PowerWater

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Title: **NPR1419 Annual Transmission Planning Report 2013/14**

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Executive Summary

The annual transmission planning report provides information to PWC's internal stakeholders, Utilities Commission, market participants and other interested parties on the current transmission capacity and emerging limitations of the Power Water Corporation (PWC) electricity transmission network.

The report covers a ten-year planning period and includes demand projections; emerging network limitations or constraints; and information on pending and proposed transmission network developments.

PWC's existing Darwin/Katherine electricity transmission network has transmission reliability levels as outlined in Network Technical Code under Network Planning Criteria for all zone substations.

For the complete planning horizon from 2014 to 2024, power flow analysis shows following two transmission constraints:

1. Proposed Wishart modular zone substation connection issue.
2. Overloading of Hudson Creek/Palmerston 66 kV circuit on an outage of Weddel/McMinn 66 kV circuit and overloading of Weddell/McMinn 66 kV circuit on an outage of Hudson Creek/Palmerston 66 kV circuit.
3. Reactive power control in Alice Springs during low demand periods due to high 66 kV cable capacitance.

Proposed temporary solution to 1st transmission constraint:

Re-establish Hudson Creek/Woolner 66 kV line and connect Wishart modular zone substation directly to 66 kV circuit which is from Archer zone substation.

Proposed permanent solution to 1st transmission constraint:

Progressively construct three 66 kV bays at Wishart modular zone substation and make existing Archer/Woolner 66 kV circuit in and out to Wishart 66 kV bus.

Proposed solution to 2nd transmission constraint:

To construct new 66 kV single transmission circuit (already identified as a pending project) between Archer and Palmerston zone substations by 2016/17.

1.0 INTRODUCTION

1.1 Demand Forecast & Network Planning

Forecasts of the power and energy demand imposed on a power system network must be made for as accurate as possible to optimise capital expenditure while maintaining chosen supply reliability and security levels.

Darwin – Katherine power network is the largest power system operated and maintained by Power and Water Corporation of Northern Territory. In recent years, it has seen nearly 300 MW of peak power demand and more than 1500GWh (1547GWh) of energy demand per year with around 60% of load factor.

Transmission network planning is based on forecasts of electricity demand rather than energy consumption to ensure sufficient capacity to meet maximum demand for electricity. A decline in large industrial demand and rapid increase of solar photovoltaic (PV) systems and energy efficiency measures have all had an impact on reducing energy consumption and, to a lesser extent, maximum demand.

1.2 Background

Power and Water Corporation (PWC) is the sole Transmission Network Service Provider (TNSP) for the Northern Territory. PWC plans, builds, owns, operates and maintains high voltage transmission network for entire state of Northern Territory.

PWC undertakes an annual review of the capability of its transmission network to meet forecast electricity demand under a variety of operating scenarios.

The above annual review covers a ten year planning period and includes zone substation peak demand projections; emerging network limitations or constraints and information on completed, committed, pending or proposed transmission developments.

2.0 DEMAND PROJECTIONS

2.1 Maximum Demand Projection

PWC's demand projection procedure for transmission planning starts with receiving and collating half-hourly zone substation transformer demands on primary side (132 or 66 kV bus). From the above data, 10 highest peak demands for each substation are recorded with the date and the time. Then the above peak demands are temperature corrected using maximum recorded temperature of the particular day that peak occurred. Highest temperature corrected peak demand is selected as the expected possible peak demand with P50 or P10 probability of exceedance.

The following table illustrates the final peak demand forecasts for zone substations within Darwin/Katherine system.

	DIVERSIFIED ZSS MAXIMUM DEMAND FORECAST BASED ON GSP										
ZSS Name	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Archer (P50)	20.35	26.88	27.92	37.63	41.43	42.47	52.70	53.74	54.77	55.81	56.85
Batchelor (P50)	2.20	1.94	1.69	1.44	1.19	0.94	0.94	0.94	0.94	0.94	0.94
Berrimah (P50)	38.50	32.70	30.76	31.16	31.56	33.12	33.52	33.92	34.32	34.72	35.12
Brocks Creek (P10)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Casuarina (P50)	51.32	52.33	34.44	34.44	34.44	34.44	34.44	34.44	34.44	34.45	34.45
Centre Yard (P10)	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41
City (P50)	57.27	47.88	48.60	49.31	50.02	50.73	51.45	52.16	52.87	53.59	54.30
[redacted]											
Wishart (P50)	0.00	9.00	9.19	9.39	9.58	9.77	9.97	10.16	10.35	10.55	10.74
Frances Bay (P50)	11.15	28.53	29.00	29.48	29.95	30.43	30.91	31.38	31.86	32.33	32.81
Humpty Doo (P50)	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Katherine (P50)	28.17	27.34	26.51	25.68	24.85	24.02	24.02	24.02	24.02	24.02	24.02
Leanyer (P50)	0.00	0.00	21.26	21.72	22.17	22.63	23.09	23.55	24.00	24.46	24.92
Manton (P50)	3.87	8.22	7.86	7.51	7.15	6.80	6.80	6.80	6.80	6.80	6.80
Mary River (P10)	3.20	3.27	3.34	3.41	3.47	3.54	3.61	3.68	3.75	3.82	3.89
McMinns (P50)	21.90	26.93	34.96	35.59	36.21	25.34	25.97	26.60	27.23	27.85	28.48
Palmerston (P50)	33.14	33.98	44.17	50.92	51.67	54.43	55.18	57.93	58.68	59.44	60.19
Pine Creek (P50)	1.29	1.32	1.35	1.37	1.40	1.43	1.46	1.48	1.51	1.54	1.57
Weddell (P50)	6.92	10.97	12.01	13.06	4.10	5.15	6.20	7.24	8.29	9.34	10.38
Woolner (P50)	44.17	46.67	49.18	51.68	54.18	56.69	59.19	61.70	64.20	66.70	69.21
[redacted]											
Total (MVA)	**341**	**376**	**400**	**422**	**422**	**420**	**438**	**448**	**457**	**465**	**473**

Table 1.1 Zone Substation Maximum Demand Projections

A regional demand forecast was developed using the correlation between Gross State Production and the system maximum demand. This has been used to determine possible maximum demands on 132 kV transmission circuits between Channel Island Power Station (CIPS) and Hudson Creek Terminal Station (HCTS).

2.2 Regional Demand Forecast

Historical maximum demand trend is taken as the base for future maximum demand projection. It was seen that the correlation between GSP and historical maximum demand trend is strong enough to develop regional maximum demand forecast. It was also seen that the temperature corrected historical maximum demand trend also have a high correlation with GSP. Therefore the linear trend between past and future GSP projections, and temperature corrected historical maximum demand trend was used to finalise the maximum demand forecast by applying correction factor for photovoltaic influence on regional maximum demand.

3.0 TRANSMISSION MODEL

3.1 Base Model

Base model for transmission planning was prepared from the existing PSSE power system model to reflect actual network connections as at the base year 2013/14. Since we are dealing with zone substation peak demands for the above year and another 10 years ahead, generation despatch was set as follows:

Channel Island Power Station - maximum of 284 MW + Slack Bus
Weddell Power Station – maximum of 120 MW
Katherine Power Station – maximum of 24 MW
Pine Creek Power Station – maximum of 20 MW

The above gives total maximum generation of 448 MW and slack bus generator was set to provide the deficit during latter years of the planning horizon.

The base network model was modified appropriately in future years to reflect committed, pending and proposed transmission developments.

4.0 POWER FLOW STUDIES AND RESULTS

4.1 Load Flow

Load flow study was performed for the base year with zone substation maximum demands for 2013/14 while noting number of iteration to converge the solution and maximum MW and MVAr bus mismatch figures. After obtaining acceptable convergence, power flow of each and every branch of the network is entered into a spreadsheet showing maximum line flows and line utilisation factors.

The above was repeated for following 10 years changing ZSS peak demands which are copied from the above demand projection while modifying the network as mentioned above.

Also load flow studies were performed on transmission line outages which are carefully selected to see the over loading conditions of alternative transmission routes.

4.2 Transmission Utilisation Factors

Transmission utilisation factors for each transmission line over the entire planning horizon are given in the Appendix A.

4.3 Contingency Loading

Contingency loading of selected transmission lines over the entire planning horizon is given in the Appendix B.

5.0 ANALYSIS AND RECOMMENDATIONS FOR D/K SYSTEM

5.1 Year 2014/15

The first year of the planning period with all zone substations loaded to undiversified and temperature corrected maximum possible demands and the network system is as same as the base year.

The following diagram shows part of the 66 kV network with load flow results with no transmission outages:

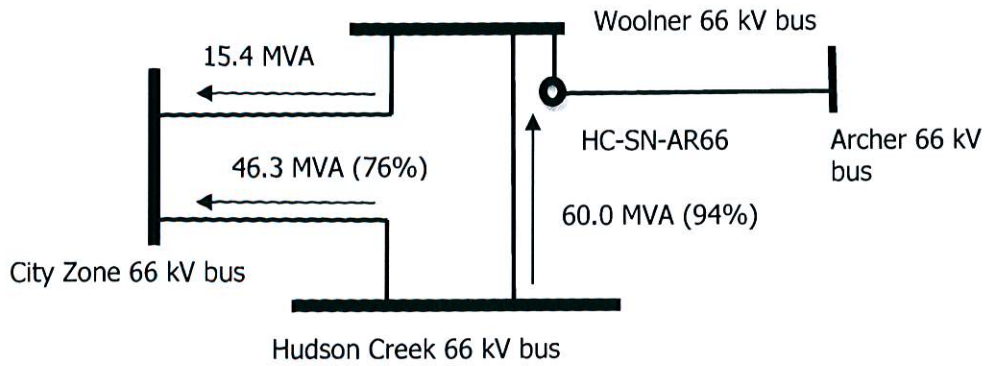


Figure 5.1 Transmission Line Loadings (2014/15)

The above diagram clearly shows that Hudson Creek/Woolner 66 kV line load is almost at its normal rating (94% loading). If we are to loose City Zone/Hudson Creek line due to an outage then Hudson Creek/Woolner line will have to carry 89.5 MVA (thermal rating of the line is 80 MVA). In other words the line loading will be almost 112% of its thermal rating.

Recommendation to avoid above overloading under contingency conditions:

1. Disconnect Archer/Woolner 66 kV line at HC point (Wishart modular substation) and connect Archer/HC-SN-AR66 line directly to Wishart zone substation (refer to figure 7.12).
2. Reconnect Hudson Creek line back to Woolner zone substaion.

The above will avoid the aforesaid overloading of Hudson Creek/Woolner line and the line flows after above network changes are given in the Appendix A.

5.2 Year 2015/16

The network system has been changed to accommodate the above recommendations.

"Transmission contingency – 1" on Contingency Loading page of Appendix A shows that an outage of Hudson Creek/Palmerston 66 kV line will over load Weddell/McMinn 66 kV line 114% of its thermal rating.

Similarly, "Transmission contingency – 2" on the same above page shows that an outage of Weddell/McMinn 66 kV line will over load Hudson Creek/Palmerston 66 kV line 103% of its thermal rating.

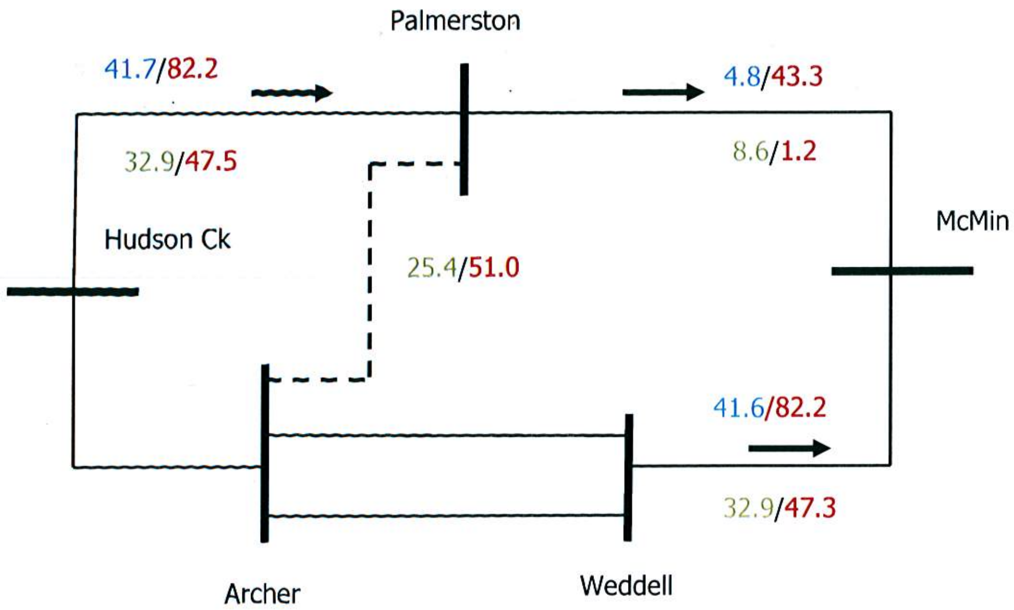
The above two contingency events clearly shows that transmission ring circuit from Hudson Creek/Palmerston/McMinn/Weddell/Archer and back to Hudson Creek will lose N-1 reliability level on two links after the year 2015/16.
In order to alleviate the above contingency overloading the following transmission development options were considered:

1. Either, to construct 2nd 66 kV circuit for Hudson Creek/Palmerston line, or;
2. To construct 2nd 66 kV circuit for Weddell/McMinn line, or;
3. To construct a new 66 kV circuit from Archer to Palmerston.

Power flow analysis and cost consideration shows that the third option is more suitable as well as long lasting solution for the above problem.

Recommendation to avoid both above over loadings under contingency conditions:

To construct a new 66 kV single circuit transmission line from Archer zone substation to Palmerston zone substation and commission it before 2016/17 wet season.



Blue & Red Fonts – normal & contingency loading for the year 2015/16
Green & Red Fonts – normal & contingency loading for the year 2016/17 after implementing the new line

Figure 5.2 Transmission Line Loadings 2015/16/17

5.3 Year 2016/17

The network been changed to accommodate aforesaid recommendation of implementing new 66 kV line between Archer and Palmerston zone substations.

Load flow analysis does not show any over loadings under normal or single contingency operating conditions.

5.4 Year 2017/18

Load flow analysis does not show any over loadings under normal or single contingency operating conditions.

5.5 Year 1018/19

Load flow analysis does not show any over loadings under normal operating conditions. However, Hudson Creek/Woolner 66 kV line-2 shows slight overloading when Hudson Creek 66 kV line-1 is out.

Recommendation to avoid above over loading under contingency conditions:

1. Make Hudson Creek/Woolner line-2 in and out to Wishart zone substation 66 kV bus (refer to figure 7.13).

5.6 Year 2019/20

Load flow analysis does not show any over loadings under normal or single contingency operating conditions.

5.7 Year 2020/21

Load flow analysis does not show any over loadings under normal or single contingency operating conditions.

5.8 Year 2021/22

Load flow analysis does not show any over loadings under normal or single contingency operating conditions.

5.9 Year 2022/23

Load flow analysis show that Hudson Creek/Woolner line-1 is fully loaded (98% of the normal rating) under normal operating conditions. Also the same circuit will be slightly overloaded (101% of the thermal rating) when Berrimah/Leanyer 66 kV line is out.

The above over loading condition under contingency conditions is not significant and do not warrant a solution other than monitoring the line closely.

5.10 Year 2023/24

Load flow analysis show that Hudson Creek/Woolner line-1 is fully loaded (100% of the normal rating) under normal operating conditions. Also the same circuit will be slightly overloaded (104% of the thermal rating) when Berrimah/Leanyer 66 kV line is out.

Load flow analysis also shows that the two 132 kV transmission circuits from Channel Island power station to Hudson Creek terminal Station will just lose their N-1 reliability level with normal ratings. However, it is not significant enough to develop a new transmission project.

The above over loading condition under contingency conditions is not significant and during the peak hours as we are using undiversified maximum demands for all zone substation. In other words all zone substations to realise its maximum demand at the same time is very rare.

Recommendation for the above overloading under a specific contingency condition:

Revisit and investigate the above condition in following years as the problem is to be occurred in final years of the planning horizon.

6.0 ANALYSIS AND RECOMMENDATIONS FOR ALICE SPRINGS

6.1 Introduction

Overhead power lines usually have higher inductive reactance between conductors compared to their capacitive reactance with earth. This phenomenon is complimented by usually inductive system demands. However, underground cables possess much higher capacitive reactance than overhead lines. Therefore, networks with considerable lengths of under-ground cables could negate inductive system demands by generating reactive power at low demand periods, improving overall power factor of the system. In some cases such improvements could be too much during very low demand periods forcing some generators to operate on under-excited mode.

Sometimes demand for electricity imposes a leading power factor on the power source. These demands do not present any problems when powered by a strong utility. However, if a collection of small generators is the power source, the leading power factor can cause instability or even failures.

Low speed generators, especially those driven by diesel engines, usually have limited operating flexibility with under-excitation. Therefore, it is desirable to compensate capacitive reactance of underground cables during low demand periods.

6.2 Background

PWC'S Alice Springs system is a comparatively smaller system with low demand density over larger geographic area. It has considerable length of underground cables which contributes substantial portion of the system's reactive power requirement. However, according to PWC's system operation planning unit, reactive power production of underground cables impose leading power factor on some generators during low system demand periods causing operational problems. It is also stated that by switching off one of the 66 kV underground cables between Owen Springs and Love Grove during low demand periods alleviate the above problem.

6.3 Investigation

6.11 Power Flow

Alice Springs PSSE model was used to simulate load flows for high demand to low demand by scaling the loads and observe generator loadings at various demand levels. The results are given below:

ALICE SPRINGS DEMAND PROFILE			
Generation		Demand	
MW	MVAR	MW	MVAR
14.6	0.2	14.5	6.3
16.2	0.7	16.1	6.9
20.2	2.2	20.1	8.4
25.3	4.5	25.1	10.2
30.4	7.2	30.2	12.1
35.5	10.6	35.3	13.9
40.4	14.4	40.2	15.7
50.6	24.1	50.3	19.3

Table 1.11 Generation Vs Demand at Various Demand levels

The following diagram shows the same above in graphical form:

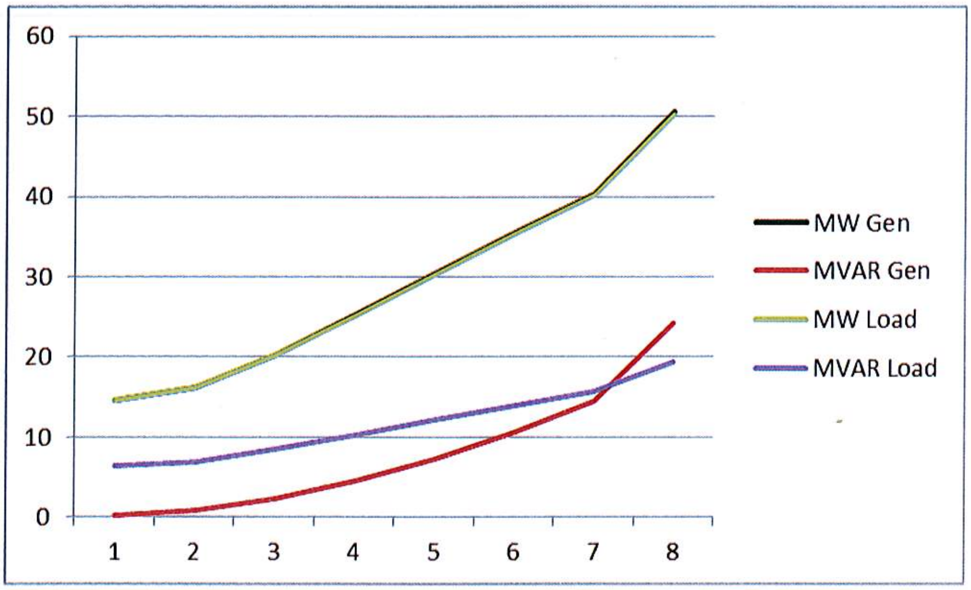


Diagram 1.11 Generation Vs Demand

The above table and diagram shows very clearly at very low demand period reactive power generation is almost zero. In fact close scrutiny of power flow results for lowest demand show that some generators absorb reactive power (under excited) from the system while others are producing (over excited).

6.12 66 kV Cable Parameters

Two 66 kV circuits from Owen Springs to Love Grove have some underground cable sections. The cable details are given below:

1200 mm, Single Core, Aluminium cables in trefoil configuration with about 60 mm spacing.

Circuit 1 – 16.921 km overhead section, 6.288 km underground section.
Circuit 2 – 15.466 km overhead section, 7.742 km underground section.

Cable capacitance is 0.35μF per km

The above is equivalent to capacitance of 2.2μF and 2.7μF for line-1 and line-2 respectively.

Therefore two cables sections capable of generating 3.0 and 3.7 MVAR of reactive power due their internal capacitance at 66 kV. Some of this reactive power will be nullified due to inductive reactance of cable sections.

6.13 Recommendation

During very low demand periods the aforesaid 66 kV cable sections produce well above 6 MVARs of reactive power which could overcome system's reactive power requirement resulting overall system power factor moving from lagging to leading.

Therefore, it is recommended to have 2 X 2 MVAR, 22 kV shunt reactors at Love Grove zone substation to use during low demand periods.

7.0 CONCLUSION

Planning for projects:

7.1 Two stage proposal 1

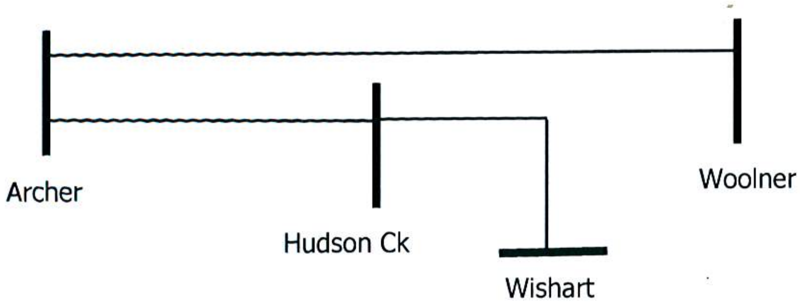


Figure 7.11 East Arm Zone Substation Connection as at present

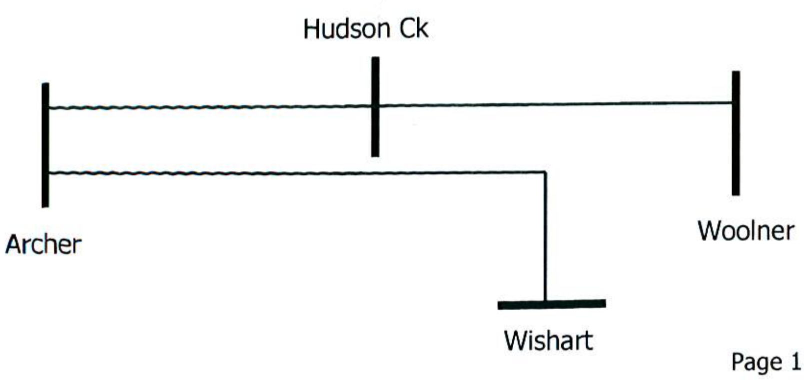


Figure 7.12 Proposed Network Changes in 2014/15

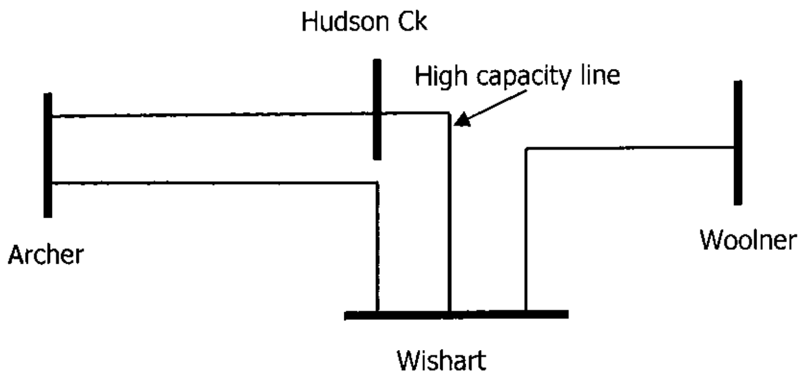


Figure 7.13 Propose Network Changes in 2018/19

It is proposed to change Wishart zone substation connections in two stages. First stage is just disconnecting Archer/Hudson Creek 66 kV line from its Hudson Creek 66 kV bay and connects it to Wishart 66 kV bay. Under the second stage, construction of two more 66 kV bays at Wishart 66 kV bus and terminate existing 66 kV circuits as shown on the above figure.

7.2 Proposal 2

To construct a new 66kV single circuit transmission line between Archer and Palmerston zone Substations. The above line has to be energised before 2016/17 wet season.

7.3 Proposal 3

To install 2 X 2.0 MVAR, 22 kV shunt reactor banks at Love Grove substation with 22 kV circuit breakers.

Appendix A Transmission Utilisation Factors - D2014/572852

Appendix B Transmission Contingency Loadings - D2014/572852