PowerWater

Program Business Need Identification

Power and Water Corporation

PRD33230

Darwin 132/66kV Transformer Capacity Upgrade

Proposed:

Jim MacKay
A/Chief Engineer
Power Networks
Date: 6/2/2018

Approved:

Michael Thomson
Chief Executive
Power and Water Corporation
Date: 23/02/2018

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Executive General Manager
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Date: 15/2/2018

Refer to email
D2018/72353

Finance Review
Date: 6/02/2018

Refer to email
D2018/61921

PMO QA
Date: 9/02/2018

1 Program Summary

Program Name:	Darwin – Hudson Creek Spare 132kV Transformer Capacity		
Program No:	PRD33230	**SAP Ref:**	
Financial Year Commencement:	2022/23		
Business Unit:	Power Networks		
Program Owner (GM):	Djuna Pollard	**Phone No:**	8985 8431
Contact Officer:	Peter Kwong	**Phone No:**	8924 5060
Date of Submission:	23/02/18	**File Ref No:**	D2017/418175
Submission Number:		**Priority Score:**	
Primary Driver:	Compliance	**Secondary Driver:**	Growth/ Demand
Program Classification:	Capital Program of Works		

2 Recommendation

2.1 MAJOR PROJECT >$1M OR PROGRAM

It is recommended that the Chief Executive note the proposed project PRD33230 Darwin – Hudson Creek Spare 132kV Transformer for an estimated budget of [redacted] and approve the inclusion of this project into the SCI for this amount, with a corresponding completion date of June 2023.

The forecast for this program of work aligns with the 2019-24 regulatory period and will be included in the 2019-24 Regulatory Proposal to the Australian Energy Regulator (AER).

Note that a Business Case will be prepared as per the PWC governance framework for capital projects and programs.

It is also recommended that IRC endorse the expenditure of $50,000 for further specification development required to reach the Preliminary Business Case Gateway.

3 Description of Issues

3.1 Background

Hudson Creek Terminal Substation ('Hudson Creek') has three 132/66 kV 75/125MVA power transformers, each with a cyclic rating of 131.5 MVA. As shown in Figure 1, Hudson Creek provides the only connection between the 132kV network from the Channel Island Power Station and the 66kV network to Darwin and surrounding areas. This connection transports most of the supply to the 66kV transmission network, with the in-feed from Weddell power station providing some supply directly to the 66kV network via Weddell substation. The transformer circuits at Hudson Creek are therefore critical to maintaining continuous supply to the entire Darwin region.

It is in PWC's long term plan to extent the 132kV network directly into the load centres in Darwin and Palmerston, ultimately including establishing a 132/66kV zone substation at Woolner. This will reduce the criticality of Hudson Creek in the transmission network.

Figure 1: System diagram

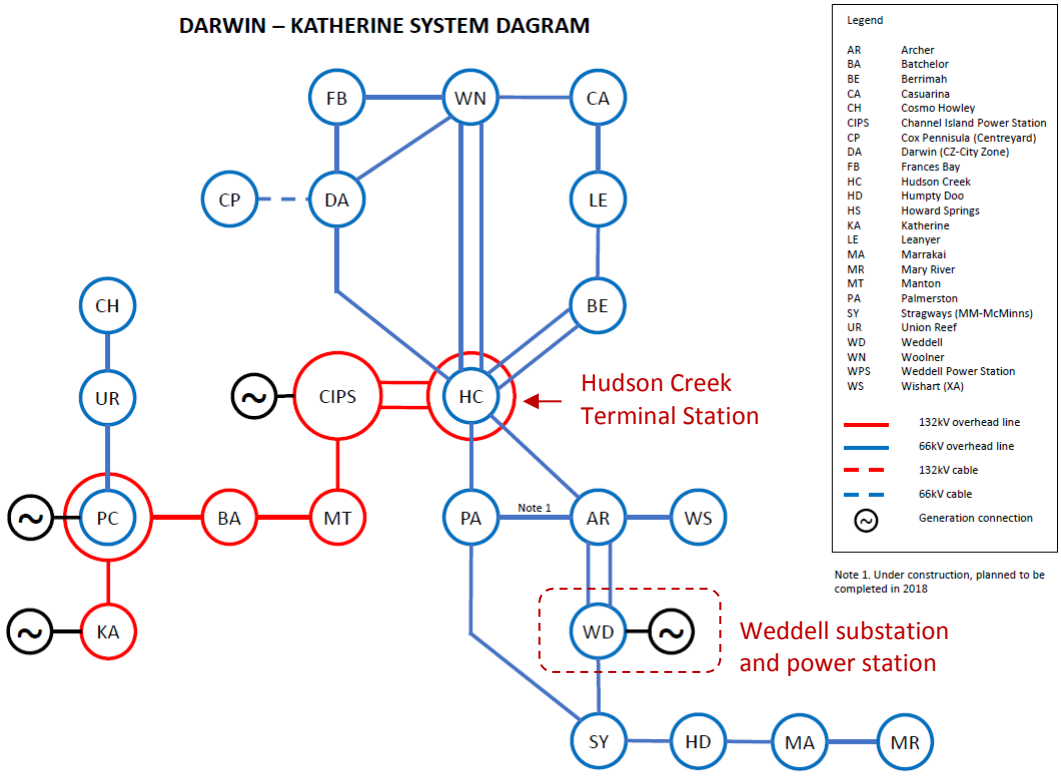


Figure 2 shows the load forecast for Hudson Creek, which is expected to decline by 29MVA over the next six years (from 195MVA in 2017/18 to 166MVA in 2023/24). This reduction is a direct reflection of the forecast decline in the maximum demand of the overall system.

The total 66kV demand for the Darwin area is forecast to decrease slightly over the next 6 years, as shown in Figure 3, due to growth in the Palmerston and rural areas

Figure 2: Hudson Creek Terminal peak demand forecast[1]

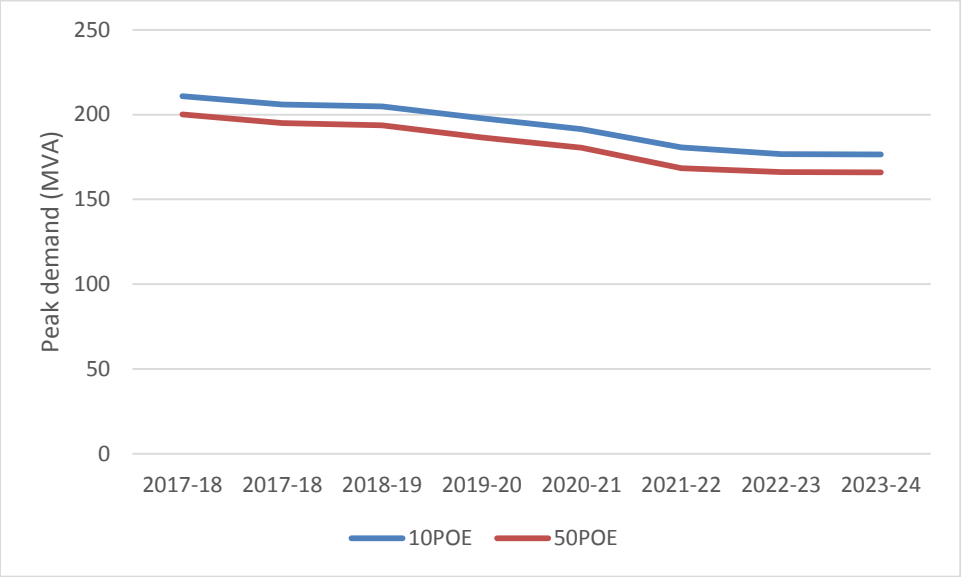
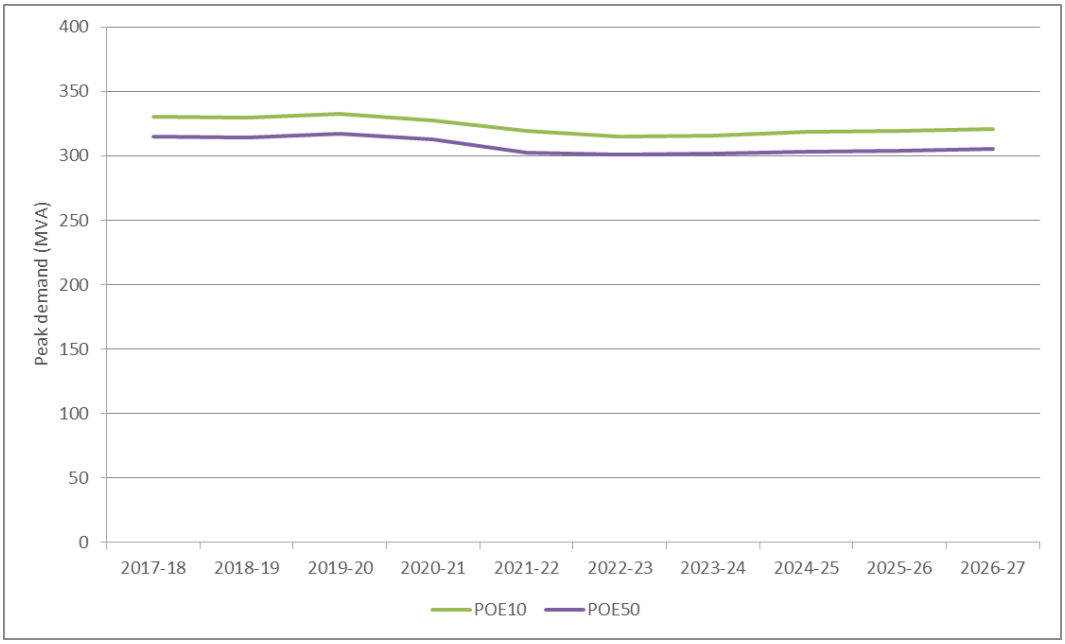


Figure 3: Total forecast Darwin and Surrounds 66kV system maximum demand[2]



[1] Source: AEMO, AERReportForPWC_V3, Hudson Creek, diversified, weather corrected Non-coincident, weather corrected maximum demand

[2] Source: AEMO, AERReportForPWC_V3, Darwin 66kV Non-coincident, weather corrected maximum demand

3.2 Project Drivers

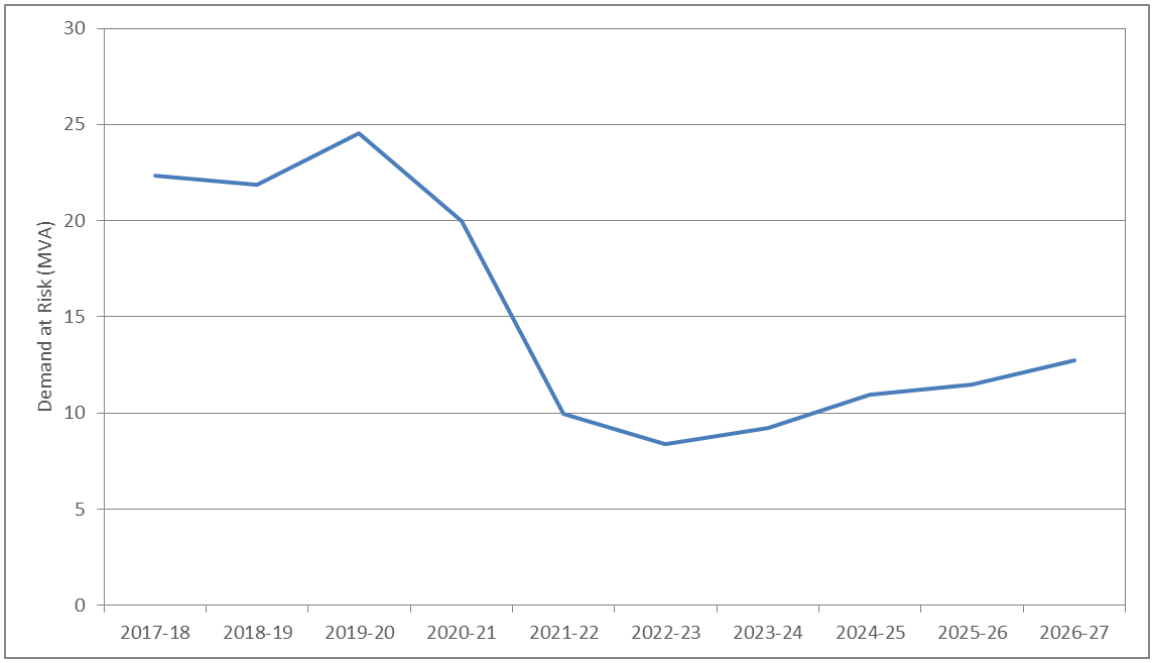
3.2.1 Compliance

For loads over 50MVA in a CBD or Urban areas, the Network Planning Criteria[3] stipulates that supply must be restored within 5 hours following a second contingency. This is referred to as class of supply D.

The critical double contingency event in the Darwin/Katherine network that affects more than 50 MVA of load is the failure of two of the three 132/66 kV transformers at Hudson Creek.

In the event of a failure of two transformers at Hudson Creek, the cyclic rating of the single remaining transformer (131.5 MVA) plus the maximum generating capacity of Weddell power station (161MVA)[4] would not provide sufficient capacity to support the peak 66kV load in the Darwin area. The increasing supply capacity shortfall from these two sources under the double-contingency event at Hudson Creek is shown in Figure 4. To avoid non-compliance, this shortfall needs to either be eliminated proactively or rectified within five hours of the second contingency event.

Figure 4: 66kV supply capacity shortfall for double contingency at Hudson Creek



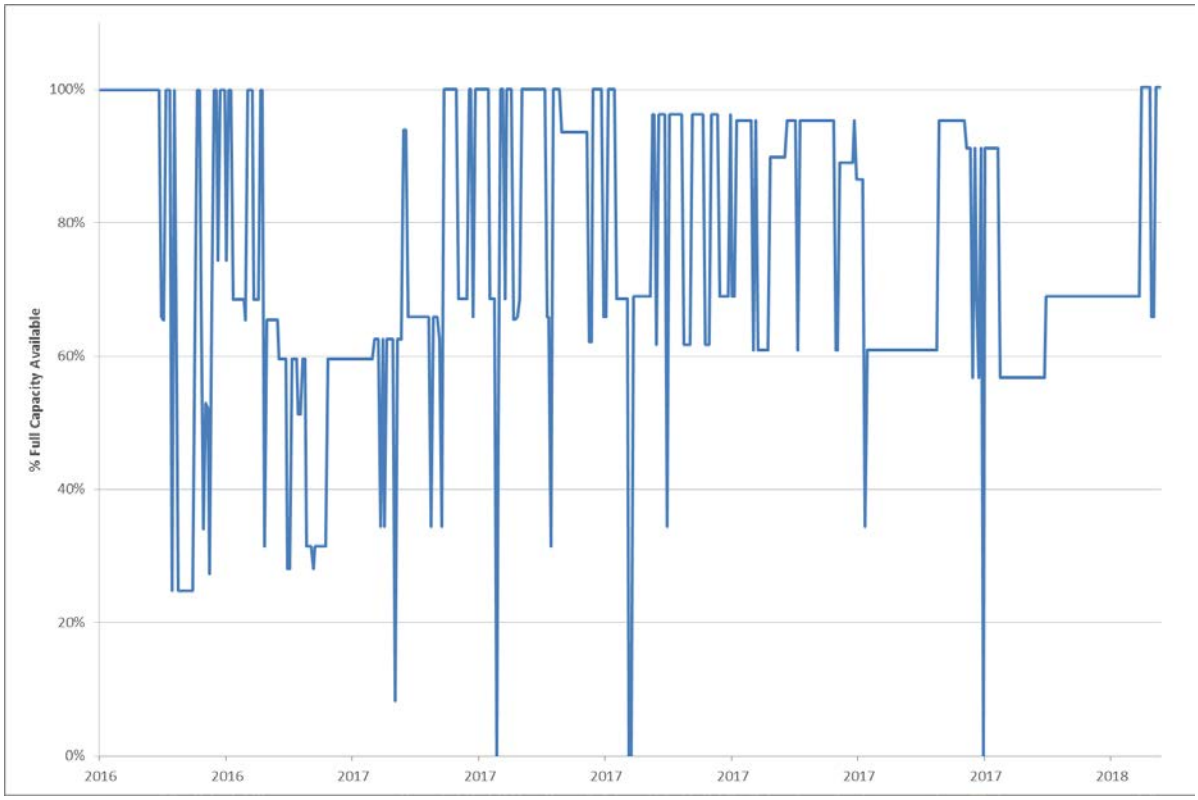
There is also the issue of availability of Weddell Power Station to consider. There are significant periods of time when the full station output is not available due to equipment failure and other

[3] Table 13, page 126

[4] The full rating of the Weddell power station is 129 MW with all three units in service. The units are capable of operation at 0.8 power factor, so the total output is up to 161 MVA

issues. From historical records, 90% capacity from Weddell power station is only available 40% of the time, significantly increasing the supply capacity shortfall.

Figure 5: Weddell Power Station available output from Sep 2016 to Jan 2018[5]



3.3 Risk Analysis

Figure 6 shows the current rating, inherent rating (in 2024, i.e. no action is taken in the interim), and residual (post-treatment) risk ratings associated with double contingency event at Hudson Creek Terminal Station.

(i) Current rating: The current rating (2017) is assessed to be "High" because it is "Rare" that there would be a double contingency event at Hudson Creek Terminal Station. However, the consequence will be "Severe" as there will be an extended disruption to service over 24 hours and sustained adverse media attention and customer condemnation.

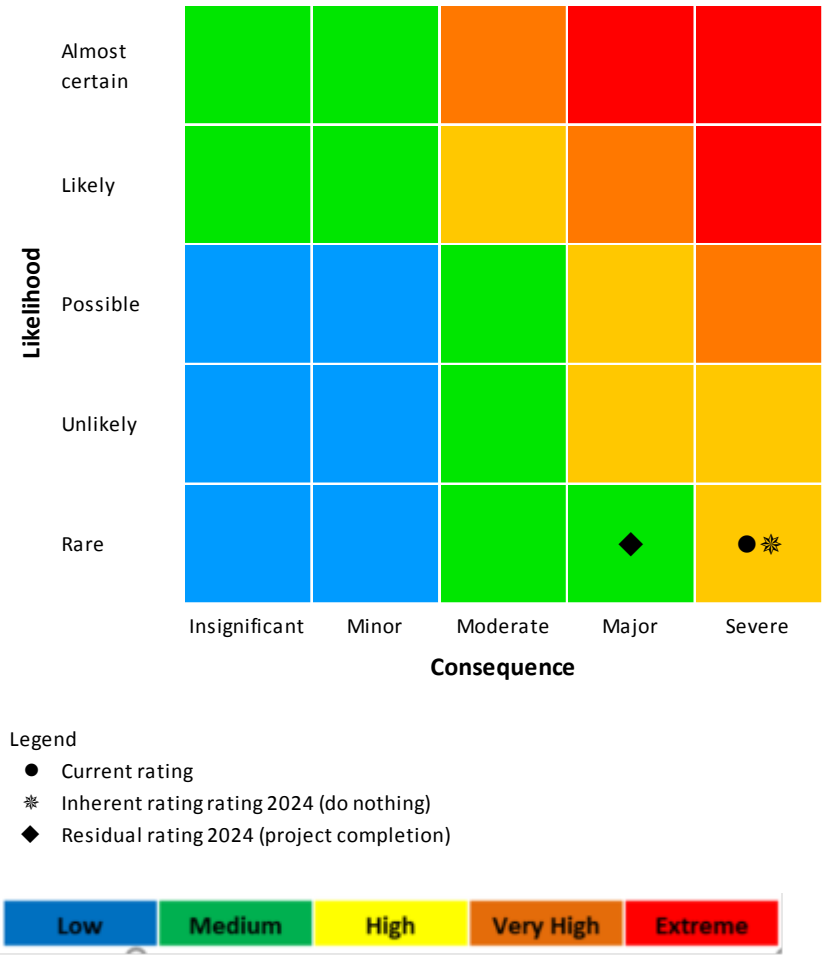
(ii) Inherent rating: If the project does not occur in the next regulatory period, the probability of double contingency event by 2024 is "Rare". The consequence will remain "Severe" and the overall risk rating is therefore "High".

(iii) Residual rating: The procurement of the spare transformer will reduce the consequence of the risk. It is likely that a faulty transformer at Hudson Creek can be replaced in 24 - 48 hours in an emergency situation. Therefore, the likelihood of an event

[5] Source: System Control medium term 12 months generation network chart

is “Rare“and the impact of the event will be significantly lessened, to a level classified as “Major”. The overall risk rating is therefore “Medium”.

Figure 6: Feeder Augmentation Risk Assessment[6]



It is Power and Water’s current practice to take action on risks that have an inherent rating of ‘HIGH’ or above. The BNI summarises the proposed response to this impending risk.

4 Potential Solution

4.1 Options Considered

The double contingency event is unplanned, coincident failure of two of the three transformers at Hudson Creek. A further assumption is that the nature of the transformer failures prevents restoration of either transformer within the allowed five hours for Class D supply.

The options considered are as follows:

[6] Based on PWC’s Risk Assessment Guide

1. *Option 1: Do nothing* – Whilst catastrophic failure of two power transformers at a terminal substation event is a rare event,[7] PWC is non-compliant with the requirements of the Network Planning Criteria if it does not take all reasonable steps to ensure it can restore supply to all customers within five hours. The repair/replacement time typically associated with such failures is many months.[8] Even if there are adequate spares available (such as a spare transformer), the replacement time will be much longer than five hours.

   This option is not considered to be prudent as it is not a reasonable response to PWC's non-compliance with the Network Planning Criteria and the supply risk exposure to the Darwin region's customers.

2. *Option 2: Purchase a contingency spare 132/66kV transformer* (Preferred Option)- Having a cold spare 132/66 kV power transformer located at Hudson Creek[9] would reduce the time needed to fully restore supply to about two weeks. The estimated cost of the spare transformer is [redacted]. Additional installation costs are only borne following transformer failure and replacement.

   The advantage of this option is that it provides a path to restoration of any supply shortfall (which may occur daily) within approximately two weeks. Therefore, the risk of extended load shedding is significantly reduced compared to the 'Do nothing' option.

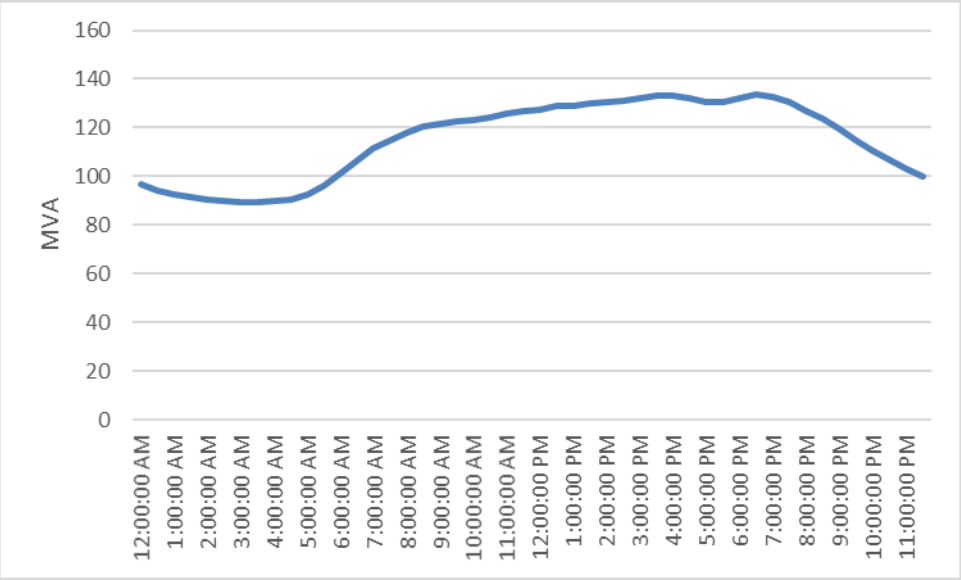
   The disadvantage of this option is that it may not render PWC fully compliant with the Network Planning Criteria because, as illustrated in Figure 4, in the two weeks it takes for the replacement transformer to be commissioned, the system will be operating in a non-secure state and rotational load shedding may be required (i.e. depending on the peak demand). The load duration curve for the 66kV supply in Darwin is relatively flat, as shown in Figure 5, which means that there is likely to be long periods each day when the demand on Hudson Creek is close to the peak.

[7] Two power transformers in the same Western Power substation failed catastrophically at different times (2012, 2014) but because of issues with repairing the first transformer, both transformers were unavailable at the same time

[8] In case of replacement, 18 months lead time would be typical; in the case of repair at the factory, rather than in situ, it could take 6-12 months to recommission the transformer

[9] The spare transformer would be selected to be compatible with the existing transformers and would be located at a safe site with all the equipment and other installation plans available to remove the failed transformer and commission the replacement

Figure 5: Hudson Creek – daily load profile (summer)[10]



3. *Option 3: Install a fourth 132/66kV transformer at Hudson Creek*

   Installation of a fourth transformer at Hudson Creek is expected to be the least cost approach to permanently installing an additional 132/66 kV transformer in the Darwin network because there is a spare 132kV circuit at Hudson Creek. The single line diagram relevant to this option is provided in Appendix B. The estimated cost of this option is [redacted].

   The main advantage of this option is that it will provide continuity of supply in the event of prolonged outage of two of the four transformers at Hudson Creek, satisfying the Class D supply criterion.

   The main disadvantage of this option is that the entire 132/66 kV transformation in the network would continue to be on a single site. This leaves the network vulnerable to a catastrophic event, leading to the loss of the entire Hudson Creek substation. However, this is an extremely low probability event.

4. *Option 4: Establish a new 132/66kV substation at Weddell*

   Option 4a*:* Connect the new substation to the nearby Channel Island to Hudson Creek 132kV line. The initial substation installation would be a single 132/66 kV 75/125 MVA transformer, 132 kV busbar, and associated circuit breakers, and secondary systems. The 66kV connection would be to the existing Weddell 66 kV busbar via a new circuit breaker. Space would be provided for a future second transformer and associated circuit breakers. A single line diagram of this proposal is shown in Appendix B.

   Option 4b**:** Connect the new substation to the Channel Island to Manton 132kV line[11]. A single line diagram showing a 132kV connection to this line is shown in Appendix B.

   The advantages of installing a transformer at a different location to Hudson Creek are:

[10] Substation load 2016-17 v2.1
[11] Weddell is located less than 1 km from the Channel Island to Manton 132 kV line

- It provides adequate capacity to cope with the unavailability of two transformers at Hudson Creek; and.
- A further advantage of establishing a 132/66 kV substation at Weddell is that it spreads the transformation 132/66 kV transformation capacity across two sites, making the network more robust against a high impact but low risk failure of all three transformers at Hudson Creek substation.

The disadvantage of this option is the relatively high capital cost for the low probability risk event.

The estimated cost of option 4a & 4b is approximately [redacted].

5. *Option 5: Establish a new 132/66kV substation at Archer*

   The establishment of a new 132/66 kV substation at Archer is electrically very similar to the establishment of a substation at Weddell (Option 4).

   The existing Archer 66/11 kV substation is located less than 300 m from the Channel Island to Hudson Creek 132 kV lines. The proposed 132/66 kV substation would connect to the existing 66 kV substation at Archer. The proposed connection is shown in a single line diagram in Appendix B.

   The Archer site option has an advantage over the Weddell site option in that it does not increase the load on the Weddell to Archer 66 kV lines and it is closer to the load centres in Darwin and Palmerston.

   This option is unlikely to be preferred to option 4a or 4b as it requires a new 8.5 km dual circuit 132 kV line, making it the most expensive network option. The estimated cost of option 5 is [redacted].

6. *Option 6: Connect additional generation*

   Connection of approximately 25MVA of additional generation capacity in the Darwin 66 kV transmission network during 2018/19 would alleviate the network constraint discussed in this report.

   PWC is not aware of any current proposals which would meet this requirement.

7. *Option 7: Non-network solution*

   Based on PWC's research, the most likely sources of demand management are via (i) curtailment contracts with large commercial and industrial customers in the Darwin area, and (ii) through initiatives targeted at residential customers, such as subsidising installation of solar PV and storage units. PWC does not have access to other forms of demand management such as ripple control or smart meter activated control of customer loads (such as air conditioners).

   To comply with the Class D Supply requirements, load curtailment would have to be achieved within 5 hours.

   Referring to Figure 4, this option requires up to 25MVA of reliable peak demand reduction, for an extended period to be available in the event of two Hudson Creek transformers being unavailable.

The major advantage of Option 7 is that if either the required dispatchable, interruptible load was available, or permanent peak load reduction was guaranteed through solar PV/storage, it would defer a network solution, allowing more time to assess actual load growth and review the load forecast.

The disadvantages of Option 7 are:

(i) PWC has no experience with securing dispatchable, interruptible load and limited experience with reliably reducing residential peak demand through PV/storage solutions;
(ii) Depending on the solution offered, the cost of non-network solutions is unlikely to be economic:
- If an opex solution is provided, the annual cost would need to be less than the annualised cost of the preferred network solution (approx $0.15m pa);[12] and
- The installed capital cost per kW of PV plus storage units is currently significantly higher than the cost/kW of the preferred network solution.[13]

PWC will continue to explore the technical and commercial viability of this option prior to submitting the Business Case for Approval. In the interim, it is not considered to be a technically viable solution due to the uncertainty of it cost effectively and reliably limiting peak load demand.

4.2 Preferred Option

The preferred approach is Option 2 (purchase of a spare transformer). In time, it may be prudent to install it as a permanent transformer at either Hudson Creek (Option 3), Weddell (Option 4), or Archer (Option 5) if the gap between the available capacity and peak demand grows to the point where this is economically justifiable.

All options will be investigated in detail in the next stage of the capital investment process.

5 Strategic Alignment

This project aligns with the Corporation's key result areas of operational performance and customer centricity, where the goals are to be an efficient provider of services and delivering on customers' expectations.

This project will allow PWC to safely and reliably meet the current and future demands for the Darwin and Palmerston areas.

6 Timing Constraints

[12] If it is available, interruptible load can be assumed to cost between $75-$350/kVA, depending on the technology deployed (refer to AusGrid, *Regulatory Proposal, 2014-19, Attachment 6.12*, page 13, and Oakley Greenwood, *Advice on the DMIS,* pages 15-17*)*

[13] Current solar PV installed costs are in the range of $800-1100/kW and storage costs are about $1000- $1400/kWh (e.g. refer to Clean Energy Council, report by Entura, *Analysis of Demand-Side Management Opportunities, Task 1C,* page 40)

The project should be completed as soon as practicable, given that the current arrangement is non-compliant with the Network Planning Criteria. Based on current estimates, the spare transformer can be procured and established as a cold spare by June 2023.

7 Expected Benefits

Driver	Benefit	Measure
Compliance	Reduced risk of prolonged energy not served to CBD and urban customers in Darwin and surrounding areas	Extent of compliance with Planning Criterion for Class D customers

8 Milestones (mm/yyyy)

Investment Planning	Project Development	Project Commitment	Project Delivery	Review
09/2017	06/2022	07/2022	06/2023	09/2023

9 Key Stakeholders

Stakeholder	Responsibility
General Manager Power Networks	Internal governance stakeholders
Group Manager Service Delivery	
Chief Engineer	
Senior Manager Network Development and Planning	Internal design stakeholders
Senior Manager Contracts and Projects	
Senior Manager Asset Management	
Manager Test & Protection Services	
Manager SCADA and Communication Services	
Local Residents	External – Unions and public
ETU	
Ministers	
Utilities Commission	External regulators

Stakeholder	Responsibility
Australian Energy Regulator	

10 Resource Requirements

Resource Type/Role	How Many	Internal/ External	Anticipated Start Date	Duration Required	Review Allocation (% time or # hrs/days/ wks/mths)
Planning Engineer	1	Internal	Jun 2022	3 Months	20%
Procurement Officer	1	Internal	Jun 2022	3 Months	20%
Planning Manager	1	Internal	Jun 2022	3 Months	20%

11 Delivery Risk

A Preliminary Project Implementation Assessment[14] was conducted for this project and the key risks to delivery of the investment are detailed below:

Risk/Impact Description	Proposed Action
System Outages will be required for connection of new equipment or modifications to existing equipment	Cutover/outage plan to be developed to minimise customer interruptions.
Work on or near existing high voltage lines/equipment	Personnel and operational staff shall follow existing Access to Apparatus Rules.
Possible budget overruns	Ensure detailed budget and business case are completed during the project development phase.
Risk of release of hydrocarbon into the environment	Ensure hydrocarbon containment systems are to current standards

The project will be delivered by the Power Networks Major Projects group, with the Investment Planning phase completed by the Power Networks Network Development and Planning group.

12 Financial Impacts

12.1 Expenditure Forecasting Method

[14] PRD33230 Preliminary Project Implementation Assessment, PWC Ref: D2017/361037

The expenditure forecast for the project was prepared as 'scoped' expenditure, based on enquiries with equipment suppliers and cost information from previous PWC projects.

12.2Historical and Forecast Expenditure

Not applicable

12.3Validation

Not applicable

12.4Capex Profile

The capex in the table below is in $2017-18, and is excluding capitalised overheads and cost escalation

Phase	2019/20 ($'000)	2020/21 ($'000)	2021/22 ($'000)	2022/23 ($'000)	2023/24 ($'000)	Balance ($'000)	Total ($'000)
Investment Planning				[redacted]			[redacted]
Project Development				[redacted]			[redacted]
Project Commitment				[redacted]			[redacted]
Project Delivery				[redacted]			[redacted]
Review				[redacted]			[redacted]
Total				[redacted]			[redacted]

12.5Opex Implications

It is expected the annual operating cost for the storage and maintenance of the spare transformer will be approximately $10,000 per annum.

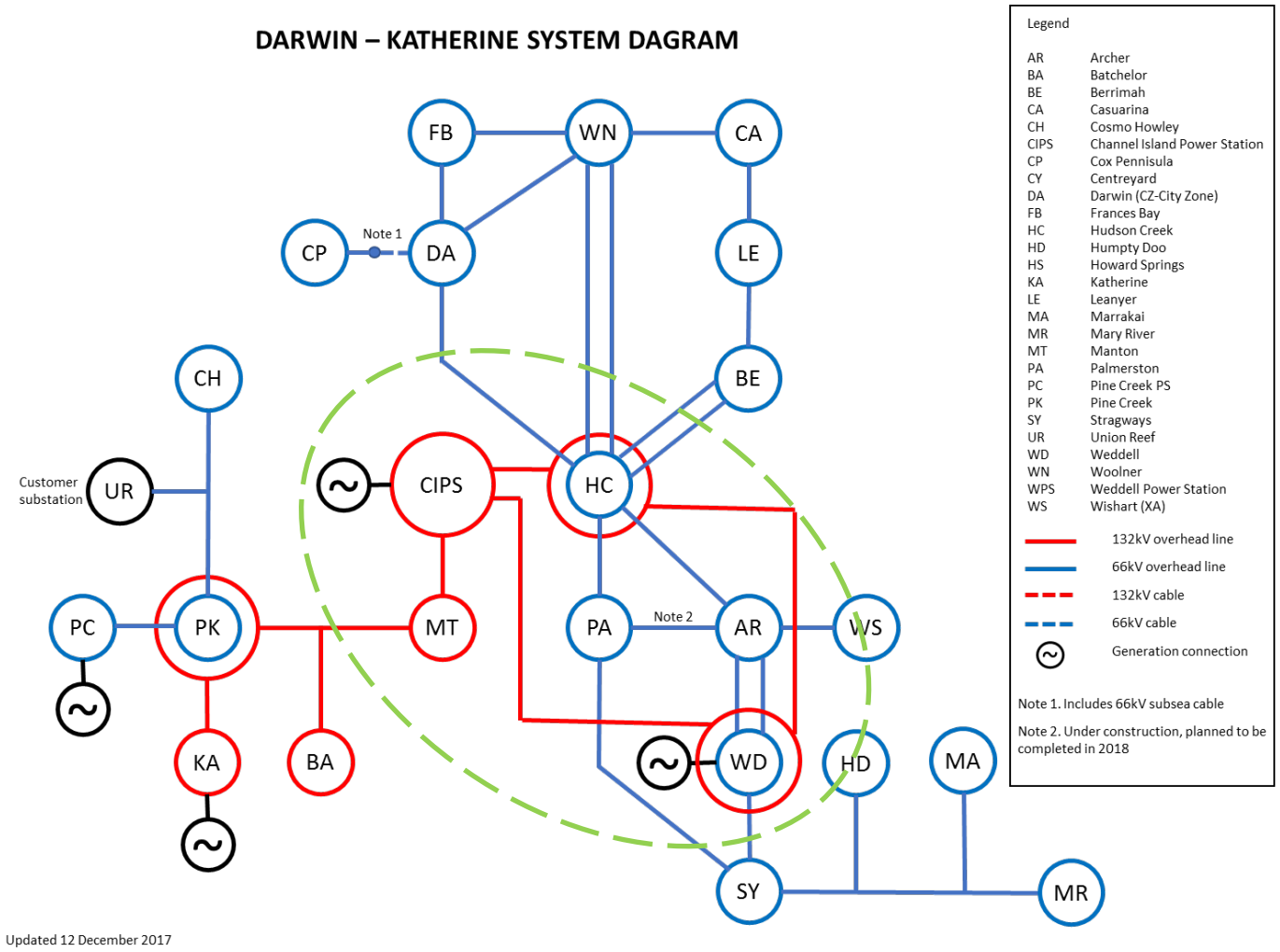
13 Document History

Date of Issue	Version	Prepared By	Description of Changes
26/09/17	1st Draft	Peter Kwong	

APPENDIX A

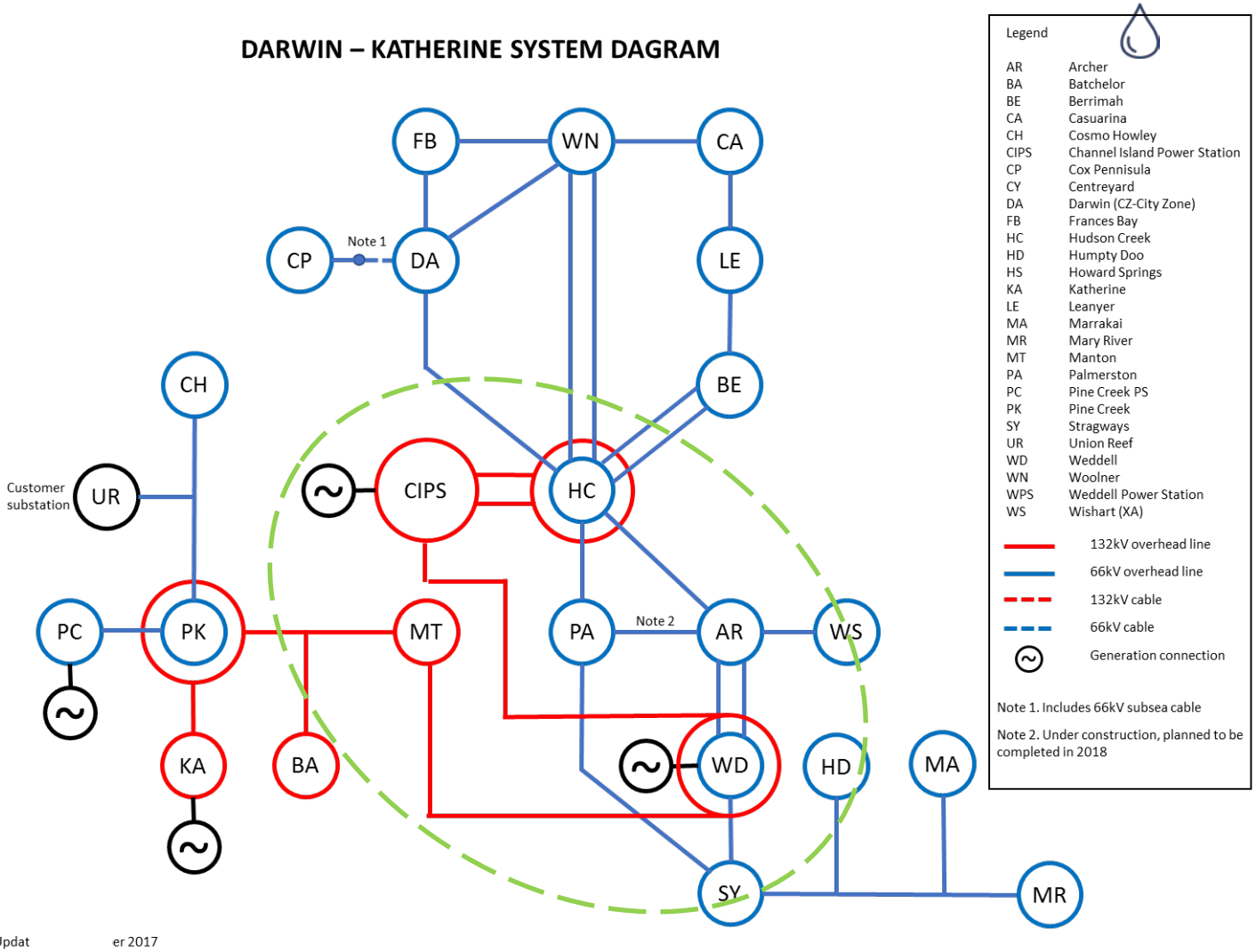
Single Line Diagrams for Options 4 and 5

Elements circled with orange highlighting are the proposed elements discussed in this report.

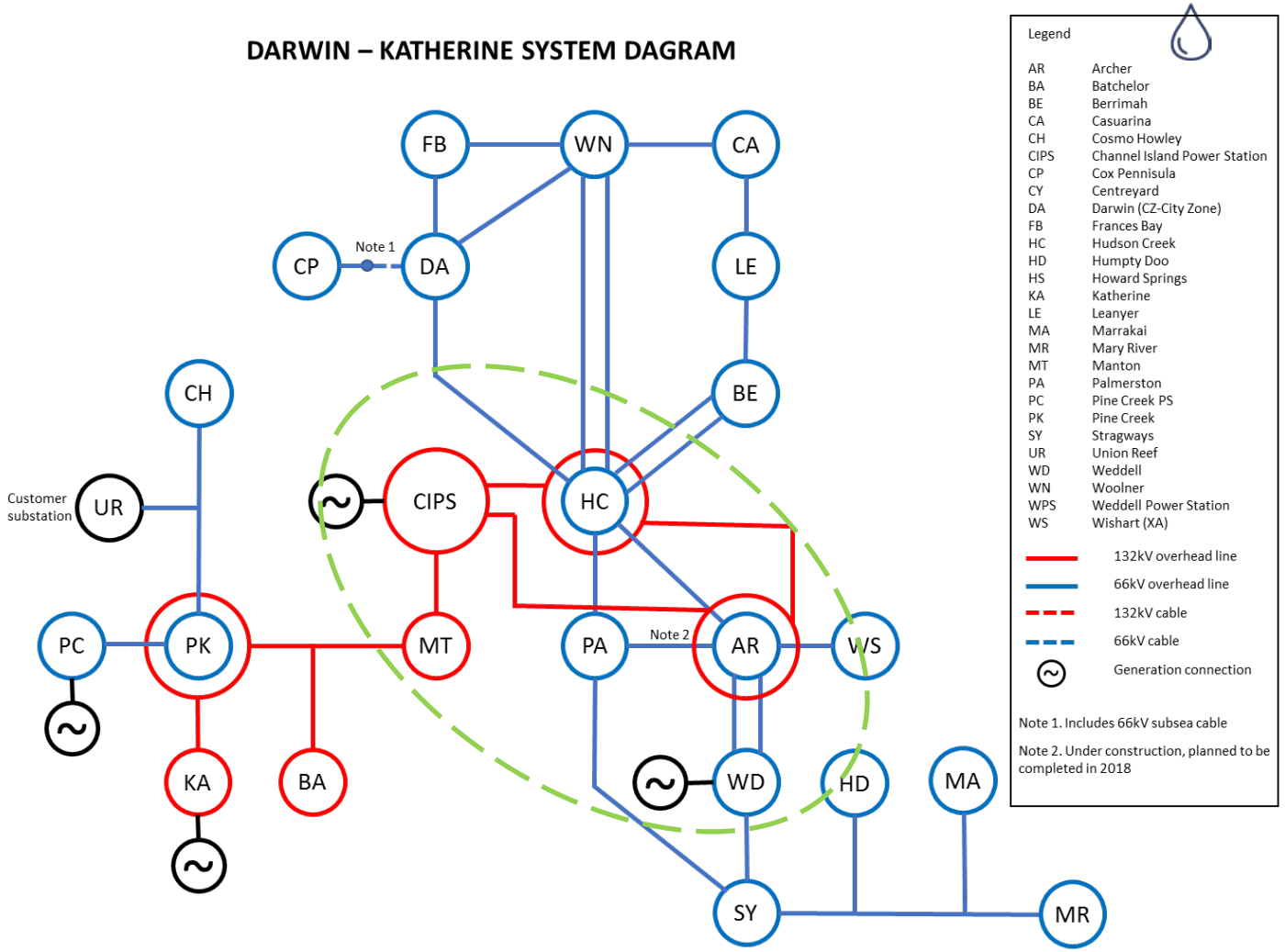


Updated 12 December 2017

Option 4a - Weddell Substation connected to Channel Island to Hudson Creek line



Option 4b - Weddell Substation connected to Channel Island to Manton line



Option 5 - Archer Substation connected to Channel Island to Hudson Creek line

APPENDIX B

PLANNING REPORT

Refer:

NPR1610 Darwin 132/66kV Transformer Capacity Upgrade

D2017/321227

PowerWater

Report No: NPR1610 File No: D2017/321227

Date: 23 August 2017 Container No: F2005/13996

Author: Craig Owens

Approved by: Tat Au-Yeung– Senior Manager Network Development and Planning

Title: Darwin 132/66 kV Transformer Capacity Upgrade

Report Circulation:

The following staff members are on the circulation list for this report:

Goutham Maddirala	Jim McKay	Christina Camilleri
Peter Kwong		

Executive Summary

This study reviews the existing and forecast loading of the Hudson Creek 132/66 kV transformers. The report demonstrates that the current configuration of three transformers does not meet the contingency requirements of the Network Technical Code and Network Planning Criteria.

Installation of a fourth 132/66 kV power transformer in the Darwin transmission network is likely to be the most cost effective option to address the second supply contingency event of the loss of two of the existing transformers, as required by the Network Planning Criteria.

Table of Contents

9. List of Figures

10. List of Tables

11. Network Planning Criteria

The relevant clauses in the Power Networks Network Technical Code and Network Planning Criteria[15], December 2013 that apply to this study are:

Part A – Legislative Requirements

Part B – Network Technical Code

1.7 Obligations

2.3 Power frequency voltage levels

4.2 Power system security principles

4.3 Power system security obligations and responsibilities

4.5 Control of network voltages

8 Disconnection and reconnection of plant and equipment

Part C – Network Planning Criteria

The purpose of Network Planning Criteria is to strike a balance between each User's need for a safe, secure, reliable, high quality electricity supply and the desire for this service to be provided at minimal cost. At the same time, environmental and social considerations shall be taken into account.

13 Introduction

14 Supply contingency criteria

[15] D2013/653383 - Network Technical Code and Network Planning Criteria v3.1

15 Steady state criteria

18 Construction standards criteria

19 Environmental criteria

Of particular importance for this study is chapter 14 of the Network Planning Criteria, 'Supply contingency criteria'.

Table 13 on page 126 of the Network Planning Criteria defines that for a load over 50 MVA in a CBD or Urban area, area demand is required to be restored within 5 hours following a second contingency. This is referred to as class of supply D.

The critical second contingency event in the Darwin/Katherine network that affects more than 50 MVA of load is the failure of two of the three 132/66 kV transformers at Hudson Creek.

12. Background

Hudson Creek Terminal Substation has three existing 132/66 kV power transformers. The transformers are rated 75 MVA ONAN/ 125 MVA ONAF[16], with a cyclic rating of 131.5 MVA. They provide the only connection between the 132 kV network from Channel Island and the 66 kV transmission network that supplies Darwin and surrounding areas. As such these assets are critical to maintaining continuous supply.

AEMO has also produced a forecast for Hudson Creek transformer maximum demand. The corresponding 10% PoE maximum demand value is 205 MVA[17], with this value forecast to decline to 177 MVA by 2023/24. AEMO does not state what level of output from Weddell power station has been used in this forecast. Figure 1 shows the load forecast for Hudson Creek.

[16] D2017/263255 - Network_Management_Plan_2013_14_to_2018_19_-_January_2017_Information_Update. Appendix 3B.
[17] D2017/485465 - AERReportForPWC_V3. 'Section 5.4 MAXIMUM DEMAND' tab.

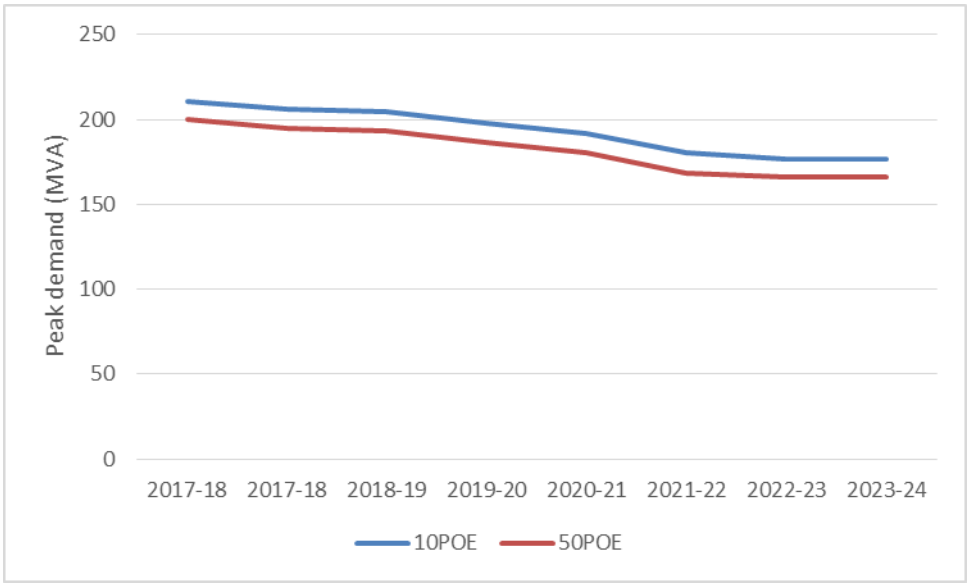


Figure 1 – Hudson Creek Terminal peak demand forecast

Figure 2 below shows the single line diagram of the Darwin- Katherine transmission network. The diagram shows that the three 132/66 kV transformers at Hudson Creek form the only connection between the 132 and 66 kV parts of the network.

Darwin city, suburbs and surrounding rural areas are supplied via the 66 kV network. The largest power station, Channel Island, is connected to the 132 kV network. This topology indicates the criticality of the 132/66 kV transformers.

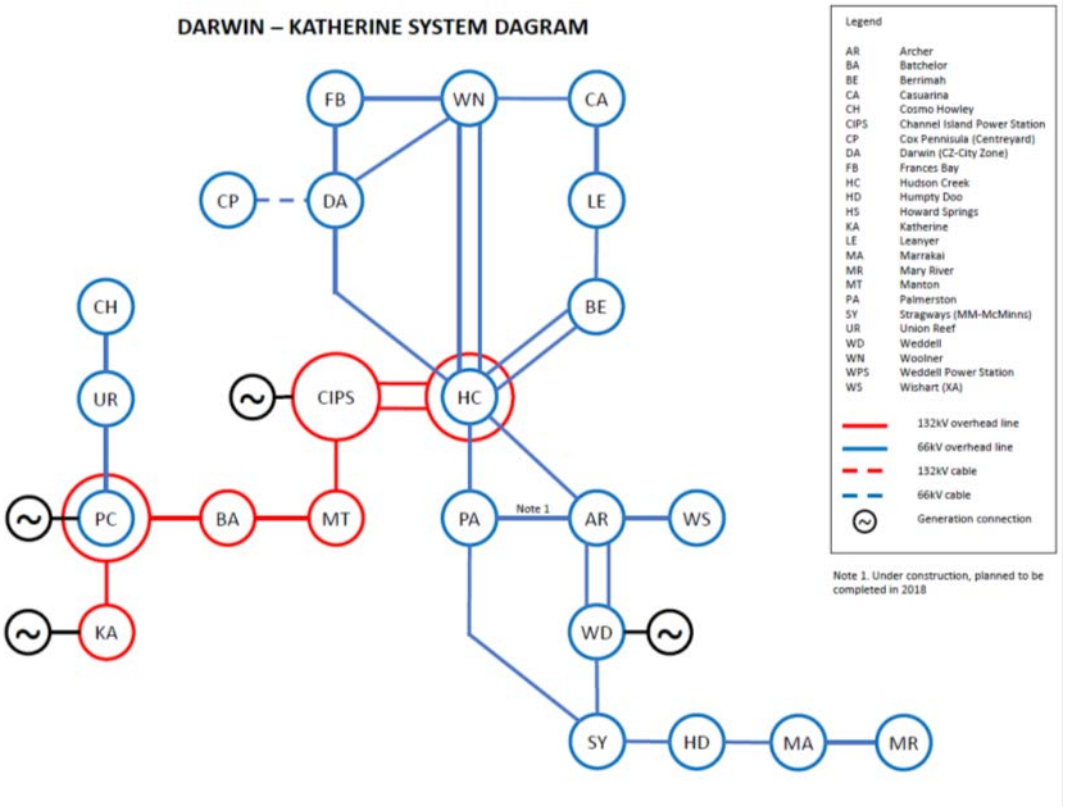


Figure 2 - Darwin Katherine Existing Transmission Network

The Network Technical Code and Network Planning Criteria set out the supply contingency criteria which the Darwin-Katherine network is designed to meet. In the case of load over 50 MVA in the CBD and Urban areas, class of supply 'D'[18] applies. This class of supply requires that area demand can be re-supplied within 5 hours in the case of a second supply contingency.

In the event of a failure of two transformers at Hudson Creek, the cyclic rating of 131.5 MVA for one transformer would apply. The full rating of the Weddell power station is 129 MW with all three units in service. Given that the units are capable of

[18] D2013/653383 - Network Technical Code and Network Planning Criteria v3.1. Table 13, page 126.

operation at 0.8 power factor this would give a total output of up to 161 MVA. In reality, the actual output will be about 15MVA less to allow one machine to regulate and provide spinning reserve.

The total forecast maximum demand to be supplied via the Darwin 66 kV network is forecast to decrease slightly over the next 6 years, as shown in Figure 3[19]. This means that in the case of a failure of two of the three 132/66 kV transformers at Hudson Creek, a shortfall in supply capacity exists, with one transformer in service at Hudson Creek, and Weddell power station at full output. The precise amount of load shedding that would be required is difficult to determine, and would depend on the actual load and power factor of the load at the time of the event, and the power factor capabilities of the generators at Weddell and the availability/reliability of the generators at Weddell.

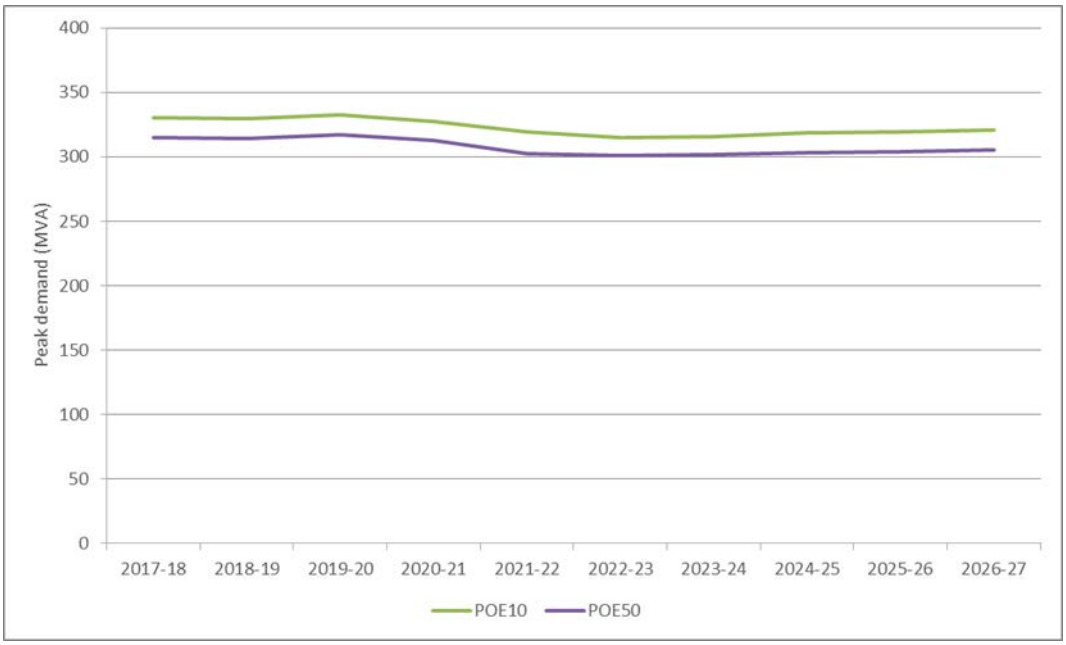


Figure 3 - Total forecast Darwin and Surrounds 66kV system maximum demand

[19] Source: AEMO, AERReportForPWC_V3, Darwin 66kV Non-coincident, weather corrected maximum demand

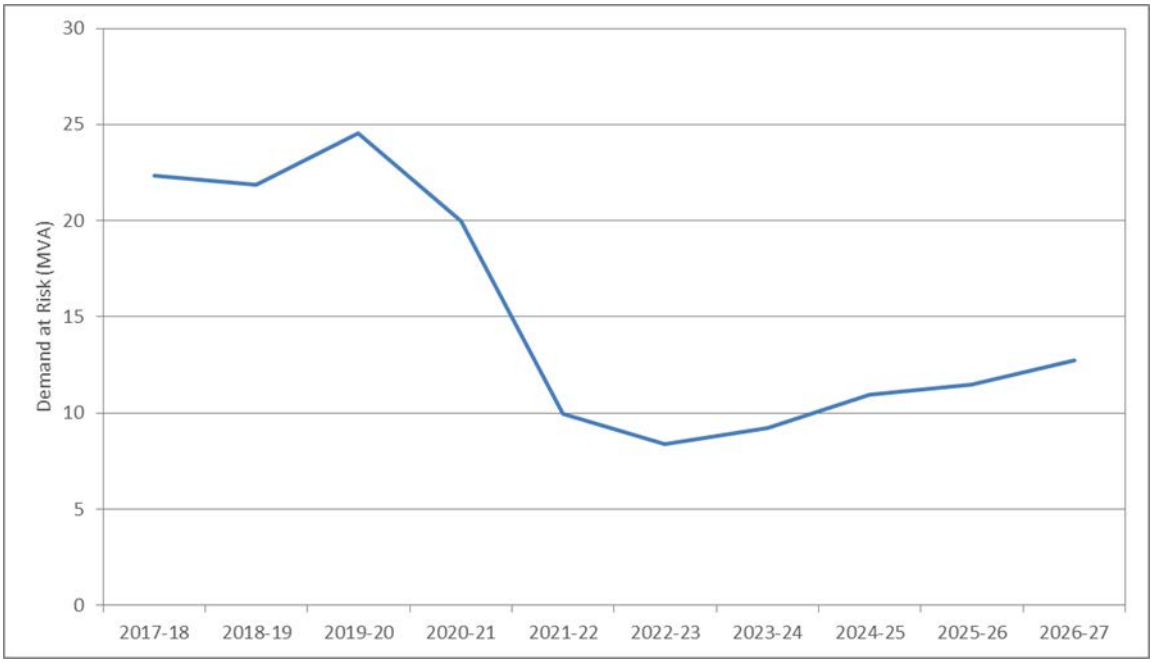


Figure 4: 66kV supply capacity shortfall for double contingency at Hudson Creek

Since it is unlikely that it would be possible to restore an outage of two transformers at Hudson Creek within five hours, it can be stated that the current network arrangement does not meet the second supply contingency requirement for class D supply. The Network Planning Criteria requires that this issue should be addressed.

13. Options Considered

13.1. *Do Nothing*

This option is not considered reasonable since the forecast post contingency maximum demand on the remaining Hudson Creek 132/66 kV transformer is expected to exceed its cyclic rating in the 2018/19 financial year. This would lead to in inability to support peak demand for the duration of the outage of two transformers.

13.2. *Demand Management*

A demand management option which reduces the maximum demand on the Darwin transmission network to be reduced would allow higher cost network investment options to be delayed.

The most likely sources of demand management are via curtailment contracts with large commercial and industrial customers or through initiatives targeted at residential customers. PWC has not identified any demand management options which would meet this requirement but will continue to explore the technical and commercial viability of this option.

13.3. *Purchase a Contingency spare 132/66 kV Transformer*

Having a spare 132/66 kV power transformer of similar specification to the existing units at Hudson Creek would greatly reduce the time need to fully restore supply following a two transformer outage during high load.

In the event of two transformers at Hudson Creek failing and being unrepairable, it may be possible to address any short term overloading of the remaining in service transformer, by maximising output from the Weddell power station, and some load shedding. Beyond a period of weeks or months, it is likely that the output from Weddell power station would have to be reduce due to maintenance or other issues.

The specification, purchase and delivery of replacement transformers would be likely to take a minimum of nine months, during which time the Darwin network would not meet the requirements of the Network Planning Criteria.

The purchase of a contingency spare 132/66 kV power transformer to match the specifications of the existing transformers at Hudson Creek seeks to reduce the risk of supply to the Darwin area failing to meet the Network Planning Criteria. In addition the availability of such a transformer would increase the operational flexibility of the network in the event of an extended single transformer outage at Hudson Creek. The transformer would be maintained in storage and be ready for installation when required. It would be expected to be possible to have the transformer installed in place of one of the two failed units and in service with two weeks of the initial outage.

13.4. *Establish a new 132/66 kV substation at Weddell*

The existing Weddell power station is connected to the 66 kV network and is sited adjacent to the Channel Island to Hudson Creek 132 kV circuits. The establishment of a 132/66 kV substation would not require extensive transmission line construction.

The initial substation installation would be a single 132/66 kV 75/125 MVA transformer with a 132 kV busbar, associated circuit breakers for two incoming lines, and the transformer. The 66 kV would be connected to the existing Weddell 66 kV busbar via a new circuit breaker. Space would be provided for a future second transformer and associated circuit breakers. A single line diagram of this proposal is shown as Option 1 in Appendix A.

Weddell Power station is located less than 1 km from the Channel Island to Manton 132 kV line. Accordingly it would be possible to connect the proposed Weddell 132/66 kV substation to this line. A single line diagram of this proposed arrangement is shown as Option 2 in Appendix A. This arrangement may be electrically preferred to Option 1.

A further advantage of establishing a 132/66 kV substation at Weddell is that it spreads the transformation 132/66 kV transformation capacity across two sites, making the network more robust against a high impact but low risk failure of all three transformers at Hudson Creek substation.

A detailed load flow will need to be conducted to quantify any constraints (if any) being placed on Weddell generations as a result of establishing a new substation at Weddell.

13.5. *Establish a new 132/66 kV substation at Archer*

The establishment of a new 132/66 kV substation at Archer is electrically very similar to the establishment of a substation at Weddell as proposed in section 5.3 above.

The existing Archer 66/11 kV substation is located less than 300 m from the Channel Island to Hudson Creek 132 kV lines. The proposed 132/66 kV substation would connect to the existing 66 kV substation at Archer.

The proposed connection is shown in a single line diagram as Option 3 in Appendix A.

Option 4 in Appendix A shows the alternative of connecting Archer 132 kV to the existing Channel Island to Manton line. This option is unlikely to be preferred, since it requires the construction of approximately 8.5 km of dual circuit 132 kV line, meaning it is expected to be the most expensive network option.

The selection between the Weddell and Archer sites should be based on electrical network analysis, land acquisition costs, and likely construction costs between the two sites. The Archer site option has an advantage over the Weddell site option in that it does not increase the load on the Weddell to Archer 66 kV lines. Further detailed study will be required to determine which of these options would be preferred.

A detailed load flow will need to be conducted to quantify any constraints (if any) being placed on Weddell generations as a result of establishing a new substation at Archer.

13.6. *Install Fourth Transformer at Hudson Creek*

The installation of a fourth transformer at Hudson Creek is expected to be the least cost location for the installation of an additional 132/66 kV transformer in the Darwin network. This is due to the fact the substation infrastructure is already in place.

A disadvantage of this option is that the entire 132/66 kV transformation would continue to be on a single site. This leaves the network continuing to be vulnerable to a catastrophic event leading to the loss of the entire Hudson Creek substation.

The single line diagram relevant to this option is shown as Option 5 in Appendix A.

13.7. *Connection of additional generation*

Connection of up to 25 MW of additional generation capacity in the Darwin 66 kV transmission network would alleviate the network constraint discussed in this report.

There are a number of solar proponents intending to connect on to the 66kV Darwin network. However, these proposals are in the early stages and none has been confirmed. PWC will continue to explore the technical and commercial viability of this option.

14. Review

Detailed options studies will be required to determine which of the proposed options provides the best benefit to cost ratio. Table 1 below lists currently understood advantages and disadvantages of the network options.

Table 1 – Network Options Evaluation

Option Number	Description	Advantages	Disadvantages
1	Weddell – CIPS to HC line	Land available for construction Minimal new line construction	
2	Weddell – CIPS to MT line	Land available for construction	700 m of 132 kV dual circuit required to be constructed
3	Archer – CIPS to HC line	Minimal new line construction	
4	Archer – CIPS to MT line		8.5 km of 132 kV dual circuit required to be constructed
5	Hudson Creek fourth transformer	Lowest cost network option	Does not address the high impact low risk failure of the Hudson Creek substation[20].

[20] D2013/653383 - Network Technical Code and Network Planning Criteria v3.1, clause 14.2(c) page 123.

15. Conclusion

In order to meet the requirements of the Network Planning Criteria, additional 132/66 kV transformation capacity, or generation connected at 66 kV, is required in the Darwin transmission network.

The purchase of a contingency transformer as described in section 5.3 above is recommended. While this option may not meet the strict requirement of the Network Planning Criteria to restore supply within 5 hours following a two transformer outage, this is the preferred option and represents good electricity industry practice, since a two transformer outage is a very low likelihood event and this option will be much more cost effective than other options.

16. Appendix A – Single Line Diagrams

Elements shown with yellow highlighting are the proposed elements discussed in this report.

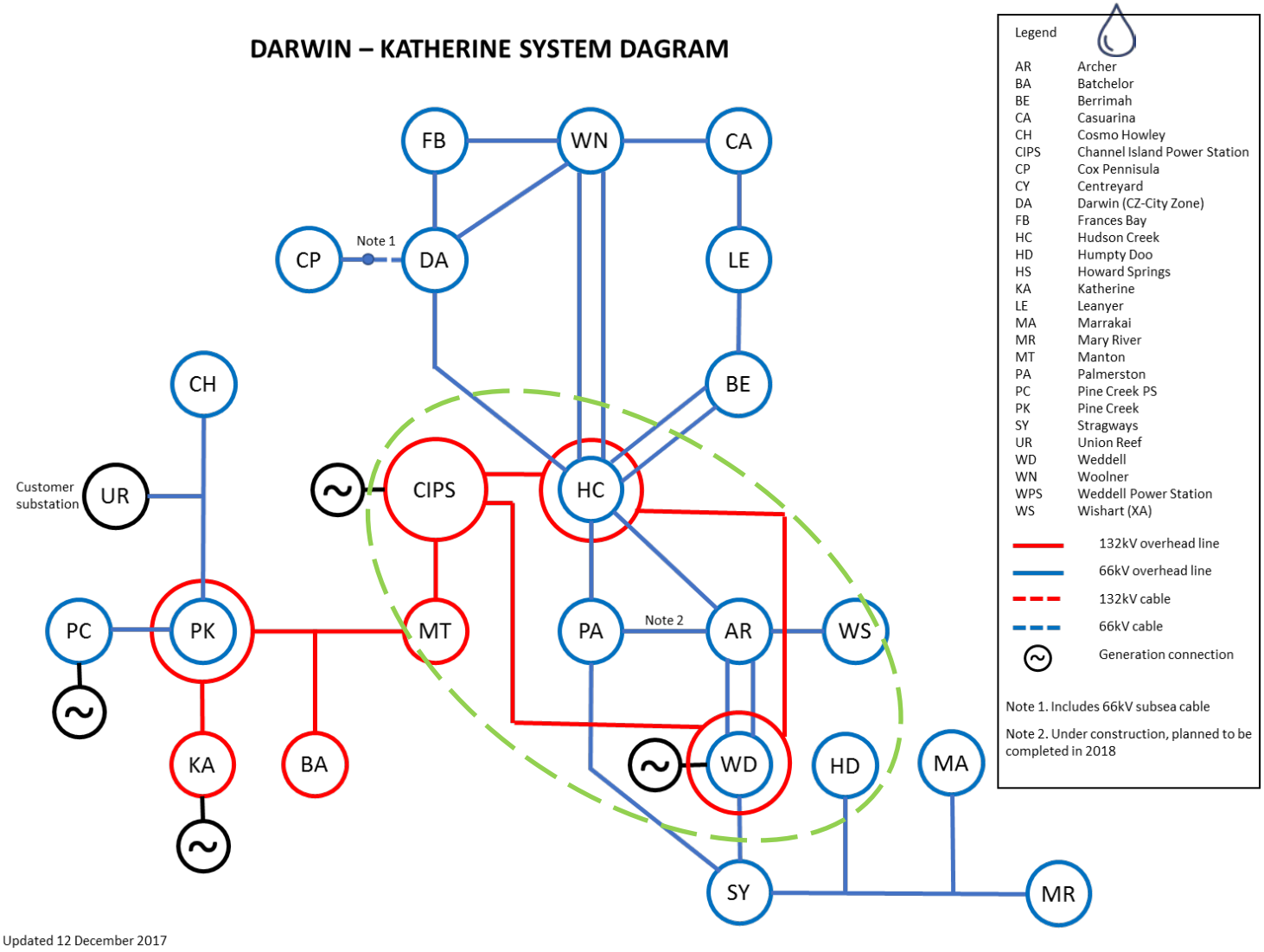


Figure 5 - Option 1 - Weddell Substation connected to Channel Island to Hudson Creek line

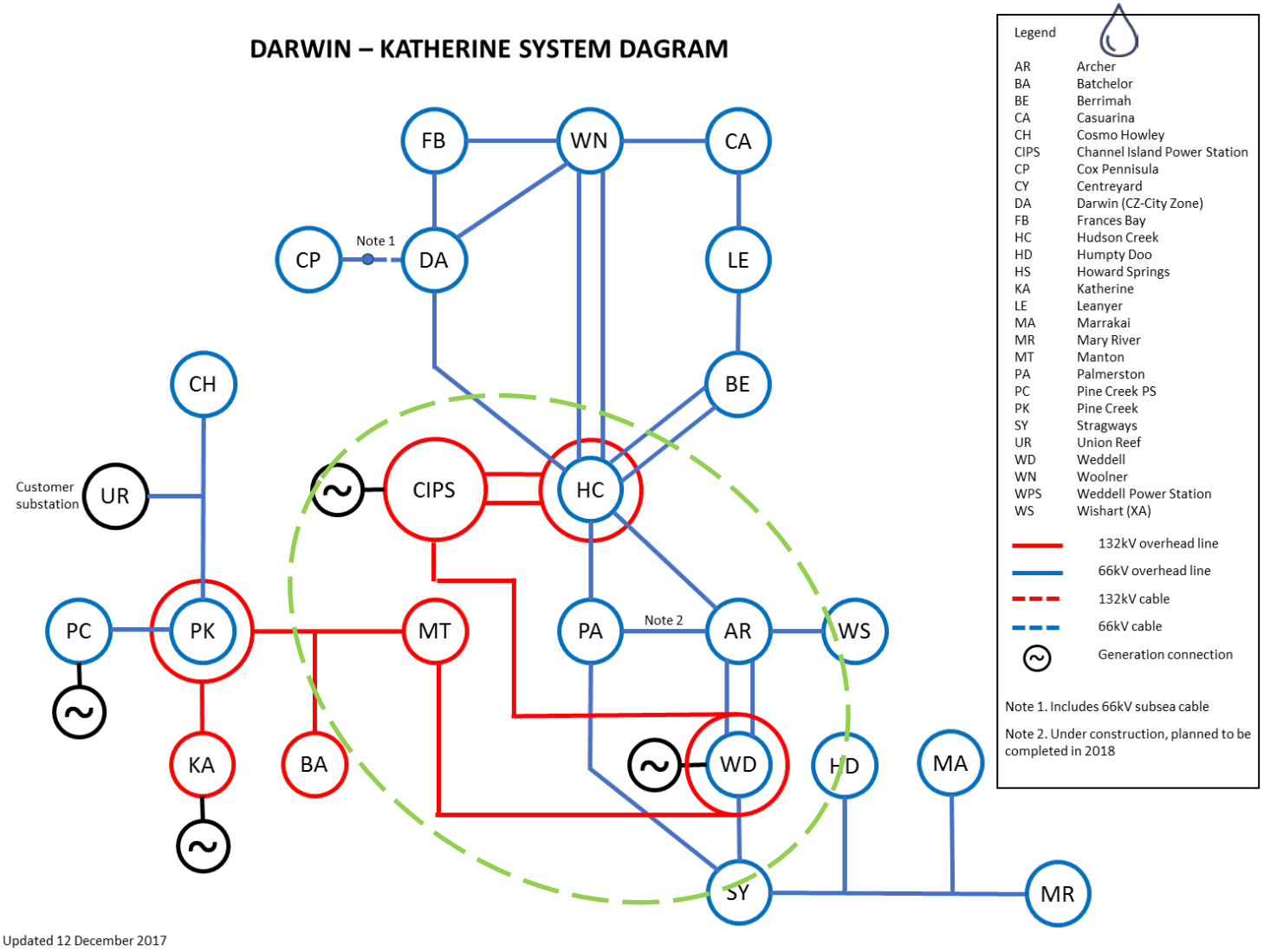


Figure 6 - Option 2 - Weddell Substation connected to Channel Island to Manton line

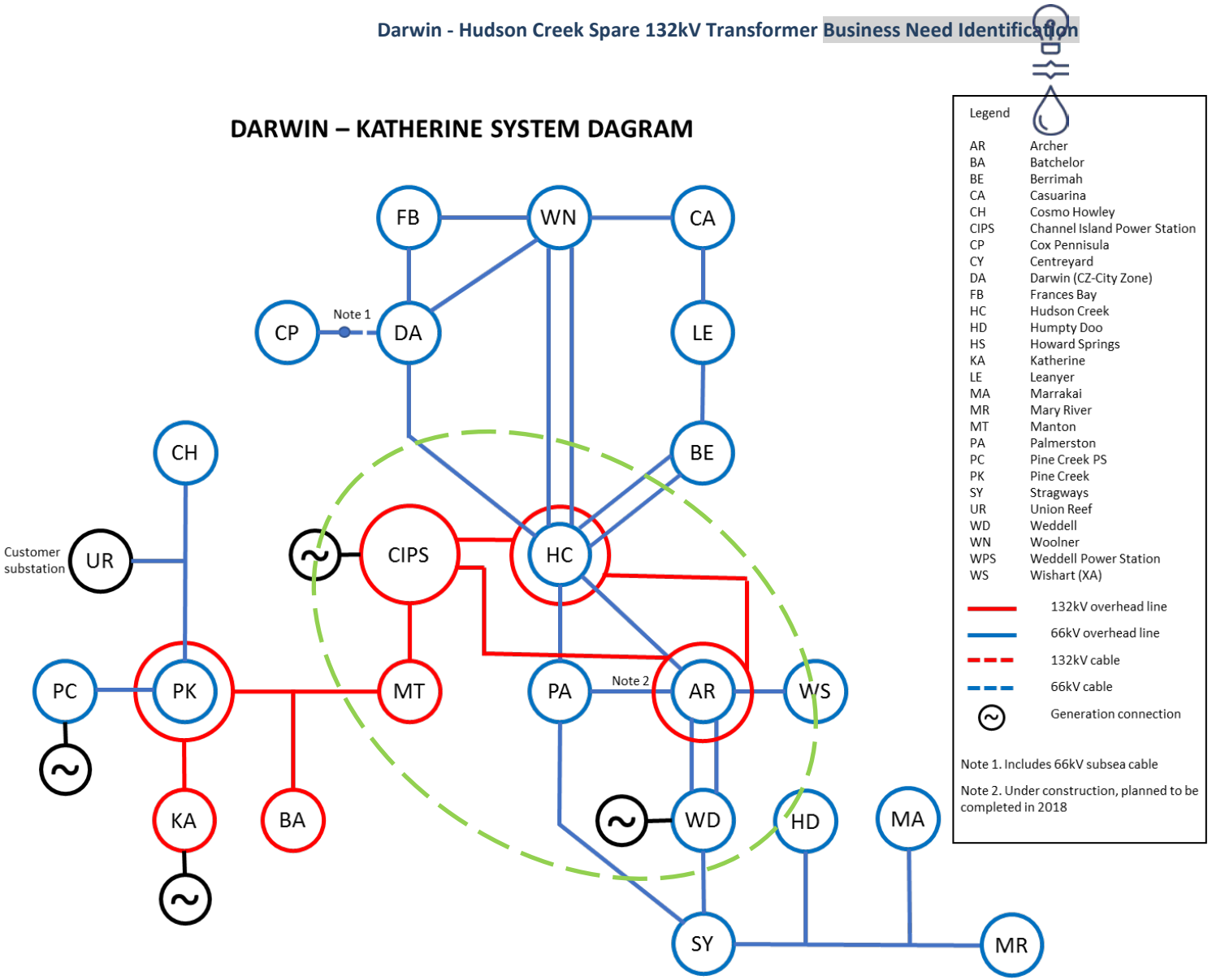


Figure 7 - Option 3 - Archer Substation connected to Channel Island to Hudson Creek line

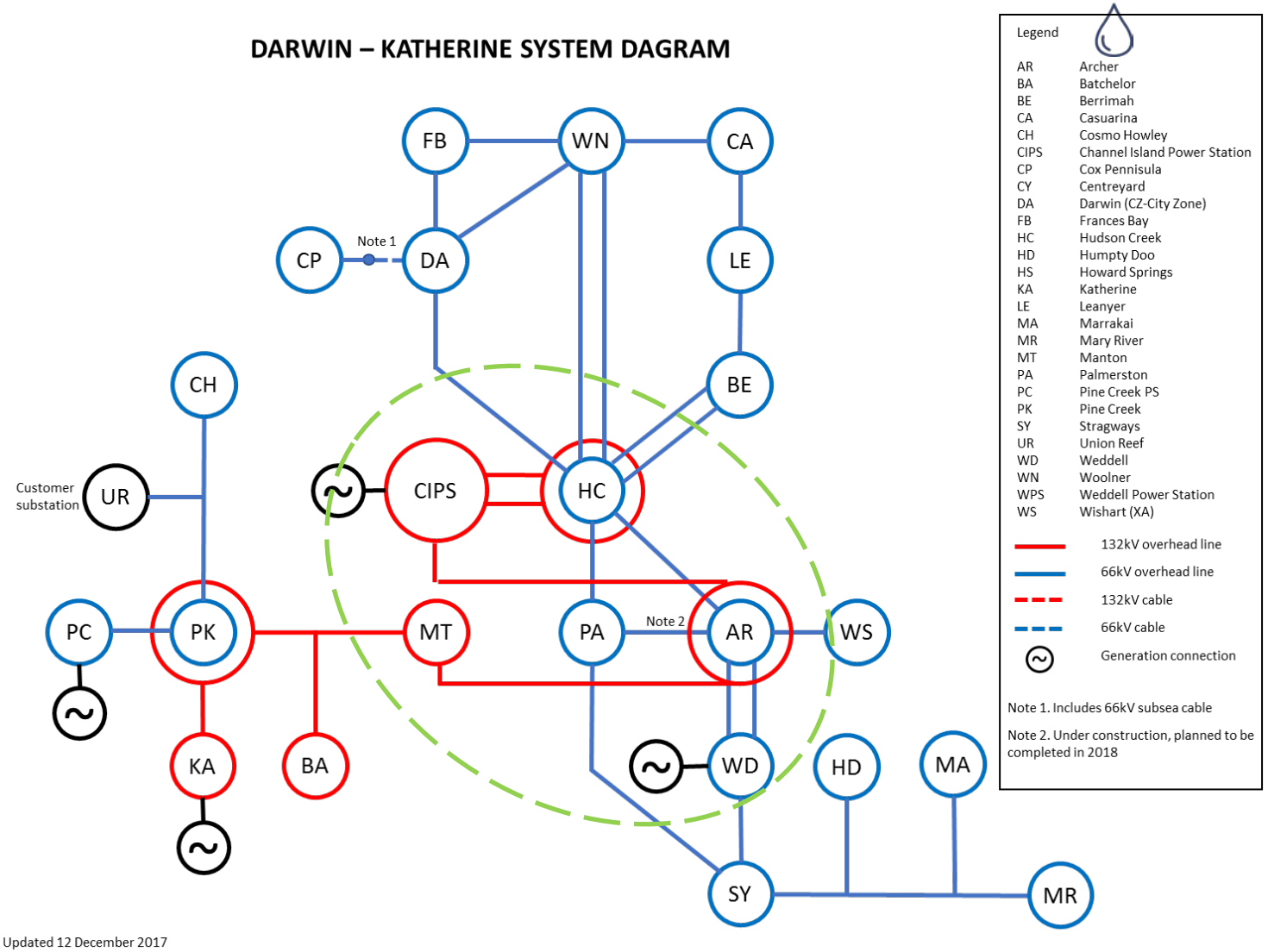


Figure 8 - Option 4 - Archer Substation connected to Channel Island to Manton line