Utilities Commission of the Northern Territory

Independent Investigation into the 12 March 2014 Darwin Katherine System Black

EVANS & PECK

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1 Executive Summary

At 01.21 on 12 March 2014, the Darwin Katherine Power System went black, resulting from the actions taken in response to a 132kV circuit breaker located at the Hudson Creek Substation failing to operate correctly during switching for planned routine maintenance on Hudson Creek 132/66kV Transformer 1. Following the failure of this circuit breaker, it was decided to cancel the planned routine maintenance and repair the failed circuit breaker instead. It was the actions taken to isolate this this circuit breaker, some 40 minutes after the initial failure of the circuit breaker, which caused the protection systems to operate and disconnect both of the Channel Island Power Station to Hudson Creek Substation 132kV power lines. This led to a widespread power outage extending from Darwin to Katherine affecting some 65,000 customers.

The key events that led to the power outage include:

- The Preparation and Restoration Instruction prepared to enable routine maintenance on Hudson Creek 132/66kV Transformer 1 incorrectly identified one of the circuit breakers that needed to be operated for the isolation of this transformer. It was this incorrectly identified circuit breaker that failed when operation was attempted.
- The subsequent switching sequence that was developed to isolate this failed circuit breaker to carry out its repair caused the protection to trip the Channel Island to Hudson Creek transmission lines. A different switching sequence would have enabled the failed circuit breaker to be isolated without tripping these transmission lines, and so avoid the system black occurrence.
- The tripping of these transmission lines disconnected Channel Island Power Station from the Darwin load. The remaining unit connected to the Darwin load, Weddell Unit 1, was unable to supply the full load requirements and tripped due to vibration problems.
- Units 4, 5, 6 and 8 at Channel Island and Units 1, 2 and 3 at Pine Creek Power Station also tripped. The entire System, including Katherine, was now black.
- The restoration of Katherine proceeded expeditiously, with all customers restored in approximately 1 hr 20 min.
- The duration of the power outage in Darwin was extended by problems at both Channel Island and Weddell Power Stations in returning the generation units to service. The majority of customers were restored by 14.30 and the remaining customers by 17.45.

1.1 Channel Island Power Station

The significant problems at Channel Island Power Station were:

- Delays in getting the new Cummins black start generator on line due to a control systems issue.
- The Kongsberg black start generator proved unreliable.
- A control systems fault in Channel Island Power Station operated the Emergency Shutdown valves in APA's gas yard. Reversal of this emergency operation required an APA operator to attend the site from Darwin.

1.2 Weddell Power Station

The significant problems at Weddell Power Station were:

- Key systems were left in non-automatic mode which prevented them from restarting as they should. This included the black start generator, the air compressors and the excitation system on Unit 1.
- Numerous trips were caused by High Gas Pressure on both Units 1 and 3. This was due to the gas regulating valves not shutting off completely.

1.3 Recommendations

A consolidated list of the recommendations developed in this report is contained in Section 15.

2 Introduction

At 01.21 on 12 March 2014, the Darwin Katherine Power System went black, resulting from the actions taken in response to a 132kV circuit breaker located at the Hudson Creek Substation failing to operate correctly during switching for planned routine maintenance on Hudson Creek 132/66kV Transformer 1. Following the failure of this circuit breaker, it was decided to cancel the planned routine maintenance and repair the failed circuit breaker instead. It was the actions taken to isolate this circuit breaker, some 40 min after the initial failure of the circuit breaker, which caused the protection systems to operate and disconnect both of the Channel Island Power Station to Hudson Creek Substation 132kV power lines. This led to a widespread power outage extending from Darwin to Katherine affecting some 65,000 customers.

Pursuant to section 6(1)(g) of the *Utilities Commission Act*, the Commission conducted an independent investigation into the system black incident on 12 March 2014. The Commission engaged Evans & Peck to assist in this investigation and the findings of our investigation are presented in this report.

The data required to prepare this report, and to conduct much of the supporting investigation, was necessarily supplied by Power and Water Corporation (PWC). This report could not have been prepared without the cooperation and assistance of PWC and its staff.

3 State of the System

3.1 State of the System Prior to the Incident

Prior to the incident, the system was in a stable, secure condition, and all the pre-requisites for the work as set out in the System/Load at Risk Notification were in place. The relevant system conditions were:

- Generating Units on line:
  - Channel Island Power Station; Units 4, 5, 6 and 8
  - Weddell Power Station; Unit 1. Unit 2 was out of service to change an auxiliary gearbox, Unit 3 unavailable as GE Contractors held maintenance permits to allow investigation of an alarm indicating debris in the oil system
  - Pine Creek Power Station; Units 1, 2 and 3 were on line
  - Katherine Power Station; No generating units on line.
- System Frequency: 50hz
- System Load: ~140MW.

The System/Load at Risk Notification sets out the pre-requisites to be met prior to undertaking the work. These were:

- System Control
  - No other 66kV or 132kV outages in the Darwin region
  - Bus outage (Part A) is limited to be completed between 00.00 and 04.00. **Darwin loading** (Load on Hudson Creek Transformers and Weddell Generation) **is to be below 150MW for Part A to proceed.**

Note: *For the Darwin load to be below 150MW the work has to be carried out within the time specified. Part A was for the routine maintenance work on Hudson Creek 132/66kV Transformer 1*

- Generation
  - At least one Weddell unit is to be available. Weddell will be dispatched to maintain load transfer on the 132/66kV Hudson Creek transformers below 135MVA.
- Networks
  - Ensure the outage can be returned to service within recall time in the event of a contingency.

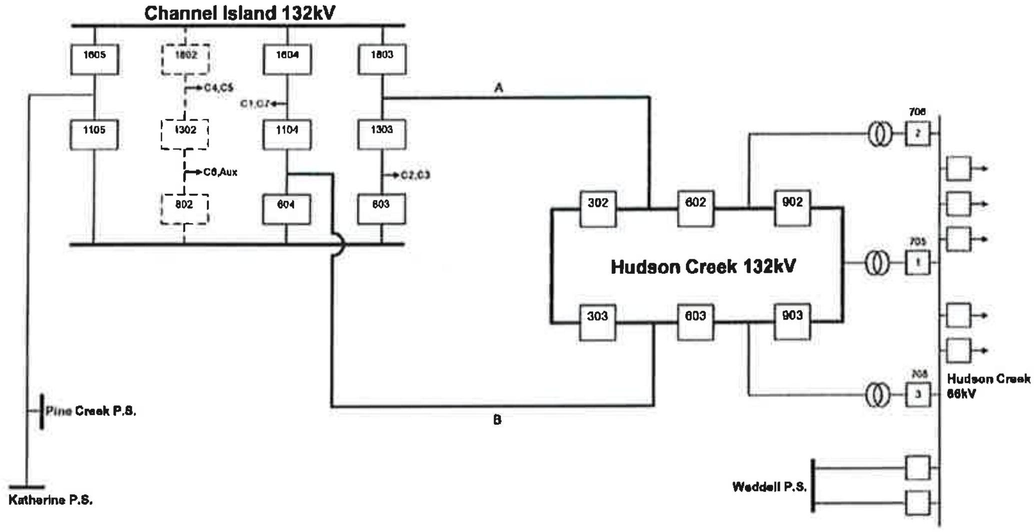
All of these pre-requisites were met before the work commenced.

3.2 Sequence of Events Leading to the Incident

In the lead up to the incident, Power Networks had requested access to undertake routine maintenance on the Hudson Creek 132/66kV Transformer 1. This required the transformer to be isolated so that the work could proceed safely. A Request for Access (RFA) had been submitted to System Control, and a Preparation and Restoration Instruction (PRI) had been prepared in response to the RFA to allow the transformer to be isolated. A copy of this PRI is attached at Appendix A.

Figure 3.1 outlines the backbone of the Darwin – Katherine 132kV system and identifies the relevant circuit breakers and transformers.

Figure 3.1: Backbone of the Darwin 132kV System



The switching sequence defined in the PRI first required CB 66HC705 (i.e. circuit breaker 66kV Hudson Creek 705, labeled 705 in the diagram above) on the low voltage side of the transformer to be opened, and this operation was successfully performed. The next step in the sequence (although incorrect as the wrong circuit breaker was specified) was to open CB 132HC602 (i.e. circuit breaker 132kV Hudson Creek 602, labeled 602 in the diagram above). This circuit breaker is a three pole unit (one pole for each phase) where successful operation requires that all three poles operate in synchronism. The operation in this case was unsuccessful, as one of the three poles (white phase) failed to open. This situation initiated a Pole Discrepancy Alarm in the Hudson Creek control room, but does not initiate the operation of any equipment, including protection devices. At this stage Line A from Channel Island to Hudson Creek was carrying normal power over all three phases. At Hudson Creek Substation, the white phase current from Line A could pass through CB 132HC602 or CB 132HC302, while the red and blue phases could only pass through CB 132HC302. Line B was carrying normal current on all three phases. During this stage the system was stable, but at risk from a single contingency.

The switching operations that were completed are shown in Table 3.1.

Table 3.1: Completed Switching Operations Preparatory to Planned Maintenance

Time	Action
00.38.55s	Open command issued CB 66HC705.
00.40.23s	Open command issued CB 132HC602. The white pole did not open; the red and blue poles did open.
00.41.31s	Close command issued CB 132HC602 as a result of pole discrepancy alarm. Protection prevented this command being executed as the circuit breaker was not in a normal operating condition. This command should not have been issued.

At this time a halt was called to the planned maintenance work (which in fact hadn't started – the switching sequence was preparatory to the maintenance work itself). After consideration of the implications of the failure of CB 132HC602, which is a critical circuit breaker in the 132kV section of Hudson Creek Substation, the staff on site decided to carry out repairs on this circuit breaker rather than continue with the previously planned maintenance activity. This required that CB 132HC602 be isolated.

A plan was developed by the Senior System Operator with the high voltage field operators to undertake the switching required to isolate CB 132HC602. The relevant part of that plan is set out in Table 3.2.

Table 3.2: Relevant Part of Planned Switching Sequence to Allow Repair of CB 132HC602 and Consequences

Time	Action
00.42.02s	Close command issued to CB 66HC705
01.20.30s	Open command issued to CB 66HC706
01.21.31s	Open command issued to CB 132HC302
Planned	Open CB 132HC902
Planned	Open CB 132CI1303
Planned	Open CB 132CI1803

However, after opening CB 132HC302, the protection system detected a Directional Earth Fault, which led to the opening of four circuit breakers at Channel Island, disconnecting Channel Island Power Station from the network and ultimately causing the System black. These circuit breaker operations are shown in Table 3.3, as are the immediate subsequent operations.

Table 3.3: Subsequent Circuit Breaker Operations

Time	Action
01.21.34s	CB 132CI604, CB 132CI1104 Tripped
01.21.35s	CB 132CI1303, CB 132CI1803 tripped.
01.21.38s	Weddell Unit 1 tripped (islanded but tripped before under-frequency load shedding could reduce Weddell island load).
01.21.50s	Close command issued to CB 132HC302. Although of no effect by this time, this operation should not have occurred, as the consequences could not have been considered by this time.
01.21.52s	Channel Island Unit 5 GCB opened (reverse power).
01.24.53s	Close command issued to CB 132CI604.
01.21.54s	Channel Island Unit 4 GCB opened (reverse power).
01.21.57s	Pine Creek Unit 1 tripped.
01.21.57s	Pine Creek Unit 2 tripped.
01.30.14s	Pine Creek Unit 3 tripped.
01.25.30s	Close command issued to CB 132CI1104.
01.26.22	Close command issued to CB 132CI1303. This command should not have been issued as one line from Channel Island to Hudson Creek was all that was required, and the second line only added capacitance to the system making VAR/voltage control more difficult.
01.26.38	Close command issued to CB 132CI1803. This command should not have been issued as one line from Channel Island to Hudson Creek was all that was required, and the second line only added capacitance to the system making VAR/voltage control more difficult.

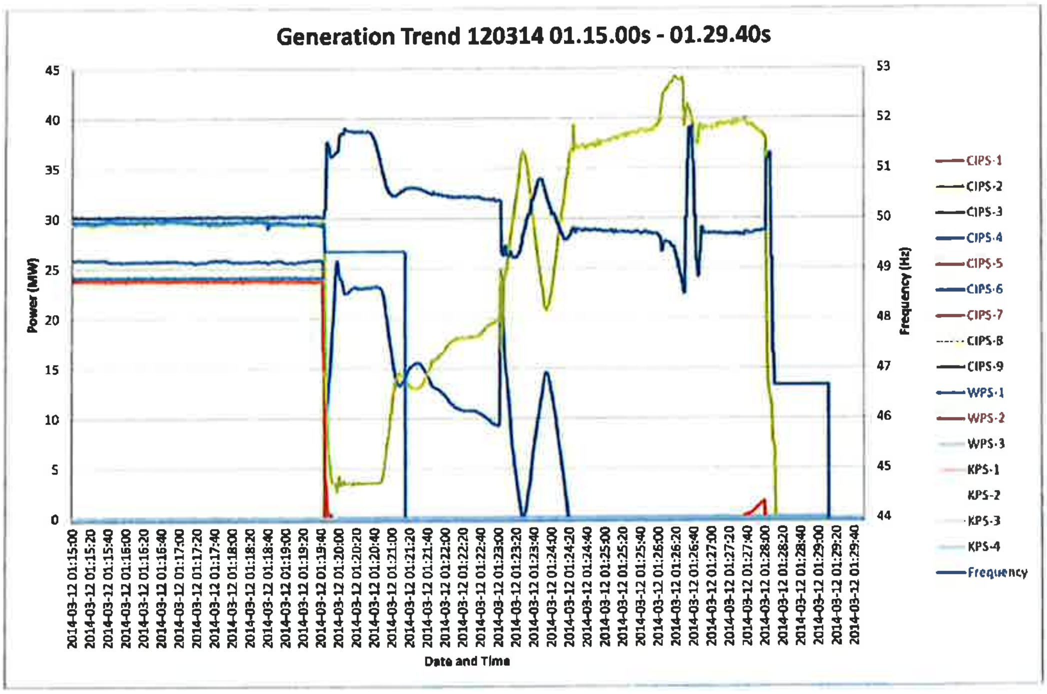
3.3 State of the System after the Incident

The operation of the protection systems caused the circuit breakers at Channel Island to trip at 01.21.35, some 40 min after the failure of CB 132HC602. The following events occurred:

- Units 4, 5, 6 and 8 at CIPS were disconnected from the Darwin Network, but stayed at synchronous speed supplying the station auxiliaries and the Katherine load. Units 4 and 5 continued to provide some heat input into the Heat Recovery Steam Generators (HRSG) while maintaining full speed at no load until 01.21.52 when their generator circuit breakers opened on reverse power. As a result, Unit 6 could only continue to operate for a limited period of time, as the heat inertia in the HRSG was exhausted. Unit 6 was manually tripped by PWC Generation operators when the steam quality deteriorated to an unsafe condition. Just prior to being tripped Unit 6 had significant load excursions as it tried to control pressure in the HRSGs, which imposed mirror image load changes on Unit 8, see Figure 3.2.
- Weddell Unit 1 tried to pick up the entire connected Darwin load at this time, but was unable to sustain that load. The unit finally tripped on high vibration.
- Some 3 min 20 sec after the Channel Island to Hudson Creek lines were tripped, Line B was re-energised, and after a further 1 min 29 sec Line A was re-energised. The re-energising of Line B provided a stabilising load for Unit 8 and assisted in keeping this unit on line. However the re-energising of Line A doubled the capacitive effect, leading to the on line generators having to absorb significant more VARs than would have been the case if the second line had not be re-energised, making voltage control more difficult.
- All four stages of the UFLS operated, leaving some 30MW of load on the system. This was being supplied by Channel Island Unit 8.
- Pine Creek Units 1, 2 and 3 tripped. The SCADA data shows that Unit 3 tripped some 8 min after Units 1 and 2. As it is a steam turbine reliant on the exhaust of Units 1 and 2 to provide steam, it seems unlikely that it could have generated for this period of time and may in fact have been motoring (i.e. acting as a motor and absorbing power from the system) for much of this period. If this was the case, it should have tripped on reverse power. This should be investigated, and as for Unit 6 at Channel Island, an automatic facility to trip Unit 3 on the loss of Units 1 and 2 would be useful. The Pine Creek operator arrived on site at 01.30.00 to find that all units were off line.
- At 01.29.34s Channel Island Unit 5 was synchronised to the grid.
- The 66kV bus at Hudson Creek was stripped by System Control, to prevent the possibility of large increments of load being placed on the generating units remaining on line at Channel Island. At this time the system was stable and the system load within the capabilities of the on line generating units to supply, and in a good position from which to rebuild the system.
- Due to the meshed nature of the 66kV system, no load was removed from the network until the last 66kV feeder from Hudson Creek was tripped by System Control, which removed the entire Darwin System load from Channel Island. This occurred at 01.29.52s, and at this stage a System black event occurred.
- At 01.29.56s Channel Island Unit 5 tripped (reverse power).
- At 01.30.03s Channel Island Unit 8 tripped (under frequency).

Figure 3.2 shows the loading on the Channel Island and Weddell machines prior to the incident and through to the System black event.

Figure 3.2: Unit loadings on the Channel Island and Weddell Power Station Units[1]



3.4 Related Subsequent Incidents

3.4.1 Channel Island Power Station

CIPS has two black start generators, the original Kongsberg machine (900kW) and a new Cummins machine (1,500kW). The new machine has only recently been installed and is in a temporary location with temporary connections to the station auxiliary systems. It is intended for this machine to be permanently located in proximity of Units 8 and 9, connected to a new Station Utilities Services board, but it is currently located between Units 1 and 2. This machine has been installed so that it can generate onto the grid to allow regular full load testing, which is good practice. During testing, the unit is required to run in droop mode to follow the system frequency. However, this mode is not applicable for connecting to a dead busbar. The machine has automatic controls to change its operating mode to suit the specific situation, but this element of the control system did not work when required, leaving the machine to operate in droop mode. On a dead busbar this causes the machine to reduce frequency and voltage to match the busbar, in this case zero. The voltage was driven to its lowest limit, 290V, which is insufficient to start 415V motors needed to start a main unit.

The Kongsberg machine was then tried, but it failed shortly after coming on line. It was tried a second time, but tripped before coming on line. This unit has been regularly tested on a monthly basis, and these tests have been successful in recent times. However it missed the February test as the Cummins unit was tested instead. The reasons for its failure to operate when required should be identified and rectified. Regular testing should continue to be carried out to confirm that the unit is reliable for black start operation. This unit should be maintained as second black start

[1] The time base on this graph is from the Channel Island control system output

generator, particularly until the Cummins unit is permanently installed in its final location and has been proven reliable.

At 03.59, the first unit at CIPS, Unit 2, was brought on line and the node energized. The unit tripped at 04.17 due to a gas stoppage. This was caused by a CIPS Field Control Station (FCS) during its reboot phase sending a signal to the gas inlet station which caused an Emergency Shut Down Valve (ESD) to operate, cutting off all gas supply to CIPS, and resulting in Unit 2 tripping.

The ESD valves are located in the gas yard operated by APA. PWC does not have access to reset these valves. APA was called and responded appropriately, but this operation still requires time for the call out staff member to attend from Darwin, slowing the restoration process. However this arrangement of restricting access to the gas yard to operate the gas supply system is an inevitable consequence of the current contractual arrangements.

APA has recommended that PWC should not be relying on their ESD system and that it is not good practice to rely on third party isolations. In this case that would mean a duplication of the ESD equipment on the power station property. While this maybe current best practice, it does not seem justified in this case. However, an analysis of the costs and benefits to justify such an investment should be carried out.

These issues (the Cummins black start generator and the gas ESD system) have identified that there were problems in the field control stations relating to the non-generating unit parts of the power station. A full review of these field control stations will be required to ensure further occurrences of this type in these and other systems do not reoccur.

Units 1 to 5, 8 and 9 are capable of operation on diesel fuel. Units 1-5 generally have this facility disabled due to a history of unreliability of this equipment. To reinstall this facility takes about a day, and is done if any risk to the gas supply system arises. It would not have helped on this occasion as it was clear that the gas supply would be reinstated before this facility could be returned to service on any of these units.

Units 8 and 9 do not have procedures developed for closing onto a dead busbar, so the restoration effort focused on Units 1 to 5 that have procedures developed and have successfully demonstrated this capability in the past. The design of Units 8 and 9 should be reviewed to ensure that they can close on to a dead busbar, the appropriate procedures developed and test program implemented.

3.4.2 Weddell Power Station

Weddell Power Station had a number of related subsequent incidents that delayed its return to service. These included:

Overall Power Station

- Weddell units automatically go into a four hour start lock out period if an operator doesn't reset the system at site within 10 minutes of the power turbine speed dropping below 300rpm after a trip. As this can only be done at site, a trip when the power station is unattended will normally result in four hour lockout.
- The black start generator was inadvertently left in the "OFF" position at some time after work on this system, so it was unable to start automatically when power was lost to the station. This resulted in the UPS batteries not being charged, leading to power not being supplied to a number of key systems once the batteries discharged. This is poor practice.
- The UPS batteries were at the end of their life, and required changing. New batteries had been purchased for this purpose, but had not been installed as it had not been possible to get the station outage required for their change out given other higher priority tasks on the network which required support from Weddell generation. Among other issues, the lack of

power from the UPS prevented the black start generator circuit breaker from operating once this generator was started, delaying the station restart.

- The air compressors were left in the "OFF" position, so there was no compressed air, similar to the black start generator, and again poor practice.
- ~3:15.00 – Staff arrived at site and started to restore emergency power, reboot computers, and prepare the units to return to service.

Unit 1

- ~5:34 - Unit 1 restart lock out automatically reset.
- 7:53:36 - Unit 1 66kV power supply was restored.
- 8:10:47 - Attempted the first Unit 1 start which failed at 8:15:31 due to high gas pressure as the gas pressure regulating valve does not completely shut off the gas flow as they should.
- Between 8:15:31 and 9:49:56, Unit 1 failed to start on four more occasions due to high gas pressure and on three occasions as the circuit breaker in the igniter circuit was in the open position.
- 10:00:41 – Unit 1 started successfully and reached full speed but tripped at 11:14:31 on loss of Motor Control Centre (MCC) power. A control fault prevented synchronisation, probably the AVR issue noted below.
- 11:22:37 – Unit 1 was restarted but tripped at 11:25:20 due to high gas pressure.
- 12:12:20 - Unit 1 was started successfully but was shut down after it failed to synchronise as the AVR was left in "Manual" rather than "Auto". Again this is similar to the black start generator issue and poor practice. These issues should have been discovered during pre-start checks that would be expected after an event such as this.
- 12:48:12 – Unit 1 was started successfully and synchronised to the grid.

Unit 3

- 7:54:08 - Unit 3 66kV power supply was restored.
- 8:40:59 – Unit 3 control system restarted.
- 8:54:34- Attempted the first Unit 3 start which failed at 8:56:05 due to high gas pressure.
- 9:01:43 – Unit 3 restart attempted but failed at 9:05:01 due to HIMA purge cycle failure. (The HIMA system is a parallel control system on the gas supply system to comply with Australian Standards, and the purge cycle is to ensure there is no residual gas in the machine prior to the introduction gas during a start).
- Between 9:15:18 and 11:27:46 - Unit 3 failed to start on five more occasions due to HIMA purge cycle failure.
- 11:49:52 – Unit 3 was successfully started and synchronised to the grid.

The restart attempts at Weddell Power Station are summarized in Table 3.4.

Table 3.4: Weddell Power Station Restart Attempts

Unit	Start Attempts	Successful Starts	Run Hours	Unsuccessful Starts/Trips
Unit 1	14	3	3	10
Unit 3	8	1	2	7

Note: Unit 2 was out of service prior to the System black incident.

PWC has prepared a "Lessons Learnt" document on the experience at Weddell, included at Appendix B. The recommendations in that document are supported, and in addition the following recommendations for restart are offered following unit trips:

1) Batteries and UPS should provide initial emergency power for control systems, lubrication during run down and emergency lighting. DCS monitoring to ensure this occurs is essential.

2) Prior to any restart attempts, ensure the plant is in a safe condition:
   (a) Check plant status and alarms
   (b) Check all switchboards locally to ensure all breakers have operated correctly
   (c) Check gas trip and vent valves have operated correctly (and any other high risk plant).

3) Diesel generators should start automatically if the station is black. If a start fails, start manually or arrange portable generators, before UPS and other backup battery systems discharge completely.

4) Conduct prestart check to ensure the unit and systems are in the correct mode for start-up, e.g. AVR on "Automatic".

5) Prepare a restart plan in consultation with System Operations and the crisis control team.

6) Restore auxiliary power (could be black start diesel generators or back feed from another station).

7) Restart units.

4 Root Cause Analysis

4.1 Actions Resulting from the Failure of Circuit Breaker 602 Hudson Creek Substation

The root cause of the System black incident can be attributed to the actions taken in response to the failure of CB 132HC602 at Hudson Creek Substation, rather than the failure of the circuit breaker itself. The failure of this circuit breaker on its own did not lead directly to the System black incident, as shown by the time the system was operated with this circuit breaker in a failed condition (approximately 40 min) without any consequences to system. Rather it was the actions taken to prepare this circuit breaker for essential maintenance that led to the System black. Issues at Channel Island and Weddell Power Stations prolonged the period of the System black.

As set out in Section 3.2 above, after the failure of CB 132HC602, the system remained in a stable situation, albeit with a Pole Discrepancy Alarm on CB 132HC602. The decision was taken to discontinue with the original planned maintenance work, and repair CB 132HC602. Given the importance of this circuit breaker to system security, in our opinion this was the correct choice. No prior planning had been done for this work, so some time was taken to prepare a plan to isolate CB 132HC602 by the staff on site. This plan was not prepared in accordance with standard work instructions, and not signed off by the writer, checker or authorizer. As a result it is not possible to know whether it had been checked or approved. No Standard Switching Instruction existed to isolate any of the 132kV Hudson Creek circuit breakers.

The key decision is the sequence of opening the circuit breakers to isolate CB 132HC602. The relevant circuit breakers (in no particular order) are:

- Hudson Creek- 66kV circuit breaker CB 66HC706, 132kV circuit breakers CB 132HC902 and CB 132HC302
- Channel Island – 132kV circuit breakers CB 132CI1803 and CB 132CI1303

The order in which they were opened leading to the System black incident was:

1) CB 66HC706
2) CB 132HC302.

At which time CB 132CI1803, CB 132CI1303, CB 132CI1104 and CB 132CI604 then tripped on a Directional Earth Fault.

The order of opening these circuit breakers which would have allowed the isolation of CB602 and avoided the system black incident is:

1) CB 66HC706
2) The remaining circuit breakers except CB 132HC302
3) CB 132HC302.

In the sequence which led to the System black, opening CB 132HC302 leaves only one path for the power in Line A to go, which is through CB 132HC602. This circuit breaker has the white phase pole closed, and the red and blue poles open, which had the same effect on the protection system as seeing a Directional Earth Fault. At this point the protection system correctly tripped the circuit breakers in the Channel Island Substation.

4.2 Protection Operation

The protection system operated correctly, disconnecting the faulted circuits as required.

5 Performance History of Relevant Network Assets

5.1 Hudson Creek Circuit Breakers

5.1.1 Maintenance History

It is well known that up until the last 3 – 4 years the circuit breakers at Hudson Creek Substation (and others) had very little maintenance other than breakdown maintenance. Power Networks advised that there are no maintenance records prior to 2010.

The 132kV circuit breakers at Hudson Creek were installed in 1987. The original equipment manufacturer, Sprecher & Schuch, no longer supports this equipment, although now Alstom does offer some support. However Alstom does not produce a like for like product that can be simply exchanged for the existing circuit breakers.

In particular, because of the arrangement of the 132kV busbars at Hudson Creek, it is difficult to arrange extended outages of CB 132HC602 and CB 132HC603, as such outages compromise system security. However, Power Networks recognize the risk these circuit breakers impose on the system in their current state of repair and have developed solutions for their replacement. This will require an outage of several days to replace a circuit breaker, rather than several weeks which would be required to refurbish them in the situ. Twelve new poles have been ordered, nine of which will be installed and three will be retained as spares.

The maintenance tasks that have been carried out since 2010 confirm the poor condition of these circuit breakers as a result of the previous lack of maintenance. As these circuit breakers were inspected, the operating mechanisms were found to be in poor condition. This includes dry and seized mechanisms, seized trip arm bearings and rust in the mechanisms. Also slightly slow trip times and high contact resistance were identified. The records show these issues have been addressed. It is believed that the root cause of the failure to trip of the white phase of CB 132HC602 was a small amount of surface corrosion on a roller within the latching mechanism which prevented its operation, demonstrating the need for ongoing maintenance on these circuit breakers.

The next round of maintenance on these circuit breakers is planned for June 2014.

5.1.2 Previous Failures of Similar Equipment

CB 132HC602 failed in a similar manner in April 2012. CB 132HC603 failed in April 2012 and in September 2013. None of these previous failures led to a System black occurrence.

5.1.3 Other Network Assets Involved

While all the other network assets involved performed as expected, it would be prudent to ensure critical assets of similar age, such as those at the Channel Island Substation, have their maintenance up to date. It would also be prudent to review the timing of planned maintenance on these breakers, as it is assumed that the corrosion that caused the latching mechanism to fail developed between planned maintenance activities – it is noted that the breaker was close to its next planned maintenance activity in June 2014.

6 Generator Response

6.1 Response of the CIPS Generators

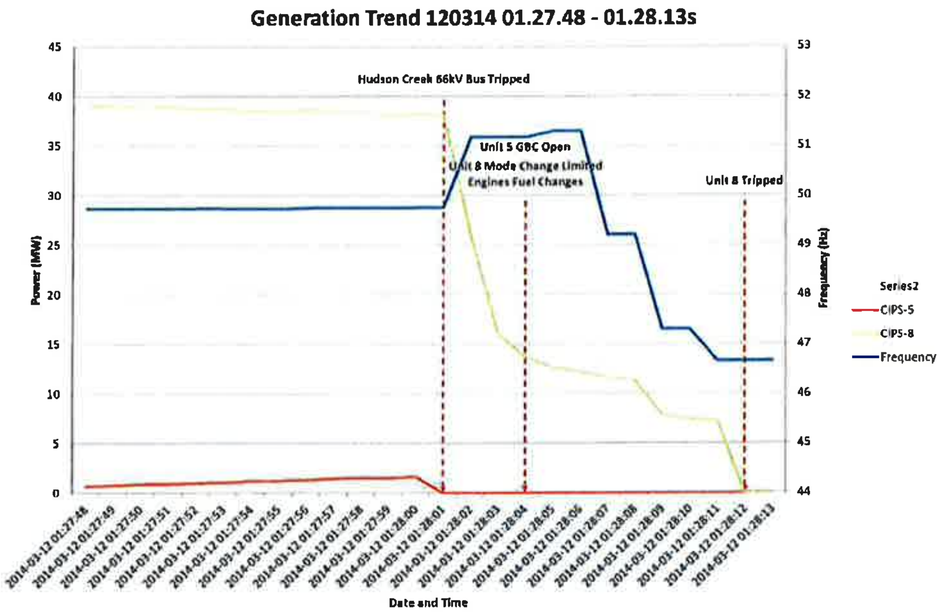
Table 6.1: Chronology of Response of CIPS Generators

Event	Unit 4	Unit 5	Unit 6	Unit 8
Last 132kV Breaker in Channel Island Switchyard Opens	01.21.35s	01.21.35s	01.21.35s	01.21.35s
Generator Circuit Breaker Opens	01.21.54s	01.21.52s	01.26.22s	
First 132kV Breaker in Channel Island Switch Closes. Channel Island reconnected to Hudson Creek	01.24.53s	01.24.53s	01.24.53s	01.24.53s
Generator Circuit Breaker Closes		01.29.34s		
Generator Circuit Breaker Opens		01.29.56s		01.30.03s

Table 6.1 sets out the chronology of the main events at Channel Island. Throughout this period Unit 8 in particular responded well, and would have provided a foundation to rebuild the system if the 66kV bus at Hudson Creek had not been stripped, see Figure 3.2.

Figure 6.1 shows the effect of stripping the 66kV bus at Hudson Creek on the two units on line at Channel Island Power Station. Unit 5 had only just synchronized and was increasing load to get to a stable operating point. Unit 8 was losing load as Unit 5 took load to maintain frequency at 49.73hz. It appears that Unit 5 lost load 1 second prior to the loss of the last 66kV feeder at Hudson Creek, but that is likely to be a data anomaly. Both Unit 5 and Unit 8 would have unloaded as the frequency increased due to the loss of load, as Figure 6.1 shows for Unit 8. However Unit 8 did not respond to the falling frequency as would normally be expected. This is probably the result of the mode change imposed by the control system which limited engine fuel changes. The importance of the operators understanding the conditions that trigger these mode changes and their consequences is highlighted by these events, as without that mode change Unit 8 may have been able to avoid an under frequency trip.

Figure 6.1: Generation Trends[2]



Consideration should be given to allow the control system to trip Unit 6 in the event that Units 4 and 5 trip, as its output can fluctuate significantly as it operates in pressure control mode to control pressure in the HRSGs, see Figure 3.2. This could de-stabilise the other units on the system, and in any case this unit can only provide a response for a short period of time without the gas turbines providing heat to the HRSGs. On this occasion Unit 8 did respond to minimize the effect of the variations of output from Unit 6.

None of the units demonstrated the ability to operate as an island supplying only the station auxiliaries. Having units in this condition speeds up restoration times, and should be considered for at least Units 4, 5, 8 and 9, as these are the most likely units to be operating at any time. Unit 8 did demonstrate that it can operate at loads below 5MW, which would be required for this type of operation. This will also need a full understanding of the operating modes that the unit control systems can impose under unusual operating conditions.

6.2 Response of the Weddell Generators

At the time of the incident, only Unit 1 at Weddell Power Station was on line. Unit 2 was unavailable due a gearbox problem, and GE had a maintenance permit on Unit 3 that required it to remain off line until the permit was returned. GE contractors attended the site in the morning and cleared the unit to start.

When the 132kV transmission lines from Channel Island to Hudson Creek tripped, the system load fell onto Unit 1 at Weddell. Clearly it couldn't supply this amount of load, although it did reach a load of some 101MW (generator electrical load, not GT output) before tripping on high vibration. The details of response of the Weddell Units during the restoration are set out in Section 3.2 and Section 3.4.2.

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[2] Note that this graph is based on the Channel Island Control system time, which 2 min 51 sec behind the System Control SCADA data used in Table 6.1

6.3 Response of the Katherine Generators

The Katherine generators were all off line at the time of the incident. Katherine was disconnected from the 132kV transmission line at 01.36, and staff called out. The black start generator started at 01.53, and Unit 1 was on line at 02.10, Unit 2 was on line at 02.19 and Unit 3 was online at 02.30. By 02.41 all Katherine customers were restored.

It was then decided to reconnect Katherine to Pine Creek and bring the Pine Creek generators on line. Katherine Transformer 1 was energized at 03.31, the 132kV line to Pine Creek was in service at 03.36, and the 66kV line from Pine Creek to Pine Creek Power Station was in service at 03.39.

The restoration of Katherine went well, and given the circumstances with minimal disruption to customers.

6.4 Response of the Pine Creek Generators

The Pine Creek Units 1 and 2 tripped at 01.21.57s. Unit 3 tripped at 01.30.14s, however it is not expected that it was generating for this period, as Unit 3 is a steam turbine relying on the exhaust from Units 1 and 2 to produce steam. It is unlikely appropriate quality steam could be produced for a period of 8 min 17 sec after Units 1 and 2 tripped, and it is probable the machine was motoring for some of this period. If that was the case it should have tripped on reverse power. An automatic trip on low steam temperature would assist but to our knowledge this has not been installed. Unit 1 at Pine Creek was on line at 04.17 and Unit 2 at 04.07. Pine Creek Unit 3 returned to service at 14.00.

6.5 Performance of the Generator Protection Systems

The generator protection systems worked as designed, with the possible exception of the reverse power trip on Pine Creek Unit 3.

7 Risk Mitigation Procedures followed by System Control

7.1 Risk Mitigation Standards and Procedures Adopted by System Control

System Control should follow standard procedures such as:

- System Control Operational Document – Work Instruction, Incident Management – Planned Outages, Request for Access
- SC 0.1.2 Writing Switching Instructions, System Control, Work Instruction
- System Control Operational Document – Work Instruction, Maintain Standards – Training and Accreditation, Direction and Recording of HV Switching Instructions
- Regulated Power System, Black System Procedures.

For the original planned maintenance work, System Control produced a System/Load at Risk Notification. This notification identified the following Risk Description/Contingency Plans, noting that Hudson Creek 132/66kV Transformer 1 is to be isolated:

- Loss of Hudson Creek 132/66kV Transformer 2, leading to
  - Overload Hudson Creek – Woolner 66kV Line to 129% (83MVA)
    - Utilise the 15 min short term rating of 90MW to do the following:
      - Manually shed load at Woolner and/or Casuarina to reduce line loading to below 64MVA
      - Recall Job to restore supply. (Recall time two hours).

Pre-requisites for this work to proceed included:

- No other 66kV or 132kV outages in the Darwin region
- Bus outage limited to the hours of 00.00 to 04.00
- Darwin load to be below 150MW

Loss of Channel Island generation was not considered to be a credible risk when preparing the System/Load at Risk Notification as there was no intention to operate CB 132HC602 to do work associated with the routine maintenance on Hudson Creek 132/66kV Transformer 1. There was a procedural failure here as the risk assessment did not consider the PRI under RFA 061158 which clearly required that CB 132HC602 be operated (incorrectly).

7.2 Implementation and Effectiveness of these Procedures

The effectiveness of these procedures broke down with the checking of the PRI for this work. The document sets out each step in the switching sequence that had to be taken to isolate the piece of plant that is to be worked upon. To isolate Hudson Creek 132/66kV Transformer 1, the circuit breakers involved are CB 132HC902 and CB 132HC903. However the PRI was prepared using CB 132HC602 rather than CB 132HC903. The following points can be made:

1) The PRI went through the review process, as set out in "SC 0.1.2 Writing Switching Instructions" up to the final step without this error being detected.

2) The "Final Check Before Dispatch" signature is missing off the PRI. Hence it is likely that this final check was not carried out.

3) The Standard Switching Instruction (SSI) to isolate Hudson Creek 132/66kV Transformer 1 was not used. The reason given for this was that additional work was to be carried out that involved the switching of two 66kV lines for which an SSI did not exist. As a result it was decided to develop a custom switching instruction for the entirety of this work.

4) The PRI that was prepared only covered the isolation of Hudson Creek 132/66kV Transformer 1, so the SSI could have been used. In any case it would have been good practice, though not mandatory, to have used the existing SSI as a starting point for the total PRI, which would have reduced the overall risk of developing a new PRI.

5) A subsequent PRI for the isolation of the two 66kV lines has not been sighted.

When CB 132HC602 failed, an emergency switching procedure was developed to isolate this circuit breaker. This is a hand written procedure on a blank sheet of paper, not signed off by the writer or checker (if it was checked). This would not be acceptable in the NEM, and is not in accordance with PWC's standard work instructions. Given that the system at that time was in a stable, if risky, situation, time should have been taken to prepare a properly checked and authorized PRI for this work. If additional staff were required to comply with SC 0.1.2, they should have been called out.

Further work was planned for the following night that did require the operation of CB 132HC602, so it is highly likely that this circuit breaker would have failed on that operation. It is a matter of conjecture as to whether this would have had the same consequences, as that depends on the resulting actions taken at that time.

8 Causal Factors

8.1 Other Factors contributing to the Occurrence and Severity of the Incident

The factors affecting Generation that extended the duration of the incident have been discussed above. However there were further actions by System Control immediately after the incident which made the restoration process more difficult. These include:

1) The "Close" command to CB 132HC302 was issued 29 sec after the incident. While not contributing to the severity of the incident it cannot have been a decision where the consequences of this action had been considered.

2) The decision to close Line B after 3 min 19 sec was appropriate.

3) The decision to close Line A after 5 min 48 sec was incorrect as it would have made VAR/Voltage control more difficult for the units on line at that time.

4) The decision to strip the 66kV busbar at Hudson Creek eventually led to the tripping of Unit 8. It was done to protect the unit against possible sudden load increases, but in fact removed the load that was stabilising Unit 8. Due to the meshed nature of the 66kV network, no load was lost as the Hudson Creek 66kV busbar was stripped until the last 66kV feeder was tripped, at which time all load was lost. It would have been preferable to separate the 66kV system into separate nodes which could have been tripped individually if necessary, and to return some Level 1 UFLS load to these nodes as soon as the online generation allowed. This would have allowed load to be shed automatically in the event of sudden load increases which resulted in under frequency. The load at the time was within Unit 8's capability to supply, and Unit 5 was also synchronised seconds before the 66kV load was lost and increasing load to a stable operating condition.

9 Speed of Response

9.1 Identification of Cause of the Incident

The cause of the incident was rapidly identified as result of the opening CB 123HC302 causing a phase unbalance resulting in a Directional Earth Fault trip of four 132kV circuit breakers at Channel Island Substation. The phase unbalance was due to the previous failure of CB 132HC602. There were then a number of further issues that exacerbated the severity of the incident, such as the failure of the black start generators at both Channel Island and Weddell Power Stations and the gas shutdown at Channel Island Power Station. These have been discussed previously.

9.2 Restoration Plan Development

The restoration plan development was in accordance with the document "Regulated Power System, Black System Procedures" Version 1. The key issues are set out in the section System Restoration Approach. It should be noted that this document should be updated annually. It has not been updated since being prepared in 2010.

9.3 Implementation of the Restoration Plan

The implementation of the Restoration Plan was delayed, mainly due to delays in the return to service of generation units, as discussed previously. While the restoration did follow the "Regulated Power System, Black Start Procedures" Version 1, concerns have been expressed about how priority customers are identified to set restoration priorities.

There were issues involving emergency generators at System Control and at the Mitchell Centre. At the Hudson Creek Control Room, the emergency generator initially ran only intermittently. Staff were called out to fix this problem, and were able to bring it into service before the UPS batteries fully discharged. This generator now appears under sized, as additional loads have been added over time. This meant that the communications/SCADA room was not being cooled, which has the potential to shut down the SCADA system. The capacity and reliability of this generator should be reviewed.

Internet services were not available at Hudson Creek from 05.44 until 07.26. This would have caused difficulties for the Crisis Management Team.

The emergency generator in the Mitchell Centre also failed. Levels 6 & 7 of this facility were without power from 04.17 until 07.14.

9.4 Communications with External Parties

The communications with external parties was managed through the Crisis Management Team and their support at Hudson Creek. The ability to obtain assistance from other divisions of PWC and from government sources would have assisted with this task. The minutes from the Crisis Management Team meetings held throughout the period of disruption indicate that this element was well managed.

10 Power System Restoration

10.1 Time to Restore

The restoration of the Katherine system was managed well, with all customers restored approximately 1 h 20 min after the incident. The Darwin system is much more complex, and takes more time to restore. However delays did occur, mainly due to delays in returning generating units to service as described earlier.

10.2 Sequence of Restoration

The sequence of restoration was developed in keeping with the principles set out set out in the "Regulated Power System, Black Start Procedures" Version 1 as follows:

- Stabilise remaining energised systems
- Restore power supply to power stations
- Establish and extend power system islands
- Progressively re-energise and reconnect.

10.3 Prioritisation of Restoration

The "Regulated Power System, Black Start Procedures" Version 1 sets out the priority for restoration as follows:

Priority order of restoration will be

- Load adjacent to power stations to achieve local island stability
- Early stage UFLS loads to protect against further failures
- Hospitals and nursing homes
- Emergency services coordination centres
- Loads that represent clear and present risks to public safety, such as key water supply pumps, key sewage facilities, key road intersections, or disaster community centres
- Loads that present as significant meeting, congregation or food dispersal areas
- Domestic load areas
- CBD and small commercial load areas
- Large commercial and industrial areas.

This is a logical priority for system restoration, but should be reviewed on an annual basis to account for changed circumstances. For example, with more people living in high rise buildings in the CBD, its place in the priority may need review, given their reliance on power for water, lifts and ventilation. However, it can't be advanced up the priority list beyond the system's ability to service the load, or there is significant risk that further load shedding will occur.

11 Recommendations to Avoid a Recurrence

11.1 Design of the Power System

The design of the power system was not the major contributor to the incident, although the design of the Hudson Creek 132kV switchyard does add an extra element of risk. With either of CB 132HC602 or CB 132HC603 out of service, the opening of any other 132kV circuit breaker at Hudson Creek will reduce the power that can flow through to the 66kV system and may lead to a complete loss of supply from Channel Island and potentially System black.

An example of these consequences is demonstrated in the Table 11.1.

Table 11.1: CB 132HC602 Out of Service, Consequence of a Further 132kV Circuit Breaker at Hudson Creek Opening

Circuit Breaker Opening	Consequences
CB 132HC302	Only Line B from Channel Island can bring power to Hudson Creek. Transfer capacity limited to 266MW instead of 532MW.
CB 132HC303	As for CB 132HC302.
CB 132HC603	Complete separation of Hudson Creek 66kV system from Channel Island. Very high likelihood of System black.
CB 132HC903	Only 132/66kV Transformer 3 receiving power from Channel Island. Transfer capacity limited to 125MW instead of 375MW
CB 132HC902	Only 132/66kV Transformers 1 and 3 receiving power from Channel Island. Transfer capacity limited to 250MW instead of 375MW.

A similar table could be developed for CB 132HC603 being out of service.

The high risk to the power system of such a single contingency failure during maintenance on one of these circuit breakers means that it is difficult to get maintenance outages of more than a few hours and only at the time of minimum system load (00.00 – 04.00).

The report "Investigating Report Arising from Black System of 30 January 2010" did recommend that system islanding schemes be implemented based on under-voltage and under-frequency schemes located at strategic locations, as restoring the system from a function power island significantly reduces recovery time. Specific points for resynchronizing the island need to be developed. These schemes have not been implemented, but should be as a high priority.

Also generating units did not demonstrate that they are able to separate from the system remain at full speed and continue supplying their own auxiliaries. Units in this state rather than at stand still will allow quicker system recovery. Unit 8 came closest, surviving a load rejection from ~30MW to ~4MW, but it remained synchronized to the system, supplying Katherine and places in between. Operating procedures should be developed for this mode of operation, and regular, say annual tests done to demonstrate the ability to operate successfully in this mode. This is a high priority.

The CIPS control system should be modified to ensure Unit 6 trips if both Units 4 and 5 trip. Unit 6 can only continue to generate for a short period of time after Units 4 and 5 trip, but is subject significant load variations which can de-stabilise other machines. This is a medium priority.

While the idea of supplying power from Katherine and /or Pine Creek to start Channel Island was raised at the time of the incident, it was considered too risky to try. The technical consideration is the capacitance of that long length of line, and whether it would be possible to control voltage at the Channel Island end. Initially this solution should be modelled, to determine if it is practical, and if not what is required to develop a safe solution. This is a medium priority.

11.2 Power System Operations

There are a number of improvements identified in the area of power systems operation. These include:

- The checking of PRI's must be more than a "tick and flick" exercise. The PRI developed for the original planned maintenance work contained a serious error that had passed through all but the last of the checking and approval processes. The last of the checking processes, the "Final Check before Dispatch" had not been signed, so it is assumed it wasn't carried out. This should have been enough for the work not to proceed until the appropriate checks and sign offs were all obtained.
- There appears to be a lack of experience in dealing with the results of a significant incident of this type. Many of the issues are set out in the Black System Procedure, including
  - Inrush current
  - Generator stability at low loads
  - Generator lockout
  - Transmission line capacitance
  - Interconnection of power islands.

  However not all of these were considered in the response to this incident.
- For system control staff this is an opportunity to increase training activities to raise confidence when dealing with these infrequent but high consequence events. PWC has invested in a simulator, which is an ideal tool to deliver this training. It is recognized that a significant programming effort may be required to develop the simulator for this training, but regular, realistic training is the best preparation for these events. The training could then be extended to include joint training with the power station teams and the Crisis Management Team. This is a high priority.
- There is a need to conduct annual reviews of "Regulated Power System, Black Start Procedures" to ensure they remain relevant. A major review should be undertaken urgently, as the system has changed significantly since 2010 with new generators, zone substations and sub transmission lines being added. Given its significance this could be included in a future Power System Review. This is a high priority.

11.3 Maintenance Practices

The main issue identified with maintenance practices on the network is the need to deal with plant items such as CB 132HC602 and CB 132HC603, which are a high risk to system security when out of service. However, it is not realistic not to do maintenance and expect high reliability out of this equipment.

For these items in particular, given their age and lack of maintenance for most of their life, consideration should be given to replacing both of them as a high priority. It is understood that 12 new poles are on order, to replace these two breakers, and have a spare new breaker. It is understood that the intention is to refurbish the breakers removed and then replace the remaining breakers with the refurbished breakers. This approach is supported. Replacing both CB 132HC602 and CB 132HC603 with new equipment as soon as possible would reduce the risk to system security from these breakers, and would allow a more rapid program to refurbish the other less critical, but still important breakers at Hudson Creek.

There are a number of issues with generation plant that have been identified earlier in the report. These include:

- A full review of the Field Control Stations (FCSs) at Channel Island to ensure that there are not more issues that affect the systems around the generating units such as the black start generator and gas supply system. This is a high priority.
- The Kongsberg black start generator needs a full investigation into its reliability problems, so a decision can be made whether to keep it in service or not. If it is to be kept in service it needs to be fully reliable. This is a high priority until the Cummins unit is permanently installed and proved reliable.
- Weddell Power Station is still experiencing reliability issues, and needs a concerted effort to overcome these. In particular the gas regulating valves should be replaced with a more reliable design, such as Gorter brand valves. This is a high priority.

12 Impact of Gas Supply on Restoration Duration

12.1 External Gas Supply

There was no problem with the supply of gas external to the power stations. At Channel Island, although gas was cut off in APA's facility, this was as a result of a control system signal from Channel Island Power Station to the Emergency Shutdown Valves in APA's facility. Without that signal from Channel Island, which should not have occurred, there would have been no gas interruption to the power station. However, once these valves had closed, it required an APA technician from Darwin to reset the valves.

There were no issues identified with APA's equipment at Weddell.

12.2 Gas Supply Internal to the Power Stations

There were no issues with gas supplies internal to Channel Island Power Station, apart from the control signal to the ESD valves.

Weddell had numerous issues with gas supply. Mainly this consisted of leaking regulating valves which allows gas to pressurize the pipework between the regulating valves to a pressure above where the control system will allow a start to occur. This has been a problem since commissioning of the units. There are two possible solutions to this issue:

1) Ensure that the control system high gas pressure alarm/control point is set as high as GE will allow (understood to be 5,516kpa). This point may be above where the control point is currently set, and could provide a greater pressure range before the high pressure trip is activated.

2) Replace the regulating valves with a more reliable valve, e.g. a Gorter brand valve. After 7 years of unreliable service, it appears unlikely that the current valves will ever be reliable.

This issue is a high priority issue.

13 Subsequent Investigations

Throughout this report a number of investigations have been identified that should be undertaken. These are listed below.

1) APA has recommended that PWC should not be relying on their ESD system and that it is not good practice to rely on third party isolations. An analysis of the costs and benefits to justify such an investment should be carried out. Priority: Medium.

2) The condition and operation of the standby power systems at CIPS should be undertaken to ensure reliability for control systems, field control stations and critical items of equipment such as lubricating oil and baring drives. Priority: Medium.

3) Studies should be undertaken to determine whether or not Katherine Power Station can be used to black start Channel Island Power Station. If not what is required to do so safely and effectively, and is the cost justified. Priority: Medium.

4) An investigation into the benefits of tripping Unit 6 if Units 4 and 5 are tripped should be undertaken. Unit 6 has only a short period of generation after such an event, and in this case experienced significant load swings which could de-stabilise other online units. Priority: Medium.

5) Procedures have not been developed for connect Channel Island Units 8 and 9 on to a dead busbar. The design of these units should be reviewed to confirm that they are capable of this, or if they are what is required to enable them to do so safely. The appropriate procedures should then be developed, and a regular testing program implemented. Priority: Medium

14 Overall Conclusions

The System black that occurred on the Darwin – Katherine system on 12 March 2014 is directly attributable to the actions taken in response to the failure of CB 132HC602 in Hudson Creek Substation. While the failure of this circuit breaker was the initiating event that led to the System black, this failure did not of itself cause the System black, as demonstrated by the fact that the system continue to operate in a stable, if risky, configuration until further actions were taken some 40 min after the failure of this circuit breaker. It is Evans & Peck's opinion that the original PRI and the emergency switching procedure developed to repair CB 132HC602 were not compliant with PWC's standard work instructions. Had these standard work instructions been complied with, it is likely that this System black incident would not have occurred.

The duration of the System black was extended by difficulties at both Channel Island and Weddell Power Stations preventing the rapid return to service of the available units. The reasons for this have been discussed previously. A number of recommendations are provided that will assist in preventing a recurrence of these delays.

PWC staff has also identified areas for improvement. Some of these have been completed; others are work in progress while others are yet to be commenced. A comprehensive implementation plan is required for these initiatives, which includes appropriate report obligations to the PWC executive management and board, the Utilities Commission and the Government.

15 Recommendations

15.1 System Operations

- The standard work procedures used by System Control should be reviewed to ensure there is a clear separation of responsibilities between the writer, checker and approver of PRIs, all of whom should be different staff members. The qualifications and position required to be able to fill those positions should also be defined. Priority: High.
- The procedures need to ensure that a PRI cannot move to the next step without the appropriate sign off from the previous step. This includes release to the field staff. Priority: High.
- The report "Investigating Report Arising from Black System of 30 January 2010" recommended system islanding schemes be implemented based on under-voltage and under-frequency schemes located at strategic locations. These recommendations should be reviewed to take account of the present system configuration and then implemented. Priority: High.
- Development of the simulator should be undertaken so that simulator training can be undertaken for incidents such as System black, which include replaying past System black events. A review of the training provided to system control staff should be carried out to ensure it meets the current needs of the system. Priority: High.
- Annual reviews of the "Regulated Power System, Black Start Procedures" should be undertaken to ensure they remain relevant. Given that this document has not been revised since it was produced in 2010, a comprehensive review is required urgently to update these procedures to reflect the current network and generating plant. Priority: High.
- The capacity and reliability of the emergency generator at Hudson Creek should be reviewed, and capacity increased if required. Priority: High

15.2 Channel Island Power Station

- The reasons for the unreliability of the Kongsberg black start unit should be identified and rectified; at least until the Cummins unit is permanently installed in its final location and has been proven reliable. This unit should be maintained as second black start generator, and as such needs to reliable. Priority: High.
- A full review of the field control stations at Channel Island is required to ensure further occurrences of this type do not reoccur, particularly during reboots after loss of power. Priority: High.
- Operating procedures should be developed that allow the units come off line but stay at full speed and supply auxiliaries – island mode. Units in this condition can be restored to load more rapidly than units in a shutdown condition. Priority: High.

15.3 Weddell Power Station

- Critical systems at Weddell Power Station should be monitored by the DCS system. This event has shown that the status of systems such as the black start generator, the air compressors and AVR's are not monitored. (If they are already monitored by the DCS system the fault is with the operators who are not responding to the indications provided). A full review of the DCS monitoring processes should be carried out. Priority: High.

- The gas regulating valves at Weddell Power Station should be replaced with more reliable valves. Priority: High.
- The high gas pressure settings in the control systems at Weddell Power Station should be reviewed to ensure that they are set as high as GE will allow, and if not reset to this value. Priority: High.
- Operating procedures should be developed that allow the units come off line but stay at full speed and supply auxiliaries – island mode. Units in this condition can be restored to load more rapidly than units in a shutdown condition. Priority: High.

15.4 Network

- The replacement of CB 132HC602 and CB 132HC603 should be pursued as a matter of urgency. Priority: High.
- The refurbishment/replacement of the remaining 132kV circuit breakers should be programmed. Priority: Medium.
- The period between planned maintenance on the 132kV circuit breakers at Hudson Creek should be reviewed. The corrosion that caused the failure of CB 132HC602 has developed since the previous inspection, so more frequent inspections may be justified. This should also include similar equipment at Channel Island Substation. Priority: Medium.

15.5 General

- Problems were experienced with black start generators at Channel Island Power Station (2 units), Weddell Power Station, Hudson Creek Control Centre and the Mitchell Centre. This indicates a lack of attention to this equipment. A review of the capacity, reliability and testing regimes of this equipment should be carried out. Priority: High

EVANS & PECK

Appendix A

Request for Access

Entered ✓

DAY	DATE	OPC	AFTERNOON	NIGHT
1	6/3	[redacted]		[redacted]
2	7		[redacted]	
3	8			
4	9			
5	10			
6	11			

Operator Planned to Switch:	FAX:	CUSTOMER ADVISED BY				No. AFFECTED
FIELD OPERATOR	PICK UP HERE	ADVERTISED: Y / N	PH	CARD	PRESS	RADIO

SHUTDOWN DAY / DATES	TIME FROM	TIME TO
MONDAY		
TUESDAY		
WEDNESDAY 12th MAR → 13th MAR	23:30	05:00
THURSDAY		

SHUTDOWN DAY / DATES	TIME FROM	TIME TO
FRIDAY		
SATURDAY		
SUNDAY		
EVENT NUMBER	Approved	

FURTHER INSTRUCTIONS AND NOTES:	DATE / INITIAL
* FOR SYSTEM REQUIREMENTS PURPOSES, PLEASE WRITE PRI TO CARRY OUT WORKS ON RAA 06115B FIRST THEN ON SAMPLE ON 208, 711 SAMPLING LAST.	
Risk Notice Attached	
[redacted]	

Operator Required		Testers		Live Line		Multiple days			

PowerWater

System Control
System/Load at Risk Notification

RFA No.: 061158, 061160

Overall Risk Level: [redacted]

Start Date (dd/mm/yy): 11/03/14 Tue

Start Time (hh:mm): 23:00

End Date (dd/mm/yy): 12/03/14 Wed

End Time (hh:mm): 5:00

Recall Time: 2 Hour

Outage Reason: Oil Sampling of Various Assets

Transmission Elements Out of Service

- Part A: Hudson Creek Bus B (Inclusive of: HC 132/66kV TF1)
- Part B: Hudson Creek - Woolner 66kV Line
- Part C: Hudson Creek - Archer 66kV Line

Effects on System:

- Part A: Hudson Creek is operating as a split bus arrangement. Hudson Creek has a firm capacity of 135 MVA. Weddell Generation is required to be online.

- Part B: Hudson Creek - Woolner 66kV Line is out of service.

- Part C: Hudson Creek - Archer 66kV Line is out of service. Weddell limited to 80 MVA (2 Machines).

Pre-requisites:

System Control
- No other 66kV or 132kV outages in the Darwin Region.
- Bus outage (Part A) is limited to be completed between 0000 and 0400. **Darwin loading** (Load on Hudson Creek Transformers and Weddell Generation) **is to be below 150MW for Part A to proceed.**

Generation
- At least one (1) Weddell machine is to be available. Weddell will be dispatched to maintain load transfer on 132/66kV Hudson Creek transformers below 135 MVA.

Networks
- Ensure the outage can be returned to service within recall time in the event of a contingency.

Risk Description/Contingency Plans:

- Loss of Hudson Creek132/66 kV Transformer 2 (T2):
  - Will overload Hudson Creek - Woolner 66kV Line to 129% (83MVA).
  - Utilise the 15 minute short term rating of 90 MVA to do the following:
    - Manually shed load at Woolner, and/or Casuarina (See below) to reduce line loading to below 64 MVA.
  - Recall Job to restore supply. (Recall Time = 2 Hours)

Loads at Risk:

Substations:	MW at Risk
Woolner Zone Substation (Including: Winnellie, Fannie Bay, Coonawarra, Parap)	Upto 10 MW
Casuarina Zone Substation (Including: Nightcliff, Marrara, Nakara, Brinkin, Moil)	Upto 20 MW

From System Controller

Sender: [redacted]

PowerWater

System Control
System/Load at Risk Notification

RFA No.	061158, 061160	**Overall Risk Level:**	[illegible]
Start Date (dd/mm/yy):	12/03/14 Wed	**Start Time (hh:mm):**	23:00
End Date (dd/mm/yy):	13/03/14 Thu	**End Time (hh:mm):**	6:00
Recall Time:	2 Hour		
Outage Reason:	Oil Sampling of Various Assets		

Transmission Elements Out of Service

- Part A: Hudson Creek Bus B (Inclusive of: HC 132/66kV TF1)
- Part B: Hudson Creek - Woolner 66kV Line
- Part C: Hudson Creek - Archer 66kV Line

Effects on System:

- Part A: Hudson Creek is operating as a split bus arrangement. Hudson Creek has a firm capacity of 135 MVA. Weddell Generation is required to be online.

- Part B: Hudson Creek - Woolner 66kV Line is out of service.

- Part C: Hudson Creek - Archer 66kV Line is out of service. Weddell limited to 84 MVA (2 Machines at Full Load).

Pre-requisites:

System Control
- No other 66kV or 132kV outages in the Darwin Region.
- Bus outage (Part A) is limited to be completed between 0000 and 0400. **Darwin loading** (Load on Hudson Creek Transformers and Weddell Generation) **is to be below 150MW for Part A to proceed.**

Generation
- At least two (2) Weddell machines are to be available. Weddell will be dispatched to maintain load transfer on 132/66kV Hudson Creek transformers below 135 MVA.

Networks
- Ensure the outage can be returned to service within recall time in the event of a contingency.

Risk Description/Contingency Plans:

- Loss of Hudson Creek132/66 kV Transformer 2 (T2):
  - Will overload Hudson Creek - Woolner 66kV Line to 139% (90MVA)
  - Utilise the 15 minute short term rating of 90 MVA to do the following:
    - Manually shed load at Woolner, City Zone, Frances Bay and/or Casuarina to reduce line loading to below 64 MVA.
  - Recall Job to restore supply. (Recall Time = 2 Hours)

Loads at Risk:

Substations:	**MW at Risk**
Various Zone Substations (Manual Load Shed Post Contingent)	Upto 30MW

From System Controller

Sender: [redacted]

PowerWater **PREPARATION AND RESTORATION INSTRUCTION** RFA No. *061158*

REGION *DARWIN* AREA *HUDSON CREEK* System Control PRI No. *3/21*

DATE *12/3/14* **OUTAGE TIME AS ADVERTISED** *2330* TO *0300* OUTAGE TIME 2 TO

BUSINESS UNIT *NETWORKS* OUTAGE TIME 3 TO

LOCATION / DESCRIPTION: **OIL SAMPLES FROM 66KV VT BUS B, 66KV VT TF1 AND CB 66HC205**

OPERATORS: RADIO No.: **INITIALLY CREATED BY/ DATE:** [redacted]

START TIME: *2300* PERMIT TIME: **CHECKED BY** [redacted]

WORKS ORDER No. : **FINAL CHECK BEFORE DISPATCH (Signature)**

Isolation Points (refer to Permit tag steps below)

HAZARD IDENTIFICATION

I am an authorised High Voltage Controller / Operator and will only be performing steps on this instruction that my Authorisation allows.
I will inspect each site covered in this instruction for hazards associated with, but not limited to, the items below.
Each step will be signed off to indicate that I have carried out the required hazard identification.

Name: **Signature:**

Electrical Hazards	Worksite Hazards	Environment Hazards	Environmental Hazards
Voltage/fault Levels Sticks/Equipment in Test Faulty Apparatus	Poles/Lines Hardware/Clearances	Traffic/Access Weather/Vegetation	Oil Leaks/Pollution Trenches Refuse

Controls	Hazards

Item	Sub	ADDRESS / LOCATION	EQUIP.	NUMBER	OPERATION	TIME/SIG.
			Disable all ARC's in yard			
1.		HUDSON CREEK	TF' S	2 AND 3 ✓ ✓	CHECK IN SERVICE	
2.		HUDSON CREEK	COOLING FANS / PUMPS	TF 2 most	SELECT MANUAL AND ON	0037
3.		HUDSON CREEK	COOLING FANS / PUMPS	TF 3 F0 ll. F0 ll.	SELECT MANUAL AND ON	
4.		HUDSON CREEK	OLTC'S	TF 1, 2, 3	SELECT MANUAL AND RAISE IF REQUIRED	
5.		HUDSON CREEK	CB	66 HC 705	OPEN AND TAG SCADA	0037
6.		HUDSON CREEK	CB	132 HC 602	OPEN AND TAG SCADA	0038
7.		HUDSON CREEK	CB	132 HC 902	OPEN AND TAG SCADA	
8.		HUDSON CREEK	CB	66 HC 205	CHECK OPEN AND TAG SCADA	
9.		HUDSON CREEK	CB	66 HC 507	OPEN AND TAG SCADA	
10.		HUDSON CREEK	CB	66 HC 704	OPEN AND TAG SCADA	
11.		HUDSON CREEK	CB	132 HC 602	CHECK OPEN AND SELECT LOCAL	
12.		HUDSON CREEK	CB	132 HC 902	CHECK OPEN AND SELECT LOCAL	

ITEM	Sub	ADDRESS / LOCATION	EQUIP.	NUMBER	OPERATION	TIME/SIG.
13.		HUDSON CREEK	ISOL	132 HC 1101	OPEN AND TAG	
14.		HUDSON CREEK	CB	132 HC 602	SELECT REMOTE	
15.		HUDSON CREEK	CB	132 HC 902	SELECT REMOTE	
16.		HUDSON CREEK	CB	132 HC 602	DETAG SACDA AND CLOSE	
17.		HUDSON CREEK	CB	132 HC 902	DETAG SACDA AND CLOSE	
18.		HUDSON CREEK	CB	66 HC 507	CHECK OPEN AND SELECT LOCAL	
19.		HUDSON CREEK	ISOL	66 HC 506	OPEN AND TAG	
20.		HUDSON CREEK	CB	66 HC 704	CHECK OPEN AND SELECT LOCAL	
21.		HUDSON CREEK	ISOL	66 HC 604	OPEN AND TAG	
22.		HUDSON CREEK	CB	66 HC 205	CHECK OPEN AND SELECT LOCAL	
23.		HUDSON CREEK	ISOL	66 HC 105	CHECK OPEN AND TAG	
23a			Isol	66HC305	Open + Tag	
24.		HUDSON CREEK	66KV VT	BUS B	ISOLATE VT SECONDARIES AND TAG	
25.		HUDSON CREEK	66 KV VT	TF 1	ISOLATE VT SECONDARIES AND TAG	
26.		HUDSON CREEK	66 KV VT	TF 1	TEST AND EARTH	
27.		HUDSON CREEK	66 KV VT	TF 1	ERECT SAFETY BARRIERS AND SIGNS	
28.		HUDSON CREEK	66KV VT	BUS B	TEST AND EARTH	
29.		HUDSON CREEK	66KV VT	BUS B	ERECT SAFETY BARRIERS AND SIGNS	
30.		HUDSON CREEK	CB	66 HC 205	TEST AND EARTH	
31.		HUDSON CREEK	CB	66 HC 205	ERECT SAFETY BARRIERS AND SIGNS	

Check no other works in progress effecting this permit area

		WORKSITE	**EQUIP**		**ISSUE REQUIRED PERMIT**	
FIELD No:		**PERMIT NO:**	**ISSUED BY:**		**DATE/TIME:**	
FIS No:		**OUTAGE:**		**ISSUED TO:**		
		WORKSITE	**EQUIP**		**CANCEL PERMIT DATE/TIME**	

Return to Service Sheet No. _____ Received from ____________________ Date____/____/____

32.		HUDSON CREEK	CB	66 HC 205	REMOVE EARTHS	
33.		HUDSON CREEK	CB	66 HC 205	REMOVE BARRIERS AND SIGNS	

ITEM	Sub	ADDRESS / LOCATION	EQUIP.	NUMBER	OPERATION	TIME/SIG.
34.		HUDSON CREEK	66KV VT	BUS B	REMOVE EARTHS	
35.		HUDSON CREEK	66KV VT	BUS B	REMOVE BARRIERS AND SIGNS	
36.		HUDSON CREEK	66 KV VT	TF 1	REMOVE EARTHS	
37.		HUDSON CREEK	66 KV VT	TF 1	REMOVE BARRIERS AND SIGNS	
38.		HUDSON CREEK	66KV VT	BUS B	DETAG AND RESTORE	
39.		HUDSON CREEK	66 KV VT	TF 1	DETAG AND RESTORE	
40.		HUDSON CREEK	ISOL	66 HC 105	DETAG AND LEAVE OPEN	
40a				66 HC 305	Detag + Close	
41.		HUDSON CREEK	CB	66 HC 704	CHECK OPEN AND SELECT LOCAL	
42.		HUDSON CREEK	ISOL	66 HC 604	DETAG AND CLOSE	
43.		HUDSON CREEK	CB	66 HC 704	SELECT REMOTE	
44.		HUDSON CREEK	CB	66 HC 507	CHECK OPEN AND SELECT LOCAL	
45.		HUDSON CREEK	ISOL	66 HC 506	DETAG AND CLOSE	
46.		HUDSON CREEK	CB	66 HC 507	SELECT REMOTE	
47.		HUDSON CREEK	CB	132 HC 602	OPEN AND TAG SCADA	
48.		HUDSON CREEK	CB	132 HC 902	OPEN AND TAG SCADA	
49.		HUDSON CREEK	CB	132 HC 602	CHECK OPEN AND SELECT LOCAL	
50.		HUDSON CREEK	CB	132 HC 902	CHECK OPEN AND SELECT LOCAL	
51.		HUDSON CREEK	ISOL	132 HC 1101	DETAG AND CLOSE	
52.		HUDSON CREEK	CB	132 HC 602	SELECT REMOTE	
53.		HUDSON CREEK	CB	132 HC 902	SELECT REMOTE	
54.		HUDSON CREEK	CB	132 HC 602	DETAG SACDA AND CLOSE	
55.		HUDSON CREEK	CB	132 HC 902	DETAG SACDA AND CLOSE	
56.		HUDSON CREEK	CB	66 HC 507	DETAG SACDA AND CLOSE	
57.		HUDSON CREEK	CB	66 HC 704	DETAG SACDA AND CLOSE	
58.		HUDSON CREEK	OLTC'S	TF 1, 2, 3	CHECK ON SAME TAP AND ADJUST IF REQUIRED	
59.		HUDSON CREEK	CB	66 HC 704	DETAG SACDA AND CLOSE	

ITEM	Sub	ADDRESS / LOCATION	EQUIP.	NUMBER	OPERATION	TIME/SIG.
60.		HUDSON CREEK	COOLING FANS / PUMPS	TF 2	SELECT AUTO	
61.		HUDSON CREEK	COOLING FANS / PUMPS	TF 3	SELECT AUTO	
Restore all ARC's						
62.						
63.						
64.						

PowerWater	REQUEST FOR ACCESS	RFA No: [redacted]8

BUSINESS UNIT	POWER NETWORK'S	REGION/LOCATION	NORTH

REQUEST FOR ACCESS DETAILS

Request for work or test is required on the following (please tick as appropriate):

ELECTRICAL	High Voltage		MECHANICAL		TESTING		HV LIVE LINE WORK	
	Low Voltage						VEGETATION MANAGEMENT	
	Communications							
CONFINED SPACE		HOT WORK	OPERATIONAL CHECKS		SCAP		AUTHORITY TO WORK IN THE VICINITY	

SEE BELOW	Person to be in charge of work or test or operational check	Proposed date of work or test		
Work order No	Name: [redacted]		DD / MM / YYYY	TIME
Recall time (Hrs) 2 HR'S	Business Unit/company: [redacted]	From	12 / 03 / 2014	0900
	Contact details: [redacted]	To	13 / 03 / 2014	0300

23:30

HUDSON CREEK Z.SS 132/66KV TF-1, 66KV BUS-B, HC-SN LINE-1 NOW A SPARE LINE 66KV (OPERATOR REQ)

66HC 705 V.T. OIL SAMPLE REQ W/O 603818
66 BUS-B V.T. OIL SAMPLE REQ W/O 600270
66 HC205 C/B OIL SAMPLE REQ W/O 581525

Proposed isolation points		Apparatus	Apparatus No		Apparatus	Apparatus No		Apparatus	Apparatus No
	1	ISOL	132HC 1101	4	ISOL	66HC 105	7		
	2	ISOL	66HC 506	5	ASSOCIATED	VT'S	8		
	3	ISOL	66HC 604	6			9		

Comments:

Breaking of conductors involved?	YES	NO	Where broken:		
Phasing out/rotation check required?	YES	NO	Members of work party available to carry out PSP	YES	NO
Risk of trip to in-service apparatus?	YES	NO	Notification required of interruption to customer supply?	YES	NO
Work subject to weather?	YES	NO	Motor/equipment heaters out of service?	YES	NO
LV isolation/streetlights?	YES	NO	Install temporary generator/mobile transformer?	YES	NO
Testing required (provide details)?	YES	NO	Amendments to operational diagrams required?	YES	NO

NAME: [redacted]	SIGNATURE: [redacted]	DATE: 20/2/14	TIME: 1300
Position: [redacted]	Contact details: [redacted]		

NAME: [redacted]	SIGNATURE: [redacted]	DATE: 5/3/14	TIME:
APPROVED: YES / NO	Contact details:		

Comments: REQUIRED - AP

The above work or test is approved to proceed WITHOUT an access authority	Op checks	Specified work/test	
CONTROLLER NAME:	SIGNATURE:	DATE:	TIME:
Person in charge of work or test			
NAME:	SIGNATURE:	DATE:	TIME:
Work or test completed			
NAME:	SIGNATURE:	DATE:	TIME:

PowerWater

REQUEST FOR ACCESS

RFA No: 061160

BUSINESS UNIT	POWER NETWORK'S	REGION/LOCATION	NORTH

Request for work or test is required on the following (please tick as appropriate):

ELECTRICAL	High Voltage	✓	MECHANICAL		TESTING		HV LIVE LINE WORK	
	Low Voltage						VEGETATION MANAGEMENT	
	Communications							
CONFINED SPACE		HOT WORK		OPERATIONAL CHECKS		SCAP	AUTHORITY TO WORK IN THE VICINITY	

SEE BELOW		Person to be in charge of work or test or operational check	Proposed date of work or test				
Work order No		Name: [redacted]	THUR	DD	MM	YYYY	TIME
Recall time (Hrs)	1 HR	Business Unit/Company: SS	From	13	03	2014	0300
		Contact details: [redacted]	To	13	03	2014	0500

HUDSON CREEK ZSS HC - WN 66KV LINE
HC - AR 66KV LINE
OPERATOR REQ

OIL SAMPLES REQUIRED FROM 66HC208 C/B W/O 604028
66HC711 C.T.'s W/O 604001

Proposed isolation points		Apparatus	Apparatus No		Apparatus	Apparatus No		Apparatus	Apparatus No
	1	ISOL	66HC611	4	ISOL	66HC10E	7		
	2	ISOL	66HC811	5	ISOL	66HC20E	8		
	3			6			9		

AIP

Comments:

Breaking of conductors involved?	YES	NO	Where broken:		
Phasing out/rotation check required?	YES	NO	Members of work party available to carry out PRI?	YES	NO
Risk of trip to in-service apparatus?	YES	NO	Notification required of interruption to customer supply?	YES	NO
Work subject to weather?	YES	NO	Motor/equipment heaters out of service?	YES	NO
LV isolation/streetlights?	YES	NO	Install temporary generator/mobile transformer?	YES	NO
Testing required (provide details)?	YES	NO	Amendments to operational diagrams required?	YES	NO

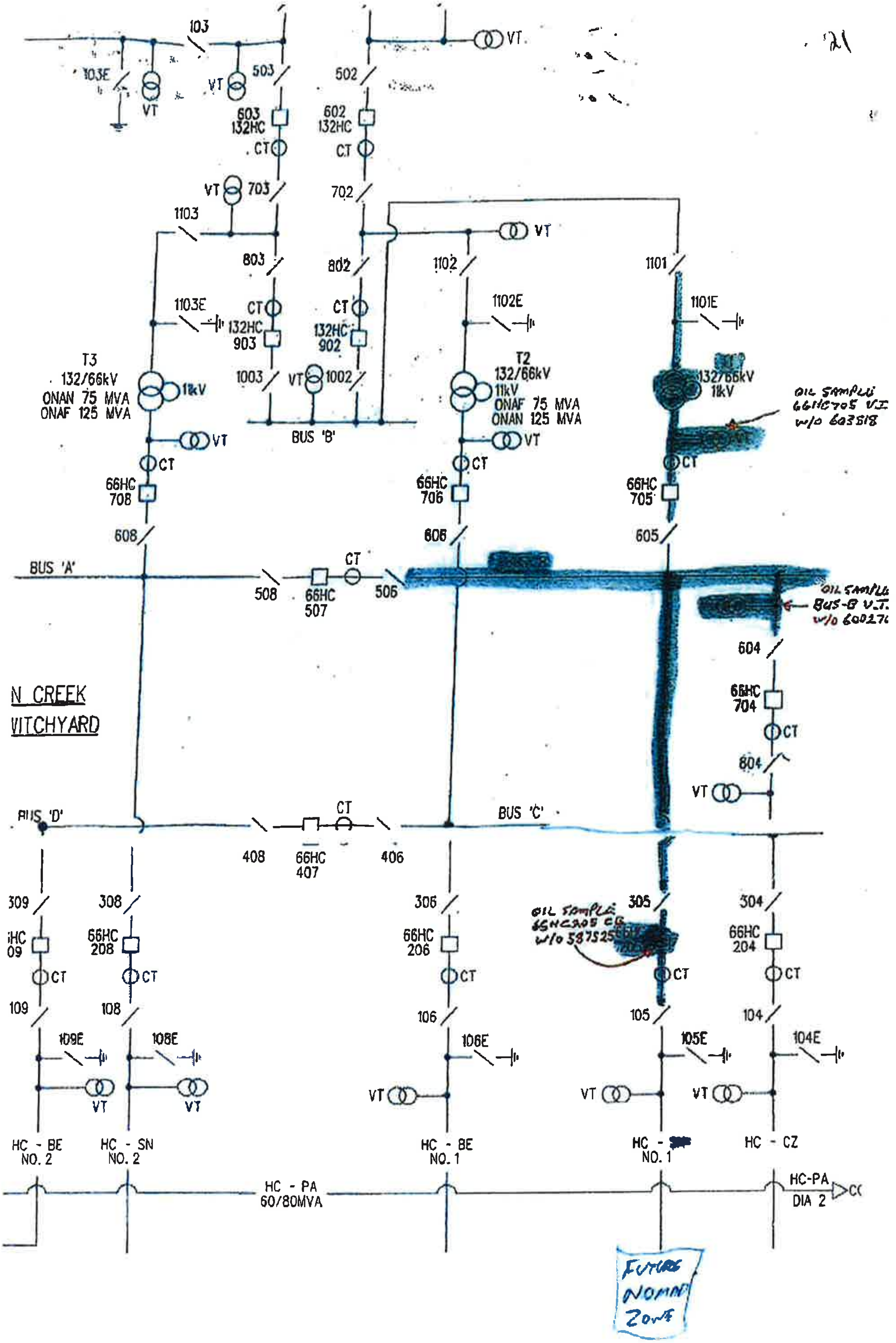
NAME: [redacted]	SIGNATURE: [redacted]	DATE: 20/2/14	TIME: 1300
Position: PWTC	Contact details: [redacted]		

NAME: [redacted]	SIGNATURE: [redacted]	DATE: 3/3/14	TIME:
APPROVED YES / NO	Contact details:		

Comments: REQUIRED - AP x 2

The above work or test is approved to proceed WITHOUT an access authority	Op checks		Specified work/test
CONTROLLER NAME:	SIGNATURE:	DATE:	TIME:
Person in charge of work or test			
NAME:	SIGNATURE:	DATE:	TIME:
Work or test completed			
NAME:	SIGNATURE:	DATE:	TIME:

21



103
103E
VT
503
502
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603
132HC
CT
602
132HC
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703
702
1103
803
802
1102
1101
1103E
CT
132HC
903
CT
132HC
902
1102E
1101E
T3
132/66kV
ONAN 75 MVA
ONAF 125 MVA
11kV
1003
VT
1002
BUS 'B'
T2
132/66kV
11kV
ONAF 75 MVA
ONAN 125 MVA
132/66kV
11kV
OIL SAMPLE
66HC705 V.T.
w/o 603518
66HC
708
66HC
706
66HC
705
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606
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BUS 'A'
508
66HC
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506
OIL SAMPLE
Bus-B V.T.
604
66HC
704
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N CREEK
VITCHYARD
BUS 'D'
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BUS 'C'
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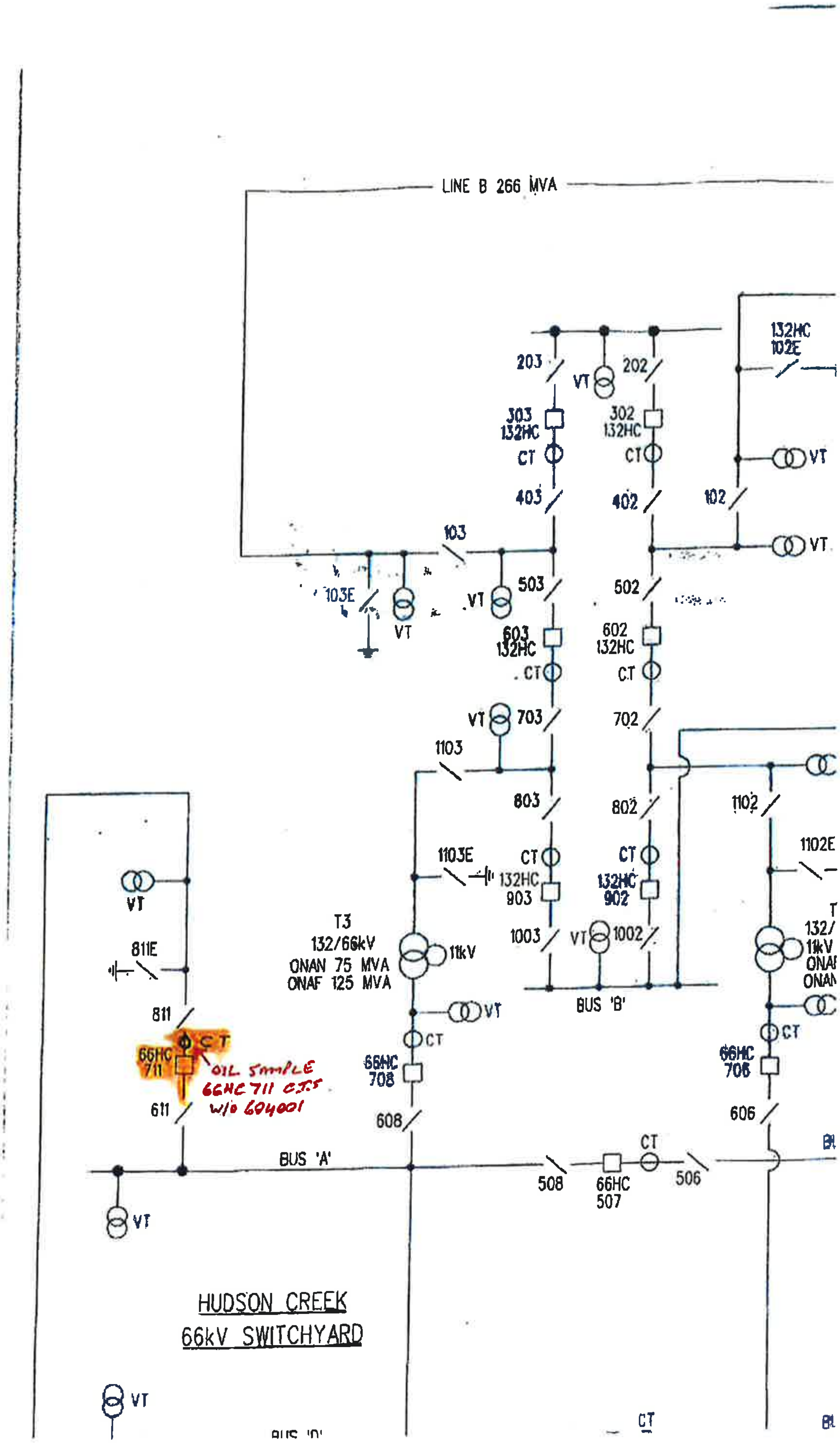
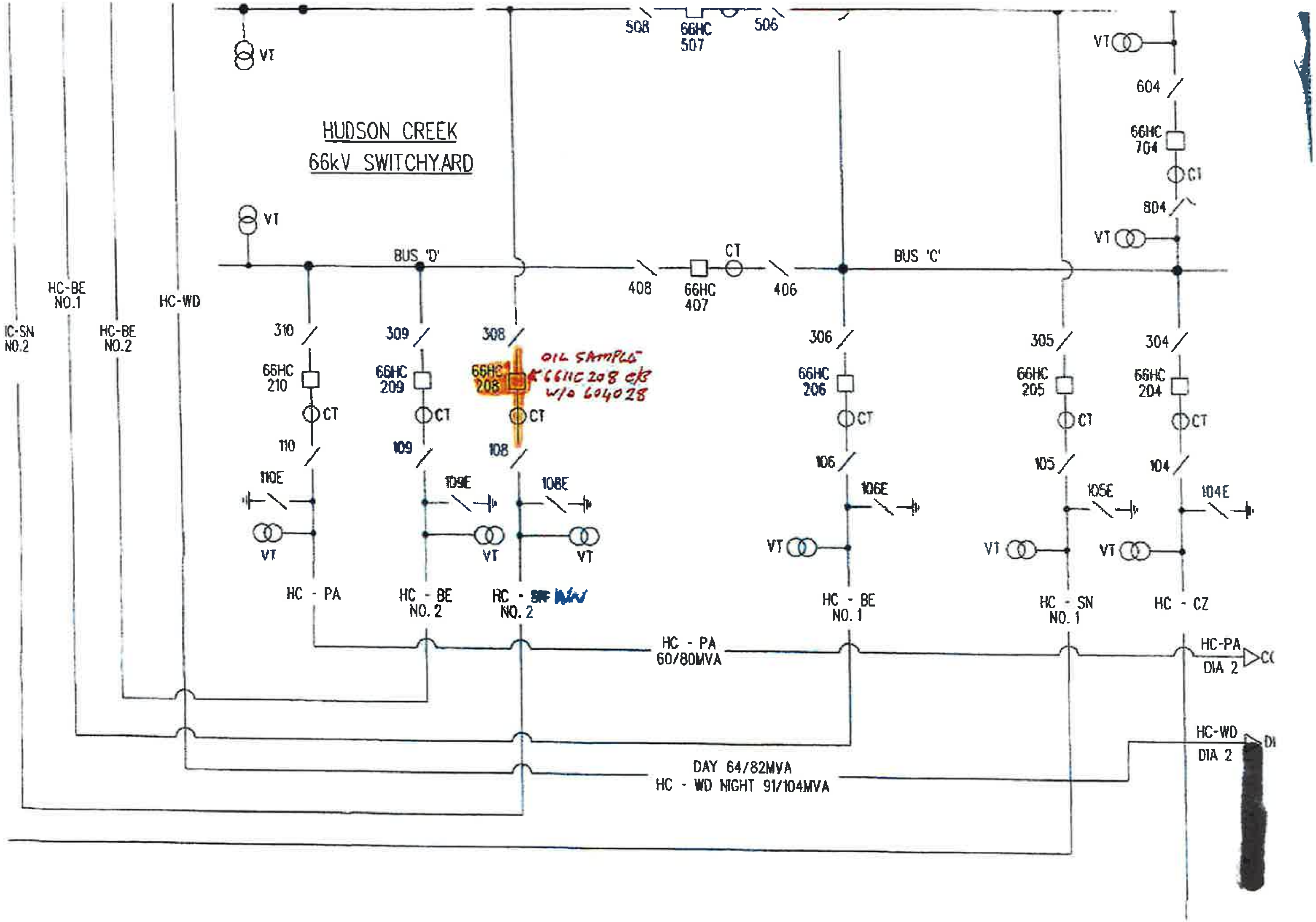


HUDSON CREEK
66kV SWITCHYARD


HUDSON CREEK
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104E
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HC - BE
NO. 2
HC - ~~SW~~
NO. 2
HC - BE
NO. 1
HC - SN
NO. 1
HC - CZ
HC - PA
60/80MVA
HC-PA
DIA 2
HC-WD
DIA 2
DAY 64/82MVA
HC - WD NIGHT 91/104MVA

[redacted]

From: [redacted]
Sent: Tuesday, 18 February 2014 4:55 PM
To: [redacted]
Cc: [redacted]
Subject: Requested Outage Assessment - HC BE AR

Steve,

The outages you have requested would be best done as 4 seperate outages, I've assumed each outage will require an 8 hour window:

1. BE Bus A

Takes out of service, 66 BE Bus A, 66 HC-BE 1, 66 BE-CA and 66/11 BE T1.
Has 3 lines overloading post contingent. System studies suggest that the maximum load allowable to not overload past short term ratings is 215 MW.
If this work is urgent, night work will be required. Currently this work can be done between 2200 and 0600.
If you require this work to be done during daylight hours, then weekends allow work to be done up until 1200. (0400 Start)
For week day work during daylight hours, this will need to wait until the end of May to be done.

2. BE Bus B

Takes out of service, 66BE Bus B, 66 HC-BE 2 and 66/11 BE T2
Has 4 lines overloading post contingent. System studies suggest that the maximum load allowable to not overload past short term ratings is 235 MW.
If this work is urgent, night work will be required. Currently this work can be done between 1900 and 0800.
If you require this work to be done during daylight hours, then weekends allow work to be done at all times.
For week day work during daylight hours, this will need to wait until May to be done. (Still weather dependent, reliably from the end of May)

3. HC Bus C

Takes out of service, 66HC Bus C, 132/66 HC T2, 66 HC-BE 1, and 66 HC-CZ
Has 5 lines overloading post contingent. System studies suggest that the maximum load allowable to not overload past short term ratings is 150 MW.
If this work is urgent, night work will be required. Currently this work can be done between 0000 and 0500.
This work must be done overnight, as daytime loads exceed 150MW at nearly all times of the year. The times which day time loading is below 150MW is weather dependent and hard to predict long term. In June the window extends to between 2300 and 0600 (most days).
Please note that Weddell Generation will have an impact on this outage.

4. HC Bus B

Takes out of service, 66HC Bus B, 132/66 HC T1
Has 1 lines overloading post contingent. System studies suggest that the maximum load allowable to not overload past short term ratings is 150 MW.
If this work is urgent, night work will be required. Currently this work can be done between 0000 and 0500.
This work must be done overnight, as daytime loads exceed 150MW at nearly all times of the year. The times which day time loading is below 150MW is weather dependent and hard to predict long term. In June the window extends to between 2300 and 0600 (most days).
Please note that Weddell Generation will have an impact on this outage.

EVANS & PECK

Appendix B

Weddell Power Station – Lessons Learnt

LESSONS LEARNT REPORT		
Name:	System Black Event that occur on 12/03/2014 (Weddell Power Station)	
Prepared By:	[redacted]	
Date (MM/DD/YYYY):	18/03/2014	
Attendees:	• [redacted]	• [redacted]
Purpose:	The purpose of this document is to record the experience gained during the System Black Event on the 12/03/2014 at Weddell Power Station. It aims to detail the points of failure and successes and identify potential areas of improvement. Implementing the compiled recommendations will help make the Black Start System more robust, improve the efficiency of the recovery efforts and shorten restoration time.	

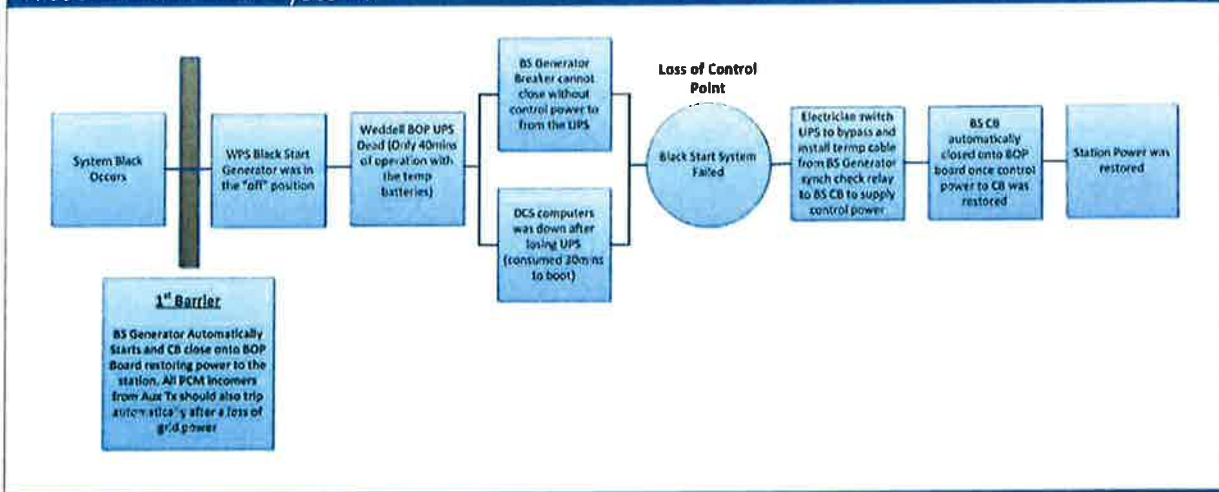
A) List of Biggest Successes: *Description*	*Factors that Promoted this Success:*
Group effort during the restoration	Everyone had knowledge and contributed to solving the complex problems during the System Black.
All work was done with safety in mind	There was good communication between all staff on site during the restoration.

B) List of Biggest Failures: *Description*	*Net Effect on Restoration:*
The Black Start Generator was left in the "Off" position.	This is the top contributing factor for the delay in the restoration of Weddell. If the BS Generator was left in the" Auto" position it would have started automatically and restored power to the BOP Board which would have changed the UPS batteries. Hence, the issues with closing the B/S generator breaker BOQ-Q3 would not have eventuated because control power from the UPS would still be live. The DCS system would also be online which would avoid the lengthy reboot time.
The UPS batteries are a known problem and were in the process of being changed out	The temporary batteries in the UPS system only have approximately 40 mins of life. Hence, by the time staff arrived to start the black start generator the UPS was already depleted. With no control power from the UPS it was not possible to close the BS generator onto the BOP Board. A temporary cable was installed from the terminals of the BS Generator to the UPS distribution board to get around this problem. This added 1-2 hours to restoring the station.
The DCS reboot time was very long	Once power was restored to the Station all the DCS computers were restarted. The reboot time consumed at least 30-45mins.
Over pressurisation	The gas pressurisation caused multiple failed starts on both Unit 1 and 3.

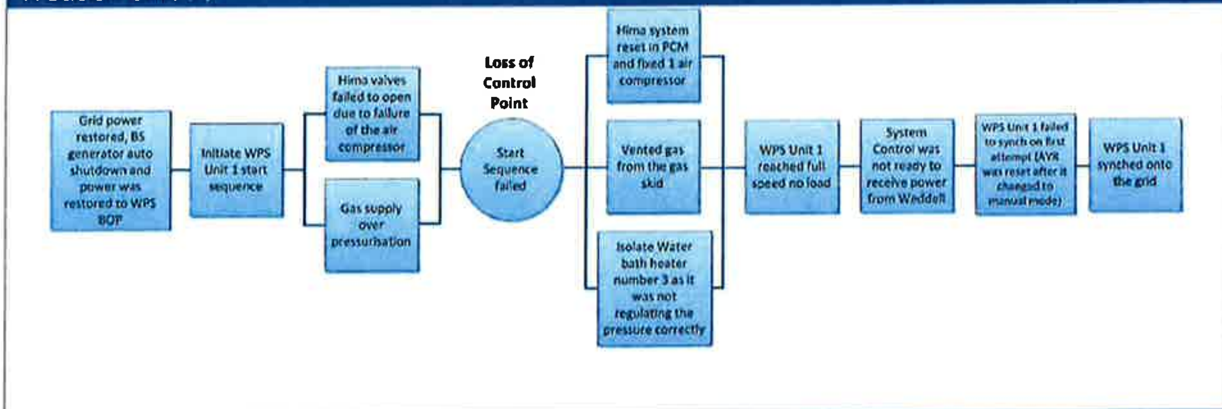
C) List of Areas of Potential Improvement: *Description*	*Possible Mitigation:*
Revise the Black Start Procedures	Review the black start procedure for Weddell and make amendments based on the system black experience. Leave a final hard copy in the control room.
Change out the UPS batteries as soon as possible	Changing out the batteries should be a high priority.
More training on the Black Start Procedure	Once the Black Start Procedure is amended it should be communicated to all operational staff.
Maintenance of Plant/Equipment relating to the Black Start System	All Plant/Equipment relating to the Black Start System should be given a high priority when maintenance is required. This includes the 7 Circuit Breakers, UPS System, Black Start Generator, BS Generator Battery Charger and BS Generator controller.
Implement monitoring of the UPS in the Control System	The status of the UPS should be monitored in the DCS with Alarms.
Add all the UPS System to an existing Government Contract	There is a contract available for monitoring, repairing and commissioning UPS System. All UPS systems at CIPS and WPS will be added to the contract.
Review the Over Pressurisation Procedure	When over-pressurisation occurs it is recommended to isolate all pressure regulators except one. This should help make the gas pressure more stable when the first

	turbine is started from a station black. Revise the over pressurisation procedure to include this.
Review the Call-out Procedure	The process for informing staff with the correct technical expertise, to attend site need to be reviewed. Staff that assisted in the restoration could have been informed earlier.
Monitor the position of the of the Black Start Generator Switch in the DCS	If possible monitor the position of the Black Start Generator Switch to avoid the same issue.
Review the spare parts for all the breakers in the BS System	The essential spares need to be reviewed, purchased and kept in stock.
Regular testing for the Black Start System as a whole	It is suggested that testing of the black start system should be conducted twice a year in April and September to prove reliability. Load testing of the BS genset should be conducted fortnightly.

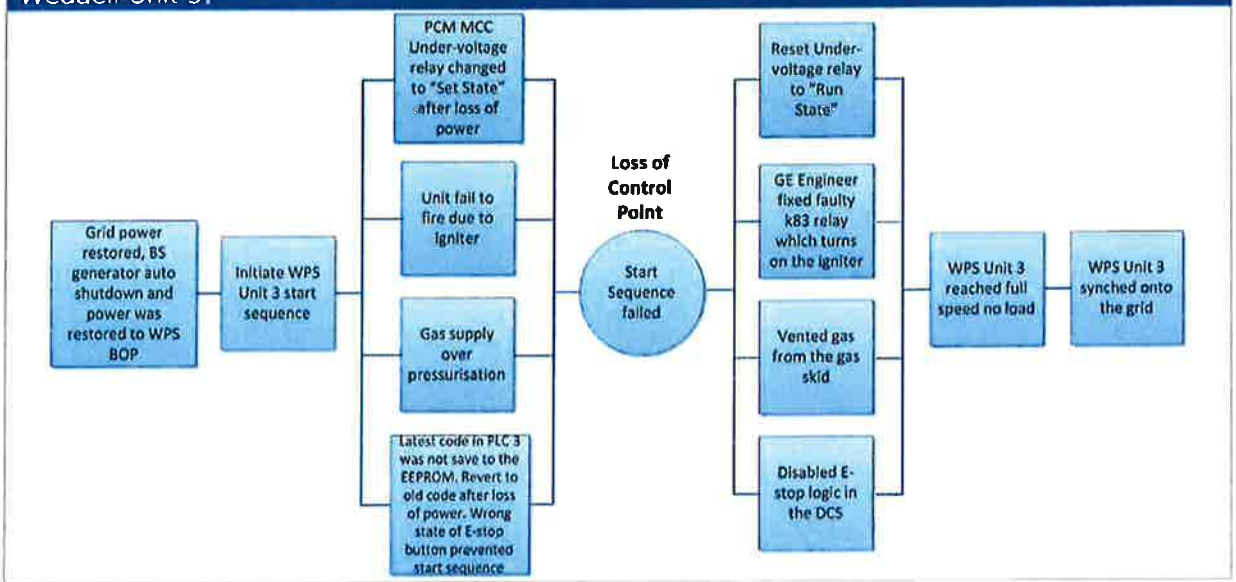
Weddell Black Start System:



Weddell Unit 1:



Weddell Unit 3:



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