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ALICE SPRINGS

System Black 13 October 2019

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Executive Summary

On Sunday 13 October 2019, the Alice Springs power system went black at 2:18pm, with approximately 12,000 customers affected for periods varying from 30 minutes and up to 10 hours. On 14 October 2019, the Territory Government announced that it had 'called an independent review into the incident to identify and investigate any system-wide issues that led to the problem occurring and the adequacy of responses, both short and long term'. This report provides the findings of that review.

Entura and the Utilities Commission staff interviewed more than 40 stakeholder representatives from ; Electrical Trades Union, Government, Jacana Energy, Owen Springs Power Station, PWC Power Services, Ron Goodin Power Station, System Control, Territory Generation and Territory Generation Remote Operations Centre. The majority of the interviews were completed in person during the week commencing 28 October 2019. The investigation team also received written submissions and responses to written queries during the course of the investigation.

The key findings of the investigation for the period leading up to system black are:

1. The initiating event for the system black was the sudden unforeseen (by those managing the system) reduction of solar generation from Uterne solar farm and from rooftop solar installations, which resulted in a discernible increase in load on dispatched synchronous generation
2. If the automatic generator control (AGC), Jenbacher generators, battery energy storage system (BESS) and under frequency load shedding (UFLS) had functioned as expected[1] then the initiating event would not have led to a system black
3. If two or more of; AGC, Jenbacher generators, BESS and UFLS had functioned as expected then a system black would likely have been avoided or limited to a technical black (parts of the system remain energised), resulting in a reduced restoration period
4. At the time of the incident the power system was not in a secure operating state; with insufficient spinning reserve and at best zero regulating reserve
5. There exists confusion or lack of agreement regarding roles and responsibilities for the control and monitoring of the Alice Springs system under the System Control Technical Code (SCTC) 'load following' arrangement.

The key findings of the investigation for the restoration period are:

6. The approved black start procedure for Owen Springs power station (MAN units 1-3) was not readily available to staff and departures from the procedure severely impacted the restoration time
7. The approved black start procedure for Ron Goodin power station had not been updated to reflect changes at the power station (installation of the BESS) and was not considered user friendly by operators. Despite this, and the power station being in a standby state, staff and operators successfully black started the station restoring service to the Hospital and the CBD

[1] The word 'expected' is used several times in this report to mean an asset or system that did not operate in a manner that would generally be expected within the industry. It does not necessarily mean an asset or system malfunctioned or operated in a manner different to how it was designed or configured.

using their own pre prepared checklist. However, decisions not to perform simple low cost maintenance to Ron Goodin unit R9 impacted the station's ability to restore more customers and be considered an effective 'plan B'

8. There was no approved, adequately tested and available black start procedure for an Owen Springs power station black start from the Jenbacher units 5-14, and failed attempts to black start the system using these machines severely impacted the restoration time
9. System Control's Alice Springs Black System Restart Procedure was outdated and did not include significant changes to the Alice Springs system, having been released on 17 June 2014. This is despite of clause 5.7.3 of the SCTC requiring the Power System Controller to review the procedure by the 31 October each year or if a generator proposes a change to its black start procedure, with both the Owen Springs and Ron Goodin power station black start procedures being updated by Territory Generation post the release date. This is a possible non-compliance with the SCTC
10. A perception that the restoration was perpetually close to complete led to a failure to stand up the Public Utilities Group in a timely manner. Consequently, communications to Government, the public, emergency services and vulnerable customers were inadequate
11. Regular training, exercise (role play), and practice of black start procedures are inadequate. These activities should be conducted both individually at power stations, the ROC and System Control and also in coordination with each other.

Additional key findings are:

12. Until an approved and sufficiently tested black start procedure is created, with multiple contingencies, which allows the Owen Springs station to black start the station using Jenbacher machines supported by just one of the MAN units 1-3, then it is inappropriate for Ron Goodin power station (RGPS) to move from a hot standby state. Furthermore, the RGPS machines that are in a serviceable or near serviceable state should continue to be maintained to acceptable levels
13. There is no evidence that System Control recommendations from major power system incident reports are adequately considered, programmed, tracked or implemented

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1. Glossary and acronyms

Acronym	Description
AEMO	The Australian Electricity Market operator. AEMO has a similar role in the eastern states to System Control's responsibilities in the NT power systems
AGC	Automatic generator control. A control system that adjusts the power setpoint of each generator enabled for AGC control to maintain system frequency / time
BESS	Battery energy storage system. Also used to refer specifically to the BESS located at Ron Goodin power station
Droop	The feature of a generator governor where it increases output if frequency falls and conversely reduced output if frequency rises
G1 or Grade 1	Assistant system controller
G2 or Grade 2	System Controller, with primary responsibility for generator dispatch
G3 or Grade 3	Senior system controller, with primary responsibility for operating the transmission and distribution networks
GOTR	Generator outage testing request
Jenbacher	The manufacturer of Owen Springs power station units OS5 – OS14
Man	The manufacturer of Owen Springs power station units OS1, OS2 & OS3
NEM	National electricity market. Also used as a collective noun for the power system comprising the eastern states plus Tasmania
OS or OSPS	Owen Springs power station
RG or RGPS	Ron Goodin power station
ROC	Remote operations centre
RTOM	Real time operations manager
UFLS	Under frequency load shedding

2. Introduction

On Sunday 13 October 2019, the Alice Springs power system went black at 2:18pm, with approximately 12,000 customers affected for periods varying from 30 minutes and up to 10 hours. The Alice Springs Hospital and communities as far as Haasts Bluff (approximately 250km from Alice Springs) were affected, with many businesses forced to close.

The Territory Government has stated in the media that the outage was caused by a generation issue. Territory Generation (TGen) has stated publically that the outage was caused by a cloud which caused a 'reasonably large increase' to the system demand. Power and Water Corporation (PWC) and TGen have both commenced investigations of the incident.

In response to the system black, the Electrical Trades Union has stated that the Territory Government has made a premature decision to close the Ron Goodin Power Station 'without enough guarantees that the new Owen Springs Power Station facilities can cope under peak load'. While Ron Goodin is not yet closed, since mid-August 2019 it has been progressively staged back with priority given to the Owen Springs Power Station, including the new Jenbacher gas generation units.

On 14 October 2019, the Territory Government announced that it had 'called an independent review into the incident to identify and investigate any system-wide issues that led to the problem occurring and the adequacy of responses, both short and long term'.

Pursuant to section 6(1)(g) of the *Utilities Commission Act 2000*, the Treasurer wrote to the Commission requesting that it conduct an independent investigation into the Alice Springs and connected communities system black. This report is the independent review completed by Entura on behalf of the Commission.

3. Investigation Approach

The Utilities Commission accepted Entura's proposal to complete the independent review on Monday 21 October.

During the first week of the investigation Entura provided lists of information required from the system participants; Territory Generation and Power and Water Corporation (System Control and Power Services). The Commission managed information requests to electricity entities, using its authority to require the provision of information under section 25 of the *Utilities Commission Act 2000*. Electricity entities were given a short period to provide the information (Friday 25 October).

During the first week Entura also reviewed power system information, relevant to the Alice Springs network, already held by the Commission for the purpose of completing its annual power system reviews.

During the second week of the review, Entura's Principal Engineer; David Wilkey travelled to Darwin and Alice springs where he and the Commission staff conducted interviews with numerous participant staff. The interviews were predominantly conducted with one interviewee at a time.

During the interview week Entura and the Commission staff also took the opportunity to visit System Control, the ROC, Owen Springs power station and Ron Goodin power station.

A small number of interviewees were not available during week 2, so they were interviewed during week 3. For most of these interviews the Commission staff met the interviewee in person while for some it was necessary to use video conference facilities. For all interviews conducted during this week Entura attended by video conference.

The report writing and office based document reviews were completed during weeks 3 and 4.

4. System Black

4.1 Sequence of events leading to system black

Terms of reference: the power system situation that existed prior to the system black incident (having regard for the current transition process from Ron Goodin Power Station to Owen Springs Power Station), the sequence of events leading to the incident and the state of the power system after the incident, plus any related subsequent incidents

4.1.1 Staged Decommissioning of Ron Goodin Power Station

The Ron Goodin power station (RGPS) is an aged station comprising several low speed dual fuel generating sets, a gas turbine generator (R9) and two station black start machines. The station is at the end of its reliable service life and is in the process of being decommissioned.

The proposed decommissioning is to be completed in a staged fashion as described, in more detail, in the Advisian report[2]. The Advisian report documents undertakings made by TGen to the TGen operators and is intended to guide TGen when planning maintenance, staffing and discussions between TGen and PWC. The operational standby requirements are formally managed through the GOTR process administered by PWC under the system control technical code. The original Advisian report describes the process as:

- Hot standby; including at least one Ron Goodin machine in service and operating at minimum load
- Cold standby; no Ron Goodin machines in service but all sets that are operational at the commencement of cold standby, to be maintained in a state of readiness that they could be started at any time
- Emergency Availability; Ron Goodin machines placed into a safe stored state so that 4 machines (including R2) could provide black start and emergency operation if required

The definitions provided in the original Advisian report are considered, by Entura, to represent normal industry understanding.

At the time of the event the station was clearly not in effective hot standby (by the Advisian definition in the original Advisian report[3]) as evidenced by the fact that no machines were in service. Prior to the event the; hot standby to cold standby transition was scheduled for 22 October subject to there being no forced outages on the Jenbacher units. It is understood the transition from hot

[2] The Advisian report, as provided by Territory Generation, includes the original August 2018 report, a July 2019 Addendum to the August 2018 report and a September 2019 Revision 1 of the Addendum to the August 2018 report

[3] Territory Generation has indicated at the time of the incident System Control did not require a machine at Ron Goodin power station to be in service and operating at minimum load, as per Advisian's definition of hot standby in its original report. In Advisian's September 2019 Revision 1 of the Addendum to the August 2018 report, Advisian state that it considers the period of four weeks in hot standby is still relevant, whether or not a set at RGPS is operating.

standby to cold standby has been rescheduled to 4 weeks from 12 November 2019, because of the system black, and remains subject to the Jenbacher units suffering no further forced outages.

It is questionable whether RGPS was in a cold standby state, as defined by the original Advisian report, because several machines were unavailable for service and there was no plan in place to return them to a serviceable condition[4].

At the time of the event Ron Goodin machine R9 was unavailable for service because a two hour repair was required. The parts for the repair were available on site, however the repair had not been scheduled. Because this machine was neither ready for service nor scheduled for repair, and yet so close to being in a serviceable state, Entura consider that the intent of the requirements for both Hot and Cold Standby were not met in accordance with the original Advisian report requirements.

Ron Goodin was available for emergency service on the day of the event as evidenced by the fact that it black started a portion of the network (including the hospital) within approximately 30 minutes.

4.1.2 The months before system black

In the months (and years) leading up to the system black event operational staff at System Control and Territory generation indicated to Entura during interviews that they have expressed concern about the fitness for purpose of the automatic generator control system (AGC). One concern in particular is directly relevant to the system black event:

- Owen Springs Man units regularly switch from AGC[5] to manual control without an operator command, thereby causing a deficit of regulating reserve

In the months leading to system black some progress was made to prepare a black start procedure to allow black start from OSPS using the newer Jenbacher machines. In Entura's opinion the definition of hot standby should not have been relaxed and maintenance / availability levels at Ron Goodin allowed to fall until this procedure had been proven and finalised. Without a serviceable plan to

[4] RGPS units 6, 8 and 9 were unavailable. Units 6 and 8 had been noted by Advisian as uneconomical to repair, however it is understood the replacement parts for one of the machines were on hand. Territory Generation has indicated management of Territory Generation were told by Ron Goodin power station maintenance staff that R9 would operate without the AC Oil Mist Fan by utilising the DC oil mist fan. As mentioned elsewhere in this report, Entura does not have direct expertise on the risks presented to gas turbine plant upon failure of the oil mist fan(s) and cannot comment on whether the machine could be safely shut down following a failure of the backup DC oil mist fan, however Entura consider at the time of the incident R9 was not fully serviceable. Unit 5 was listed as available but was unable to be used during the restoration. The date for determining which machines must be available for cold standby is in the future and PWC/TGen could declare, on that date, that these machines are not required. So it is not possible to categorically conclude that the conditions for cold standby are not met. However, in Entura's opinion the intent of the original Advision report was not met.

[5] AGC is a relatively slow control system that automatically commands generators to increase or reduce their output slightly in response to changing load on the power system. In contrast, droop control is a faster system where each generator can autonomously 'decide' to change its output if AGC has been unable (or too slow) to act. When the power system is operating correctly, over time AGC action causes the droop action to return to zero.

black start from the Jenbacher sets or sufficient serviceable machines at RGPS to black start from RGPS there was a total reliance on being able to black start using the Man machines[6].

Operational staff expressed a view that testing of the black start procedure from OSPS to the Lovegrove busbar was inadequate and that the test needed to include the addition of load at Lovegrove. This was somewhat validated during the restoration from system black, as it was found that the system could be restored to Lovegrove and that adding load was initially unsuccessful.

4.1.3 The hours before system black

Prior to the system black the power system was supplied predominantly by OSPS and Uterne solar power station. The generators on line at OSPS were unit #1 (a Man unit) and sufficient Jenbacher machines to meet the system demand.

OSPS

The Man machine is a dual fuel machine capable of running on Gas or Diesel. The machine can run without restriction on diesel, however this is expensive and it is always preferred to use gas if possible. There are a number of factors such as machine loading, ambient temperature, knocking and fault conditions that cause the machine control system to change from gas fuel to diesel fuel.

On this particular day the machine was set for AGC control and it has been indicated had a maximum power output of 8MW configured (compared to 10.8 MW rated). The reduced maximum output was directed in a System Control risk notification prior to the event.

Approximately 7 hours prior to system black OSPS unit #1 came out of AGC control, a possible cause, among others, is a transition between fuel types. The machine was returned to AGC control 10-15 minutes later by operator intervention[7].

Approximately 4 hours prior to system black OSPS unit #1 came out of AGC control again. This change of control mode was not detected by the operators at System Control or at the ROC.

Uterne

The output of Uterne solar station was relatively constant at around 3.3 MW until 1:43 PM. At 1:43 PM a cloud passed over the station and station output became highly variable with reductions in output to as low as 0.5 MW according to data provided by Uterne and TGen[8]. The following figure showing solar variability is based on data provided by Uterne Solar farm and includes swings of almost 3 MW in just over one minute.

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[6] There are 3 Man machines of which one was out of service for major maintenance. Both of the remaining Man units are required to complete a black start using the existing approved procedure.

[7] TGen cause report figure 3.

[8] TGen cause report figure 6.

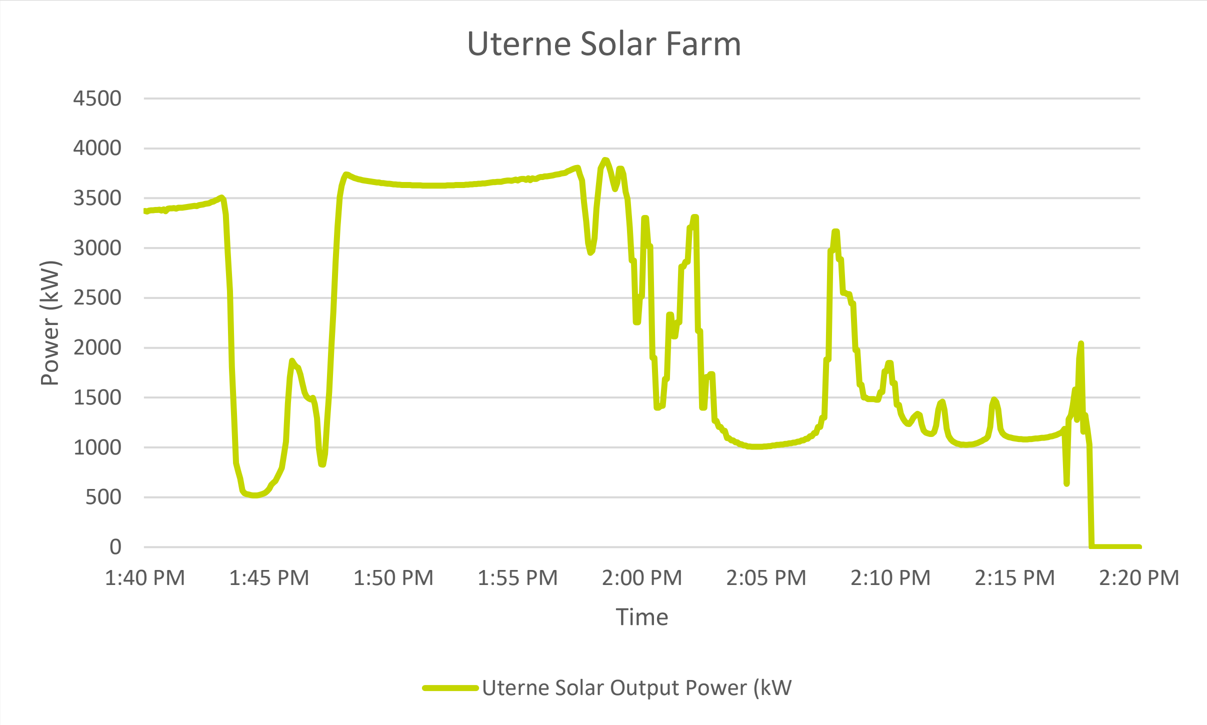

Figure 4.1: Uterne Solar Farm Power Output

4.1.4 State of the system immediately prior to system black

Approximately 30 minutes before the event the power system status was:

- OSPS Unit #1 (Man) was online. The machine was thought to be under AGC control but was in fact in manual/droop control. Had the machine been in AGC control, then it has been indicated that its maximum output would have been limited to 8 MW
- OSPS units 05, 08, 10, 12 and 13 (Jenbachers) were online and operating at close to maximum capacity. Maximum capacity was less than the machine nameplate rating due to high ambient temperatures on the day. These units were all in AGC control
- OSPS unit 09 (Jenbacher) was in the final stages of loading after having been started to maintain system spinning reserve
- Uterne solar was generating at approximately 3.6 MW, close to its maximum of 4MW
- The BESS was in service operating at approximately 0 MW ready to provide power if required
- Ron Goodin power station was shutdown with operating personnel on site and had several machines ready for service. Notably the largest machine R9 was not available for service[9]

According to the TGen cause report a phone call occurred from the ROC to System Control approximately 2 minutes before system black, during which it was observed "(there is) Tonne of

[9] As discussed elsewhere in this report, RGPS units 6, 8 and 9 were unavailable. Unit 5 was listed as available but was unable to be used during the restoration.

cloud" and it was decided to start another machine. From this decision until the machine reaches full power would typically take 5-15 minutes. This decision was likely influenced by an evolving spinning reserve deficit.

The minimum spinning reserve of 8 MW was breached at approximately 14:10 and continued to fall until it reached 4 MW at the time that the first generator tripped.

4.2 Initiating event (root cause)

Terms of reference: the root causes of the incident from a technical standpoint including any operational and maintenance activities

The initiating event for system black was the sudden unforeseen (by those managing the system) cloud cover significantly reducing the output of Uterne solar power station and reduced output of rooftop solar.

Entura do not consider that sudden cloud cover can be considered to be a root cause. Cloud cover is a credible event and therefore should not lead to system black. Power systems must be designed as far as practicable to be sufficiently robust to withstand all credible events.

In small systems it may not be reasonable to maintain supply to all customers for the most severe credible events but in Entura's opinion total system black should and can be avoided.

The Alice Springs system was not sufficiently robust to avoid system black. Key weaknesses in the system at the time were:

- Regulating reserve was less than the operators believed because OSPS unit #1 was not in AGC control
- OSPS unit #1 had a maximum AGC control set-point of 8 MW (rating 10.8 MW)
- The Jenbacher units have insufficient controls to maintain their operating temperature within acceptable limits
- The BESS has insufficient controls to maintain the unit within acceptable limits
- Under frequency load shedding (UFLS) stage #3 was faulty
- UFLS, generator droop and machine control settings are not adequately coordinated
- Spinning reserve requirement was breached

4.3 Automation response

Terms of reference: the response of automatic dispatch and automatic generator control systems during the incident

4.3.1 Generator dispatch

The Alice Springs power system does not currently have automatic generator dispatch. Day ahead load forecasting is done by System Control to allow a generator schedule to be prepared for the following day.

On 13 October 2019 the manual system of generator dispatch resulted in a significant spinning reserve deficit at the moment of the initiating event and therefore likely contributed to the occurrence of system black.

During interviews there appeared to be a lack of clarity, agreement and common interpretation of the system control technical code over who is responsible for dispatching machines in real time. This confusion was surprising because the PWC document "Operational protocol with Territory Generation Alice Springs Interim – Prior to Ron Goodin standby status" provided to the Commission by TGen provides a reasonable level of clarity of roles and responsibilities. It is not clear from this document if TGen was consulted when preparing this document or if they have endorsed/agreed with it.

The TGen document "ROC Principles of Operation" states that the ROC receives dispatch instructions from System Control. This is an apparent conflict with the PWC document. Entura **recommends** [6] that PWC review the TGen document and vice versa and the two documents be made consistent and agreed.

The System Control Grade 2 operator (G2) is responsible for dispatching generation and (according to System Control) the ROC is responsible for maintaining spinning reserve. This situation is untenable because the trigger for dispatching additional generation is an impending breach of the spinning reserve requirement.

This is an area of disagreement between System Control and TGen and is subject to different interpretations of the System Control Technical Code.

Entura **recommends** [6] that System Control should be required to determine the amount of synchronous generation needed to be in service at each point in time taking into account the need for spinning reserve, the state of Uterne and the state of the BESS, because these are system security issues. Then TGen could be responsible for determining which machines to place into service to meet that spinning reserve requirement and System Controls other system security requirements.

On 13 October 2019 the manual system of generator dispatch resulted in a significant spinning reserve deficit at the moment of the initiating event and therefore likely contributed to the occurrence of system black.

4.3.2 Automatic Generation Control (AGC)

During the interviews there was almost universal agreement that the current AGC system is not fit for purpose. On this basis Entura **recommends** [14] a review be completed of the AGC system to determine if it is fit for purpose, and if still deemed necessary, how to improve its function and reliability.

The AGC system functioned as follows on 13 October 2019:

1. OSPS Unit #1 (Man) withdrew from AGC at approximately 7 hours pre-event. This was noticed and the unit was returned to AGC control

2. OSPS Unit #1 (Man) withdrew from AGC at approximately 4 hours pre-event. This was not noticed and the unit was not returned to AGC control
3. When the initiating event occurred AGC correctly commanded all generators under its control (excludes OSPS #1) to increase output
4. When the machines under AGC control reached de-rated output AGC continued to command them to increase output
5. When the Jenbacher machines received AGC raise commands they continued to accept those commands and raised their output above their de-rated capability

In Entura's opinion items 1, 2, 4 and 5 are not features of a well-engineered AGC system. An idealised response would have been:

1. OSPS Unit #1 (Man) remained in AGC
2. When the initiating event occurred AGC correctly commanded all generators under its control (including OSPS #1) to increase output
3. When the machines under AGC control reached de-rated output AGC stopped commanding them to increase output
4. If the Jenbacher machines received AGC raise commands they ignored those commands and held their output at their de-rated capability
5. The power system frequency fell if the AGC response was still insufficient
6. Any machines with capacity to provide a droop response do so
7. Operator action or under frequency load shedding restored the power system frequency

4.4 Machine and protection response

Terms of reference: the response of generators to the disturbance and their protection systems

The response of generators and their protection systems[10] to the event is described well in the TGen report "Alice Springs System Black Event 2019-10-13 Cause". Entura has verified the sequence of events (SOE) data in the TGen report against the SOE provided by System Control and summarised the key points below.

4.4.1 Summary of sequence of events

The key items of the cascading failure of the Alice Springs power system on 13 October 2019 were:

- Cloud cover significantly reduced the output of Uterne solar power station

[10] In general power systems equipment is provided with **controls** that function to keep that equipment operating within a safe envelope. Equipment is typically also provided with **protection** equipment that turns the equipment off if it has deviated from its usual operating envelope sufficiently to put people or equipment at risk of harm. Good control design aims to avoid the need for protection to operate, but this is an unachievable ideal. Protection systems also operate during plant or control failures.

- Cloud cover reduced the output of embedded rooftop solar installations
- AGC drove the OSPS Jenbacher units to their nameplate rating (greater than their sustained capability given prevailing conditions)
- AGC did not adjust OSPS unit #1 because it was not in AGC control
- Frequency falls marginally, remaining within the normal bounds so UFLS does not occur
- First Jenbacher machine trips on high cooling water temperature
- Frequency falls approximately to 49.6 Hz transiently
- BESS begins to generate causing frequency recovery to approximately 49.8 Hz.
- Second Jenbacher machine trips on high cooling water temperature
- BESS output increases to ~6MW causing frequency recovery to approximately 49.6 Hz.
- Third Jenbacher machine trips on high cooling water temperature
- BESS is commanded to maximum output (8MW). Actual output goes to 8.7 MW.
- BESS LV circuit breaker opens on overcurrent
- Frequency falls significantly and Stage #1 UFLS trips some customers
- Fourth, fifth and sixth Jenbacher machines trip
- Stage #2 UFLS trips further customers
- Stage #3 UFLS fails to trip
- System collapses and final machines go offline leaving the system black

4.4.2 Owen Springs Man units

A single Owen Springs Man unit was in service at the time of the system black (unit #1). The unit was understood by operators at System Control and the ROC to be in AGC control with an upper limit of 8 MW. The machine was not in AGC control because of a control system shortcoming that was well known to System Control and TGen but had not been rectified.

Had this unit been in AGC control an additional 3 MW of regulating reserve would have been available to the system. This would have caused the Jenbacher units to take less load both under AGC and under droop control. The exact load reduction that would have resulted on the Jenbacher units is difficult to determine, but is likely to be in the order of 0.3 MW (each) and is unlikely to have been enough to avoid the cascading tripping of machines.

Had the Man machine been in AGC control with an upper limit of 10-10.9 MW then it is possible that load reduction on the Jenbacher machines would have been enough to avoid the cascading failure.

Entura **recommend**:

- TGen in consultation with System Control determine why the Man units are coming out of AGC control without an operator command [11]
- TGen make any required design modifications to stop the Man units coming out of AGC control when they shouldn’t [11]

- Both TGen and System control add alarms to their system that rapidly bring to their operator's attention that a unit has come out of AGC control [1], [11]
- Both TGen and System control track spinning reserve and regulating reserve separately so that it can be seen when the two are not equal [1], [11]

4.4.3 Owen Springs Jenbacher Units

During the power system event the Jenbacher machines increased their power output automatically. Ultimately, that power increase exceeded the machine's capability and caused most of the Jenbacher machines to trip on cooling water over temperature. The machine power output increased through two command mechanisms:

- AGC commanded the machines to increase output
- Generator speed droop caused the output to increase when system frequency began to fall

The control systems on any generator should control the machine so that it does not need to trip. This includes limiting the machine output under all control modes so that the cooling water does not exceed the trip setpoint. The Jenbacher machine operation is not currently consistent with this design principle.

Subject to qualifications below, Entura **agrees** with TGen's proposed philosophy, outlined in an interview with senior management, of including a relatively slow control loop around the machine controller that reduces the machine power output to match the machine de-rated capability over a period in the order of 30-90 seconds. This inner/outer control loop approach is consistent with good industry practice. Using this approach forces other machines to pick up the load and if that is not possible then the system frequency falls and UFLS operates to avoid a system black.

However, based on some of the interviews conducted it is not clear whether this is a new philosophy or a proposal to fix an existing control system issue with the Jenbacher machines that did not function as expected and/or adequately. There also seems to be considerable confusion about details of how the control system works. If there is already a second (power control) loop operating outside of the speed control loop then Entura would **recommend** [8] not adding a further power control loop outside of an existing power control loop. Instead the existing power loop should be adjusted to give the required performance.

Entura **recommends** [8] that TGen consider designing the outer control loop so that it automatically suspend its own operation, when the system frequency is a small margin below the UFLS stage 3 setpoint. This would help to arrest frequency decline at a low frequency even at the risk of machine over temperature tripping.

Entura **recommends** [8] that the OSPS control system be modified such that AGC raise signals are not passed to Jenbacher machines that are operating above their de-rate limit. Therefore, operation above rated capability would only occur due to speed droop, and then only for a short time.

4.4.4 Under frequency load shedding (UFLS)

Stages #1 and #2 of under frequency load shedding operated as designed and Stage #3 load shedding failed to operate. However, the operation of load shedding including Stages #1 and #2 was not optimised for the power system event that occurred.

By the time UFLS Stage #1 operated power generation had been withdrawn from Uterne solar farm and 3 Jenbacher machines. The power system may have stabilised due to the operation of this UFLS stage if further tripping of the BESS and Jenbacher units had not occurred.

By the time UFLS Stage #2 operated power generation had been withdrawn from Uterne solar farm and 6 Jenbacher machines. The operation of UFLS stage #2 was too little too late.

If UFLS Stage #3 had operated correctly the power system would likely have suffered a “technical black”, system black would have been avoided and system restoration would have occurred more quickly.

During a technical black the majority of customers lose supply but a small number of generators remain in service and the network remains energised ready for the reconnection of customers. In all probability, if a technical black had occurred on 13 October then the duration of the outage would have been reduced such that 80% of customers would have been restored within 90 minutes.

Entura **recommends** [12] a complete review of the UFLS scheme setpoints and time delays. This review must take into account the operation of the BESS and may require coordinated changes to the BESS droop settings. The reason for the failure of UFLS stage #3 also needs to be determined and corrected.

4.4.5 The battery (BESS)

The BESS responded aggressively to the trip of OSPS unit 8 by injecting approximately 2 MW[11] into the network to support frequency. The injection of 2 MW is approximately 50% of the lost generation. When OSPS unit 9 tripped the BESS output increased to approximately 6 MW or 75% of the total lost generation.

Subsequently, when the third Jenbacher machine tripped the BESS was commanded to 8 MW. The BESS output went to 8.7 MW possibly due to speed droop and output a significant amount of reactive power. The total MVA output of the BESS exceeded its short time capability and an internal protection element tripped the BESS from service.

Battery energy systems overheat very quickly when operated above their rated capability, so they must have fast protection systems to prevent damage to their internal electronics. In this context fast means less than one tenth of a second which can be compared with durations in the order of 60 seconds for traditional machines.

It is crucial that a BESS has control systems that can limit its output to stay within the unit capability and therefore avoid the operation of protection circuits. Entura **recommends** [10] that the limiter settings be checked and adjusted as necessary to ensure that the BESS does not trip during power system events.

There is some evidence that the aggressive intervention of the BESS (and the Jenbacher units) may have been counterproductive. By injecting more power than the equipment can sustain, the power system frequency was held close to 50 Hz and the UFLS scheme was unable to detect that the power system was under severe stress. Had the frequency been allowed to fall the UFLS would have removed load from the power system and system black would have been avoided.

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[11] TGen Cause report figure 21.

As part of a UFLS scheme review Entura **recommends** [12] studying and documenting in detail whether capping the BESS output[12] at its long term rating (5MW) until after UFLS stages #1 and #2 have operated would improve system security. This would reserve the BESS overload capability (a further 3 MW) to be reserved for avoiding system black and improving the likelihood of achieving technical black.

4.5 Causal Factors

Terms of reference: any other causal factors and factors contributing to both the occurrence and severity of the incident

If any one of the following systems had performed as expected then it is likely that system black would not have occurred and no load shedding would have been required:

- OSPS unit #1 was in AGC control and available to provide its full output of 10.9 MW, or
- The Jenbacher units ignored AGC controls once they reached their maximum de-rated capability[13]

If any one of the following systems had performed as expected then it is likely that load shedding would have been necessary but the system would not have gone black and restoration would have occurred more quickly and without the need for Ron Goodin power station to participate:

- The BESS limited its output to match its sustained capability, or
- Under frequency load shedding (UFLS) stage #3 operated correctly, or
- Spinning reserve requirement achieved throughout

Real time cloud forecasting is becoming commercially available. It is reasonable to expect that if real time Solar forecasting had been in use on 13 October then the participants may have decided to start OSPS unit 8 a few minutes earlier, and therefore maintain the spinning reserve requirement throughout.

Entura **recommends** [2] that System Control and TGen collaborate to determine if a system such as solar forecasting is useful for Alice Springs. Furthermore we **recommend** [2] that the data from such a system be held by the party responsible for maintaining spinning reserve (currently unclear if that is System Control or TGen).

4.6 Standards and procedures to avoid major events

Terms of reference: standards and procedures followed by System Control to mitigate the risk of system insecurity and their performance against these standards during this incident (including black start procedures and adequacy of employees training)

[12] This can be achieved by suitable adjustment of the BESS active power droop curve.

[13] It may also be necessary to limit the time for which droop control can drive these machines beyond their de-rated capability.

The key standard to mitigate against system insecurity due to a sudden reduction of available generation or increase of load is the spinning reserve policy. The spinning reserve policy is sometimes adjusted by the issue of risk notices but at the time of the incident the usual daytime requirement for 8MW of spinning reserve was in place. The system was required to operate with 8 MW of spinning reserve during daylight hours and 5 MW of spinning reserve at night.

Spinning reserve of 8 MW should be sufficient to maintain system security for any one of the following events:

- Severe reduction of output from Uterne solar farm coincident with severe reduction of output from embedded solar generation (the initiating event on 13 October 2019)
- Tripping of a single Jenbacher machine
- Tripping of a Man machine perhaps with operation of some load shedding depending on the pre-event loading on the Man machine

At the time of the event the power system did not have 8 MW of spinning reserve. The insufficiency of spinning reserve had been identified by System Control and the ROC and additional reserve was in the process of coming online. If the system black had not occurred then according to the Secure System Guidelines this would not have been considered a spinning reserve breach, as the guidelines allow reserve to fall below 8 MW for up to 30 minutes to allow an additional machine to be started.

Entura **recommends** [6] that measures be taken to avoid spinning reserve falling below 8 MW even for brief periods and if this cannot be achieved, it should be considered a system security breach. This can be achieved either by forecasting that a breach will occur (due to either solar fluctuation or load increase) with sufficient time to put an additional machine into service, or by placing an additional machine into service whenever reserve falls below 10 MW and load is expected to continue to increase. This de facto new spinning reserve of 10 MW would necessarily increase the cost of operating the power system.

High quality solar power forecasting is necessary if System Control or the ROC are to reliably predict a spinning reserve breach with sufficient time to bring an additional machine online. Solar forecasting is discussed elsewhere in this report.

Entura found no evidence of any intentional breach of the system security provisions leading up to the system black event. The system was operated with inadequate regulating reserve but this was due to latent technical issues with the AGC and generator control systems.

5. Restoration

5.1 Sequence of events during restoration

> Terms of reference: the power system situation that existed prior to the system black incident (having regard for the current transition process from Ron Goodin Power Station to Owen Springs Power Station), the sequence of events leading to the incident and the state of the power system after the incident, plus any related subsequent incidents

This ToR item does not directly call for analysis of the sequence of events **during** the restoration. However, Entura consider this to be a critical portion of the analysis.

5.1.1 Ron Goodin Power Station

The following sequence of events has been copied from the TGen restoration report (extended version). Entura has verified the sequence of events against interviewee information and other sources making minor adjustments to times where appropriate. Entura has also removed names of non-managerial staff from the data, made minor edits to improve clarity or removed items that are considered too detailed for the Commissions requirements:

1. 1418hrs – System Black event
2. 1420hrs - House Set[14] noted to be running.
3. **Immediately following the event, Ron Goodin operators followed the Black Start procedure, all Circuit Breakers checked and confirmed for correct open/close status**
4. 1430hrs – Ron Goodin senior operator requested operator to start RG2
5. 1430hrs - RG2 closed online, local light and power restored
6. **1433hrs - ROC phoned Ron Goodin Senior operator (SGO) and informed him the G2 was deciding where to initiate the Alice Springs Black Start from, RGPS or OSPS, the SGO informed the ROC he would ring back when RG2 online**
7. 1435hrs – Ron Goodin SGO told ROC OK to restore town, was told to liaise with G2 to restore town.
8. 1435hrs – Ron Goodin SGO rang G2 and was informed by him RGPS was to initiate the Black Start
9. RG6 auxiliaries started to provide parasitic load
10. **Approx. 1440hrs - Ron Goodin Station Manager rang in to request RG9 started and that TGen General Manager Assets and Operations had requested we get anyone we need to attend**
11. Emergency Services attended - Police, Ambulance and Firemen. They told Ron Goodin operator that they had had a report from the public of a Fire and Explosion at the RGPS.
12. 1449hrs - RG3 online
13. **Hospital feeder (11RG07 closed 14:43:49) and CBD feeder (11RG08 closed 14:44:34) were put in service by Hudson Creek System Control.**
14. 1455hrs - RG4 online (not confirmed by Entura)
15. Operators attend to various control difficulties
16. **Approx. 1440hrs – Ron Goodin SGO informed, not to start RG9 unless instructed by System Control**
17. **Approx. 1441hrs – Ron Goodin SGO rang G2 to inform him RGPS could not start RG9 unless instructed by System Control and asked if RG9 required, told not required**

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[14] The terms "House Set" and "Black start generator" are used interchangeably. In this context they mean a small generator at the power station, used to provide auxiliary power while a larger generator is started. The House Set typically doesn't provide any power to customers outside of the power station.

18. 1454hrs - RG2 Shutdown online, possible Reverse Power
19. 1511hrs - RG7 online
20. Feeder (11RG21 closed 15:13:32)
21. 1543hrs - RG2 online
22. 1545hrs - RG1 online
23. Feeders (11RG02 closed 15:45:31, 11RG06 closed 15:46:51, 11RG01 closed 15:47:54)
24. 1557hrs - RG5 placed online in manual control
25. 1606hrs - RG5 shutdown online, reason unknown
26. 1640hrs – message from G2 - Do Not Energise 11RG11 (BESS)
27. 1715hrs - RG1 load reduced due to high Jacket Water Inlet temps
28. 1728hrs – RG5 attempt to start, shutdown, no excitation noted
29. 1729hrs - RG2 taken offline due to Start Air valves passing combustion gases back into Start Air Rail
30. **1734hrs – G2 request Ron Goodin SGO to start RG9, G2 was told that could not start RG9 immediately and would need AC Mist Fan replaced and tested prior to running online. Permit issued to AC Mist Fan.**
31. 2148hrs – RG9 online
32. 2211hrs – Sadadeen breakers for Sadadeen – Lovegrove feeders closed
33. 2244hrs – RG1 taken offline
34. 2252hrs – Brewer circuit breakers closed
35. 2304hrs – Lovegrove breakers for Sadadeen – Lovegrove feeders closed
36. 2304hrs – back to one grid
37. 2313hrs – 11RG11 closed on request of G3

Entura consider that the items marked in bold (items 3, 6, 10, 13, 16, 17 and 30) each reflect a management system that either worked well (3, 6 & 13), worked sufficiently poorly to require remediation (30) or requires clarification (10, 16 & 17). These items are discussed in Section 6.

5.1.2 Owen Springs Power Station (14:18 – 16:30)

During the period 14:18 through until 16:30 the focus of activity at the Owen Springs power station was on black starting a portion of the Alice Springs system (to Lovegrove) using the Man machines OS1, OS2 and OS3. The TGen restoration report (extended version) gives a sequence of events during this period, however Entura observed significant discrepancies between that SOE and the events described by staff who were at the station during the event. Entura considers the following list to be the most likely credible sequence of events during that period:

1. Prior to 15:06 the decision was made in consultation with the ROC and System Control to start Man machine OS1

2. OSPS operators followed their existing procedure, from memory[15], to black start the station for the Man machines
3. 15:06. Machine OS1 has achieved rated speed as required by black start procedure step 3 sub-item 13.
4. **It has been suggested OSPS operators were instructed by the ROC to commence starting Man machine OS3 (step 3 sub item 16 on their black start procedure)**
5. OSPS operators expressed the view that this would not work. They needed to close OS1 onto the 11 kV busbar first. In effect they wanted to complete Step 3 sub-items 14 and 15 first
6. **It has be suggested the ROC insisted that machine OS3 must be started (it is unclear whether this was a result of a direction or perceived direction from System Control[16])**
7. 15:14. Upon attempting to start OS3 machine OS1 and OS3 both suffered protection trips
8. The shutdown of OS1 was neither a standard machine trip nor a standard machine shutdown. This may have placed OS1, the auxiliary supplies for OS3 and the fuel supplies for OS1 and OS3 into an unusual state, leaving both machines unavailable for return to service

If the operators had recommenced their system black procedure at Step 1 sub-item 1 then it is possible that they may have discovered the reason why the machines would not start and therefore have been able to restart OS1 and OS3. However, the operator did not have a physical copy of the procedure and was operating from memory. Also, it is likely that due to the unusual shutdown sequence they may have needed to fault find other systems such as the fuel supply system. However, due to the high level of stress that they were operating under, it is our opinion that it is unreasonable to expect the operator to do anything other than restart the system black procedure at Step 1.

Entura consider that the items marked in bold (items 4 and 6) each reflect a management system failure. Key decisions about the machine startup procedure should have been made by the person with the most relevant knowledge, and that person is the station operator. These items are discussed in Section 6.

In Entura's opinion the errors made at items 4 and 6 above likely had a major impact on the total restoration time of the Alice Springs network.

5.1.3 Owen Springs Power Station (16:30 – 18:35)

During the period 16:30 through until 18:35 the focus of activity at the Owen Springs power station was on black starting a portion of the Alice Springs system (to Lovegrove) using the Jenbacher machines OS5 – OS14.

1. 16:32 – 16:42. OSPS unit 7 used to soft start the step-up transformer and energise the station 66 kV busbar
2. 16:42:44 Circuit breaker 66OS207 closed to energise the 66 kV lines to Lovegrove

[15] There was no printed copy of the procedure readily available in the control room.

[16] There is discrepancy between Territory Generation and System Control's information and feedback in relation to where this possible direction originated, however Entura consider regardless of which party may have given a direction, the overarching issue was the lack of access to a black start procedure and/or practice of those procedures.

3. 16:42:46 there is a large reactive power disturbance and over voltage[17] detected. Machine OS7 trips off returning the system to **black status**
4. 16:49 – 16:54. OSPS unit 8 used to soft start the step-up transformer and energise the station 66 kV busbar
5. 17:00: OSPS units 12 and 14 start initiated
6. 17:03:53. OSPS unit 12 trips – frequency too low
7. 17:04:53. OSPS unit 14 circuit breaker closed to operate in parallel with OS7
8. 17:05 – 17:11. OSPS unit 9 attempts to start and fails.
9. 17:11 – 17:15. OSPS unit 5 attempts to start and fails.
10. 17:17 – 17:29. Dia.ne control system on units OS5, OS7, OS9, OS12 are all rebooted
11. 17:30 – 17:36. OSPS unit 5 is started and synchronised
12. 17:36 Dia.ne control system on unit 13 is rebooted
13. 17:37 - 17:39. Network restored sequentially from OSPS to Lovegrove 22 kV busbar
14. 17:39. Lovegrove feeder restored adding 1.3 MW of load. Load on Jenbachers goes from ~0.24MW to 0.62, 0.64 and 0.72 MW
15. Frequency falls from 50.36 Hz to 47.5 Hz over 4 seconds and appears to stabilise.
16. Various load, network and generator circuit breakers trip returning the system to **black status**
17. 17:42 – 17:52. System restored to Lovegrove 22 kV busbar using a similar procedure to items 4-13 above. Using machines OS12, OS13, OS7, though OS12 tripped.
18. 17:53. Closed on one feeder at Lovegrove adding approximately 1.1 MW of load.
19. System frequency fell from 51.1 to 48.1 Hz over 2.1 seconds and the feeder tripped. Most likely on UFLS.
20. 17:54. Closed on one feeder at Lovegrove adding approximately 1.8 MW of load.
21. System frequency fell from 50.9 to 47.8 Hz over 1.4 seconds and the feeder tripped. Most likely on UFLS.
22. 17:54 - 18:10. Unit 13 trip. Unit 9 is started
23. 18:14 - 18:27. Network restored sequentially from OSPS to Lovegrove 22 kV busbar
24. 18:27 – 18:30. Two Lovegrove feeders are partially restored part of a feeder at a time to give a total load of approximately 1.3 MW
25. 18:30. Another Lovegrove feeder closed adding approximately 1.3 MW of load (not verified by Entura)
26. 18:34. System frequency fell from 50.3 to 47.1 Hz over 1.2 seconds and the feeder tripped.
27. 18:35. Jenbacher machines OS8, OS9, OS5 all tripped in a cascading manner returning the system to **black status**.

[17] The over voltage and consequent tripping was caused in part by incorrect reactive power limiters set in the Jenbacher machine voltage regulators.

5.1.4 Owen Springs Power Station (18:35 – 00:00)

During the period 18:35 through until 19:30 the focus of activity at the Owen Springs power station turned to a hybrid black start model using both Man units and Jenbacher units.

1. 18:35 – 18:53. Switching performed, Dia.ne control system reboots performed and other activities to prepare the station to for another black start attempt
2. 18:53. Man unit OS1 started
3. 19:03. Soft energise of transformer using Jenbacher unit OS7
4. 19:03 – 19:15. Station switching to correctly configure auxiliaries
5. 19:17 – 19:19. OSPS unit 5 attempts to start and fails.
6. 19:22 – 19:29. OSPS units OS1 and OS13 started
7. 19:29 – 19:32. Network restored from OSPS to Lovegrove 22 kV busbar
8. 19:32 – 19:34. Three part feeders of load restored at Lovegrove
9. 19:34 – 19:55. OSPS units OS3 and OS8 started and synchronised
10. 19:55 – 20:01. Multiple feeders at Lovegrove partially restored

At this point it was decided to strengthen the power system by re-energising a 66/11 kV transformer at OSPS. In the absence of a detailed black start procedure this was a reasonable decision that set the power system on a path back to system black.

11. **Circuit breaker 66OS706 closed to energise a second grid stepup transformer**
12. Protection on the in service transformer operated (negative sequence current) disconnecting OSPS from the network
13. 20:04 – 20:16. The system is **black status**. OS1, OS3 and OS13 trip. The network is reconfigured for another attempt.
14. 20:16 – 20:23. OSPS units OS1 and OS3 are started and circuit breakers closed
15. 20:24 – 20:30. OSPS Units 7 and 8 trip and Network restored from OSPS to Lovegrove 22 kV busbar
16. 20:30 – 20:32. Four partial feeders at Lovegrove restored
17. 20:32 – 20:50. Multiple Dia.ne control system reboots, OS9 started, OS9 tripped additional 22/11kV transformers at Lovegrove brought into service
18. 20:50 – 21:01. OSPS Until 11 started and CB closed, more feeders energised and additional 22/11 kV transformers brought into service
19. 21:01 – 21:14. OSPS Unit A started and CB closed
20. 21:18 – 23:00. OSPS island almost fully restored and ready for synchronising to Ron Goodin island
21. 23:00 – 00:00. Restoration substantially complete including synchronisation of two islands

5.2 Duration of restoration

Terms of reference: the time taken to restore the system, including any issues that may have negatively impacted the restoration time, and compliance with and adequacy of current power system restoration procedures, including the identification of any gaps

Ron Goodin power station achieved black start of a small island including the Alice Springs Hospital and CBD within approximately 30 minutes of system black. In Entura's opinion Ron Goodin power station was unable to black start the remainder of the network because there were insufficient machines available for service. Additional maintenance would have made two[18] more machines available for service, likely allowing a full black start from RGPS.

Owen Springs power station suffered multiple failed attempts to black start, leading to a final successful attempt that commenced approximately 6 hours after system black.

5.2.1 Could the restoration have taken considerably longer?

The Entura terms of reference require investigation into why the restoration took so long. However, it became apparent to Entura during the investigation that the restoration could have taken considerably longer in similar but slightly different circumstances.

Ron Goodin

Ron Goodin power station had a number of machines in a state that Entura considers to be cold standby and the station was manned with a senior generator operator and a generator operator. The operators had some warning that system black was a possibility in the minutes leading up to the event based on their observation at power station

Had the Ron Goodin power station not been manned at the time of the incident then it is reasonable to expect that the hospital and CBD would have been off supply for at least 90 minutes instead of the actual period of approximately 30 minutes.

In Entura's opinion, had the Ron Goodin power station been de-commissioned at the time of the incident then the hospital and CBD would have been off supply for at least 6 hours.

Owen Springs

Ultimately the OSPS was re-energised using a procedure that was dependant on using Man generators. However, there were portions of the day during which the Man generators were not available and it appears that no one knew how to re-establish their availability. Entura were unable to determine how the machines ultimately became available and it is likely that this was simply a fortuitous combination of circumstances or intervention by someone at OSPS that we have not been made aware of.

[18] R9 certainly could have been repaired easily and according to interviewees a further machine would have been available if a repair to its turbo had been completed, noting at least some of the major parts were available.

In the event that the Man machines had not come available then the system would likely have remained black until Ron Goodin machine R9 was returned to service and the entire system was restored from Ron Goodin.

Staffing

When the system black occurred many staff were called in to the power stations, the ROC and System Control. This was particularly apparent at System Control where the System Controller, RTOM, Operations Support Coordinator and Engineering staff were all present in addition. Further, staff in Alice Springs arrived at work based on their own desire to help.

Had the restoration extended any longer then each location (but particularly System Control) may have been faced with an inability to fully staff a second shift of engineering and management staff to assist with the restoration, during the following 12 hours. The support staff would have been excessively fatigued and serious mistakes may have been made.

Entura note that the G1, G2 and G3 operators and the ROC operators continued with their normal shift patterns and these roles could have been adequately staffed indefinitely.

Throughout the event there was an unstated assumption that restoration was perpetually less than 2 hours away. This assumption was clearly incorrect.

5.2.2 Ron Goodin

The availability of Ron Goodin's largest machine R9 was unclear during the restoration. The machine required a small (2 hour) repair task using parts that were available to restore it to reasonable working order, however some managerial staff considered that the machine was available for emergency service. Communication failures clearly impacted upon the availability and use of R9.

The instruction was issued that R9 would not be started unless a direction to start it was received from System Control. Some staff understood this instruction to mean that the repair of R9 would not be commenced without receiving a direction to repair from System Control. It is not clear to Entura which interpretation is correct.

System control were informed that R9 would not be started unless a direction was received from them. However, it is not clear if System Control were informed that the machine needed a simple repair and that would not commence unless they provided an instruction.

Nearly 3 hours later System Control directed Ron Goodin to start R9 and were informed that was not possible because the mist fan repair needed to be completed first. R9 entered service after a further 4 hours.

Entura does not have direct expertise on the risks presented to gas turbine plant upon failure of the oil mist fan(s) and cannot comment on whether the machine could be safely shut down following a failure of the backup DC oil mist fan. Unless the operator could be convinced ahead of time that it is safe to operate the machine without a backup oil mist fan, then the only prudent decision they could make would be not to start R9 without first having the repair completed.

If unit R9 had been available and started earlier in the restoration period then the number of customers off supply for an extended period would have been significantly reduced.

The Ron Goodin operators resisted unauthorised requests for the BESS to be restored, which was shutoff as part of the restoration. They consulted with System Control about this decision which was based on an understanding that the BESS has a large inrush current and could compromise their small island. Based on the information available to them at the time, Entura considers that the best possible decision was made.

Entura **recommend** [10] that studies be completed to determine the actual inrush current consumed by the BESS and to determine how it should be used during a system black event.

5.2.3 Owen Springs (14:18 – 16:30)

During the period 14:18 until 16:30 the focus at OSPS was on completing a black start, from memory, according to an existing procedure that had been proven effective several times in the past. It has been suggested that the procedure was deviated from according to a direction from the ROC and consequently the black start procedure failed. As discussed elsewhere in this report, it is unclear if the direction originated from the ROC or System Control.

The opportunity existed to avoid this serious error because the station operators understood that the deviation would likely result in failure of the procedure. However, the direction was sustained after they expressed their concerns.

The consequences of the departure from the procedure were more serious than the operators anticipated and contributed to the Man machines being unable to be started until 4 hours after system black.

Entura **recommend** [7] that the OSPS system black procedure be amended to give the station operator more autonomy. In the event of system black the station operator should be authorised to notify System Control of their intention to complete their system black procedure and only report to System Control when they have achieved an energised 66 kV busbar and are ready to accept load.

The current split of responsibilities between System Control and OSPS is at the station 11 kV busbars. For technical reasons, Entura **recommends** [7] that the power station be responsible for energising the 66 kV busbars. This recommendation would likely require a change to the System Control Technical Code.

With these changes Entura expects that the black start would have been substantially complete within 2 hours from system black.

5.2.4 Owen Springs (16:30 – 18:35)

During the period 16:30 – 18:35 the focus at OSPS was on completing a black start according to a draft procedure that was not physically available to the power station staff. The procedure had been partially tested in the weeks leading up to system black, though not to the complete satisfaction of many operational staff. A more complete test was scheduled for the weeks following system black.

During this period the draft system black procedure was ineffective with three distinct attempts to black start the station. During these attempts an excessive number of generator trips occurred during the portion of the black start procedure that had been tested. Further, the black start failed each time during the untested portion of the procedure returning the system to black status.

During this period the following 4 issues combined to lower the likelihood of a successful, timely black start:

- A well-known issue with the Jenbacher Dia.ne control system requiring the control system to be manually rebooted after each generator trip. Entura **recommends** [9] that this issue be investigated and addressed
- Inappropriate voltage regulator settings on the Jenbacher that meant the machines could not adequately control voltage during black start. This error should have been identified during station design, owner due diligence, pre connection power system studies[19] and/or during commissioning. Entura **recommends** [9] that all power factor limiters be removed and replaced with limiters that reflect likely mechanisms of damage to the machines[20].
- Generator under frequency protection settings that may be unnecessarily sensitive. Entura **recommends** [9] reviewing the under frequency settings to ensure that they are no more sensitive than is necessary to protect the machines from damage
- An apparent inability of the Jenbacher machines to respond to sudden application of load exceeding 10% of their rating. Entura **recommends** [9] determining the source of this restriction and correcting it.

5.2.5 Owen Springs (18:35 - 00:00)

During the period 18:35 – 00:00 the focus at OSPS was on completing a black start according to a hybrid procedure determined at the time. The procedure failed once, however was ultimately successful.

The procedure failed when the decision was made to strengthen the power system by adding another generator step-up transformer. A maloperation of the protection resulted in the system returning to black status. In the absence of a written procedure, with the information on hand at the time, Entura considers the decision to strengthen the network was sound despite being ultimately unsuccessful.

If the procedure had been properly documented and tested prior to the system black incident then Entura believes that this procedure would likely have been successful at the first attempt and the restoration time may have been reduced by 1 hour.

6. Management systems

6.1 History of major events

Terms of reference: the Alice Springs power system's history of major incidents, their investigation and implementation of remedial actions

[19] There are issues with the power system model for the Alice Springs power system. However, this particular issue could easily be discovered using a very simplistic model.

[20] Typically, field over current limiter and PQ based under excitation limiters.

System black has occurred on the Alice Springs system 3 times since January 2015:

- 30 Jan 2016, duration 6 hours
- 09 Nov 2017, duration 6 hours
- 13 Oct 2019, duration 10 hours

On an additional 6 occasions an event has resulted in 5000 or more customers off supply for more than 30 minutes (average event duration 4 hours).

Major investigation reports are prepared by System Control with input from system participants as required including TGen and PWC Power Services. However, the reports are not provided in a timely manner and Entura are concerned that this indicates remedial actions will not be implemented in a timely manner, if they are adequately tracked or implemented at all. Poor major incident reporting just for the Alice Springs system include:

- Since January 2015 the time taken to provide major incident reports has been, on average 268 calendar days
- For the calendar year commencing January 2019 only two major incident reports have been provided. These reports were provided 499 and 292 days post incident
- There are currently 6 major incident reports outstanding excluding the 13 October system black. Four of those are for incidents more than 100 days ago

TGen have responded to a request for information on how major event recommendations are tracked as follows:

> TGen does have a recommendations tracking system managed by the risk and compliance team but it currently does not track the major system event recommendations. Currently all recommendations related to major system events are either accepted or rejected by the Operations team on a case by case basis. Accepted recommendations are implemented and tracked by the Operations team.
>
> TGen sees an opportunity for improvement and as a result going forward, the risk and compliance team will add major system event recommendations to the tracking system and provide reports to the Executive Leadership Team.

System control responded to the same request by advising that their tracking spreadsheet has not been updated for a number of years.

Reporting of major incidents is a System Control responsibility and they can draw upon assistance from TGen, PWC Power Services, Uterne, EDL, Jacana Energy and others if necessary to prepare those reports. The tracking of recommendations should be completely transparent and accountable, in particular the lack of tracking of recommendations from major system events, their status, their reasons for acceptance or rejection and their predicted date for completion is unsatisfactory. Entura **recommend** [13] that a tracking spreadsheet be prepared by System Control to the satisfaction of the Commission incorporating all recommendations from all system events back until January 2015. This spreadsheet should be provided to the commission each year as part of the Commissions annual Power System Review. The document should also be updated and provided with each major incident report.

Entura are concerned that significant recommendations may not be being implemented and that repeat issues and recommendations may not be recognised.

6.2 Communications, standards and procedures for responding to major event

Terms of reference: the adequacy and speed of the response to the incident, including established emergency management protocols, external communication and mitigations to protect vulnerable consumers

6.2.1 Public Utilities Group (PUG)[21]

The leader of the Public Utilities Group is PWC General Manager, Core Operations. The leader was notified of the system black event within 15 minutes of the event occurring.

According to PWC there was a general expectation that system black was unlikely to extend beyond 6 hours based on the experience of previous events and the expectation that learnings from previous events would allow the system to be restored more quickly this time. PWC also noted the partial restoration of the network from Ron Goodin supported this point of view.

On this basis it was initially decided not to convene the Public Utilities Group. It was decided to convene the Public Utilities Group at approximately 19:30 and the first group meeting occurred at 19:55.

Entura consider that, based on PWC's PUG Emergency Management Plan, the PUG leadership should have determined that this was a level 3 incident and advised the Emergency Management Group. The Emergency Management Group and/or the PUG should in turn have completed the following well prior to 19:55:

- The needs of electricity customer with life support needs should have been assessed and a process for contacting those customers started, in line with a recommendation in this report
- Appropriate members of government should have been contacted
- Department of health, police fire and emergency services should have been contacted
- Contingency plans should have been in place to maintain secure water supplies, including in connected communities
- Public notifications should have been provided on radio.

On this basis Entura **recommend** [7] that PWC amend the PUG procedure to require the PUG to be convened within 90 minutes of system black for any future event on any of the regulated systems.

6.2.2 System Control Internal communications

During normal operations System Control has 3 operators:

- Grade 3 (G3): overall in charge. The only operator with authority to authorise switching of the network

[21] Information in this section is based on written information submitted by PWC on 1 November 2019 as part of an additional information request sent by the Commission to PWC on 30 October 2019.

- Grade 2 (G2): Responsible for day to day operation and dispatch of generators
- Grade 1 (G1): Responsible for preparing switching instructions and to manage the public messaging service

During weekdays System Control has two further operational staff:

- RTOM: Real time operations manager. The RTOM is also the line manager for the Grade 3 controllers
- Operations support coordinator. This is a technical support role and has the dual role of being the relief RTOM on alternate weekends and other times when the RTOM is not available

Entura found that there is confusion about who is overall in charge during a system black restoration. Some staff believe that the G3 is in charge while others consider it obvious that the RTOM is in charge. Entura has no opinion on which of these staff should be in charge but we believe it must be clear. Either of two models can work:

1. The RTOM is always in command and when he is absent (e.g. at night) the G3 takes charge as a delegated authority, or
2. The G3 is always in command. He can gain advice from anywhere he/she wishes including their RTOM/line manager, but the decisions are theirs.

A further level for potential confusion occurred because both the RTOM and the Operations support coordinator were present. Entura observes that the RTOM largely supported the G3 while the Operations support coordinator largely supported the G2. However, this may have exacerbated a potential confusion that exists between the G2 and the G3 controller roles.

Entura **recommend** [3] that during a system black event only the RTOM or the Operations support coordinator should be present. The person who is not present should be making preparations to takeover if the event extends beyond the fatigue limit of the duty person.

The roles of G2 and G3 are potentially confused. During day to day operations the G2 is clearly responsible for generation while the G3 is overall in charge. The G2 has authority to complete their duties without continually referring back to the G3. The correct procedure seems to be that during a system black event the G2 becomes an advisor to the G3 who issues all instructions. This was only partially successful on the day because there were too many advisors in the room. Some G2 operators had less access to their G3 operator than they required due to the number of additional personnel present.

Engineering staff were also present in the control room. They were mainly advising the G2 operator but they were also communicating directly with the power stations.

Communications failures, caused in part by too many advisors being present, contributed to the duration of the system black.

Entura **recommends** [3] a complete plan be prepared for who may be in the control room during a major system event.

We anticipate that the plan might say:

Control room staff shall be limited to G1, G2, G3 and RTOM (or their delegate)

Control room staff may be augmented with an additional G2 and/or G3 if that is necessary to allocate separate controllers to the unaffected networks

Engineering and other staff shall remain in the conference room and will pass all communications to/from the control room via the RTOM

6.2.3 The role of the ROC

The remote operations centre is a relatively new control room operated by TGen. The ROC is intended to be the single point of interface between System Control and TGen's generating assets (excluding the Darwin Generators).

Entura has no opinion on whether the ROC makes operational sense during normal system operation. We do note that in the NEM states generating companies typically have an equivalent of the ROC to act as a single point of interface between their generating assets and AEMO. This makes sense in the NEM where a generator owner may have 5 or more power stations connected to the same grid.

It is TGen's intention that the ROC would be the single point of contact during both routine and abnormal (e.g. system black) conditions. However, System Control are allowed to take any action they reasonably consider necessary to restore power system security. This might include bypassing the ROC if they consider that is necessary to restore system security.

Several interviewees indicated that System Control and the ROC agreed that communications would be direct from System Control to the power stations. Entura considers that while it was a departure from day-to-day protocol it was an understandable decision as the ROC potentially added little value as a "post box" for information adding unnecessary steps, time delays and the potential for miscommunications.

In Entura's view the decision to have a ROC and direct all communications through that facility during normal operation is a business decision entirely up to TGen. However, Entura **recommends** [3] that the operating protocols be modified such that the formal primary path for communication during major system events be directly between System Control and the power stations. A technological solution should be considered to keep the ROC up to date with those communications.

6.2.4 System Black Procedures

As required by the system control technical code system black procedures comprise a suite of procedures one each defining:

1. How Ron Goodin power station should black start and report back when it has established an energised busbar that can be loaded
2. How OSPS power station should black start and report back when it has established an energised busbar that can be loaded (Entura recommends elsewhere that this is changed to the 66 kV busbar)
3. How System Control should rebuild the electricity network **once** Ron Goodin and/or Owen springs power station has established an energised busbar ready to accept load

By splitting the responsibilities in this way the need for communication and coordination between sites could be minimised. Entura observe that there may be unnecessary communications between

System Control and the power stations required by the existing system black procedures. These unnecessary communications likely contributed to System Control and the ROC playing a larger part than was necessary or helpful, prior to the power stations reaching the end of their procedures.

The following deficiencies existed at the time of the system black:

1. The black start procedure for Owen Springs power station (Man units 1-3) was not readily available to staff and departures from that procedure severely impacted the restoration time
2. There was no approved black start procedure for Owen Springs power station Jenbacher units 5-14 and failed attempts to black start the system using these machines severely impacted the restoration time
3. The approved black start procedure for Ron Goodin power station had not been updated to reflect changes at the power station (installation of the BESS) and was not considered user friendly by operators. Despite this, and the power station being in a standby state, staff and operators successfully black started the station restoring service to the Hospital and the CBD using their own pre prepared checklist.

Ron Goodin

It is unclear if a formal black start procedure was available at the power station prior to the event or if a black start procedure was sent to the site in the period after the event. However, the operational staff at the site had prepared a black start checklist on a double sided A4 sheet of paper (laminated) that was kept in the control room. It is understood that the checklist had been proven during previous black start events and lead to the rapid/successful energisation of Ron Goodin, the Hospital and the CBD.

Both the formal procedure provided after the event and the operators informal checklist had not been updated to take the relatively new BESS into account. A strict reading of either document implied that the BESS should be disconnected.

Owen Springs Man station

A formal approved black start procedure existed for the Owen Springs Man machines (OS1, OS2, OS3) but was not readily available to the operator during the restoration. If this procedure had been available and followed then the restoration is likely to have been completed more quickly. It appears a direction from the ROC or System Control via the ROC (it is not clear which) resulted in this procedure failing to black start the system.

Owen Springs Jenbacher station

An as yet unapproved/unproven black start procedure existed for the Owen Springs Jenbacher machines. After the failed attempt to start machines OS1 and OS3, the decision was made by System Control to attempt to use this unapproved procedure to attempt a black start from the Jenbacher station. During the attempt a copy of the document was not available to the OSPS staff in part due to a communications network failure.

The black start attempts for the Jenbacher station were led by a TGen contracted engineer from the commissioning of the site. TGen needs to consider whether this was appropriate. Once the Jenbacher site has been proven and released for operation it should be operated exclusively by the station operators.

Entura **recommend** [7] that a formal black start procedure be printed and stored prominently at each site. We further recommend that operators be extensively engaged in preparation of the document and, if they feel it necessary, allowed to produce their own black start checklist for inclusion as an appendix in the controlled black start document.

Entura **recommend** [7] that the suite of black start procedures be updated, harmonised and published at all control room and power station sites. The documents should be modified to minimise the need for communication and coordination between the sites.

System Control

System control do not have a Black System Restart Procedure (required under the System Control Technical Code) that was used during the restoration. Furthermore, some staff felt that there are too many variables to allow a procedure to be prepared.

Entura **recommends** [7] that a System Control system black procedure be prepared to correct the current non-compliance with the system control technical code. That procedure should be prepared on the basis that System Control's role will largely be a network switching role and that the power stations will be responsible for providing an energised 66 kV busbar at OSPS ready for System Control to restore the network. The system control procedure needs to be flexible covering all likely combinations of power station busbars energised ready for service and the likely ability of that busbar to accept real and reactive power loads.

General

Entura **recommends** [7] that the various system black procedures should be rehearsed at regular intervals, both individually and in coordination.

6.2.5 Planning and power system modelling

During the interview process the claim was made many times that there is no power system model for the Alice Springs power system. Subsequently PWC provided a copy of the PSS/e power system model which is dated 27 March 2015 and indicated that they are in the process of having a new model created in DigSilent (an alternative software platform to PSS/e).

The earlier PSS/e model was provided to the Commission for previous power system reviews (PSR) circa. 2015. Using the models provided to the Commission the 2015/16 and 2017/18 PSRs recommended significant development and verification occur for the Alice Springs dynamic models.

An accurate power system model would allow simulations of system black to be completed. During those simulations the incorrect reactive power setting of the Jenbacher AVRs may have been discovered. Furthermore if the models were accurate then the Jenbacher's inability to accept load increments exceeding 10% may have been discovered. Armed with this information, it would be concluded either;

- Corrective measures are required to allow black start to occur from the Jenbacher station, or
- Attempting to black start the Jenbacher station cannot work and all efforts should have been put into starting the OSPS Man units and Ron Goodin machine R9.

Either of these actions would likely have reduced the duration of the restoration.

6.2.6 Vulnerable Customers

Entura observed that in general there was a lack of awareness of vulnerable customers with the exception of the Alice Springs Hospital. More generally, vulnerable customers were only mentioned in interviews with the Minister and with network staff located at Sadadeen.

Entura observed that the response to system black was a highly technical response where tunnel vision likely developed based on the need to restore electricity supply. This is where there is an opportunity through the PUG process and consequently the emergency management process for wider community issues to be considered and interventions to occur for particularly vulnerable customers.

In particular there was no evidence provided by PWC in its information submission to the Commission or in discussions with the Deputy PUG Leader that any of the following issues were considered:

- The welfare of elderly people living in retirement facilities
- The continued supply of water to remote communities and its likely interruption due to lack of power supply for water pumping
- Prioritising the return of supply to locations such as shopping centres where vulnerable people may choose to seek respite from the heat
- Providing direct communication and/or advice to the many customers known to have medical needs for electricity
- Providing communications in a form accessible by all community members including those who are not familiar with new media such as Twitter and Facebook

Entura notes that PWC has since advised that it engaged with the Department of Health ‘as the agency ultimately responsible for contacting life support customers’ as well as the Alice Springs Local Council, Telstra (via the Northern Territory Government) and the Police Night Commander.

Discussions with some stakeholders indicate that there may be a gap in relation to allocating explicit responsibility to a party, such as PWC or the Department of Health, to advise vulnerable customers, including those requiring life support equipment at home and aged care facilities, to implement their emergency action plans in the case of a system black or other unplanned interruption.

A review of the Territory Emergency Plan, including responsibilities allocated to the PUG and the Medical Group led by the Department of Health appears to support this feedback, noting the Medical Group’s responsibility involving the ‘coordination of medically vulnerable clients’ is not considered explicit enough to cover vulnerable customers in their homes.

While PWC as the network provider is required under the Electricity Retail Supply Code (from 1 December 2019) to keep an up to date register of customers’ premises that require life support equipment, and the Department of Health is likely to have its own list of vulnerable residents in Alice Springs and connected communities, Entura does not have a view on which party should be allocated this responsibility, noting it is primarily a communication role.

Entura **recommends** [15] that the Government consider allocating explicit responsibility to an appropriate party to advise vulnerable customers, such as those requiring life support equipment at home, to implement their emergency action plans in the case of a system black or other unplanned interruption.

6.3 Spinning reserve

Terms of reference: the adequacy of the Alice Springs spinning reserve policy and automatic generator controls to respond to system events thereby providing reliable and secure power in the future

The spinning reserve requirement of 8 MW reserve during daytime operation and 5 MW during night-time operation may be adequate. The system black event of 13 October does not itself indicate that the policy is insufficient. However, it has been System Controls intention for several years (and reported in several PSRs) to review the spinning reserve requirements and this does not seem to have occurred. While the system is continually changing (e.g. by the installation of new Jenbacher machines) it is necessary to maintain the system in a secure operating state through all transitional periods.

When considering spinning reserve all of the following factors must be considered:

- The size of the largest in service generator
- The availability of UFLS to reduce load for a large event
- The operation and settings of the BESS
- The amount of solar generation coming from Uterne
- The amount of embedded (rooftop) solar
- The likelihood of cloud cover reducing solar generation

Entura **recommend** [12] a study be completed (and recommendations implemented) to coordinate the settings of the UFLS system, the droop characteristic of the battery and the spinning reserve policy.

At the time the system went black the system was in breach of the spinning reserve requirement. Had the system not gone black the breach would not have been reportable because it lasted for less than 30 minutes.

Further we recommended in Section 4.5 that a solar forecasting tool be investigated and all spinning reserve breaches (including short duration ones) be avoided.

6.4 Knowledge and training

Terms of reference: whether limits of normal operation of automated generator control are understood and, therefore, at what point operations determine that system security is at risk and remedial action needs to be taken, including the implementation of system constraints

6.4.1 General

The majority of Interviewees, from both PWC System Control and Territory Generation considered their training to be inadequate. However, Entura observed that further discussion revealed that there was likely more training than staff gave their employer credit for. In Entura's view the following are likely factors:

- There is a genuine lack of meaningful relevant training
- There is a tendency of staff to discount some kinds of training (e.g. first aid, fire extinguishers etc.)
- There is a tendency of staff to discount the time they spend reading incident reports, instruction manuals and other materials that are available to them to examine during quieter periods. It is not clear if these activities are encouraged or discouraged and if these activities are completed there is no evidence that records are kept.
- There is a genuine lack of ability to complete self-study as the operator's spare time is very fragmented
- The operators talk about a father/son (or apprenticeship) mentoring model as if there is a better model. Provided these systems have appropriate monitoring and competency based assessment, then in Entura's opinion they can form a valuable part of a structured training program

6.4.2 PWC

Interviewees indicated that training at System Control for operational staff is almost non-existent and where it does exist the training is compliance training aimed at topics such as first aid and fire extinguishers. The operational staff expressed a desire for technical training that is directly relevant to understanding and operating the power system. In particular they indicated that their training needs include subjects like:

- Understanding how adjustment of a voltage in one part of the network will impact reactive power flows and voltages in other parts of the network
- Generator voltage regulators and governors
- The specific machines on the Alice Springs network and their particular characteristics
- How an AGC system should function

There was a strong desire to have access to:

- A working power system simulator (there is one but it is reportedly non-functional and not adequately configured)
- Power system modelling software and power system models for the 3 regulated systems so that operators can learn about the system characteristics by performing what-if analysis

In Entura's opinion these operator desires/requirements for training and tools are no more than the tools provided to operators of other networks.

Entura **recommends** [7] that all PWC technical staff (operators, electricians, engineers) should have a simple training record. That training record could be based on the Engineers Australia CPD model with targets for each type of training and each mode of delivery including the technical classroom training that is most valued by technical staff. Such a training record would explicitly record training in separate areas such as:

- Compliance training
- Corporate training
- Power system operator skills
- Power system operator background technical knowledge

6.4.3 TGen

Interviewees indicated that training at the power stations and the ROC for operational staff is inadequate. They expressed a strong desire for the ROC staff in particular to have considerably more training and familiarisation with each of the relevant power stations.

TGen provided a simple training tracking sheet that demonstrates a reasonable attempt to record training as it happens. Examining a random sample of the records showed 2-6 entries during the 2018 calendar year for each staff member. Typically 1 of the entries was for BESS training and for staff with more line items typically 3 are for compliance and corporate items such as site inductions, first aid and MS excel.

A record was also provided demonstrating some use of the TGen power system simulator.

The interviewees typically provided positive feedback for the recent battery energy system (BESS) training.

Given the diverse backgrounds of the ROC staff and the short time that they have been in these roles the amount of documented training appears to be inadequate.

Entura **recommends** [7] that all TGen technical staff (operators, electricians, engineers) should have a simple training record. That training record could be based on the Engineers Australia CPD model with targets for each type of training and each mode of delivery including the technical classroom training that is most valued by technical staff. Such a training record would explicitly record training in separate areas such as:

- Compliance training
- Corporate training
- Power system operator skills
- Power system operator background technical knowledge

7. Outlook including Ron Goodin closure

> Terms of reference: the outlook for the system over the next 12 months, including how the plans for the retirement of the Ron Goodin Rower Power Station and the battery commissioning (separately and combined) are assisting or undermining the capacity of the network to manage these incidents, and whether the plans and emergency responses are adequate for each phase

In Entura's opinion the suite of system black procedures currently in place is not sufficient to allow Ron Goodin power station to be decommissioned. Before Ron Goodin is decommissioned there needs to be a reliable black start procedure that is sufficiently robust to be effective when:

- One Owen Springs Man machine is out of service for long duration maintenance
- One Owen Springs Man machine is out of service due to a forced outage
- One Owen Springs Man machine is available for service

In Entura's opinion the BESS is a very effective piece of equipment with a variety of characteristics that are helpful to avoid system black. However, insufficient work has been done to determine if the BESS has a role to play in system restoration. It is likely that because of the BESS' remote location relative to OSPS that the BESS cannot be of assistance for system restoration.

One of the most significant difficulties that generator operators faced during restoration was keeping the load on every generator above zero during the restoration. When the load falls below zero a 'reverse power' trip occurs to protect the machine from damage. Entura **recommend** [5] that TGen complete a study, including modelling and cost benefit analysis, to consider all options that reduce or remove these difficulties. Some alternatives that should be examined include:

- Switching arrangements that allow the Brewer load to be used to stabilise the operation of the machines
- Any other switching arrangements that allow a stable load block to be formed without energising the 66 kV portions of the network
- Installation of a thyristor controlled load bank at Owen Springs power station to simplify the restoration process and reduce the risk of restoration delays
- Relocation of the BESS from Ron Goodin to OSPS so that it can function as a load bank during restoration
- Determining if the reverse power protection settings are more sensitive than is necessary during a black start

8. Further Investigations

Terms of reference: subsequent investigations and appropriate timing, if the above matters are unable to be addressed within the specified timeframe.

Entura has recommended a number of short investigations be completed by PWC and TGen. We have no recommendations for further work to be completed by the Utilities Commission as a direct response to the system black. However, we do **recommend** [14] that the Commission place a focus on determining if the recommendations of this report and other major event reports have been tracked and implemented during their annual power system reviews (PSRs). On occasion further observation by the Commission may be required between annual PSRs.

Entura **recommends** [15] that Government consider developing a documented process for the reporting and implementation of the recommendations of this and other major event reports by

System Control and TGen. The reporting mechanism should require the respective Boards to report to the shareholding Minister and/or Minister for Renewables, Energy and Essential Services. Potentially, there could be a role for the Commission or another independent body to approve how that evidence is to be structured and presented and to review progress or the failure to prioritise appropriately.

9. Summary of Recommendations

> Terms of reference: actions that may be required to prevent a recurrence of such an incident including the design of the power system and related power system operation and maintenance practices

Recommendations are placed into this report at the appropriate location. Each recommendation is then paraphrased in this section along with a section reference to where the context can be found within the body of this report. Consequently, the 'full' recommendation within the text of this report is to be considered the recommendation to be actioned.

Items marked as 'high' priority are considered to be either easily / quickly implemented or critical to the restoration of the system from system black. Until these items have been completed Entura recommends that the Ron Goodin power station be maintained in a state that it could black start the entire system thereby providing an alternative for the possibility that the OSPS Man machines are not available. In our view all high priority items could be completed within 8 weeks.

All other items are marked as 'medium' priority. In Entura's opinion these items could and should be completed within 8 months. Where the output of the recommendation item is a report, the implementation of that report's findings should not take longer than a further 8 months.

ID	Recommendation	Ref.	Responsible	Priority
1	Modify the System Control operator screens at Hudson Creek control centre to improve their operational awareness: • add alarms that rapidly bring to their System Control operator's attention that a generator has come out of AGC control • track spinning reserve and regulating reserve separately so that it can be seen when the two are not equal	4.4.2	System Control	High
2	Consider solar forecasting in addition to the existing load forecasting procedures. In particular:	4.5	System Control and TGen	Medium

ID	Recommendation	Ref.	Responsible	Priority
	• System Control and TGen collaborate to determine how a solar forecasting system can be used to improve security of the Alice Springs system • data from the solar forecasting system be held by the party responsible for maintaining spinning reserve			
3	Clarify and communicate protocols around how System Control is to operate during a system black event. We recommend the following principles: • prepare a complete plan for who may be in the control room during a major system event • only the RTOM or the Operations support coordinator should be present. The person who is not present should be making preparations to takeover if the event extends beyond the fatigue limit of the duty person • modify the operating protocols such that the formal primary path for communication during major system events be directly between System Control and the power stations.	6.2.2, 6.2.3	System Control and TGen	Medium
4	Complete a review of the AGC system to determine if it is fit for purpose and if still deemed necessary how to improve its function and reliability.	4.3.2	System Control	Medium
5	TGen prepare a report considering options to simplify the starting and loading of generators during black start. In particular the report should consider options to reduce the risk of generators tripping due to reverse power during restoration. Options for review should include: • Switching arrangements that allow the Brewer load to be used to stabilise the operation of the machines • Any other switching arrangements that allow a stable load block to be formed without energising the 66 kV portions of the network • Installation of a thyristor controlled load bank at Owen Springs • Relocation of the BESS from Ron Goodin to OSPS so that it can function as a load bank during restoration • Determining if the reverse power protection settings are more sensitive than is necessary during a black start	7	TGen	High

ID	Recommendation	Ref.	Responsible	Priority
6	The apparent confusion between TGen and System Control about who is responsible for dispatch and load following should be resolved. Operating protocols need to be thoroughly consulted upon and communicated. We recommend the following principles: • System Control should be required to determine the amount of synchronous generation needed to be in service at each point in time taking into account the need for spinning reserve, the state of Uterne and the state of the BESS, because these are system security issues. • TGen and PWC review each other's operation document and the two documents made consistent and agreed • TGen could be responsible for determining which machines to place into service to meet that spinning reserve requirement and System Controls other system security requirements. • Implement measures to avoid spinning reserve falling below 8 MW during the day for even for brief periods	4.3.1, 4.6	TGen and System Control	Medium
7	Other procedural recommendations include: • A System Control Black System Restart Procedure be prepared • PWC amend the PUG procedure to require that the PUC be convened within 90 minutes of system black for any future event • make changes to provide that during restoration the current split of responsibilities between System Control and OSPS should be at the station 66 kV busbars. • a formal set of black start procedures to be updated, harmonised, printed and stored prominently at all control room and power station sites • system black procedure be amended to give the station operator more autonomy • various system black procedures should be rehearsed at regular intervals, both individually and in coordination • all technical staff (operators, electricians, engineers) should have a simple training record based on the Engineers Australia CPD model (for example) with targets for each type of training and mode of delivery including technical classroom training	5.2.3, 6.2.1, 6.2.4, 6.4.2, 6.4.3	PWC and TGen	 High Medium Medium Medium High High Medium

ID	Recommendation	Ref.	Responsible	Priority
8	Make engineering changes to avoid the Jenbacher units becoming overloaded during power system events: • modify OSPS control system so that AGC raise signals are not passed to Jenbacher machines that are operating above their de-rate limit. • do not add a further power control loop outside of an existing power control loop. • consider designing the outer control loop so that it automatically suspends its own operation, when the system frequency is a small margin below the UFLS stage 3 setpoint.	4.4.3	TGen	High
9	Make further control changes and investigations of the performance of the Jenbacher units: • investigate and address issues in relation to the need for Dia.ne control system reboot after a unit trip • remove all power factor limiters and replace them with limiters that reflect likely mechanisms of damage to the machines • review and adjust the under frequency settings to ensure that they are no more sensitive than is necessary to protect the machines from damage • determine and address the source of an apparent inability of the Jenbacher machines to respond to sudden application of load exceeding 10% of their rating	5.2.4	TGen	High
10	Make engineering changes to avoid the BESS becoming overloaded during power system events: • check and adjust the limiter settings to ensure that the BESS does not trip during power system disturbances • Determine the inrush current of the BESS to determine how it should be used during a system black event	4.4.5, 5.2.2	TGen	High
11	Address issues adversely affecting system security. In particular: • investigate and implement modifications to stop the Man units (or any other unit) coming out of AGC control without an operator command or unforeseeable fault condition • add alarms that rapidly bring to the ROC operator’s attention that a generator has come out of AGC control • Track spinning reserve and regulating reserve separately	4.4.2	TGen	High

ID	Recommendation	Ref.	Responsible	Priority
12	Improve the under frequency load shedding scheme (UFLS). In particular a review and report should be prepared by System Control that addresses: • UFLS scheme optimised setpoints and time delays • coordinated changes to the BESS droop settings • coordination of the settings of the UFLS system with the spinning reserve policy • failure of UFLS stage #3 during the system black • whether the BESS output should be capped at its long term rating (5MW) until after UFLS stages #1 and #2 have operated for system security purposes	4.4.4, 4.4.5, 6.3	PWC	Medium
13	System Control prepare a tracking spreadsheet to the satisfaction of the Commission incorporating all recommendations from all system black events back until January 2015	6.1	System Control	High
14	The Utilities Commission place a focus on determining if the recommendations of this report and other major event reports have been tracked and implemented during their annual power system reviews. Government consider developing a documented process for the reporting and implementation of the recommendations of this and other major event reports by System Control and TGen, with a potential role for the Commission or another independent body.	8	Utilities Commission and Government	Medium
15	Government consider allocating explicit responsibility to an appropriate party to advise vulnerable customers, such as those requiring life support equipment at home, to implement their emergency action plans in the case of a system black or other unplanned interruption.	6.2.6	Government	Medium

10. Acknowledgment

Entura would like to acknowledge the assistance of all of the interviewees. In particular the operational staff were open and forthcoming with details of the event and their insights into causes and the challenges that they faced during the restoration.