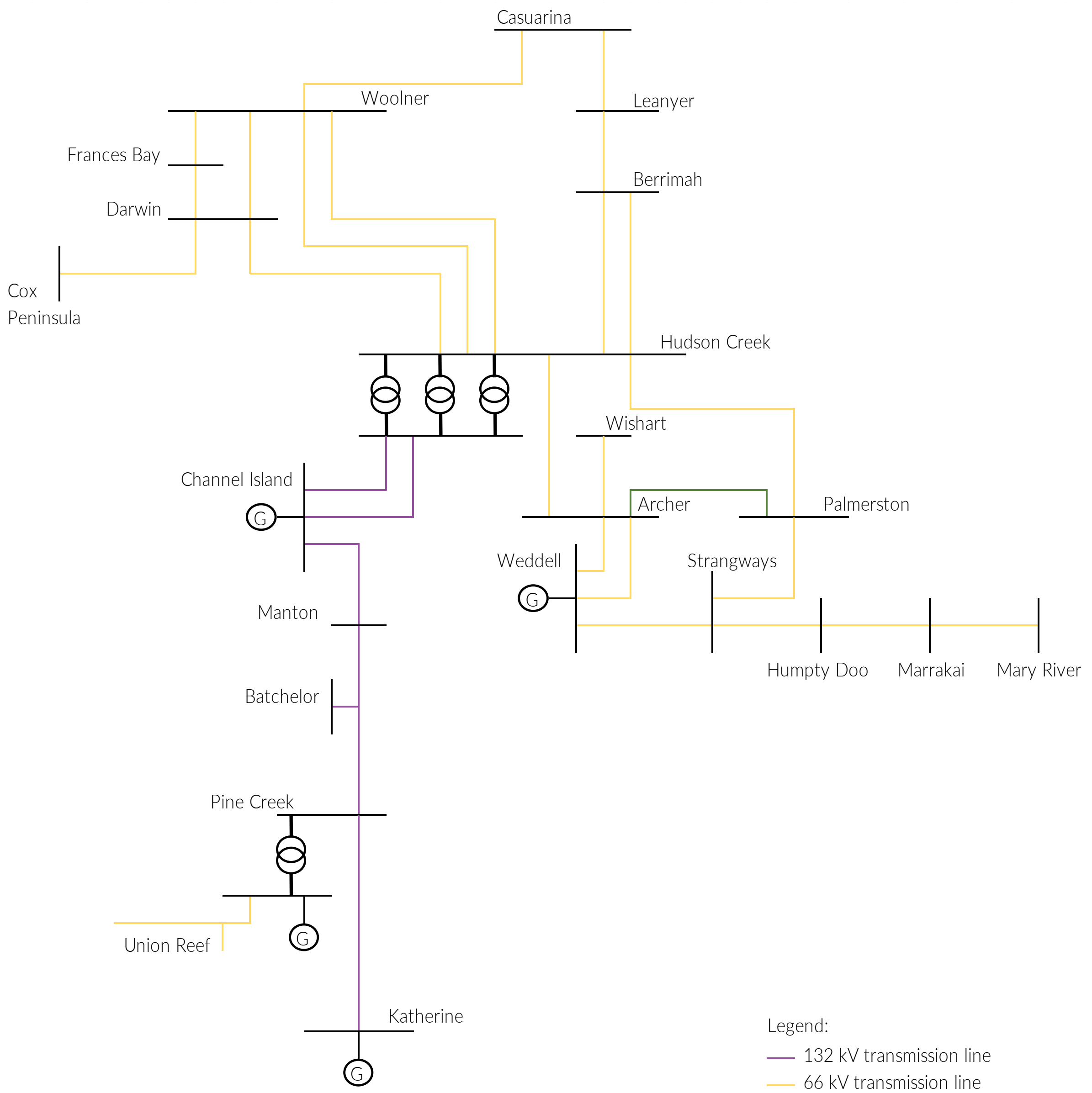
Figure 1 illustrates the Darwin-Katherine power system. The only transmission lines in this system are from Katherine to Channel Island and Channel Island to Hudson Creek. A 132(kV) double-circuit overhead transmission line from Channel Island to Hudson Creek serves the Darwin area. The 300 kilometre (km) 132 kV single circuit Channel Island to Katherine line runs south from Darwin to Manton, Batchelor, Pine Creek and Katherine.

The operational consumption in 2017- 18 is shown in the Table 1.

Table 1: Darwin-Katherine operational consumption in 2017-18

Power system	Energy sent out (GWh)
Darwin-Katherine	1 620

Figure 1: Darwin-Katherine power system



The total generation capacity in the Darwin-Katherine power system is around 476 megawatts (MW) across five power stations as summarised in Table 2. The fuel type of the generation units is made up of dual fuel (gas/diesel), gas only, heat recovery steam and landfill gas.

Table 2: Total generation capacity in Darwin-Katherine during 2017-18[1]

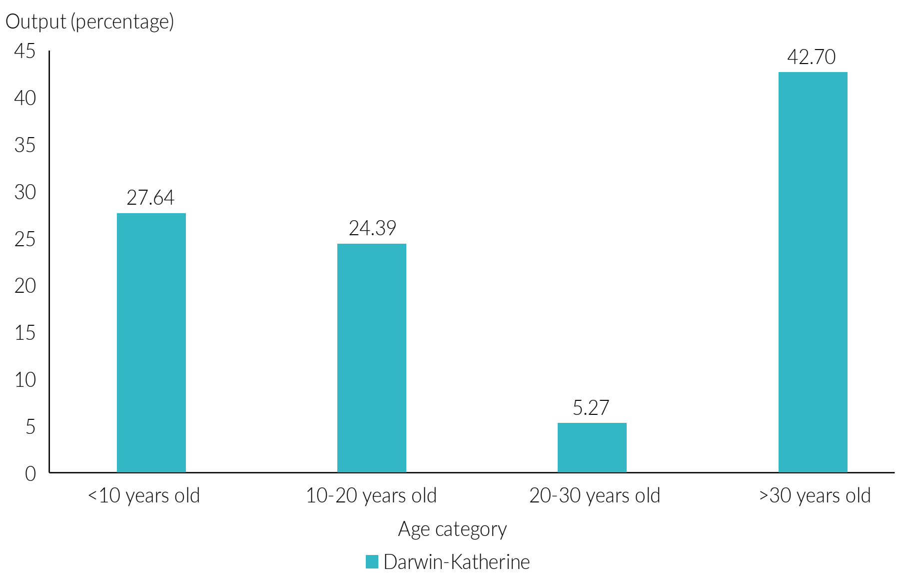
Power station	(MW)
Channel Island	310
Weddell	102[2]
Katherine	36.5
EDL's Pine Creek	26.4
Shoal Bay landfill	1.1
Total Generation	476

1 Generation capacities provided are used in the Northern Territory Electricity Outlook Report. Capacity values can vary depending on the definition of capacity applied, such as nameplate, summer and winter capacity.

2 Weddell power station's normal operating capacity is 102MW. For short periods, the generators can be operated in 'sprint' mode, which increases the power station's capacity to 126MW. The 2016-17 Power System Review used the 'sprint' capacity, this has been revised for 2017-18 to the normal operating capacity.

Figure 2 shows almost 43 per cent of Darwin-Katherine power system generators are more than 30 years old.

Figure 2: Age of generators as a percentage of output in Darwin-Katherine



The issues relating to the age of the generation fleet are discussed further in the Darwin-Katherine generator adequacy section later in this chapter.

Overall customer impact

This section provides data related to the overall performance of the power system for the Darwin-Katherine region.

Table 3 shows the impact on customers from all incidents in the Darwin-Katherine region across the last three years.

Table 3: Customer minutes without supply for the Darwin-Katherine region

		2015-16[1]	2016-17	2017-18	2017-18 excluding TC Marcus
Darwin-Katherine	Number of incidents	10	78	72	71
	Customers impacted	70 310	131 976	138 268	111 368
	Total duration without supply (minutes)	308	10 853	28 539	10 939
	Customer minutes without supply[2]	3 102 720	11 447 402	487 410 253	13 970 253
	Customer minutes without supply/ customer	45.5	169.3	6781.9	194.4
	System Blacks				
	Region wide	0	0	0	0
	Katherine island blacks	6	7	7	7
Darwin	Number of incidents	4	68	62	
	Customers impacted	55 800	106 876	110 423	
	Total duration (minutes)	175	10 269	27 533	
	Customer minutes without supply	2 720 700	9 958 522	485 469 318	
	Customer minutes without supply/ customer	42.5	156.9	7193.5	
Katherine	Number of incidents	6	10	10	
	Customers impacted	14 510	25 100	27 845	
	Total duration (minutes)	133	584	1 006	
	Customer minutes without supply	382 020	1 488 880	1 940 935	
	Customer minutes without supply/ customer	91.7	360.2	442.9	

1 Minor incidents were first recorded in 2016-17. Therefore, any increase from 2015-16 to 2016-17 is in part explained by the inclusion of minor incidents.

2 Customer minutes without supply is calculated by multiplying the number of customers impacted by the duration of the incident (in minutes).

It is noted that customer minutes without supply in Darwin have significantly increased over the last three years from around 3 million to over 485 million. The large increase is almost solely due to the impact of Tropical Cyclone (TC) Marcus. Excluding TC Marcus, the result for 2017-18 resembles that for 2016-17.

Generation

Overall generation within the Darwin-Katherine power system continues to perform within an acceptable band but with room for improvement. Those necessary improvements relate to:

- coordination of outages
- design and commissioning processes for system protection and communications
- condition monitoring.

These are discussed more throughout this chapter.

Generator performance

The Electricity Industry Performance Code (the Code) does not set targets for generation System Average Interruption Duration Index (SAIDI) and System Average Interruption Frequency Index (SAIFI) performance indicators. Historical performance is used to provide commentary on licensed generator's performance in 2017-18.

Darwin region

The generation service level for the Darwin region is shown using the SAIDI and SAIFI performance (Figure 3).

Figure 3: SAIDI and SAIFI performance indices for generation, Darwin

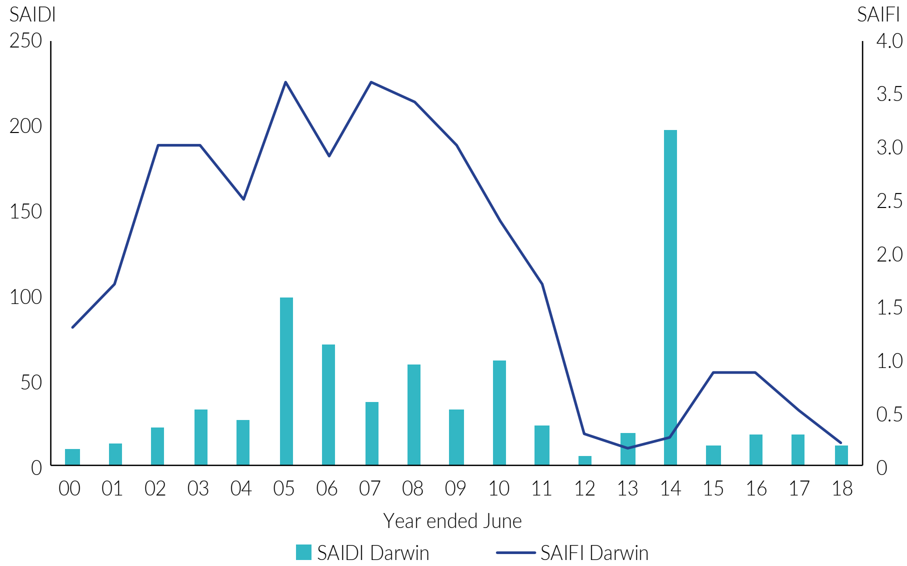


Figure 3 illustrates that for Darwin, SAIDI has been relatively stable since 2014-15.

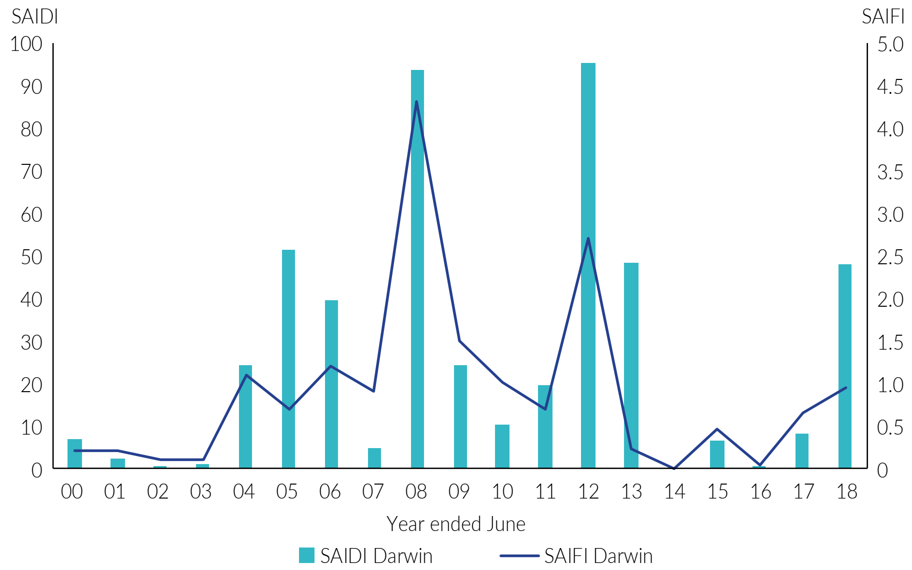
SAIFI continues to sit in its new normal in contrast to the 10 years prior. Entura assesses this current level of performance to be satisfactory but observes it could be better with greater emphasis on performance and condition monitoring of generators.

The improvement to date has been mostly due to the change in the frequency control regime and in particular the UFLS changes. There are more changes to come in this area, with the transition to the new UFLS scheme all but complete. This should further remove the likelihood of load shedding occurring for single unit failures while also minimising the likelihood of over-tripping for severe incidents. The underlying cause of the poor performance leading up to 2009-10, specifically the frequency of generating unit trips, is still prevalent in the system. This is discussed in more detail under the observed UFLS and single generation trips section of this chapter.

Katherine region

Treating Katherine generation separately for the purposes of SAIDI and SAIFI does not appear to be a useful measure unless it is limited to those periods where Katherine operates as an island and all generation sources within that island are considered. Nonetheless, it is noted that 2017-18 performance appears to have deteriorated compared with typical levels over the last three to four years (see Figure 4).

Figure 4: SAIDI and SAIFI performance indices for generation, Katherine



The poorer SAIDI result is indicative of a number of system black incidents that occurred in the region (Katherine island black) in 2017-18. These incidents are discussed further (major generation incidents section) in this chapter.

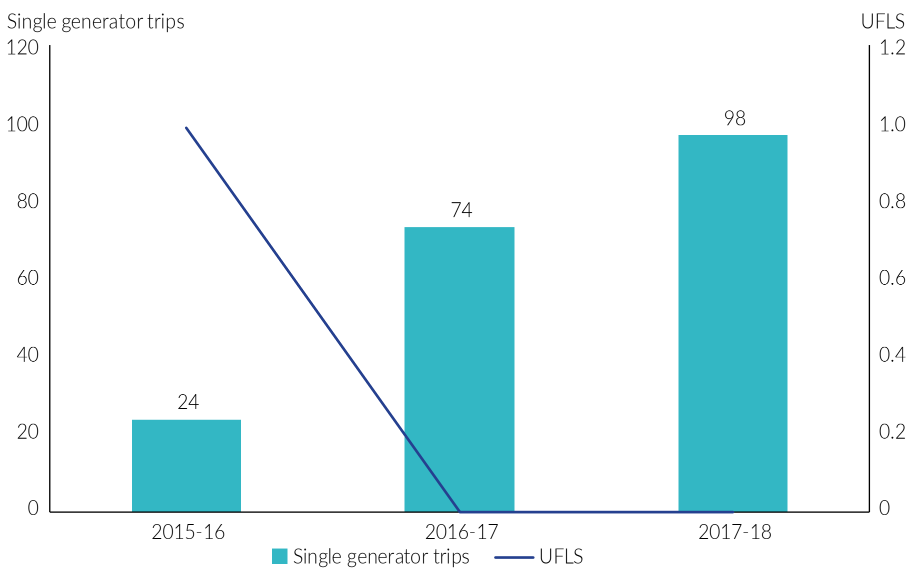
The SAIFI result compares favourably with the long-term mid-range level but is still worse than the last five years. With the long single circuit supply to Katherine, some variability in the SAIFI index is inevitable due to, among others, varying storm activity.

Observed UFLS and single generator trips

Darwin-Katherine customers have seen a significant reduction in UFLS from single generator trips, indicating a significant improvement in the effectiveness of managing these incidents. However, the number of generator trips is showing signs of increasing.

System Control's half-yearly reports, which are provided to the commission, show the annual rise in unit trips as summarised in Figure 5.

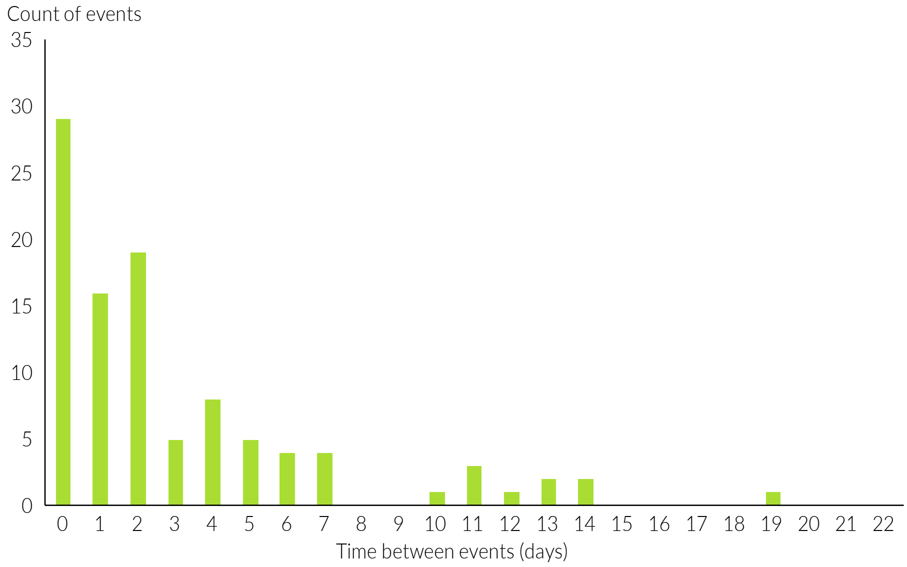
Figure 5: Darwin-Katherine single generator trips versus UFLS (due to single generator trips)



While some variation will occur due to weather and network factors, the 98 trips in the 2017-18 period is far more than for each of the preceding years. The number of single unit trips may represent an unacceptable lack of robustness in the generation fleet. While Entura previously observed improvement in the reliability of the fleet, these gains appear to have been eroded. From a customer perspective, it is noted these single unit trips have not resulted in loss of supply. The adjustments to the early stages of the UFLS and the increased allowance for frequency support from the generating units appear to be effective in reducing and, for now, eliminating the need for UFLS on single unit trips.

System Control also provide the statistics relating to the time between single unit trips. These are shown in Figure 6.

Figure 6: Time between single unit trips in Darwin-Katherine



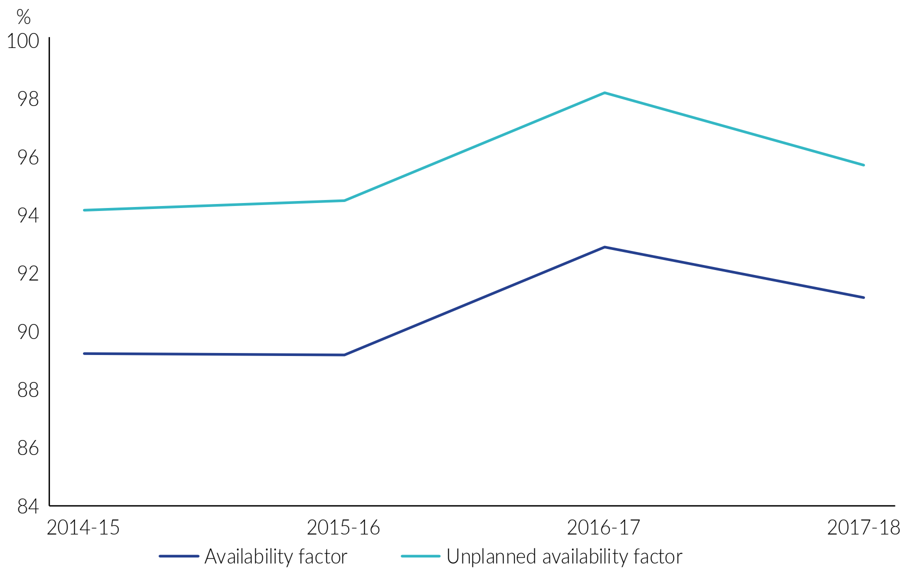
The data shows single unit trips occur in clusters with the most common interval between trips being less than one day. These statistics show it is rare for the system to operate for a week without a unit trip. Entura is concerned this shows external factors may not be being managed appropriately. The cause of these trips should also be reported to enable better scrutiny of the plant performance. Subsequently, the commission will request System Control to include a brief description of the cause of single generator trips in their half-yearly reporting to the commission.

Generation availability

Availability factor

The overall availability of the generators showed a slight decline in 2017-18 over the previous period (see Figure 7). Entura observes that perhaps the 2016-17 year was an unusually good year for the Weddell power station and 2017-18 is more consistent with the 'normal' performance.

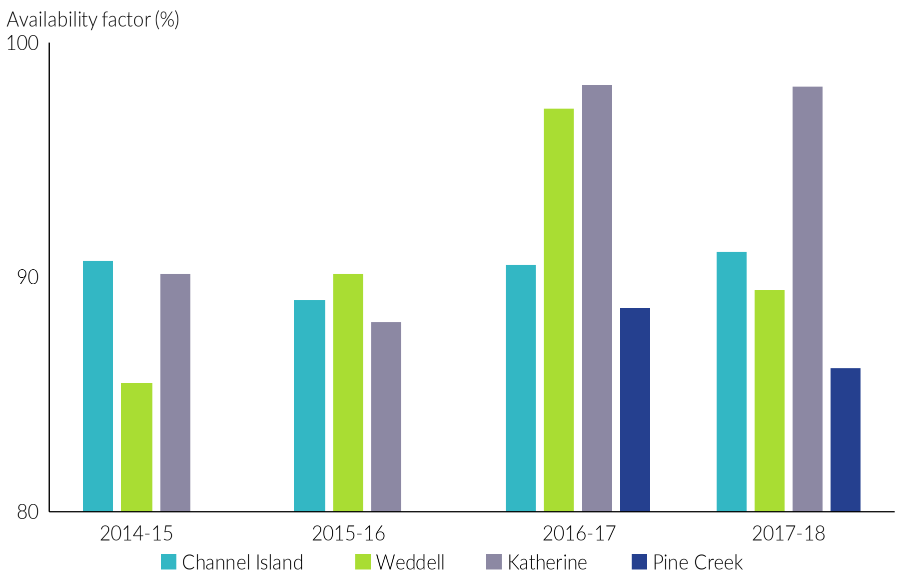
Figure 7: Capacity weighted average availability factor for Darwin-Katherine generating units



It is noted that overall availability and unplanned availability track within a 2 per cent band. The stable performance of Channel Island, the largest power station, limits the effect of the smaller power stations on the overall result.

Figure 8 shows the availability factor for the individual Darwin-Katherine power stations.

Figure 8: Availability Factor for Darwin-Katherine power stations[1]



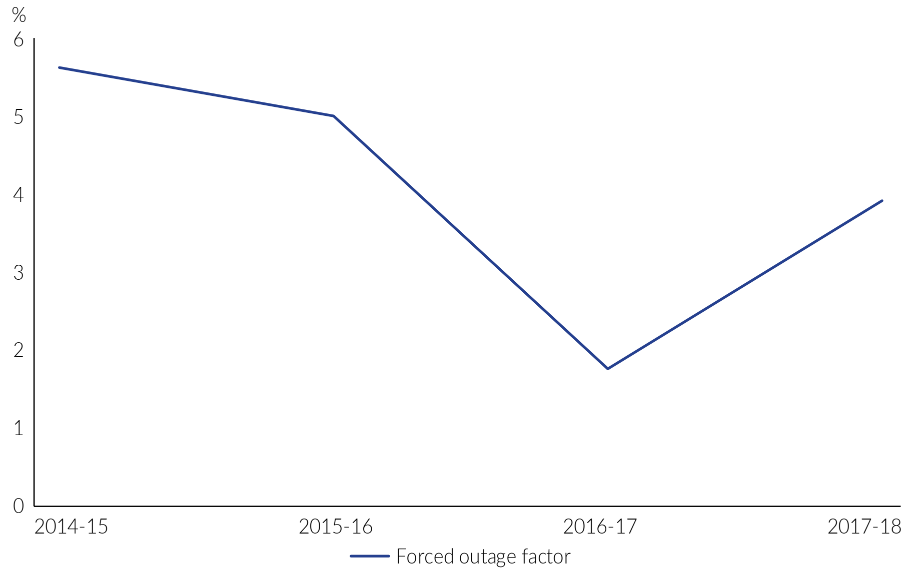
1 No data for Pine Creek until 2016-17 as this is when it became a licensee.

The low availability factor of the Pine Creek power station generators links to the overall system performance as evidenced by its impact on the major incidents in the Katherine region (discussed in the Darwin-Katherine generation incidents section). While the unit availability may not be the direct cause of the incidents, the failure of the network controls or the units themselves has led to forced outages and loss of customer supply.

Forced outage factor

As discussed in the Darwin-Katherine observed UFLS and single generation trips section, the Darwin-Katherine generators as a whole suffered many more trips in 2017-18 compared to 2016-17. This is reflected in the combined forced outage factor more than doubling from the previous period (see Figure 9).

Figure 9: Capacity weighted average forced outage factor for Darwin-Katherine generating units

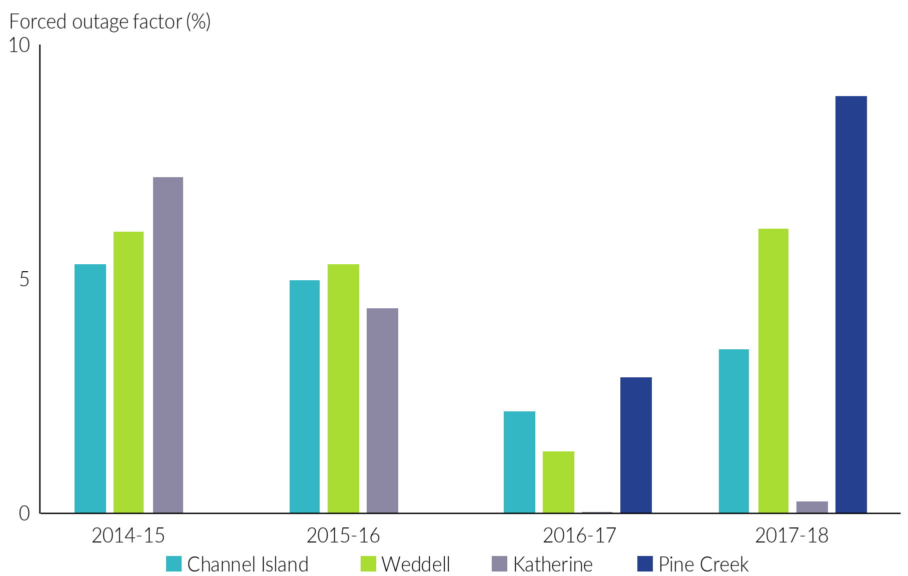


As illustrated in Figure 9, the unusually good result in 2016-17 was followed by a result closer to the trend in 2017-18. However, if the breakdown across the power stations is considered, it would seem 2017-18 is not in fact typical. Remembering that Channel Island power station has a large influence on the overall result, the continued good performance of its units is being undermined by the poor performance at Weddell power station and to a lesser extent Pine Creek power station.

Figure 10 shows the forced outage factor for the four main power stations in the Darwin-Katherine region. The doubling in the overall factor masks the much more serious reduction in availability of Weddell and Pine Creek power stations due to the size of these stations relative to that of Channel Island power station.

This reduced performance at Weddell and Pine Creek power stations relates to a number of major forced outages.

Figure 10: Forced Outage Factor for Darwin-Katherine power stations



Entura remains concerned with this aspect of the generation assessment results. The data indicates an inconsistency in the management of the generating units and this is having an impact on their usefulness in ensuring supply adequacy. While there remains significant margin for generator-forced outages (see the next section) within the requirements of peak demand, the unreliability and increased system risk from high forced outage rates will affect the efficiency of supply and customer experience. This result contributes to Entura's finding with respect to the need for improved performance and condition monitoring of generators.

Performance and condition monitoring

A number of the major power system incidents relating to generation were the result of incorrect operation of generation plant or controls. The link between condition monitoring, preventative maintenance and improved machine availability is of interest. Other jurisdictions would treat these aspects of plant ownership and operation as a priority, recognising it is part of good electricity industry practice.

It is acknowledged there is a trade-off whereby too much maintenance or condition monitoring is costly and reduces overall availability. However, with too little, forced outage rates increase and the ability to plan the generation input to the system diminishes. Achieving an appropriate level should lead to a more robust and lower cost of supply.

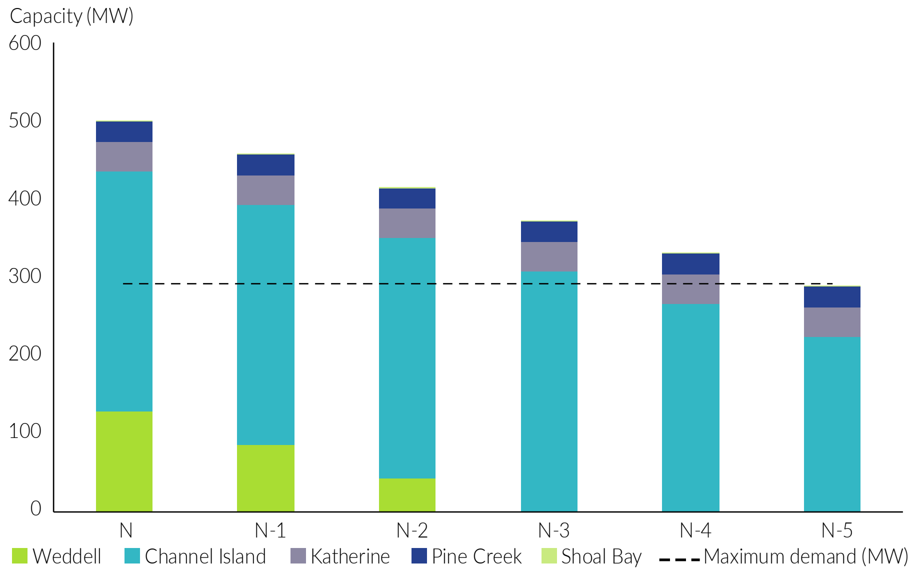
On this basis, the commission will seek input from generation licence holders as to an appropriate level of reporting regarding this aspect of asset operation and management as part of the commission's review of the Code. This should improve the ability of the commission to identify and where necessary highlight issues as part of its annual performance reporting. This cooperative approach will ensure confidence that generators are working to manage the risk of generating unit trips to an acceptable level.

Generation adequacy

The Darwin-Katherine region continues to have an abundance of installed generation capacity, which is sufficient if not over-supplied.

Figure 11 shows the N-X assessment of generation adequacy, where each step along the x-axis shows the loss of a generator. Prior to the structural separation of PWC, the commission maintained an N-2 benchmark for planning purposes. This was extended during the Channel Island life extension works.

Figure 11: N–X exposure in Darwin-Katherine in 2017-18 under base scenario



The operational flexibility this over supply of generation capacity provides means even though, as shown in the previous section, some units continue to have high forced outage rates, this does not necessarily flow on to affect customers. However, the current level of surplus suggests an inefficient level of installed capacity, which likely translates to higher costs of electricity supply.

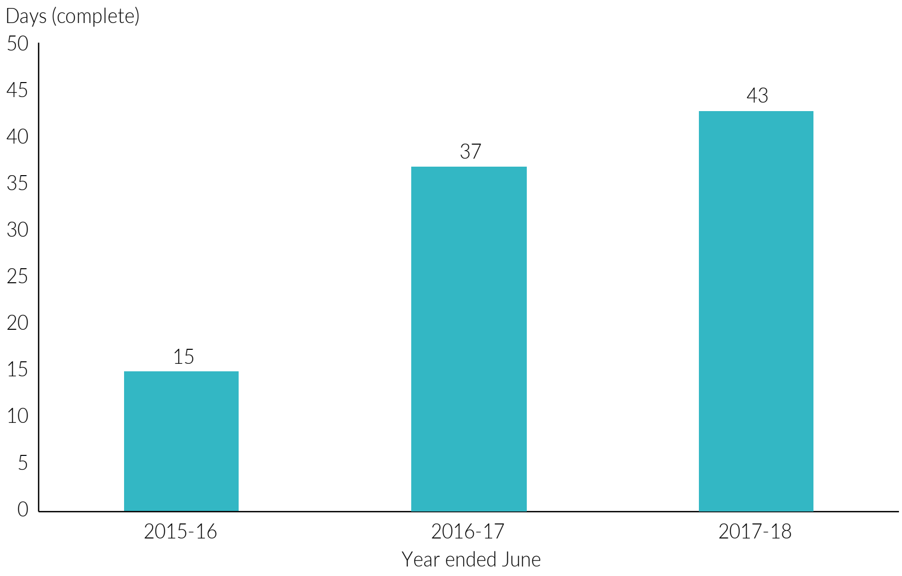
The forward-looking assessment, included in the commission's Northern Territory Electricity Outlook Report (NTEOR) is a better indicator of overall generation adequacy than this simplistic analysis. This is because that analysis combines the forced outage rates across the fleet and can identify periods of low supply margin.

Entura considers the age of the generation fleet to be the biggest challenge to adequacy in the future. This is supported by the commission's NTEOR which highlights reliability concerns around 2026-27.

Non-reliable periods

Entura observes the length of time the Darwin-Katherine region is under a non-reliable notice has grown across the three available reporting periods. It is of further concern that this is due mostly to generation. In fact, in the 2017-18 year, all non-reliable periods were due to generation.

Figure 12: Non-reliable periods for generators in Darwin-Katherine



While Entura accepts more notices may actually be a positive step as System Control is becoming more adept at identifying periods of non-reliability, the trend is not encouraging.

Scrutiny of the non-reliable notices suggests many of the non-reliable periods caused by generation are due to planned maintenance activities. This appears to suggest poor coordination between the needs of the system and ongoing maintenance imperatives of the generating units. This is supported by the commission's NTEOR which forecasts supply concerns arising from planned maintenance at high summer demand periods. Both PWC and TGen have indicated to the commission that a level of co-ordination exists for outages on a short-term (days), medium-term (months) and long-term (up to five years) horizon. PWC agree with Entura that the increase in non-reliable periods is in part due to increased monitoring. PWC and TGen both agree that there has been an increase in generation outages, which include planned outages for major works, such as a recent node reconfiguration at Channel Island power station.

PWC has advised the commission that it plans to commence a review of its outage coordination processes in early 2019-20 with the intended outcome to be streamlined and updated processes that will allow for the automation of outage co-ordination. Further, in parallel, PWC has stated there will be development of a more robust operating protocol which is intended to influence the level and detail of communication between PWC and outage planners.

Generation incidents

There were six major generation incidents in the Darwin-Katherine system, which are summarised in Table 4.

Table 4: Darwin-Katherine generation incident summary

ID	Date of incident	Description	Cause	UFLS/black	Incident duration (minutes)	Customer minutes without supply
1	05-Sep-2017	CIPS 132kV bus 3 trip – 132kV separation	Error in undertaking injection testing	Pine Creek and Katherine	221	1 032 070
2	01-Nov-2017	Katherine unit 4 tripped	Incorrect mode of operation K4	Katherine – UFLS Stage 2	14	28 840
3	22-Nov-2017	KPS unit 1 and Pine Creek unit 1 tripped	Secondary systems errors	Pine Creek and Katherine black	16	68 160
4	04-Dec-2017	Channel Island unit 9, C9	Unauthorised testing of generation plant		0	0
5	08-Jan-2018	Weddell unit 1 and 2 tripped	Equipment failure (failure of water bath heaters)	DK UFLS stage 2B	62	781 200
6	01-Mar-2018	C8 tripped – equipment failure	Protection settings (failure of the RTD input card)	UFLS malfunction	5	5 750

The incidents fall into three categories, namely testing errors, secondary system failures and auxiliary plant failure.

Testing errors

Incidents 1 and 4 fall into this category.

It is Entura's opinion that testing errors are almost inevitable, therefore they must be managed.

It is observed, based on the incident reports, the approval of test plans and procedures, and their coordination through generation dispatch changes or changes to the timing of tests to reduce the risk to customers was deficient in both incidents. Fortunately only one of these incidents led to a loss of supply to customers.

This category accounts for 54 per cent of the customer minutes without supply due to major generation incidents from 2017-18.

Secondary system failures

Incidents 2, 3 and 6 fall into this category.

Incidents 2 and 3 are a repeat of the same issue, being the controls between Katherine and Pine Creek power stations appearing not to have been tested fully, or possibly there were failures in signalling. Regardless, there appears to be a need to increase the rigour of commissioning and planning to which supervisory control and data acquisition (SCADA)-based controls that have a direct impact on system security are subjected.

Incident 6 is an equipment failure made worse by an incorrect setting of an UFLS relay.

This category accounts for five per cent of the customer minutes without supply due to major generation incidents from 2017-18.

Auxiliary plant failure

Incident 5 falls into this category.

Incident 5 appears to be a single point of failure leading to two generators tripping. This was only the case because another unmonitored piece of plant had failed. This unseen plant vulnerability compromised the robustness of the two generators.

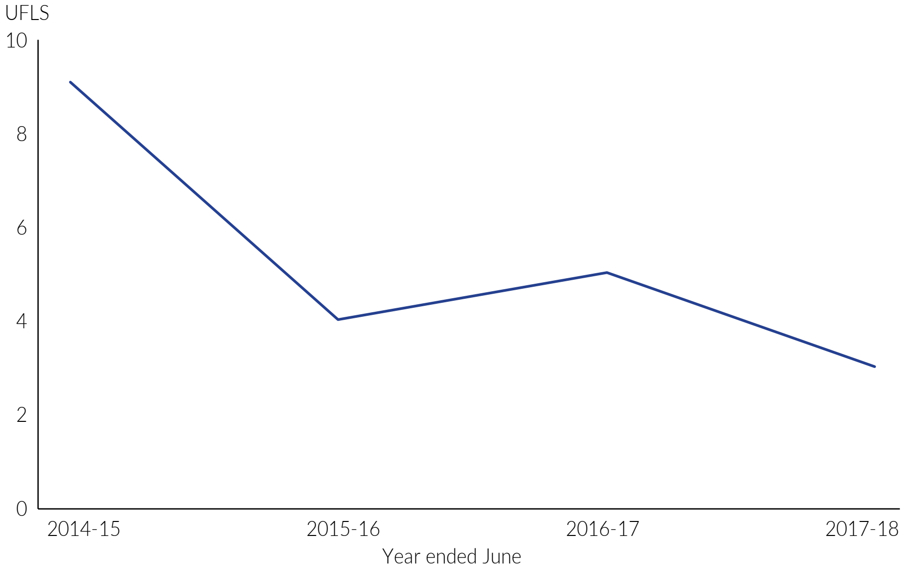
These types of issues are of great concern. It can be seen in the Darwin-Katherine observed UFLS and single generator trips section that the reliability of the generating units is questionable with around two generator trips a week on average. This may be a symptom of poor condition monitoring. Poor condition monitoring certainly led to incident 5 being more severe than it would be normally.

This category accounts for 41 per cent of the customer minutes without supply due to generation incidents from 2017-18. This issue is discussed further earlier in this chapter.

Impact of incidents

The great transformation in the Darwin-Katherine region has been the reduction in UFLS incidents. This is mainly due to the changes in philosophy around spinning reserve allocation and management. Figure 13 shows this decline.

Figure 13: Number of generation UFLS incidents in Darwin-Katherine



However, while the number of UFLS incidents decreased, the time to restore customers increased slightly (Table 5).

Table 5: Customer minutes without supply (generation incidents) for Darwin-Katherine

	2015-16	2016-17	2017-18
Number of incidents	3	5	6
Customers impacted	49 300	34 170	24 740
Total duration (minutes)	156	237	318
Customer minutes without supply	2 597 200	1 691 070	1 916 020
Customer minutes without supply/customer	39.1	24.8	28.3
System blacks			
Number	0	0	0
Katherine island blacks	0	2	2

1 Customer minutes without supply is calculated by multiplying the number of customers impacted by the duration of the incident (in minutes).

The overall result in terms of customer minutes without supply per customer is around half an hour for 2017-18. It should be noted this is only the generation portion of the incidents. It is Entura's opinion this performance is acceptable from a customer perspective.

Generation constraints

Table 6 summarises the generation constraints in the Darwin-Katherine region.

Table 6: Darwin-Katherine normal system constraints

	Constraint description	Applied to	Limit	System condition	Comments
1	C8/C9 maximum output constraint	Channel Island units C8 and C9	35 MW each	System demand above 180 MW	Prevent UFLS operation from a C8 or C9 trip
2	C8/C9 maximum output constraint	Channel Island units C8 and C9	30 MW each	System demand below 180 MW	Prevent UFLS operation from a C8 or C9 trip
3	C4/C5/C6 maximum output constraint	Channel Island units C4, C5 and C6	Combined output less than 75 % of system demand	In practice this limit applies at low demand times	Controls rate of change of frequency to within the technical envelope of the UFLS scheme so simultaneous loss of C4/C5/C6 does not lead to system black.

The lack of inertia on units other than the older frame 6 machines at Channel Island power station and the limited governor response of the other units make frequency management in the region difficult. Accordingly, System Control have put in place the above constraints to limit the contingency size of the largest credible generation incident to limit the rate of change of frequency (RoCoF). RoCoF is proportional to the incident's size and inversely proportional to the system inertia. That is, a large incident on a low inertia 'light' system has a higher level of RoCoF than a smaller incident with the same inertia or the same incident with a higher 'heavier' inertia. RoCoF must be managed to ensure secondary controls such as UFLS can operate fast enough to maintain frequency within the frequency standard.

These constraints lead to some degree of inefficiency in the dispatch of generation in the Darwin-Katherine region. Larger spinning reserve margins or faster governor response would likely allow the first two constraints to be lifted.

A switching rearrangement in the Channel Island substation (completed in the second half of 2018) has reduced the impact of the C4/C5/C6 units. Prior to this work, a single fault could remove all three units. Even under a switching rearrangement, it would still be the case that a single fault could remove half the output of the C4/C5/C6 combined cycle combination. This would be a slower incident that could be more easily managed by spinning reserve. It is noted that System Control plan to reassess the constraint in the first half of 2019.

Planned and recent enhancements

While there are a number of licence applications for new generation in the Darwin-Katherine region, none has come on-line in 2017-18, and it is unlikely that any additional generation will be added in 2018-19.

The Darwin-Katherine region remains a challenging place for new generation to connect. Three contributing factors are worth noting:

- The large existing installed capacity – this is discussed in the generation adequacy section of this chapter.
- Network topology – to some extent, this is linked to the fault level and frequency control issue, especially for intending renewable connections. However, the network topology of the Darwin-Katherine system, as shown in Figure 1, consists of the population centres of Darwin and Katherine with a single 132kV line connecting the two centres. The electricity transfer on the line has traditionally flowed in a southern direction to Katherine. The single line has no network redundancy and this vulnerability in the system, to date, only impacted customers south of Darwin.
- Fault level and frequency control – this relates to the nature of the PV inverters themselves as well as the likely location of large-scale solar PV (the majority of proposed generators are large-scale solar PV) and the network impacts on frequency and fault level management. PV invertors do not provide system strength or inertia, therefore in isolation PV invertors are limited in their ability to control significant system frequency variations. There are a number of factors that make connecting to the single transmission line between Darwin and Katherine attractive to new entrants, these include among others surplus network capacity, availability of economically viable land and greater solar irradiance. Significant generation connecting to the single 132 kV line is likely to reverse the electricity transfer on the line to a northern direction towards Darwin. Subsequently, this will introduce a contingency for Darwin customers related to the loss of the line. This contingency would initially be covered under normal spinning reserve arrangements. However, a point would come where the generation capacity on the line would not be covered by the current spinning reserve margin, which would result in increased risk, a need to change ancillary services requirements or curtailment of generation on the line.

Design and commissioning processes

A number of system incidents appear to have arisen because equipment has failed to operate as designed or its design has failed to take into account certain operational requirements. The best examples of this are:

- an occurrence of incorrect application of UFLS settings in Darwin
- a failure of frequency control between Pine Creek and Katherine under islanded conditions.

Issues related to design and commissioning processes, and associated coordination between the network and generation assets are not limited to the Darwin-Katherine power system. For example, in Alice Springs insufficient redundancy of auxiliary supplies to Owen Springs generating units was observed because of fault level limitations. Further, the issues do not only relate to the primary interface but to secondary interfaces as well. These include elements such as UFLS.

It is observed that there does not appear to be a robust method of design checking in terms of the inter-operability of generation and network controls, and protection. More robust approaches to overall design and commissioning for network and generation enhancements should be adopted. In other jurisdictions, this coordination is undertaken by the network service provider.

The commission sought comment from PWC on this observation. Consequently, PWC has indicated that its current approach is to undertake internal discussion forums during the project development stage, with feedback received used to shape the project development. Further, as part of continual improvement, PWC advised that it intends to place a stronger focus on inter-operability of controls and protection for generation and networks during key stages of the project cycle from the concept design to commissioning.

Network

The Darwin-Katherine network covers the Darwin and Katherine areas with a corridor between Darwin and Katherine to the South. The highest transmission voltage is 132 kilovolt (kV). The network in Darwin is relatively robust with the 66 kV network forming a series of loops. The 132 kV and 66 kV networks are strongly interconnected, albeit at a single point at Hudson Creek.

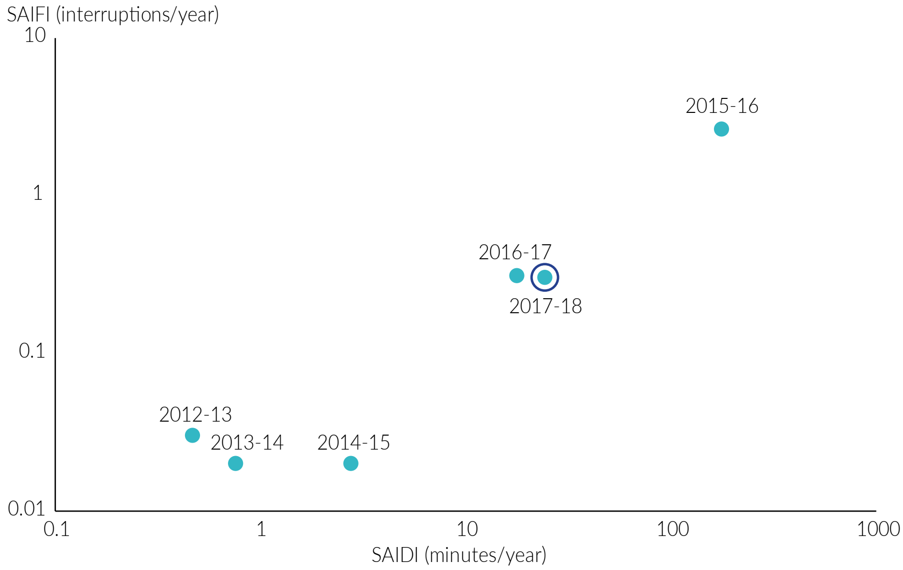
The southern extremities of the network are supported by EDL NGD (NT) Pty Ltd's (EDL) Pine Creek power station, with Territory Generation's Katherine power station also available. The long single circuit provides challenges from a system robustness perspective.

Transmission performance

Transmission performance is measured and reported by PWC as part of the Code requirements.

The SAIDI and SAIFI performance for the Darwin-Katherine transmission networks are presented in Figure 14.

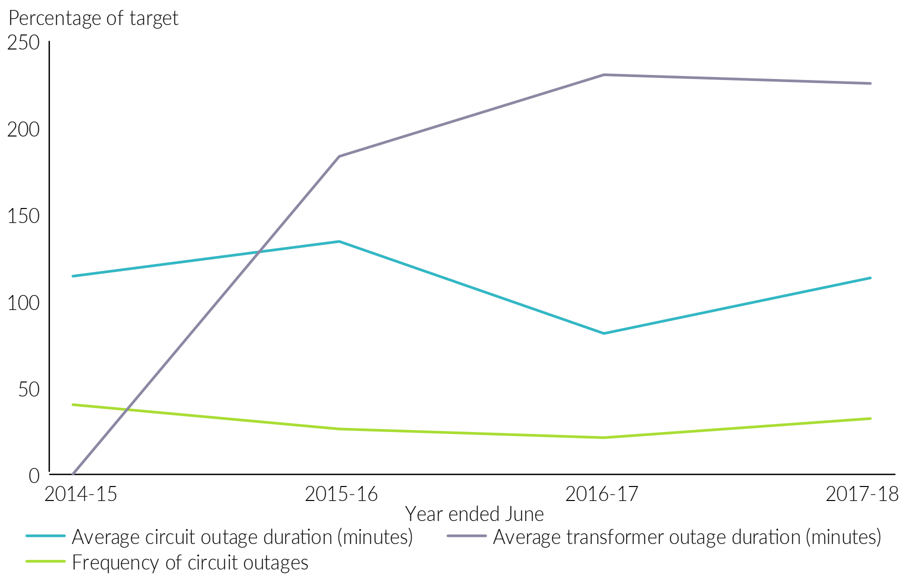
Figure 14: SAIDI and SAIFI performance indices for transmission network, Darwin-Katherine



The last three years (2015-16 to 2017-18) show a departure from the performance of the previous years (2012-13 to 2014-15). There is no standard stipulated for the transmission SAIDI or SAIFI indices but it is worth considering how this performance relates to the customer experience. On average, if there is an interruption then it will go for 24 minutes (SAIDI) and each customer will likely have 0.3 interruptions (SAIFI) from transmission incidents. In other jurisdictions, where the transmission network is generally N-1 reliable at both line and transformer level, this would be unacceptable.

SAIDI and SAIFI standards are not defined for most transmission systems since in larger transmission networks there are not enough incidents that impact customers from transmission failures to make these meaningful measures. Instead, actual outage statistics are used (see Figure 15).

Figure 15: Transmission network – adjusted performance indicators Darwin-Kathrine (% of the target)



This view shows, in general, the PWC Network is performing within acceptable limits since the average circuit outage duration (ACOD) and frequency of circuit outages (FCO) are safely below the target. The current targets were approved by the commission in July 2013 for the current determination period from 1 July 2014 to 30 June 2019.

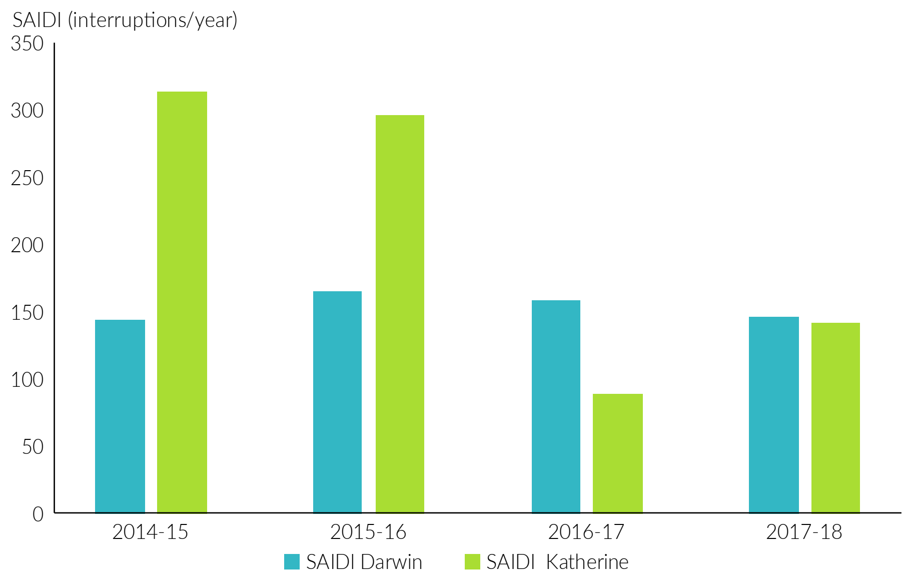
The average transformer outage duration (ATOD) result has been in excess of the target for the last three periods. PWC Power Services advise this year's result was due in the most part to an oil leak on a transformer and so the result relates to a single incident that took nearly four hours to fix. The target would have required this to occur in 123.3 minutes. Evidently, these incidents are rare and transformer faults can vary in severity and rectification time. Entura accepts the description of the incident warrants a longer outage length in this case. Entura also acknowledges it is in fact meritorious there have not been other, shorter-lived outages, that otherwise would have reduced the average outage time.

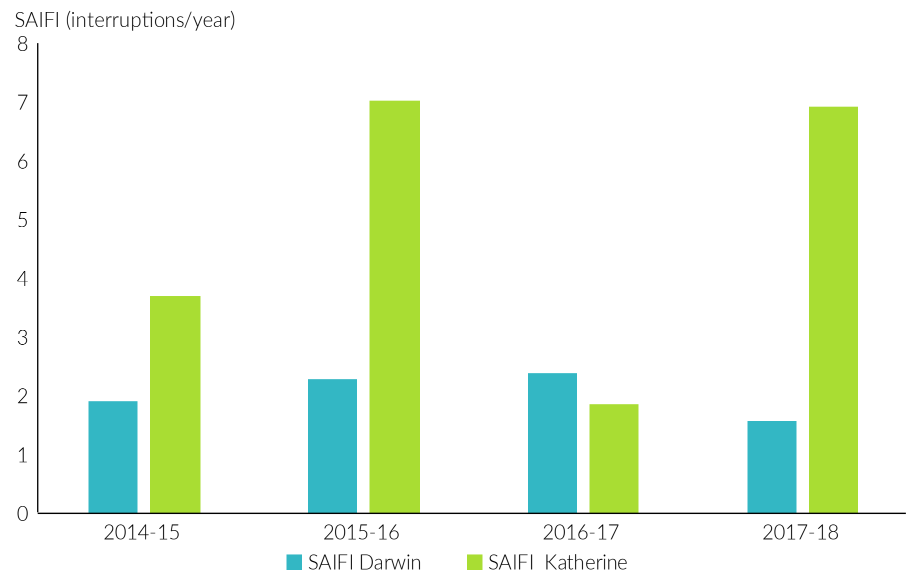
Distribution performance

The overall measure of SAIDI and SAIFI do not have a standard set. The standards are set at the feeder type level for the sum of the three regulated power systems. The targets were met for the combination of the three regulated networks.

The SAIDI and SAIFI performance for the Darwin and Katherine distribution networks are presented in Figure 16.

Figure 16: SAIDI and SAIFI performance indices for distribution network, Darwin and Katherine





The SAIDI results are similar to last year, with some degradation in Katherine. This effect is particularly evident in the SAIFI results. The overall result should be unpacked through looking at the individual feeder type measures (see Table 7 and Table 8).

Table 7: Darwin and Katherine SAIDI feeder breakdown

	2014-15	2015-16	2016-17	2017-18	Global target[1]
Darwin					
CBD	0.7	1.61	2.41	4.99	18.8
Urban	95.5	103.25	83.32	91.17	136
Rural Short	414.5	534.21	593.48	605.4	496.3
Rural Long	n.a.	n.a.	n.a.	n.a.	2164.9
Katherine					
CBD	n.a.	n.a.	n.a.	n.a.	18.8
Urban	257.1	218.89	41.11	103.00	136
Rural Short	432.2	470.92	136.47	257.98	496.3
Rural Long	892	795.47	367.82	582.57	2164.9

1 Reference only.

Table 8: Darwin and Katherine SAIFI feeder breakdown

	2014-15	2015-16	2016-17	2017-18	Global target[1]
Darwin					
CBD	0.10	0.01	0.03	0.17	0.4
Urban	1.30	1.58	1.30	1.14	2.5
Rural Short	5.20	6.48	7.50	6.18	8.1
Rural Long	n.a.	n.a.	n.a.	n.a.	35.1
Katherine					
CBD	n.a.	n.a.	n.a.	n.a.	0.4
Urban	3.40	7.45	1.25	6.45	2.5
Rural Short	5.10	7.99	2.68	9.89	8.1
Rural Long	6.90	10.95	4.23	10.09	35.1

1 Reference only.

If the global target is applied to these regional indices, the SAIFI performance of the Katherine network and the SAIDI performance of short rural feeders in Darwin are of concern.

The Darwin result suggests a lack of focus on this category of outage in terms of response. The SAIFI is within the target for this category.

The Katherine result is consistent with the high number of incidents relating to supply in Katherine, which is shown by the Katherine region generally not meeting the SAIFI target. Entura considers the management of Katherine supply to be a key issue.

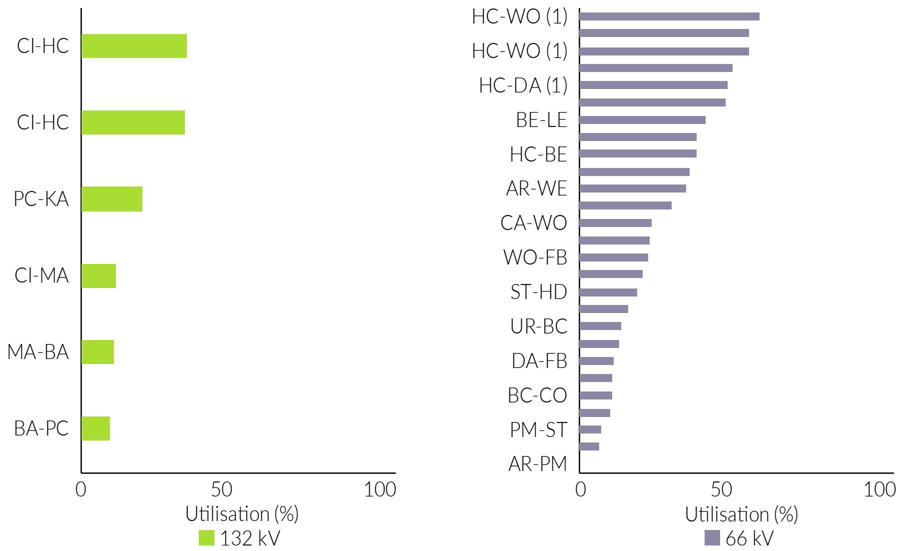
Network utilisation

The network utilisation (see Figure 17) shows an updated dataset to that of previous reviews. The only lines to exceed 50 per cent utilisation are lines out of Hudson Creek and the Weddell Strangways line.

It is expected the loop flows from Hudson Creek would not lead to overloads after line tripping occurs.

The Weddell Strangways line flow will be reduced once the Archer-Palmerston 66 kV line is completed.

Figure 17: Transmission network utilisation Darwin-Katherine

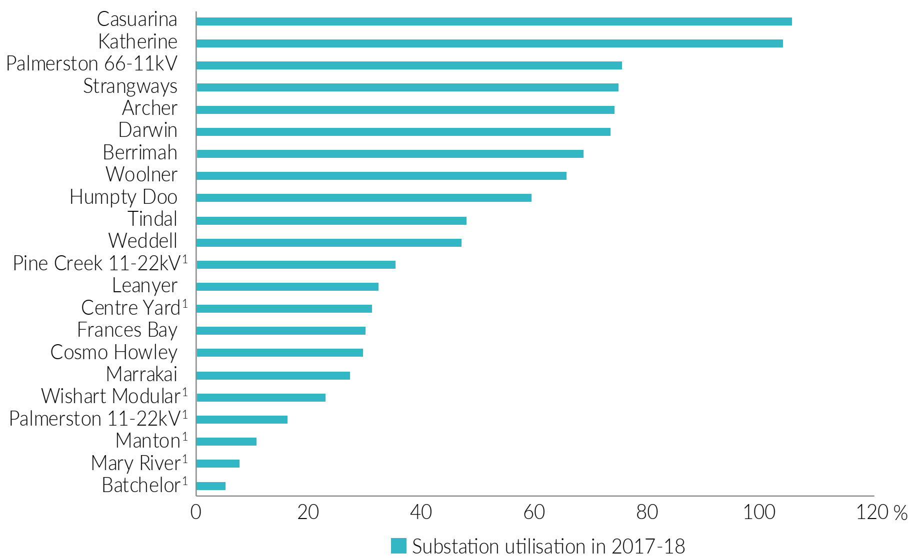


The planned upgrades between Hudson Creek and Palmerston appear to be effective in reducing flows on the existing circuits in that corridor. Entura notes the ongoing load balancing issues required in the Weddell 66 kV loop. The Archer-Palmerston 66 kV line will reduce the reliance on generation from Weddell power station to manage network flows.

Network adequacy

The zone substation transformer loading under N-1 conditions is shown in Figure 18.

Figure 18: Substation utilisation in N-1 conditions on 2017-18 Darwin-Katherine (POE 10)



1 The Substation with (*) the rating for (N) is considered.

The N-1 POE 10 loadings at Casuarina and Katherine all exceed the remaining transformer capacity. At Casuarina, there has been a replacement of the three transformers to units of a lower rating with attendant load transfers. This has meant the POE 10 demand exceeds the N-1 capacity of the transformers. Further load transfers will be required to rectify this situation, depending on actual demand growth.

At Katherine, the N-1 capacity of the transformers is within one MVA of the POE 10 demand. Katherine generation can be used to unload the transformer if an overload occurs.

The POE 10 demand is a harsh test of network adequacy. PWC appear to use POE 50 in their Network Management Plan. Entura observes that over time, PWC demonstrated adequate oversight of demand changes relative to capacities.

Network incidents

There were 14 major network incidents in Darwin-Katherine in 2017-18 (see Table 9).

Table 9: Darwin-Katherine network incident summary

ID	Date of incident	Description	Cause	UFLS/black	Incident duration (minutes)	Customer minutes without supply
1	30-Jul-2017	66kV CP-CZ line trip – loss of supply to CPZSS	Equipment failure		101	28 280
2	08-Aug-2017	132kV MT-CI line trip	Testing error	Pine Creek and Katherine black	56	240 800
3	21-Aug-2017	Palmerston zone substation – loss of 11kV buses 3 & 4	Equipment failure		14	50 400
4	30-Aug-2017	Berrimah zone substation – loss of supply to BEZSS	Switching error		401	1 908 760
5	22-Sep-2017	66kV BE-LE line trip – loss of supply to LEZSS	Transient fault		13	42 380
6	25-Sep-2017	132kV MT-CI line planned outage	Secondary systems errors	Unplanned Pine Creek-Katherine island black	9	38 700
7	25-Sep-2017	132kV MT-CI line planned outage	Secondary systems errors	UFLS stage 1	24	48 720
8	25-Sep-2017	132kV MT-CI line planned outage	Secondary systems errors	UFLS stage 1	9	16 110
9	21-Nov-2017	132kV CI-MT line tripped	Secondary systems errors	Pine Creek and Katherine black	56	238 560
10	04-Jan-2018	132 PK-KA line tripped	Lightning	Katherine island black	259	1 139 600
11	05-Jan-2018	66PK01 circuit breaker failure	Equipment failure	Pine Creek island black	212	53 000
12	17-Mar-2018	TC Marcus	Multiple faults	Yes	17 600	473 440 000
13	09-May-2018	Frances Bay substation – Loss of supply to West Bennett switching station bus 1	Operator error		118	53 100
14	28-May-2018	Operational non-conformance	Secondary systems errors	UFLS not assigned at multiple zone substations	0	0

The incidents fall into four categories, namely secondary system failures, equipment failure, operator error and other (including storms).

Secondary system failures

Incidents 6, 7, 8, 9 and 14 fall into this category.

Entura's view is loss of supply through secondary system failures on the transmission network should be rare. The design of redundancy, modern supervision techniques and record management should allow systems to be designed, implemented, tested and monitored in such a way as to not fail with resulting loss of load.

This category accounts for 8.9 per cent of the customer minutes without supply due to major network incidents from 2017-18, if the effects of TC Marcus are excluded.

Equipment failure

Incidents 1, 3 and 11 fall into this category.

Network operation will inevitably see some failures. If they occur at the distribution level, they will lead to loss of customer load. Incidents 1 and 3 are examples of this where a system is not designed for N-1 reliability. The standards of service require these incidents to be effectively rare and short, which PWC appear to be managing effectively. Entura has more concern with incident 11.

The System Control report for incident 11 describes a large number of incorrect or sub-optimal plant behaviours. The initiating incident was the failure of a 66 kV circuit breaker to open all three phases. While this will occur from time to time, System Control have rightly called for a review of preventative maintenance practices. The incident uncovered a number of relaying, SCADA and incident monitoring discrepancies. These are more akin to the secondary system failures category above.

This category accounts for 3.4 per cent of the customer minutes without supply due to major network incidents from 2017-18, if the effects of TC Marcus are excluded.

Operator error

Incidents 2, 4 and 13 fall into this category.

These incidents include a range of operation errors. Entura observes the serious nature of these incidents, particularly from a work health and safety (WHS) perspective. Entura is pleased to note the recommendations in the incident report relating to safety and emergency response, as well as a comprehensive list of hardware and system improvements to assist personnel to operate the network safely and correctly.

However, while System Control maintains a register of these recommendations, the response or progress on recommendations is not reported on. Accordingly, Entura is concerned there is little scrutiny of these recommendations as to progress or acceptance.

This category accounts for 57.1 per cent of the customer minutes without supply due to major network incidents from 2017-18, if the effects of TC Marcus are excluded.

Other (including storms)

Incidents 5, 10 and 12 fall into this category.

This category of incidents is unavoidable. The measure of performance here relates to the scale of customer impact in terms of both load and duration.

The TC Marcus incident (12) is discussed separately below.

Focussing on the remaining two incidents, Entura observes that incident 5 occurred during a time of low or non-reliability. The risk notice clearly identified the incident as being likely or possible and included plans for managing the incident. The risk notice was in place for almost two weeks with a 10-day recall period.

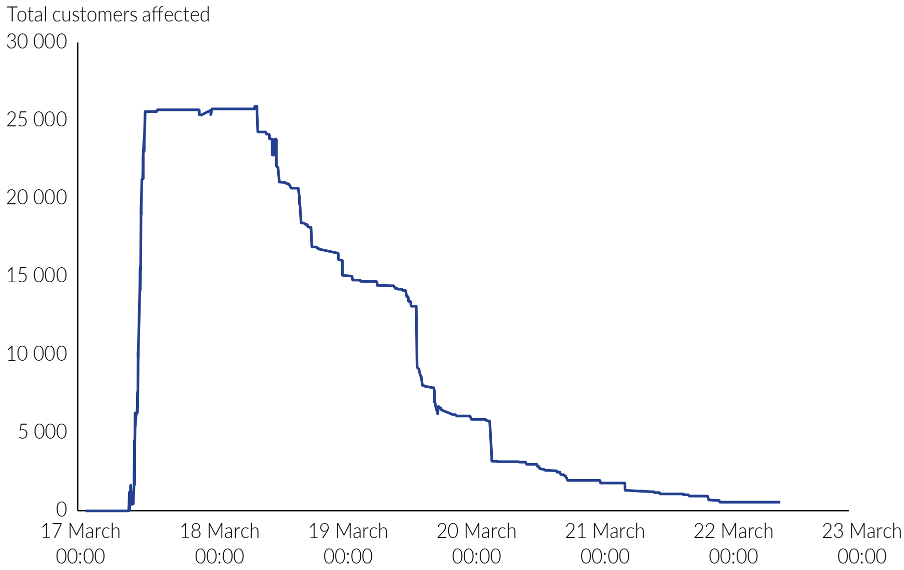
Entura is concerned that even though mitigations were put in place in the form of load transfer, there was still some load at risk. The overall system risk was reduced but the risk to those customers remaining on the vulnerable nodes was not. This being the case, Entura questions whether the risk to those customers' supply was kept as low as reasonably possible.

Incident 10 relates to a lightning strike to the 132 kV line between Channel Island and Katherine. This line is a major source of system disturbances for the network in terms of both exposing the Darwin region to a wider range of storm and lightning strike risk, as well as posing a high likelihood of islanding for Pine Creek and Katherine. The high likelihood of islanding of the Pine Creek and Katherine system leads Entura to conclude the robustness of the supply to this area should be carefully considered. It appears to Entura the existing operating protocols and equipment do not deliver the levels of robustness that could reasonably be expected.

Tropical Cyclone Marcus

TC Marcus (incident 12) caused a major disruption to supply in the Darwin-Katherine region between 17 and 22 March 2018. The load reconnection rate can be seen in the following figure from the System Control situation report of 22 March 2018.

Figure 19: Customer reconnection after TC Marcus



Customer disconnections are inevitable for storms of this magnitude. Entura acknowledges the efforts that PWC and Territory Generation made regarding the swift and safe reconnection of customer supply in the aftermath of these incidents. An independent report was commissioned by PWC into the response to the incident, which acknowledged the effectiveness of PWC's response in the electrical network sphere and identified a number of opportunities for improvement.

Entura notes an outage management system change is already in train. Entura is of the opinion that the emergency response approach PWC maintains is adequate but it could be improved and its future efficacy assured through adopting a more rigorous continuous improvement methodology.

Impact of incidents

Overall, more incidents that lasted longer occurred in 2017-18. This is even the case if TC Marcus outages are excluded from the statistics (see Table 10 and Figure 20).

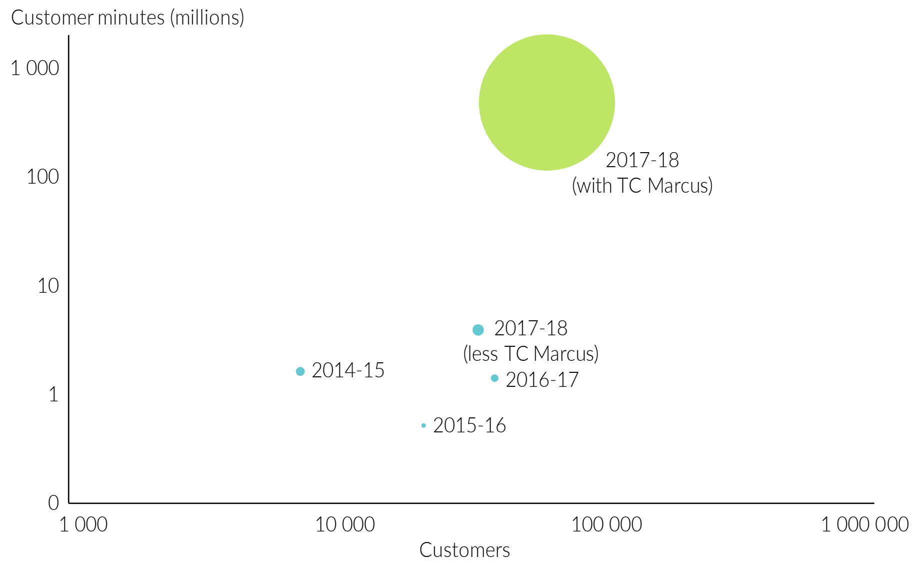
Table 10: Comparison of network incident duration and customer impact

	2015-16	2016-17	2017-18	2017-18 (less TC Marcus)
Number of incidents	7	10	14	13
Customers impacted	21 010	38 630	60 580	33 680
Total duration (minutes)	152	360	18 872	1272
Customer minutes without supply[1]	505 520	1 406 610	477 298 410	3 858 410
Customer minutes without supply/ customer	7.4	20.8	6 641.2	53.7
System blacks				
Darwin	0	0	0	0
Katherine island blacks	6	5	5	5

1 Customer minutes without supply is calculated by multiplying the number of customers impacted by the duration of the incident (in minutes).

While the number of system blacks for Katherine (Katherine island blacks) remains between five and six incidents in recent years, the number of major incidents is more than recent levels. This is reflected in an increase in the average customer minutes without supply. Graphically the data can be seen more clearly (see Figure 21). The circle sizes represent the average customer minutes without supply experienced by each customer. The x-axis is the total number of customers affected by outages (over 33 000 for 2017-18 without TC Marcus). The y-axis is the number of customer minutes without supply (nearly four million in 2017-18 without TC Marcus).

Figure 20: Customer minutes without supply versus affected customers (2014-17)



The figure shows that the 2017-18 incidents were longer while affecting around the same number of customers. It also illustrates how much impact the cyclone had and why it remains important to report on performance without considering the effect of TC Marcus.

Entura is not satisfied the network is being operated in a way that minimises interruptions to customers.

Outage coordination

At least one of the major system incidents discussed in this section occurred during a long-running outage that left the network at a high level of risk. While it is accepted this is sometimes inevitable, there is an expectation that risk is properly assessed and managed. The removal of redundancy from a supply that would, under normal network conditions have a redundant supply, must be carefully coordinated. This review has seen evidence of these considerations, which is further strengthened by a response received from PWC that shows a level of detailed consideration is taken. However, Entura does not think they extend far enough in terms of risk reduction.

The reduction of risk should be to the extent that is reasonable not to the extent that is easy or readily achieved.

The System Controller's rigorous reporting of system non-reliability is welcomed. The assessment of risk associated with system non-reliability notices will be scrutinised and discussion included in future reviews on the effectiveness of this system if issues are identified.

Network constraints

There are no binding network constraints within the Darwin-Katherine network.

Planned and recent network enhancements

The following network enhancement is noted from the System Control half-yearly reports:

- Casuarina zone substation – upgrade undertaken to replace the air insulated outdoor 66kV switchgear with indoor 66kV gas insulated switchgear (GIS) and replace the original transformers with new.

The following upgrades are noted from the PWC Network Management Plan:

- Hudson Creek – East Arm 66 kV reconnection (2019-20)
- East Arm – Woolner 66 kV reconnection (2019-20)

Each of these upgrades enhances the robustness of customer supply in the 66 kV network around Darwin.

The revised regulatory proposal PWC submitted to the Australian Energy Regulator (AER) included a non-network solution for the Wishart zone substation and replacement works at the Berrimah zone substation.

Networks customer power quality notifications

PWC report on the number and types of power quality complaints. Figure 21 shows the Darwin-Katherine customer notifications marginally increased in 2017-18.

Figure 21: Total customer notifications relating to the quality of supply in Darwin-Katherine

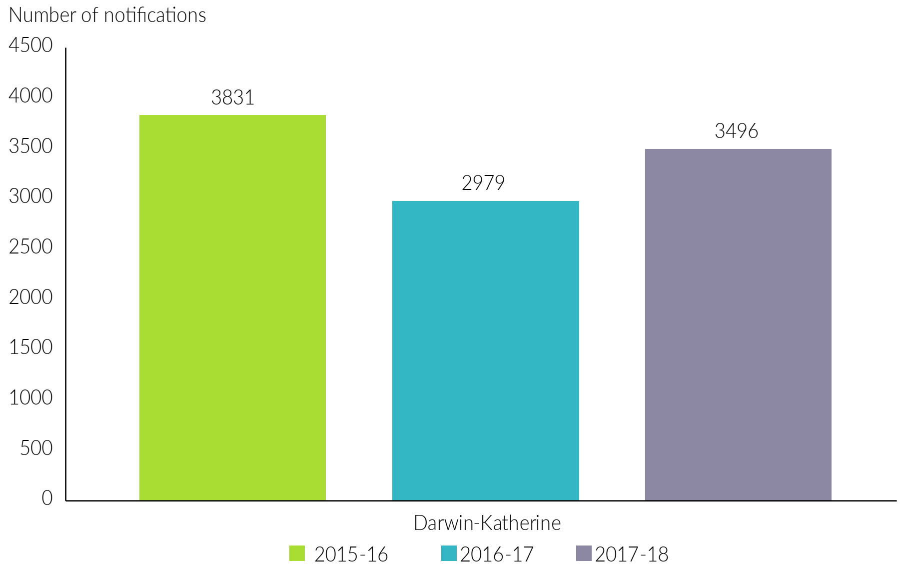
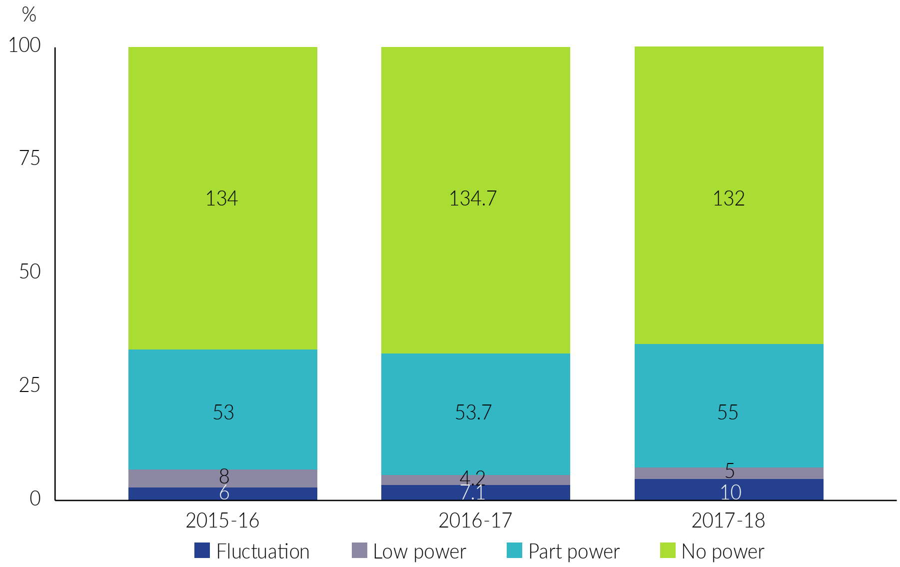


Figure 22 shows notifications are largely made in response to no power rather than in relation to part or the quality of power.

Figure 22: Type of customer notifications relating to the quality of supply in Darwin-Katherine



Entura notes that even with the inclusion of TC Marcus, the number of complaints remained consistent with previous years. This may be further evidence of the acceptability of the response to TC Marcus.

2 | Alice Springs power system

This chapter focuses on the 2017-18 generation and network performance of the Alice Springs power system. Where possible it compares 2017-18 performance to historical data to identify trends. Specifically this chapter considers:

- overall customer impact
- generator performance, observed under frequency load shedding (UFLS) and single generator trips, generation availability, generation adequacy, non-reliable periods, major generation incidents, generation constraints, and generation planned and recent enhancements
- transmission and distribution network performance, network utilisation, network adequacy, major network incidents, network constraints, network planned and recent enhancements, and network power quality notifications.

Power system description

The Alice Springs power system is the second largest power system in the Territory. It supplies the township of Alice Springs and surrounding rural areas from the Ron Goodin, Owen Springs and Uterne (solar) power stations.

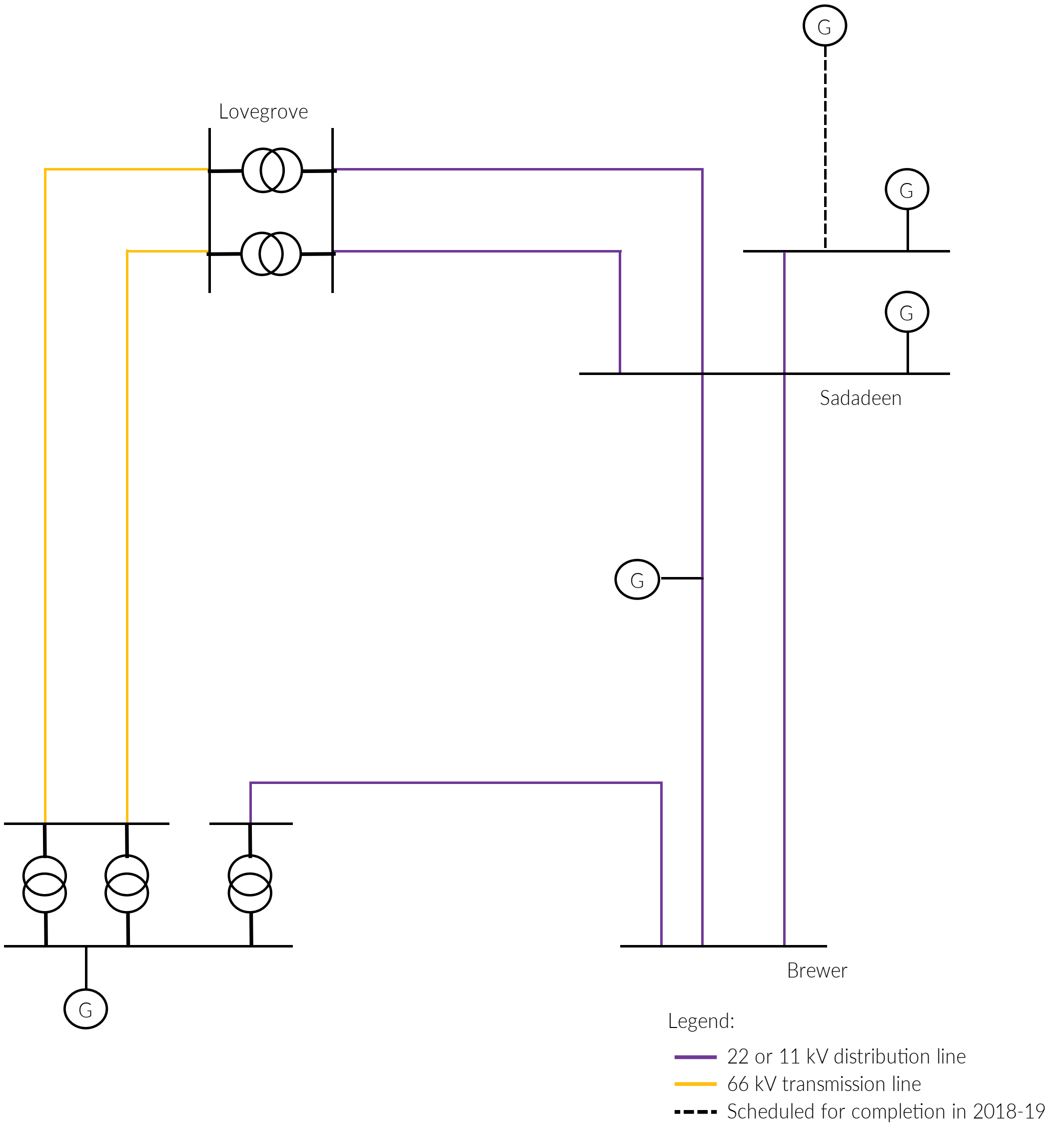
Figure 24 illustrates the Alice Springs power system. The highest voltage of the network is 66 kilovolt (kV).

The operational consumption in 2017-18 is shown in Table 11.

Table 11. Alice Springs operational consumption in 2017-18

Power system	Energy sent out (GWh)
Alice Springs	214

Figure 23: Alice Springs power system



The total generation capacity in the Alice Springs power system is around 124 MW across three power stations as summarised in Table 12. The fuel type of the generation units is made up of dual fuel (gas/diesel), diesel only, gas only and solar PV. The operational maximum demand in 2017-18 was around 63 MW.

Table 12: Total generation capacity in Alice Springs during 2017-18[1]

Power station	(MW)
Ron Goodin	42.6
Uterne	4
Owen Springs	77.1[2]
Total generation	123.7

1 Generation capacities provided are used in the Northern Territory Electricity Outlook Report. Capacity values can vary depending on the definition of capacity applied, such as nameplate, summer and winter capacity.
2 Includes Owen Springs power stations A and B. Owen Springs B is not scheduled for commissioning until beyond the 2017-18 period.

The generation totals include Ron Goodin and Owen Springs new generation. Ron Goodin is expected to be decommissioned during 2019. Owen Springs new generators were proposed to be fully commissioned by January 2019. Testing was ongoing in March 2019.

Overall customer impact

This section shows the overall performance for the Alice Springs region.

Table 13 shows the impact on customers from all incidents in the Alice Springs region across the last three years.

Table 13: Customer minutes without supply for the Alice Spring

	2015-16[1]	2016-17	2017-18
Number of incidents	13	10	14
Customers impacted	58 620	33 730	43 270
Total duration (minutes)	739	415	1 247
Customer minutes without supply[2]	5 766 380	1 863 670	7 156 280
Customer minutes without supply per customer	466.8	152.9	570.3
System blacks	1	0	2[3]

1 Minor incidents were first recorded in 2016-17. Therefore, any increase from 2015-16 to 2016-17 is in part explained by the inclusion of minor incidents.

2 Customer minutes without supply is calculated by multiplying the number of customers impacted by the duration of the incident (in minutes).

3 There was one system black and one incident categorised as a technical black. System Control categorised a major incident on 13 November 2017 as a technical black rather than a system black due to a busbar remaining energised. The commission understands this is not a widely used term.

The system black and technical black incidents in 2017-18 have added significant additional customer minutes without supply to the Alice Springs system. The results from 2016-17 indicate the effect on customers can be less. Entura expects the completion of upgrades at Owen Springs and Sadadeen (discussed later in this chapter) will make the operation of the Alice Springs network more robust.

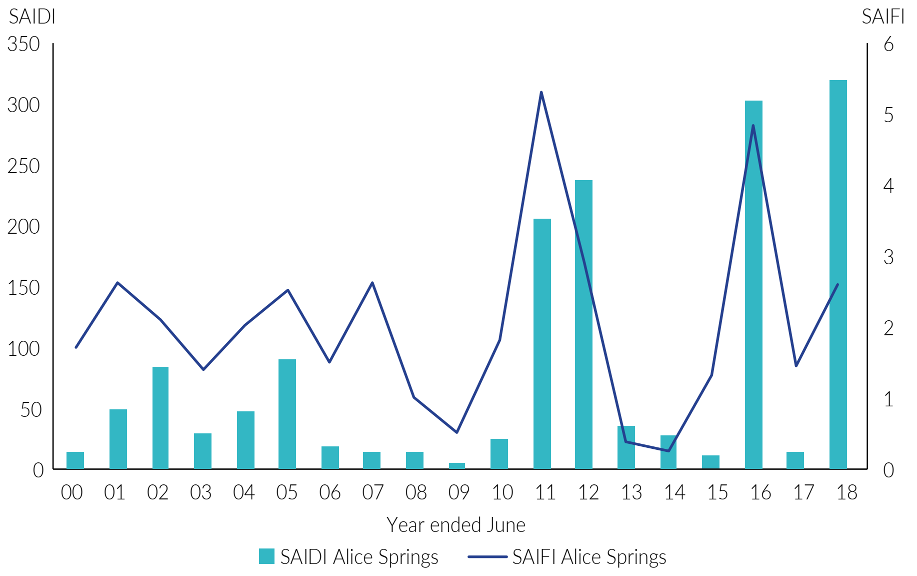
Generation

The following sections show the generation in Alice Springs continues to present reliability and availability challenges.

Generator performance

The System Average Interruption Duration Index (SAIDI) and System Average Interruption Frequency Index (SAIFI) performance for the Alice Springs generating units are presented in Figure 24.

Figure 24: SAIDI and SAIFI performance indices for generation, Alice Springs



The two indices demonstrate the number of issues that have beset Alice Springs over the last 10 years. There is no strong relationship between the two indices indicating a range of outage causes and incident types, and a change of these outage characteristics across time.

Entura has been expecting the generation upgrades at Owen Springs and the battery energy storage system (BESS) to improve the performance. However, unfortunately these upgrades are yet to be fully commissioned and so customers are yet to see the benefits. In fact, the incident reports suggest the process of the upgrades has further weakened the robustness of the system through a number of teething issues. Entura is concerned the removal of the Ron Goodin power station may lead to a further adjustment period and so the poor performance may be sustained for the next period at least.

Entura appreciates, in the absence of these upgrades, the generation mix and high penetration of solar PV leads to a challenging system control problem. While there still appears to be a number of UFLS incidents, the number that can be attributed to single unit trips is reducing. However, the number of single contingency incidents that led to secondary trips is still of great concern.

Observed UFLS and single generation trips

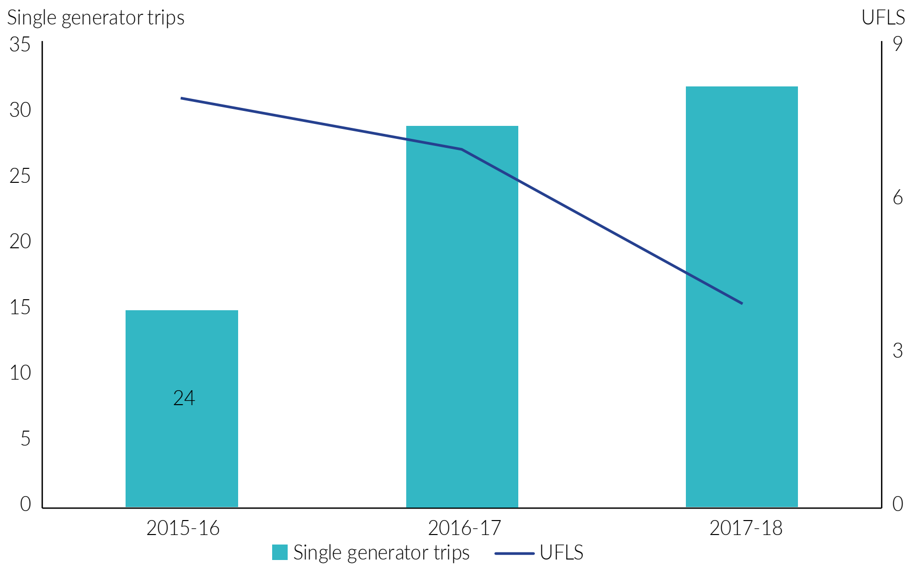
There were a large number of single unit incidents (32) in Alice Springs for the 2017-18 period. Four of these incidents resulted in UFLS operation. These incidents are shown in Table 14.

Table 14: Alice Springs single generator major incident summary

Date of incident	Description	Cause	UFLS/black	Incident duration (minutes)	Customer minutes without supply
25-Aug-2017	Ron Goodin power station (RGPS) unit 9 tripped	Equipment failure	UFLS stage 1A and 1B	10	15 200
26-Sep-2017	Owen Springs power station (OSPS) unit 3 trip	Gas supply failure	UFLS stage 1A and 1B	17	42 670
29-Nov-2017	OSPS unit 2 tripped	Equipment failure	UFLS stage 1	19	79 800
16-Jan-2018	OSPS unit A tripped	Not known	UFLS stage 1	20	52 000

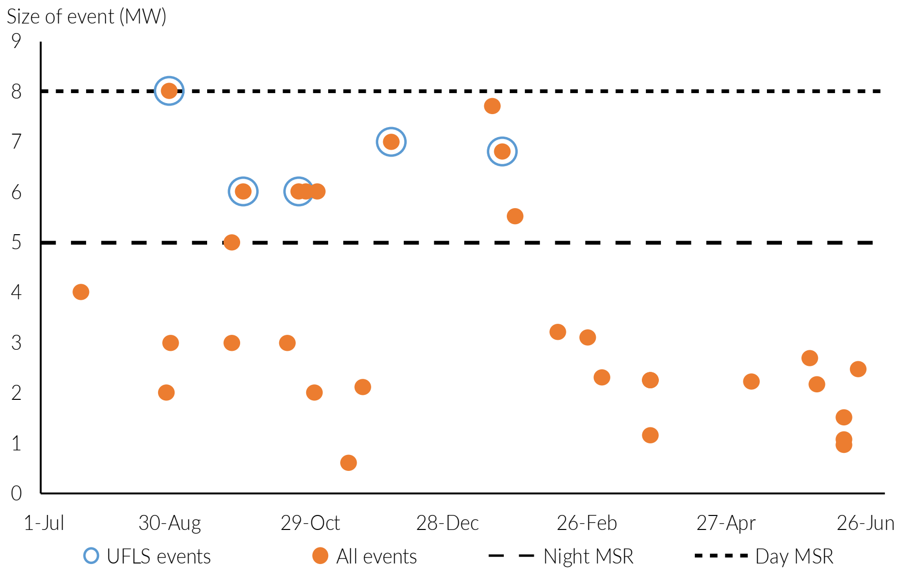
This is a similar result to previous years. The UFLS incidents are discussed in more detail in the Alice Springs generation incidents section.

Figure 25: Alice Springs single generator trips versus UFLS (due to single generator trips)



It continues to be a concern to Entura that so many single unit trips occur. It is observed that the robustness of individual generator units at both the Owen Springs and Ron Goodin power stations is not acceptable. This lack of robustness is affecting customers and must be improved. However, it is positive that the number of UFLS incidents due to these trips appears to have stabilised. Part of this stabilisation is due to the stricter approach to spinning reserve. System Control enforces maximum dispatch totals and minimum spinning reserve (MSR) margins. It should be noted that this may impact costs. Figure 26 shows the size of the incidents across the 2017-18 period with the UFLS incidents highlighted.

Figure 26: Single generating unit trips by size



The variability of the results above 5 MW are of interest. If the MSR was adequate, it would be expected that incidents less than 8 MW would not require UFLS. There is a 3 MW buffer applied. Entura would like to understand whether the MSR or this buffer is appropriate. Many of the single machine UFLS incidents occurred with spinning reserve below the minimum spinning reserve level. This regime is likely to change once the BESS is installed in the Alice Springs system.

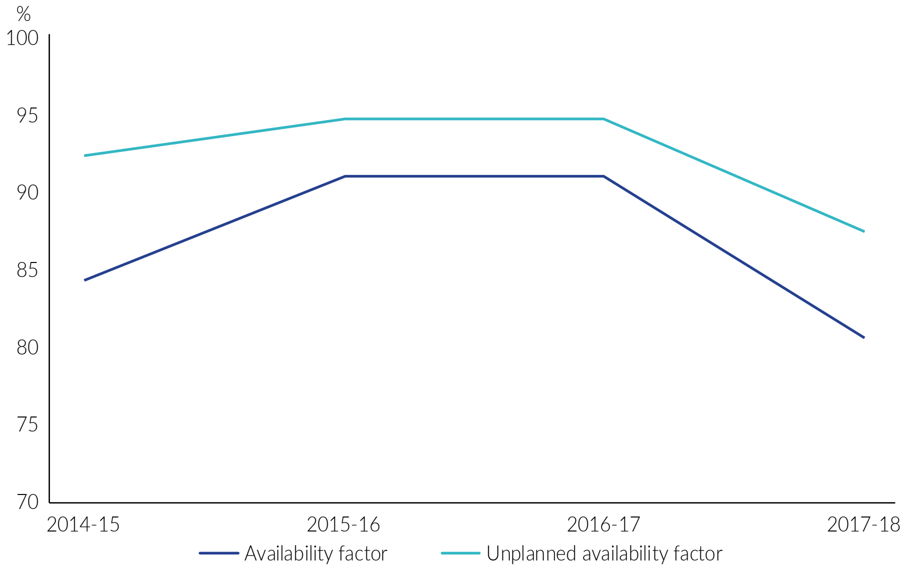
TGen has indicated that the number of generator trips is in part due to a reliance on old generators at the Ron Goodin power station, and a requirement for a minimum number of generators to be operating. That has a flow on effect for maintenance and the ability of a generator to withstand system changes at low load periods. Further, TGen states that the results should improve, although new generation at Owen Springs power station may initially increase single unit trips, due to commissioning issues.

Generation availability

Availability factor

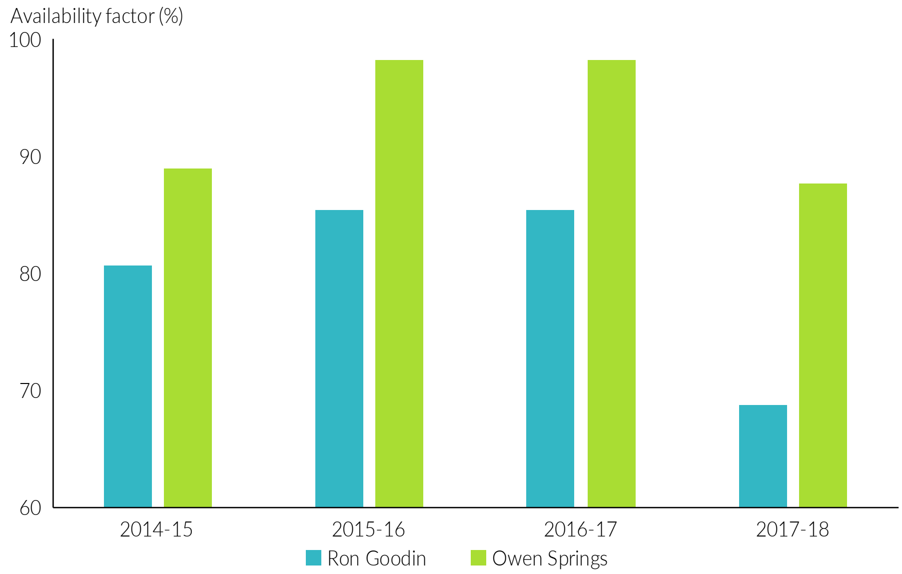
The overall availability for the generators showed a large decline in 2017-18 over the previous period (see Figure 27).

Figure 27: Capacity weighted average availability factor for Alice Springs generating units



The power station results (see Figure 28) indicate both stations have performed poorly.

Figure 28: Availability factor for Alice Springs power stations



As illustrated in Figure 28, Ron Goodin in particular has seen very low availability for the period, noting this is not only to do with forced outages. However, the decrease is understandable as the transition to Owen Springs approaches and focus on the Ron Goodin power station machines decreases.

Entura is concerned with the availability at Owen Springs power station. With the station about to take almost full responsibility for Alice Springs supply, an availability below 90 per cent may not prove suitable.

Forced outage factor

2017-18 sees a marked increase in the forced outage factor over previous periods (see Figure 29).

Figure 29: Capacity weighted average Forced Outage Factor for Alice Springs generating units

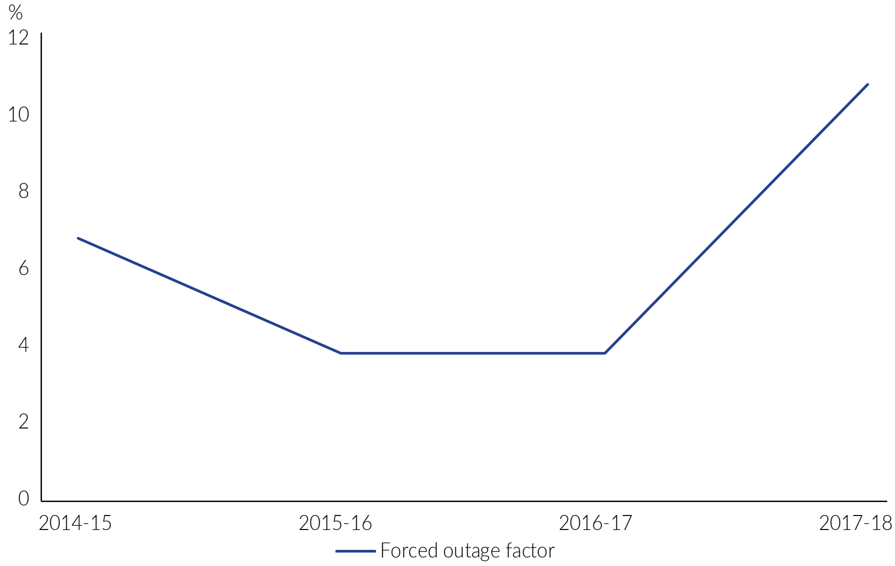
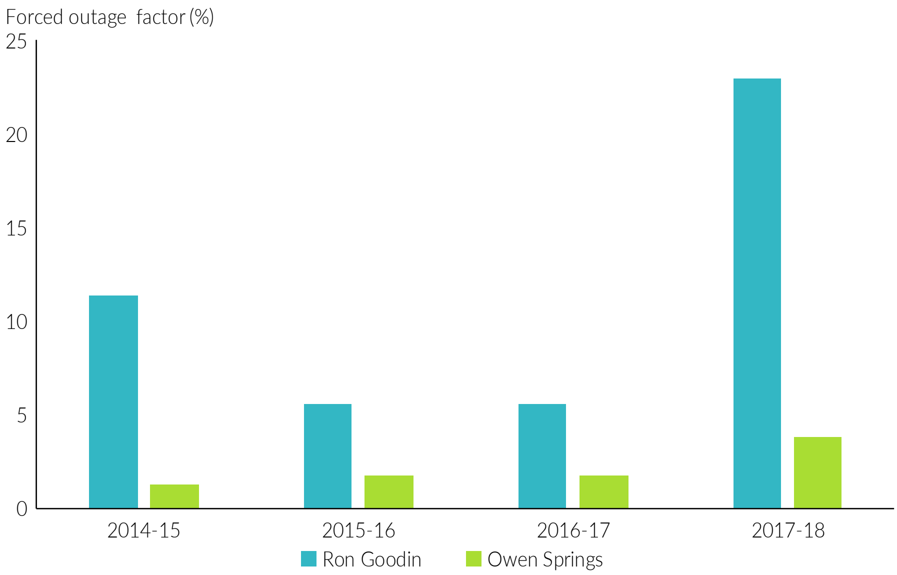


Figure 30 compares the performance of the two stations and shows a large decrease in performance at Ron Goodin. While Owen Springs' performance was significantly better than Ron Goodin's it should be noted that Owen Springs' forced outage rate doubled from 2016-17 to 2017-18.

Figure 30: Force outage factor for Alice Springs power stations

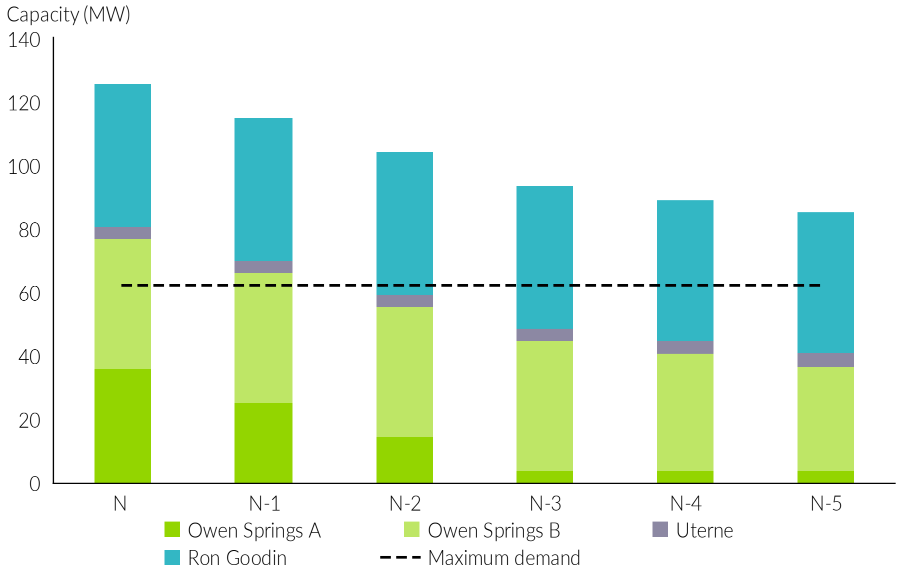


The forced outage rates at both stations are too high. Entura is expecting the new Jenbacher machines at the Owen Springs power station and the retirement of Ron Goodin will lead to better performance.

Generation adequacy

Figure 31 shows the N-X adequacy assessment for the Alice Springs system. The analysis shows the contribution of Ron Goodin when, at the time of writing, it was still operational. Only Owen Springs should be considered to gain a longer-term appreciation of adequacy.

Figure 31: N-X exposure in Alice Springs in 2017-18



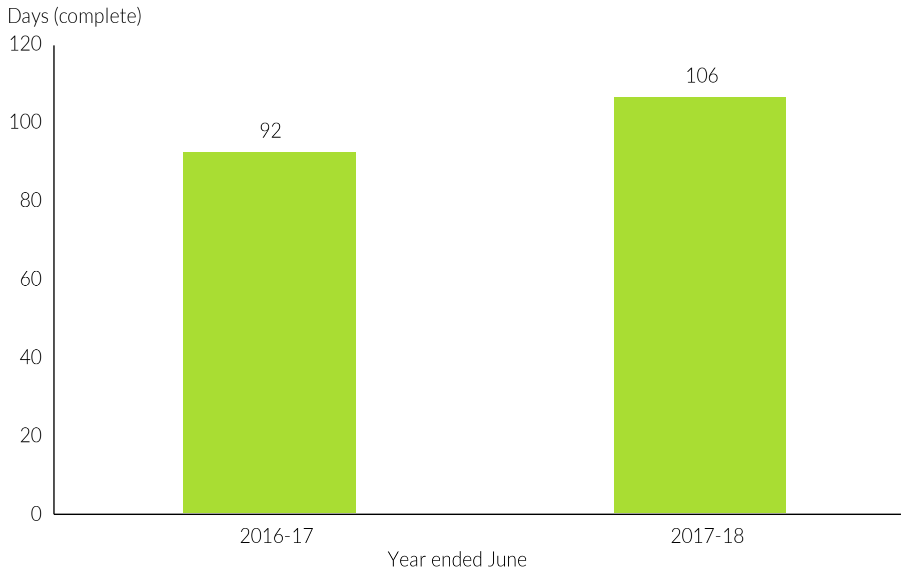
This assessment continues to show generation within the Alice Springs region is just sufficient. That is, the peak demand does not exceed the N-1 capacity of the generating units when the ultimate arrangement with the new Owen Springs power station machines and Ron Goodin power station decommissioning is considered. The N-X margin is improved slightly by the second stage of Owen Springs power station coming on line but still not enough to achieve N-2.

It should be noted, Uterne should not strictly be included in this analysis since it is intermittent. This is a conservative approach. In general, with the rise of intermittency, this adequacy analysis can be more meaningfully made through assessments such as the ones included in the commission's Northern Territory Electricity Outlook Report. The combination of forced or planned outages and low levels of intermittent generation combined with higher demand provides a better understanding of the actual risk of supply inadequacy than the N-X analysis. The effective probability of each N-X level varies from year to year based on the outage rates for the generators. This becomes more important as the penetration of intermittent generation grows.

Non-reliable periods

There were slightly more non-reliable periods in Alice Springs in 2017-18 than for the previous period.

Figure 32: Non-reliable periods for generators at Alice Springs



The non-reliable periods were all due to generation issues. The increase is therefore explained by the higher outage rates for the generating units.

Generation incidents

All seven major incidents in Alice Springs in 2017-18 were generation incidents.

Table 15: Alice Springs generation incident summary

ID	Date of incident	Description	Cause	UFLS/black	Incident duration (minutes)	Customer minutes without supply
1	25-Aug-2017	RGPS unit 9 tripped	Equipment failure	UFLS stage 1A and 1B	10	15 200
2	26-Sep-2017	OSPS unit 3 trip	Gas supply failure	UFLS stage 1A and 1B	17	42 670
3	20-Oct-2017	OSPS unit 1 and Unit 2 trip	Equipment failure	UFLS stage 1A and 1B	16	40 640
4	09-Nov-2017	Alice Spring power system	Coordination of voltage and frequency controls across AS system	System black	367	4 293 900
5	13-Nov-2017	Alice Spring power system	Gen auxiliary power loss	UFLS stage 3	196	2 126 600
6	29-Nov-2017	OSPS unit 2 tripped	Equipment failure	UFLS stage 1	19	79 800
7	16-Jan-2018	OSPS unit A tripped		UFLS stage 1	20	52 000

The incidents fall into three categories, namely equipment failure (single unit), equipment failure (multiple units) and system failure.

Equipment failure (single unit)

Incidents 1, 2, 6 and 7 fall into this category.

It is generally accepted that generating units will trip from time to time and the power system is operated to minimise the impact on customers from these incidents. The spinning reserve in Alice Springs only provides partial coverage of single generating unit trips and so any single unit incident in Alice Springs becomes a major system incident.

Entura is concerned, in each one of these single unit incidents, other systems did not appear to operate correctly or at least the operability of the system was questioned. The most serious was the incorrectly installed UFLS modules for incident 1. Other issues around protection settings and supervisory control and data acquisition (SCADA) alarming suggest a lack of system level consideration of the operation of the network. This is of major concern to Entura and is discussed further in the Darwin-Katherine generation planned and recent enhancements section.

Equipment failure (multiple units)

Incident 3 falls into this category.

At the time of writing, System Control had not finalised the report for this incident.

System failure

Incidents 4 and 5 fall into this category.

Both of these incidents led to large-scale outages. Both were initiated with a network fault that led to loss of generation. Entura appreciates that in small systems this can be unavoidable due to the lack of redundancy in the network. However, this does not seem to be legitimate in either of these cases.

In incident 4, there appears to be a lack of coordination of generating unit voltage and frequency controls across the network to allow proper regulation of these quantities post a major disturbance. Entura is aware the dynamic modelling of the system may allow investigation of these issues in detail but it is not accurate enough to provide sufficient insight into these issues. This should not continue. Entura feels with the streamlining of generation to Owen Springs power station and the introduction of the BESS to Alice Springs, the dynamic modelling should be brought up to standard and work can be done to define the technical envelope of dispatch in the region.

Incident 5 is of a slightly different nature. It relates to the system thinking required to ensure robust operation of a power station. Consideration of fault levels, switching arrangements and the redundancy of supplies for auxiliary plant must be coordinated at the design stage of power stations if those stations are to meet the reliability standard expected.

Entura observes the level of coordination between generation and networks following the structural separation of PWC is a work in progress. The review of designs and commissioning plans should be improved so primary, secondary and operational interfaces are better understood at the design phase and changes can be made prior to installation. Entura acknowledges this will not completely remove the possibility of such incidents occurring but expect it is a part of good electricity industry practice that must be improved to reduce the risk of supply interruptions to as low as reasonably possible.

Impact of incidents

The impact of these generation incidents relative to the previous years is shown in Table 16.

Table 16: Customer minutes without supply (generation incidents) for Alice Springs

	2015-16	2016-17	2017-18
Number of incidents	12	7	6
Customers impacted	51 120	18 700	33 320
Total duration (minutes)	676	189	625
Customer minutes without supply[1]	5 293 880	523 000	6 598 810
Customer minutes without supply/customer	429	43	526
System blacks			
Number	1	0	1

1 Customer minutes without supply is calculated by multiplying the number of customers impacted by the duration of the incident (in minutes).

The overall result in terms of customer minutes without supply per customer is around half an hour for the year or 0.1 per cent, which is unfavourable. It should be noted this is only the generation portion of the incidents before taking network incidents into consideration. Entura is concerned this level of interruption may be unacceptable from a customer perspective.

Generation constraints

The generation constraints applied in the Alice Springs region up to the end of the 2017-18 period are shown in Table 17.

Table 17: Alice Springs normal system constraints

ID	Constraint description	Applied to	Limit	System condition	Comments
1	Minimum load	OSPS	19 MVA	Load dependent	Prevent overloading of Lovegrove Sadadeen Ties 1 or 2 in the incidents of a contingency
2	Maximum dispatch	OSPS	45 × power factor	All	Prevent overloading of 66/11kV Owen Springs transformers 1 or 2
3	Maximum dispatch	OSPS	Dynamic limit based on acceptable contingency size	Loss of a single auxiliary transformer would result in loss of all generation	Reduce of a system black incident from loss of OSPS
4	Maximum dispatch	O1 and O2 at OSPS	Dynamic limit based on acceptable contingency size	All	Reduction in output to allow frequency management of common mode failure

Constraints 1 and 2 are network type constraints. They curtail generation either at the low or high end. While these are not ideal, the move to supply solely from Owen Springs power station should render the first obsolete. The second constraint provides some operational inflexibility at Owen Springs. This may increase the cost of supply from the station but this would only be at times of high demand.

Constraints 3 and 4 are temporary constraints due to design and setting issues on the Owen Springs units. They are designed to minimise the impact of these performance issues on customers while remedial or corrective actions are undertaken.

Planned and recent enhancements

Two major changes to the Alice Springs network are imminent:

- Owen Springs power station stage 2

These generating units have had a number of technical issues during commissioning, which are being worked through by Territory Generation and System Control.

As part of the upgrade, a third Owen Springs transformer (T3) has been commissioned:

- BESS at Ron Goodin power station

The intent of this battery is to provide frequency support to allow for the lower inertia of Owen Springs stage 2 units. Commissioning commenced in the first half of 2018.

Both of these enhancements are intended to make the management of generation dispatch and frequency in Alice Springs more robust.

Network operation without Ron Goodin power station

With the imminent decommissioning of Ron Goodin power station comes a radical change to the way the Alice Springs network has been supplied. It is acknowledged this is likely to be a challenging time for the System Controller and the commission expects care to be taken to ensure a robust set of operating protocols is developed to allow for safe and secure operation of the network without the support the Ron Goodin power station has provided to date.

Entura is concerned there may be protection and control issues that will not become apparent until the last unit is disconnected. This may lead to a period of intolerable supply reliability for Alice Springs customers.

PWC has indicated to the commission that, in collaboration with TGen, it has undertaken a substantive and multi-staged approach to facilitate the transition. This includes work undertaken early in the project to identify changes in operational parameters, which led to the development of the battery energy storage system. PWC has advised that the steps taken to date include robust compliance, performance and reliability testing of the new Owen Springs generators, and a staged decommissioning of Ron Goodin power station.

Network

Transmission performance

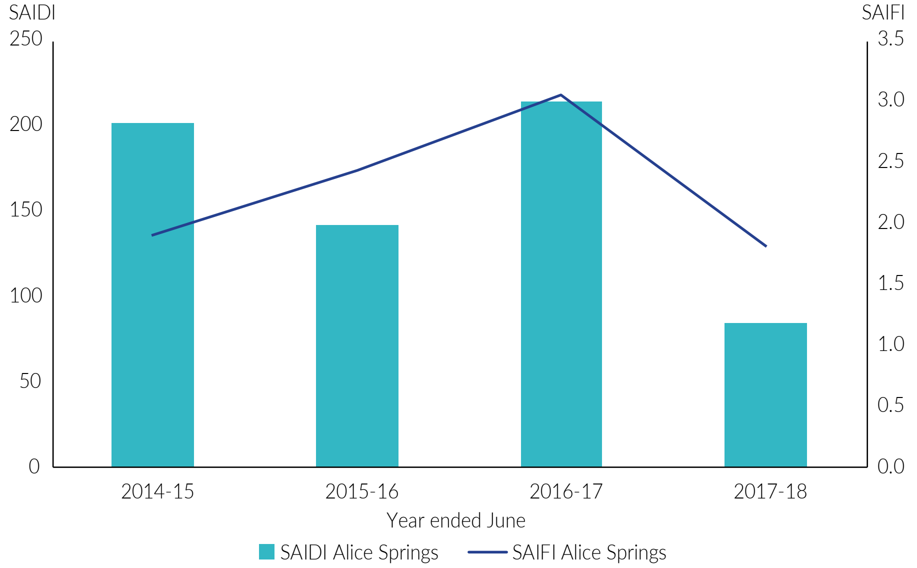
There have been no transmission level outages in Alice Springs across the last four financial years. This is an excellent result. Entura is concerned the change in operation in the network associated with the decommissioning of the Ron Goodin power station may lead to some unexpected network incidents in the future. Entura would expect the System Controller to work to pre-empt these issues where possible.

Distribution performance

The overall measure of SAIDI and SAIFI do not have a standard set. The standards are set at the feeder type level for the sum of the three systems.

The SAIDI and SAIFI performance for the Alice Springs distribution network is presented in Figure 33.

Figure 33: SAIDI and SAIFI performance indices for distribution network, Alice Springs



The results for 2017-18 are the best in the four-year period for both indices. Table 18 and Table 19 show the performance broken down across the feeder categories.

Table 18: Alice Springs SAIDI feeder breakdown

Alice Springs	2014-15	2015-16	2016-17	2017-18	Global target
CBD	n.a.	n.a.	n.a.	n.a.	18.5
Urban	214.7	132.86	86.24	62.15	136
Rural short	44.2	40.37	213.03	372.10	496.3
Rural long	n.a.	n.a.	n.a.	n.a.	2 164.9

Table 19: Alice Springs SAIFI feeder breakdown

Alice Springs	2014-15	2015-16	2016-17	2017-18	Global Target
CBD	n.a.	n.a.	n.a.	n.a.	0.4
Urban	1.80	2.22	1.65	1.41	2.5
Rural short	2.10	1.08	3.01	8.90	8.1
Rural long	n.a.	n.a.	n.a.	n.a.	35.1

The performance of the network appears to be strong across all feeder types with the possible exception of the short rural feeders. This category has seen a large increase in both SAIDI and SAIFI. Neither index significantly breaches the global standard. PWC has indicated the dominant causes of the interruptions for this feeder category are:

- trees blown into mains
- no cause found – not weather
- no cause found – weather
- equipment – failure or defect.

Further, PWC states the first three interruption categories listed are generally due to vegetation, animals or adverse weather and the interruptions are successfully restored without the cause being visually confirmed. For the final category listed PWC has indicated equipment failures were mainly caused by failure of conductors, EDO assembly failure, protection relays, cable terminations, insulators and distribution transformers. PWC has outlined a number of measures it believes will have a positive impact on the performance of this feeder category.

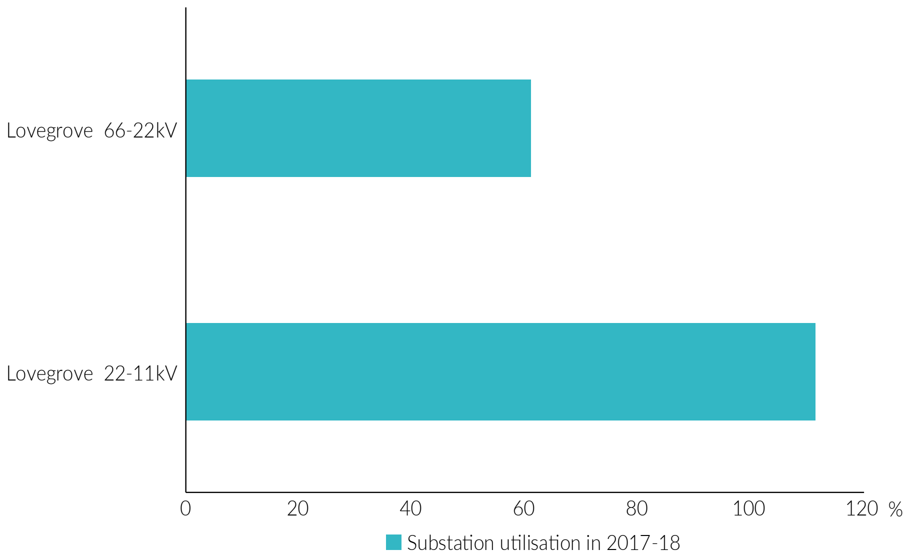
Network utilisation

The 66 kV lines between Owen Springs and Lovegrove are presently lightly loaded due to the load sharing between Ron Goodin and Owen Springs power stations. This loading will change as Ron Goodin is decommissioned. The 66 kV lines will become very important for the Alice Springs supply and the management of the ring normally open will need to be carefully considered. The utilisation of these lines will be driven by Alice Springs demand and the operation of the BESS.

Network adequacy

The substation transformer loading under N-1 conditions is shown in Figure 34.

Figure 34: Substation utilisation in N-1 conditions on 2017-18 Alice Springs



Entura's analysis shows the load on the Lovegrove 22:11 kV transformers exceeds the contingency cyclic rating. This differs from PWC's analysis, which shows it is just sufficient to supply the POE 10 demand. Entura takes a more conservative approach to the assessment of N-1 than PWC. PWC plans to upgrade these transformers in 2020-21.

Network incidents

There were no major network incidents reported in Alice Springs for 2017-18.

Table 20 shows the impact to customers of the major network incidents in Alice Springs across the last three years.

Impact of incidents

Table 20: Alice Springs customer impact of major network incidents

	2015-16	2016-17	2017-18
Number of incidents	1	3	0
Customers impacted	7 500	15 030	0
Total duration (minutes)	63	226	0
Customer minutes without supply[1]	472 500	1 340 670	0
Customer minutes without supply/customer	38.3	110.0	0.0
System blacks	0	0	0

1 Customer minutes without supply is calculated by multiplying the number of customers impacted by the duration of the incident (in minutes).

The 2017-18 result is obviously very good after a poor result in 2016-17. Entura observes this variability is almost inevitable in a smaller network such as Alice Springs.

Network constraints

Table 21 shows the constraints currently applied to the Alice Springs network.

Table 21: Alice Springs network constraints

Asset description	Location	Limit	System condition	Comments
22/11kV transformers	Sadadeen	17 MVA	All	
66 kV lines	OSPS – Lovegrove	Single circuit operation	Low load	Reduces capacitive loading in the network
66 kV transformers	Lovegrove or Owen Springs	Single unit operation	All	Fault contribution limitation

The two 66 kV constraints are unusual in the opinion of Entura. While line switching is an established method to reduce capacitive charging in the network, Entura is concerned the switching of this line poses an unacceptable risk to system security. Entura further expects this will not be an acceptable mode of operation once generation is solely located at Owen Springs.

Similarly, the disconnection of transformers poses a security risk. Entura accepts this is a temporary measure while the Owen Springs auxiliaries issue is resolved. This highlights the importance of system thinking in the design of power stations.

While the basis for the above protocols is well founded, it is a concern that enshrining these practices rather than addressing them through additional network equipment may limit the flexibility of the network to meet customer demand.

PWC has indicated to the commission that it updates constraints as system conditions change, which would include a review of the current constraints and operating practices prior to the full decommissioning of Ron Goodin power station.

Further, PWC has advised that it is currently improving processes in addressing operational network issues that are being managed through constraints, including regular meetings to be held between Power Services and System Control.

Planned and recent network enhancements

There have been no recent network enhancements.

The most notable planned enhancements are the replacement of the Lovegrove 22:11 kV transformers in 2020-21.

The reorganisation and replacement of the Sadadeen substation is planned for 2018-19. This is required to accommodate the network rearrangements required with the retirement of the Ron Goodin power station. To date the commission has not seen any evidence this has occurred.

Networks customer power quality notifications

PWC report on the number and types of power quality complaints. Figure 35 shows the Alice Springs customer notifications stayed relatively constant in 2017-18.

Figure 35: Total customer notifications relating to the quality of supply in Alice Springs

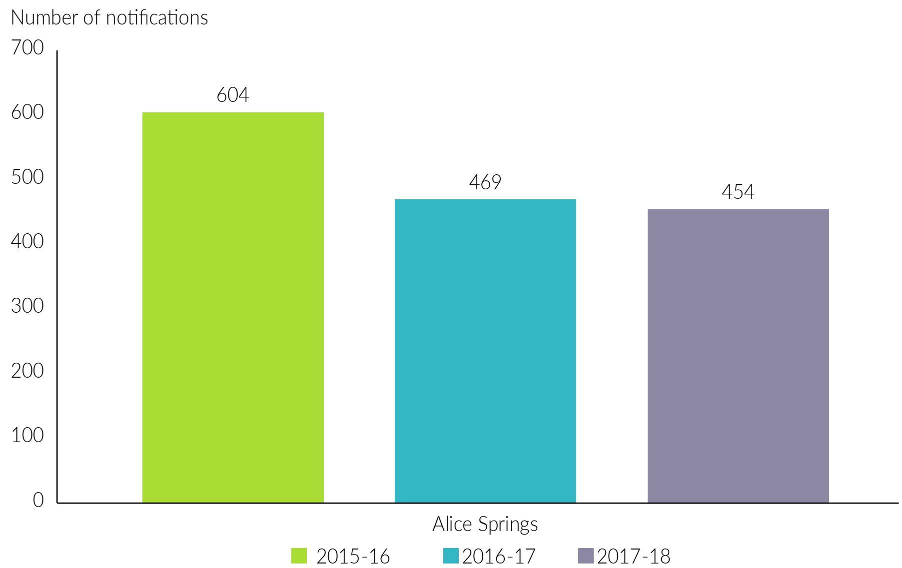


Figure 36: Type of customer notifications relating to the quality of supply in Alice Springs

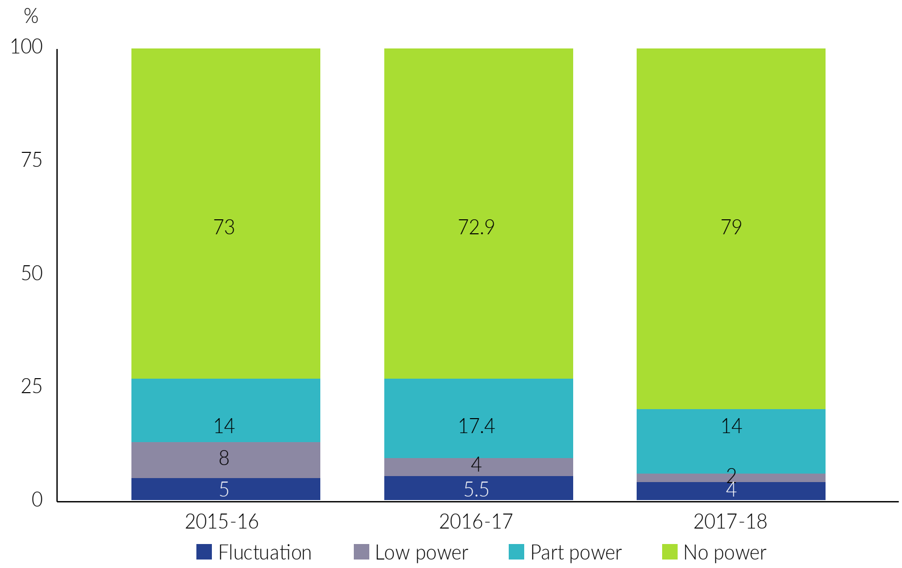


Figure 36 shows the share of complaints became more heavily centred on loss of power as would be expected considering the significant major incidents[1].

1 A system black and an incident classified by System Control as a technical black.

3 | Tennant Creek power system

This chapter focuses on the 2017-18 generation and network performance of the Tennant Creek power system. Where possible it compares 2017-18 performance to historical data to identify trends. Specifically this chapter considers:

- overall customer impact
- generator performance, observed UFLS and single generator trips, generation availability, generation adequacy, non-reliable periods, major generation incidents, generation constraints, and generation planned and recent enhancements
- transmission and distribution network performance, network utilisation, network adequacy, major network incidents, network constraints, network planned and recent enhancements, and network power quality notifications.

Power system description

The Tennant Creek power system is the smallest of the regulated systems in the Northern Territory. This system supplies the township of Tennant Creek and surrounding rural areas from its centrally located power station. The operational consumption in 2017-18 is shown in Table 22.

Table 22: Tennant Creek operational consumption in 2017-18

Power system	Energy sent out (GWh)
Tennant Creek	29

The total generation capacity in the Tennant Creek power system is around 24 MW[2], which includes three new Jenbacher generators. The fuel type of the generation units is made up of diesel and gas.

The power station at Tennant Creek is undergoing a radical transformation with the commissioning of new generating units and decommissioning of a large number of existing units. This is expected to occur in the first half of 2019.

Overall customer impact

This section shows the overall performance for the Tennant Creek system.

Table 23 shows the impact on customers from all incidents in the Tennant Creek region across the last three years.

2 Generation capacities provided are those used in the Northern Territory Electricity Outlook Report. Capacity values can vary depending on the definition of capacity applied, such as nameplate, summer and winter capacity.

Table 23: Customer minutes without supply (major incidents) for Tennant Creek

	2015-16[1]	2016-17	2017-18
Number of incidents	6	7	11
Customers impacted	600	3 780	6 435
Total duration (minutes)	170	225	1 784
Customer minutes without supply[2]	17 000	143 500	584 409
Customer minutes without supply per customer	10.4	93.7	363.2
System blacks	0	2	2

1 Minor incidents were first recorded in 2016-17. Therefore, any increase from 2015-16 to 2016-17 is in part explained by the inclusion of minor incidents.

2 Customer minutes without supply is calculated by multiplying the number of customers impacted by the duration of the incident (in minutes).

Customer minutes without supply have significantly increased over the last three years.

Entura has made recommendations elsewhere in this report regarding coordination of protection between generating units and feeders that it is hoped will reduce the number and severity of incidents in the Tennant Creek system in the future.

Generation

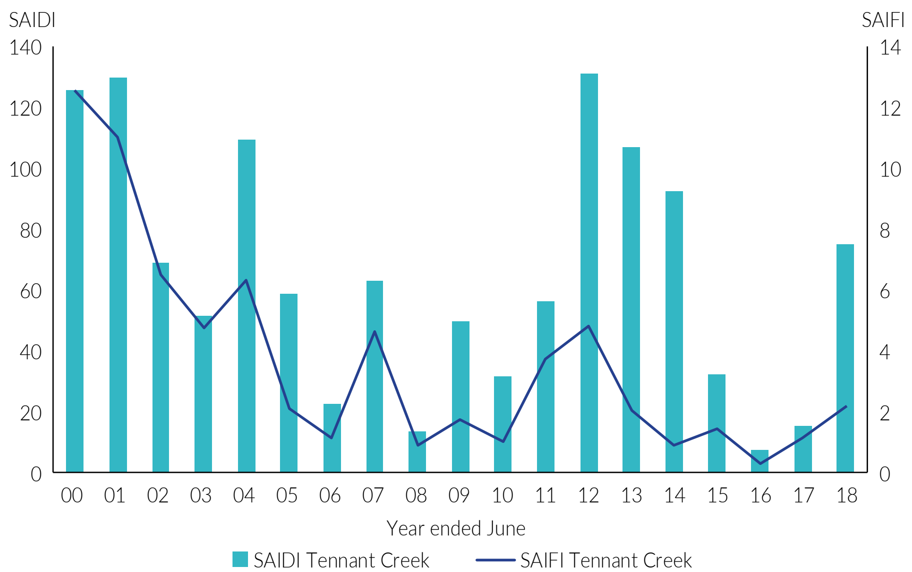
The generation system has performed well in 2017-18 with a low System Average Interruption Frequency Index (SAIFI) result compared to historical data. Entura expects this to be maintained once the new generators are commissioned and the old machines are decommissioned.

The increase in System Average Interruption Duration Index (SAIDI) leads Entura to conclude that too many generation incidents lead to network incidents or vice-versa and so these incidents are of longer duration than a simple generation incident should be.

Generator performance

The SAIDI and SAIFI performance for the Tennant Creek generating units are presented in Figure 37.

Figure 37: SAIDI and SAIFI performance indices for generation, Tennant Creek



The SAIDI and SAIFI results are both within the range of previous results across the full record. The SAIDI result shows a significant increase over the preceding three periods. Entura would expect this would improve with the commissioning of the new generators.

Observed UFLS and single generation trips

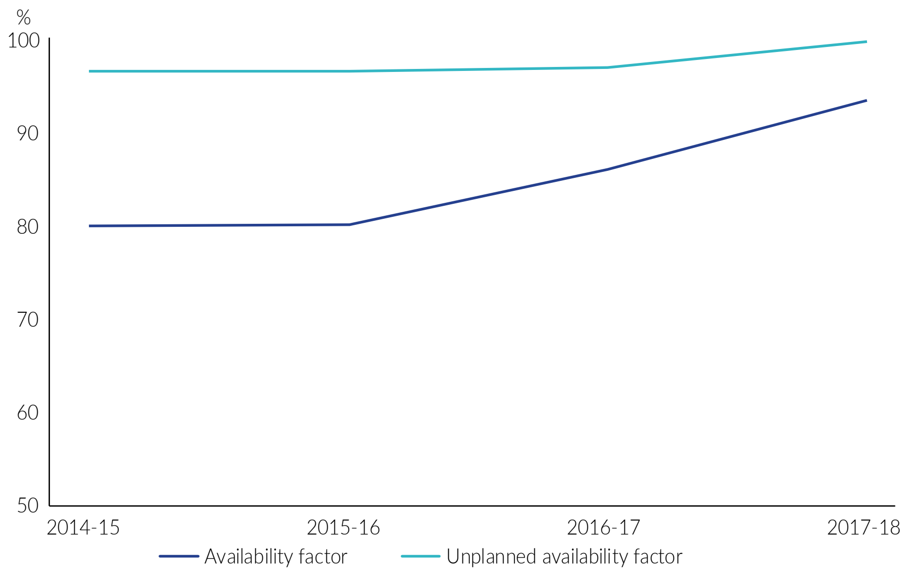
It is rare for a single unit trip to not result in UFLS in Tennant Creek due to the minimum spinning reserve approach taken in this network. Generation trips appear to be rare incidents in Tennant Creek (only two in 2017-18). These trips (major incidents) are discussed in the generation incident section of this chapter.

Generation availability

Availability factor

The availability for the generators has improved further in 2017-18 (see Figure 38).

Figure 38: Availability factor for Tennant Creek power generators

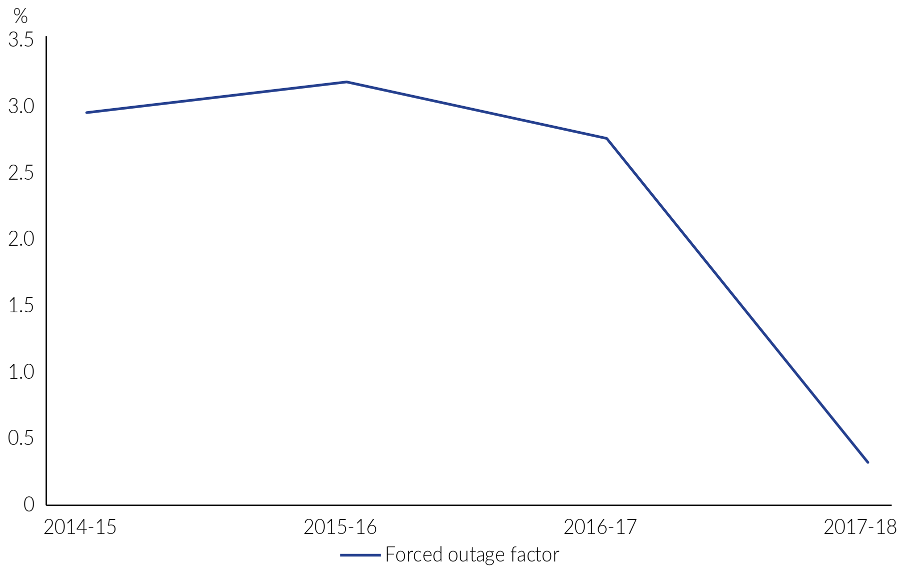


This is a particularly strong result. The renewal of the power station appears to be paying dividends and Entura expects this result to be consolidated in future years with the replacement and retirement of many of the older generating units at the power station.

Forced outage factor

The improvement in availability in 2017-18 is attributable to the improvement in the forced outage factor (Figure 39).

Figure 39: Forced outage factor for Tennant Creek power generators

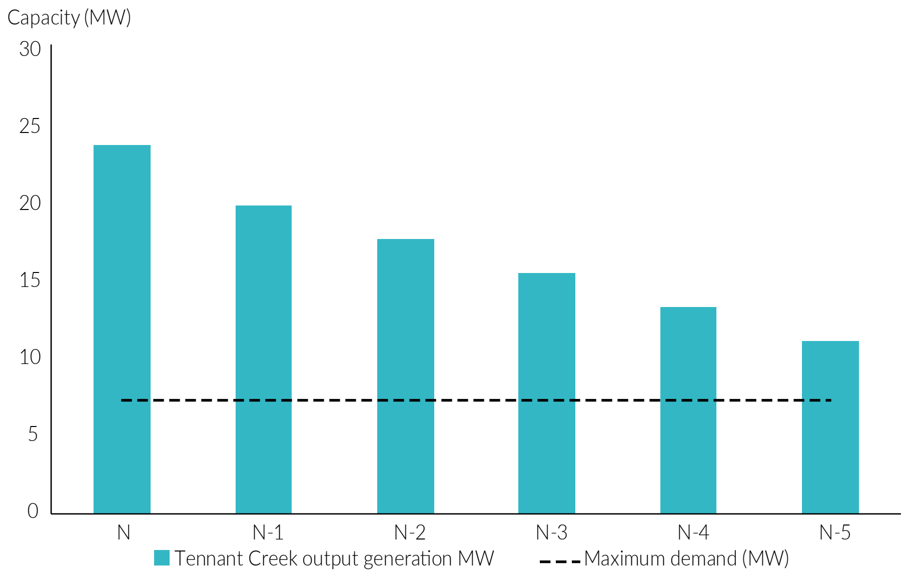


This is clearly an exceptionally low result. Tennant Creek is a challenging region to operate a power system. These challenges are significantly reduced when the generating units are reliable.

Generation adequacy

The installed generation capacity of around 24 MW in the Tennant Creek region is much greater than the maximum demand of 7.37 MW. The total installed generation is in a state of transition as new generators are commissioned and old generators are decommissioned at the Tennant Creek power station. This surplus capacity is also reflected in the N-X assessment (Figure 40).

Figure 40: N–X exposure in Tennant Creek in 2017-18



This assessment continues to show that the generation within the Tennant Creek region is sufficient, if not over-supplied.

Non-reliable periods

There were seven days of non-reliable periods across 2017-18 in Tennant Creek. It appears this is the first year such notices have been issued in the last three years. It is the best performing region in this regard. The system is simple and the abundance of generation options should lead to this level of reliability.

Generation incidents

There were two major generation incidents in the Tennant Creek system in 2017-18. The incidents are summarised in Table 24.

Table 24: Tennant Creek generation incident summary

ID	Date of incident	Description	Cause	UFLS/black	Incident duration (minutes)	Customer minutes without supply
1	26-Oct-2017	Unit 14 trip	High gas pressure	UFLS stage 1	20	1000
2	22-May-2018	Tennant Creek unit 13 tripped	Unknown	UFLS stage 1	7	728

The impact of gas supply on these units (and those at Owen Springs power station in Alice Springs) has had reliability impacts in the past. Entura accepts, to some degree, gas-related trips are inevitable (incident 1).

Impact of incidents

The impact of these generation incidents relative to the previous years is shown in Table 25.

Table 25: Generation incident impact

	2015-16	2016-17	2017-18
Number of incidents	5	4	2
Customers impacted	500	1 730	154
Total duration (minutes)	153	91	27
Customer minutes without supply[1]	15 300	37 100	1 728
Customer minutes without supply/customer	9.4	24.2	1.1
System blacks	0	1	0

1 Customer minutes without supply is calculated by multiplying the number of customers impacted by the duration of the incident (in minutes).

This is further evidence of the reduction in customer impact from the improved performance of the generation fleet at Tennant Creek.

Generation protection settings, robustness and coordination with networks

The system incidents discussed in this section suggest a review of generation protection, both mechanical and electrical, may yield some performance improvements.

The Tennant Creek network is a challenging assignment for a generating unit. It would appear in some cases there are ‘generic’ or strong network settings embedded in some of the protection relays associated with the generating units that are artificially limiting the ability of the generating units to support the network.

Although not related to generation but relevant, Power and Water Corporation (PWC) Power Services are continuing a review of the protection coordination at Tennant Creek. Previous reviews have noted the challenge PWC Power Services face in this regard. The length of the feeders in Tennant Creek make fast protection difficult to achieve.

Generation constraints

No normal generation constraints are applied to the Tennant Creek system.

Planned and recent enhancements

The following enhancements have been completed or are in progress:

- 22 kV indoor switchboard – this equipment is now commissioned and all feeders have been transferred to this board. The old board remains in service to support generation connection but will be decommissioned once the generation upgrade is complete.
- Generation upgrade – Units 17 to 21 are expected to be commissioned in January 2019 (the commission understands that units 17 and 18 are still to be commissioned). This will then allow decommissioning of units 1 to 5 in March and April 2019 (the commission is unaware whether this has commenced).

Network

This network has a single zone substation and a maximum voltage of 22 kV.

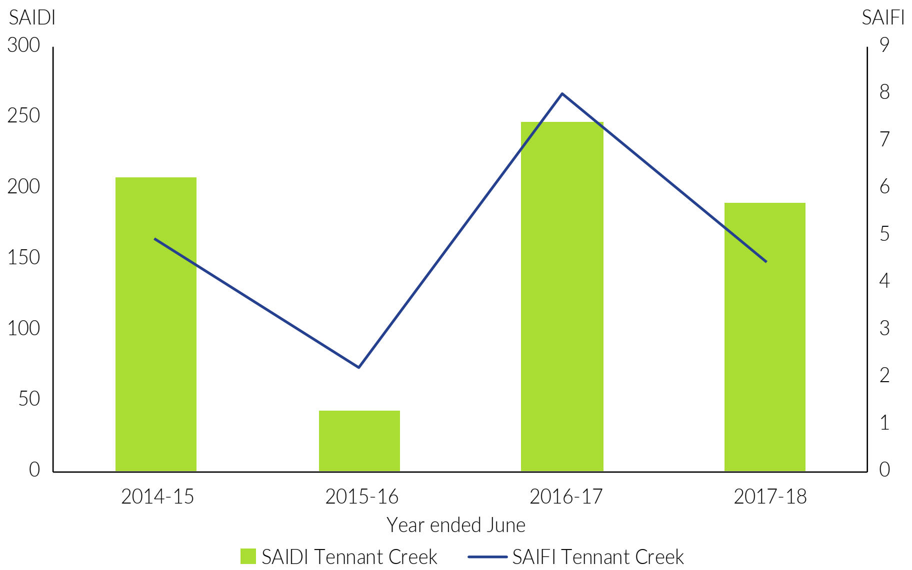
Transmission performance

There is no transmission infrastructure in the Tennant Creek network.

Distribution performance

The SAIDI and SAIFI performance for the Tennant Creek distribution network is presented in Figure 41.

Figure 41: SAIDI and SAIFI performance indices for distribution network, Tennant Creek



The overall network performance is similar in three out of the four recent periods. While the Tennant Creek performance did not meet the global target, this is also to be expected (see tables 26 and 27).

Table 26: Tennant Creek SAIDI feeder breakdown

Tennant Creek	2014-15	2015-16	2016-17	2017-18	Global target
CBD	n.a.	n.a.	n.a.	n.a.	18.5
Urban	229.5	45.24	194.72	142.12	136
Rural short	1 144	202	550.6	1 674.61	496.3
Rural long	390.6	112.28	394.23	1 824.81	2 164.9

Table 27: Tennant Creek SAIFI feeder breakdown

Tennant Creek	2014-15	2015-16	2016-17	2017-18	Global target
CBD	n.a.	n.a.	n.a.	n.a.	0.4
Urban	5.50	2.36	7.36	4.43	2.5
Rural short	31.00	12.00	14.00	5.25	8.1
Rural long	8.10	5.24	8.89	17.93	35.1

The global targets are set with the expectation of the less populous networks having slightly lower performance than the others. This is borne out by these results. The SAIFI results are relatively good for 2017-18 while the SAIDI index, particularly for the rural categories, is poor. This indicates a lower number of longer duration incidents being experienced in the region. The region continues to show poor resilience to network faults. This is discussed further in the network incidents section of this chapter.

Network utilisation

All feeders remain lightly loaded across the period of the Network Management Plan. The rating of the feeders are 223 amps. Loads on each feeder are typically less than 70 amps.

Network adequacy

The network adequacy is defined by the amount of transformer capacity to supply peak demand. In the Tennant Creek system, there are 22:11 kV transformers that link the 11 kV generating units to the 22 kV distribution system. There are generating units directly connected to the 22 kV and so the transformer capacity at N-1 is irrelevant. The transformers are able to meet the POE 50 level at N-1.

Network incidents

There were 10 major incidents in Tennant Creek in 2017-18. Of these, eight were network incidents.

Table 28: Tennant Creek network incident summary

ID	Date of incident	Description	Cause	UFLS/black	Incident duration (minutes)	Customer minutes without supply
1	29-Oct-2017	System black	Equipment failure	System black	103	151 410
2	30-Oct-2017	Tennant Creek power system	Equipment failure	UFLS stage 3	2	1 220
3	25-Nov-2017	22TC09 units 15 and 11 tripped	Equipment failure	System black – UFLS stage 1	167	243 820
4	27-Nov-2017	22TC09 tripped	Equipment failure	UFLS stage 1	847	38 115
5	24-Feb-2018	Tennant Creek power system	unknown	System black	44	74 096
6	23-Apr-2018	22TC01 Ali Curung tripped	Feeder overloaded	UFLS stage 1	14	1 456
7	25-Apr-2018	22TC07 Three Ways feeder tripped	Transient fault	UFLS stage 3	24	16 896
8	03-Jun-2018	22TC010 Ali Curung tripped	Transient fault	UFLS stage 1	17	1 768

The incidents fall into three categories, namely system black, network faults and equipment failure.

System black

Incidents 1, 3 and 5 fall in this category.

Each of these incidents appears to be similar to each other (notwithstanding the lack of information on incident 5) and there is an initiating fault in each incident. If the fault is close to the power station then the feeder trips relatively quickly, if not, then the clearance takes a little longer.

In incident 1, the auto-reclose function seems to have interacted with generation controls to cause a generating unit to trip. Once a generating unit trips, UFLS operation inevitably follows. However, this may lead to further stress on the remaining generating units. If this stress is too great, they trip and the system goes black. If the fault is remote from the power station, it appears as additional load on the system and slows the generating units. This can lead to UFLS operation, but also prolonged under-voltage operation will cause generating unit protection to operate. Once this stage is reached, the same cascading failure can occur and often does.

This is the challenge of the Tennant Creek power system. The long and lightly loaded network is hard to protect and prone to intermittent faults from animals and atmospheric phenomena. Entura observes that unless significant upgrades are undertaken, these incidents are likely to continue. Entura therefore welcomes the scrutiny the System Controller is placing on the dynamic performance of the new generating units. This, and better coordination between the protection settings of the generating units, their actual capacities and the requirements of the network, should reduce the instances of cascade failure.

Network faults

Incidents 7 and 8 fall in this category.

Further to the analysis of category 1, these incidents are network incidents that do not result in cascade failure and hence the network does not go black. These types of incidents are inevitable but short in duration.

Equipment failure

Incidents 2, 4 and 6 fall in this category.

Similar to these types of failures in the other regions, Entura is concerned that equipment failure is a symptom of poor condition monitoring, preventative maintenance practices or inappropriate equipment. Entura also observes that often it is equipment failing that is the critical element in these incidents because the system relies on too many individual elements with little or no redundancy.

In a network like Tennant Creek, this is possibly justified. All customers have a supply with a single mode of failure and so building redundancy into controls and secondary systems does not always seem justified. However, plant, personnel and customer safety must not be compromised by this approach. Entura welcomes the protection grading review being undertaken by PWC Power Services and looks forward to performance that is more robust.

Impact of incidents

Table 29 shows the impact to customers of the major network incidents in Tennant Creek across the last three years.

Table 29: Tennant Creek customer impact of major network incidents

	2015-16	2016-17	2017-18
Number of incidents	1	3	9
Customers impacted	100	2 050	6 281
Total duration (minutes)	17	134	1 757
Customer minutes without supply[1]	1 700	106 400	582 681
Customer minutes without supply/customer	1.0	69.5	362.1
System blacks	0	1	2

1 Customer minutes without supply is calculated by multiplying the number of customers impacted by the duration of the incident (in minutes).

The 2017-18 result is poor. The results show a three-fold increase in the number of customers affected and a five-fold increase in the average duration. Entura expects some variation year on year in a small network such as Tennant Creek. Entura also expects the generator and switchboard upgrade will lead to better performance in the future.

Network constraints

There are no network constraints applied to the Tennant Creek network in the current period.

Planned and recent network enhancements

The 22 kV switchboard enhancement is common to the network and generation assets and described in the generation planned and recent enhancements section of this report.

Networks customer power quality notifications

Tennant Creek is still experiencing a gradual increase in notifications from its customers (see Figure 42).

Figure 42: Total customer notifications relating to the quality of supply in Tennant Creek

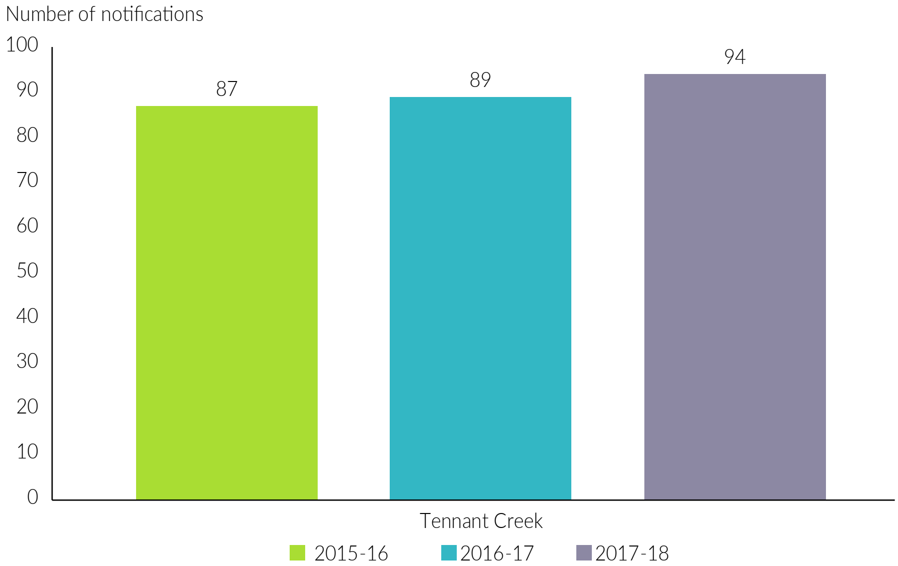


Figure 43: Type of customer notifications relating to the quality of supply in Tennant Creek

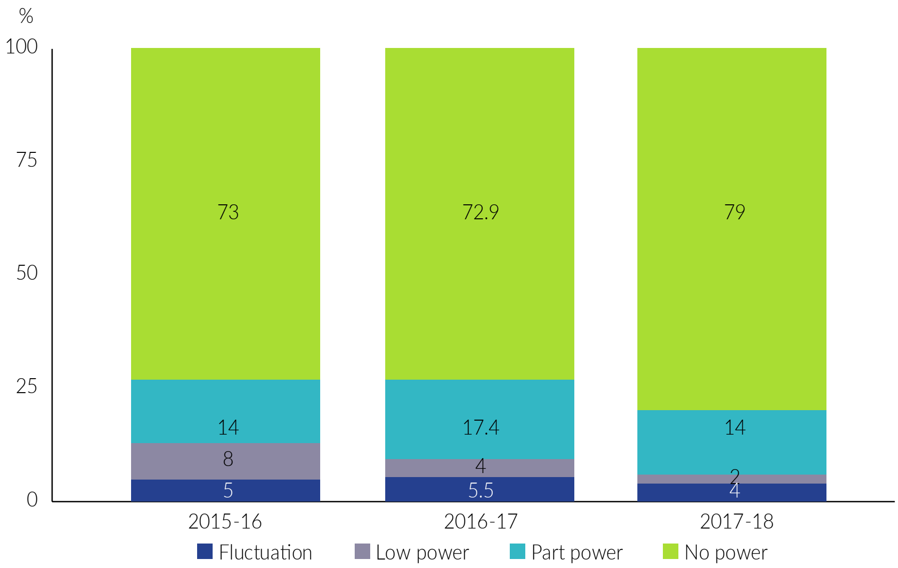


Figure 43 shows a slightly larger share of complaints is being made due to loss of power over the three years.

Appendix: Connections and reconnections

Table 30 sets out the total number of connections over the last three reporting periods. Further, the number of connections not achieved in five days for CBD and urban customers, and 10 days for rural customers are shown.

Table 30: Connections and reconnections performance

	Total number			Percentage of total not undertaken within timeframe		
Performance measure	2015-16	2016-17	2017-18	2015-16	2016-17	2017-18
Total number of connections – CBD/urban	1 132	918	608			
New connections not undertaken in the CBD/urban areas within five days (excluding where minor extensions or augmentation is required)	15	36	27	1.30	3.90	4.40
New connections not undertaken in the rural areas within 10 days (excluding where minor extensions or augmentation is required)	0	0	0			

The table illustrates, since 2015-16, PWC has successfully met the minimum rural requirement on all occasions. PWC's performance in the CBD and urban areas has been mixed, especially taking into account the large reduction in connections since 2015-16.

Table 31 sets out the number of connections in new subdivisions and the average length of time it takes to install these connections.

Table 31: New connections in urban areas to new subdivisions

	2015-16	2016-17	2017-18
Total	83	53	60
Average weeks	11.1	10.8	11.45

The table shows the number of connections rose slightly in the last period, however, the length of time required to make those connections has not changed appreciably.

Appendix: Glossary

ACOD	Average circuit outage duration index
AER	Australian Energy Regulator
ATOD	Average transformer outage duration index
BESS	Battery energy storage system
CIPS	Territory Generation's Channel Island power station
Code	Electricity Industry Performance Code
Customer minutes without supply	Number of minutes customers are without supply, calculated by multiplying the number of customers impacted by the duration of the incident
EDL	EDL NGD (NT) Pty Ltd
FCO	Frequency of circuit outage index
GIS	Gas insulated switchgear
GW	Gigawatt, 1GW = 1 billion watts
KPS	Territory Generation's Katherine power station
kV	Kilovolt, 1kV = 1 thousand volts
kW	kilowatt, 1kW = 1 thousand watts
Major incident	Defined by section 7.3.2 of the System Control Technical Code version 5
MSR	Minimum spinning reserve
MVA	Megavolt ampere
MW	megawatt, 1MW = 1 million watts
OSPS	Territory Generation's Owen Springs power station
N-X	Planning criteria allowing for full supply to be maintained to an area supplied by the installed capacity of N independent supply sources, with X number of those sources out of service (with X usually being the units with the largest installed capacity)
POE	Point of exceedance
PSR	Power System Review
PWC	Power and Water Corporation
PV	Photovoltaic
Regulated systems	Northern Territory power systems that are subject to economic regulation and include Darwin-Katherine, Tennant Creek and Alice Springs power systems
RGPS	Territory Generation's Ron Goodin power station
RoCoF	Rate of change of frequency
SCADA	Supervisory control and data acquisition
SAIDI	System average interruption duration index
SAIFI	System average interruption frequency index
TC	Tropical Cyclone
Territory	Northern Territory
UFLS	under frequency load shedding
ZSS	zone substation