TRANSPOWER

System Vision Investigation

Grid Vision
(Technical Feasibility)

330/400 kV Transmission Line Upgrade Study

Analysis of costs and Practicality of upgrading two existing 220 kV lines to 330 kV Operation

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1. Executive Summary

A high level investigation based on the preliminary design criteria has shown that the cost of converting the ROX-ISL A and OTA-WKM A 220 kV lines for 330 kV operation is about 75% of a new line cost, if continuos and unrestricted outages can be obtained to build.

However, planning studies indicates that outages will be possible only around 1 a.m. to 6 a.m. during summer months even as early as 2005 and becomes even more restrictive in the subsequent years.

When practicality and provision for minimising outages are taken into account, the cost of conversion varies between 107% and 112% of new line costs. .

Therefore the conversion of the above two lines to 330 kV operation is not considered to be a viable or a practical option.

The conversion of SFD-TMN A and HLY-TMN A 220 kV double circuit line to 330 kV double circuit is neither feasible nor economic.

2. Purpose

To present the findings of the high level investigation conducted on the practicality of converting existing 220 kV lines for 330 kV operation.

This report is based on a very high level preliminary engineering work completed on two core grid lines namely, ROX-ISL A (ISL-LIV section) and OTA-WKM A lines. Overview comments on the practicality of converting SFD-HLY A line to 330 kV double circuit are also included.

3. Introduction

As part of the Grid Vision investigations, a high level analysis of converting some of the existing 220 kV circuits to 330 kV was undertaken. In addition, the options of building new 330 and 400 kV single and double circuit lines are also being investigated.

Teshmont Consultants have carried out a Pre-feasibility study of converting some of the existing 220 kV lines (Ref. 2). The preliminary results indicated that it may be possible to convert to 330 kV and that the cost of the upgrade varies from 35 to 80% without allowing for practicality issues.

In order to assess the practicality of conversion as well as to narrow down the costs, **Power line Solutions (PLS) NZ Ltd** was engaged to complete a high level quantitative analysis of the practicality of conversion and to derive associated costs, based on preliminary design information provided by Transpower.

The references used in this report are provided in Appendix A.

A copy of the PLS report is included in Appendix C.

4. Scope of Investigation

Phase 1 of the System Vision Project includes the investigation of technical feasibility of conversion of three critical transmission lines, namely ROX-ISL A (LIV-ISL section), OTA-WKM A and HLY-SFD A lines, to 330 kV operation. However, **PLS brief included only ROX-ISL A and OTA-WKM A lines**.

The scope for PLS included**:**

- Practicality of upgrading existing structures for 330 kV operation
- Outage requirements for strengthening works and for installing new conductors
- Work methods to reduce outage durations
- live-line maintenance constraints on existing structures
- order of magnitude cost estimates for conversion options
- Comparative costs for new 330 and 400 kV lines.

A detailed scope is provided in Appendix B.

Transpower provided the following information as input to PLS investigation.

- Extent of structural modifications and height increases required on the towers for conversion of 220 kV single cct towers to 330 kV (for ISL-LIV section of ROX-ISL A and OTA-WKM A lines)
- Approximate weights of tower steel required for strengthening existing 220 kV towers for 330 kV operation
- Average tower weights for new 330 and 400 kV lines.
- Comments from Field Services and Network support on various practicality aspects of conversion options.

Reports from the preliminary feasibility engineering assessment by Teshmont Consultants were also made available to PLS prior to this work.

Tower weights for new lines were estimated from outline drawings based on spacing and clearance requirements to comply with the preliminary design criteria formulated by the Technology and Engineering (T&E) Group and conductor selection completed by Meritec.

Appendix C provides details of conductor configurations and weights of new 330/400 kV Towers used in the analysis.

5. Summary Findings from PLS Study

Main findings from the PLS study are:

- Conversion of the two lines for 330 kV operation is feasible
- Cost of conversion to 330 kV with continuos and unrestricted outages is about 75% of a new line cost with equivalent transfer capability.
- If outages are to be minimised using temporary bypass lines, then the conversion cost becomes approximately 107 to 112 % of new line costs
- Bare hand live maintenance is not feasible on converted lines compared to new build lines.

The cost of achieving bare hand capability on new lines is only marginally higher. Therefore if the costs were adjusted to remove this facility from new lines, it is not expected to alter the cost relativity to any significant level. Alternatively to include barehand capability on converted lines would mean major modifications to the tower superstructure.

Table 1 highlights the order of magnitude cost estimates and estimated outage periods required for line construction. The overall durations of construction, however, will depend on the availability of outage windows. This could span a few years depending on the options taken and on availability of outage windows.

Table 1 - Summary of Overall Estimated Costs and Outages

Line	Option Ref #	Description	Cost $M	Outages Days
ROX ISL A (ISL-LIV)	1	Conversion to 330 kV using outages for wiring	71	129
	2A	Conversion to 330 kV using bypasses and outages to connect and disconnect	99	89
	2B	Conversion to 330 kV using bypasses & live work to connect and disconnect bypasses	99	15
	3	New 330 kV single circuit line parallel to the existing line	93	2
OTA WK M A	1	Conversion to 330 kV using outages for wiring	54	106
	2A	Conversion to 330 kV using bypasses and outages to connect and disconnect	82	74
	2B	Conversion to 330 kV using bypasses & live work to connect and disconnect bypasses	82	12
	3	New 330 kV single circuit line parallel to the existing line	73	2

Note – (1) above figures do not include cost of easements, land acquisition, RMA compliance costs or outage related costs, but includes design and project management costs

(2) Cost of dismantling existing lines, which may happen with option 3 are not included in the costs. These will be considered separately in the overall economic analysis.

The PLS report has been reviewed internally by Field Services and Network Support.

5.1 General

It should be recognised that within the accuracy of estimates (30%) the conversion costs are in the same order of magnitude as the new line costs, with out the cost of outages.

Estimated costs from PLS are based on budgetary prices of main materials. Estimates of erection rates are based on productivity levels in Australia and New Zealand. Preliminary inquiries indicate that the tower steel supply rate could vary as much as 100% depending on the country of origin. This can amount to a variation of upto about 20% in the total installed costs given in the PLS report.

There are also some intangible aspects associated with the different options that cannot be easily quantified. These aspects are compared in Table 2.

Table 2 - Comparison of modified and new 330 kV single circuit lines.

Item	Modified existing line	New 330 kV SC Line
Tower Strength	Barely meets current design Criteria	Adequately meets current design criteria
Reliability	Acceptable	High
Tower Condition	Need to repaint every 10-20 years to maintain structural integrity	Structural integrity will be maintained for at least 60 yrs+ without painting.
Foundations	2/3rds new concrete 1/3rd grillages converted to concrete	All new concrete
Conductor	New twin Moose	New twin Moose
Insulation	New composite	New composite
Earthwires	1 OPGW and 1 A/C Steel	1 OPGW and 1 A/C Steel
Live Work Constraints	Hot stick access only	Full bare hand access
Ongoing Maintenance Costs	Average	Below average
Avoided Future Maintenance	Moderate	High

It must be noted that the converted towers do not have provision for bare hand maintenance work. A proper comparison can only be made if this can be quantified. The maintenance costs during the first 30 to 40 years will normally be limited to replacing insulators from flashover incidents. These will be very rare and not predictable. Alternatively provision for bare hand capability on converted towers will result in major modifications to towers.

5.2 Option 1 – Conversion with total outages

Option 1 requires 129 and 106 days of continuos outages for ISL-LIV and OTA-WKM A lines respectively. It is extremely unlikely that long outages can be obtained for the reasons given below.

Indications from load duration curves for the Canterbury region are that it is only feasible to have the outages during the period 1 a.m. to 6 a.m. in summer months, even as early as the year 2005 (ref 4, Appendix A). A similar situation exists in the Central North Island region

The outage period can be significantly reduced (from 129/106 to 2 days) with new line construction

Therefore Option 1 cannot be considered as a viable or practical option.

5.3 Option 2A – Conversion with temporary bypass lines

Option 2A also requires 89 and 74 days of outages for ISL-LIV and OTA-WKM A respectively. The costs for this option are 7 to 12% higher than that for a new line and **therefore unlikely to become a preferred option.**

5.4 Option 2B - Conversion with temporary bypass lines and live connection/disconnection of bypasses

Option 2B requires 15 and 12 days of outages for ROX-ISL A and OTA-WKM A respectively and have been based on the assumption of being able to connect and disconnect bypasses using live line techniques. As these techniques have not been used so far in New Zealand, they may need significant development and trialing prior to implementation. **However, as for option 2A, due to higher costs this option is not favoured.**

5.5 Option 3 – New Line Construction

Out of the viable options, the new line cost is 7 to 12% cheaper than the conversion options with bypasses. In addition the new line will be fully compliant and will have reduced maintenance costs. **Accordingly it is considered to be the preferred option for 330 kV.**

6. Limitations of the Investigation

The investigation has the following limitations

- **Tower strengthening requirements for conversion to 330 kV**

  Only the predominant tower type (standard suspension) was analysed on both lines. Tower strengthening requirements for other tower types have been extrapolated. It is possible that the extent of strengthening and therefore the extra steel weights could vary when subjected to detailed designs. Therefore, if more tower steel is required for strengthening, then additional costs will occur for conversion to 330 kV making it more costly.

- **Tower crossarm lengths on existing single circuit towers**

  The crossarm lengths were found to be adequate for 330 kV based on tower outline drawings produced earlier by Teshmont. It appears that the insulator lengths used by Teshmont were shorter compared to data received from Maclean Power Systems (MPS) in USA.(MPS is a regular supplier of insulators and fittings to Transpower). The maximum allowable swing angles with the existing towers will be limited to about 47 deg in comparison to 65 deg used on new tower designs. Tower strengthening weights will increase significantly if longer arms have to be provided. This is not considered to be a major deficiency. However, this will impact negatively on 330 kV conversion option.

- **Conductor selection was based on preliminary deign criteria**

  Design criteria with regard to allowable RFI and EMFs is yet to be finalised. These parameters can influence the conductor sizes, phase spacings and tower heights and hence changes to these limits will change the overall costs. This will apply to both new and converted lines.

- **Tower steel supply rate**

  This rate can vary within wide limits depending on the origin. A budgetary price from the only Australian supplier is still awaited and in the meantime a median price has been used. The impact on the overall cost is about 20% of the change in the steel price.

- **Tower height increases to meet EMF requirements for conversion option**

  The tower height increases for 330 kV were based on a cursory examination of limited ALS data available and existing profile drawings. Existing profile drawings sometimes do not reflect the actual site conditions due to changes in land use and design/construction errors. Once again this will have a negative impact on the conversion option.

- **New Line costs**

New line costs are constructed from estimated material quantities and unit prices for materials and erection rates. In the absence of any preliminary line design work, the tower quantities for new lines were based on tower for tower replacement of existing lines. Economic line designs may be possible on green field line routes.

These costs exclude easement, land, RMA compliance costs as well as any dismantling costs of existing lines that the new lines replace.

7. Sensitivity Analysis

A sensitivity analysis is carried out in the next section to establish the influence on the overall analysis.

7.1 Increase in Crossarm lengths

This is based on needing additional 0.6 T of steel per tower to allow for swing angles upto 65 ^{o} (the limit on converted towers without arm extension is 47 ^{o})

Table 3 – Extended outer phase crosarms- ROX-ISL A			
Option	Description	Base Cost Estimate $ m	Revised Cost $ m
1	Modify Existing line with 100% Outages	70.7	74.8
2A	Modify Existing with Bypasses & Outages	99.1	103.1
2B	Modify Existing with Bypasses & Live Work Outages	99.3	103.4
3	New 330 kV Single Circuit	92.7	92.7

The increase in total costs is about 6%, which is within the accuracy of the estimates.

7.2 Tower Steel Supply Rate

Table below shows the sensitivity of tower steel supply rate changing by ±20%.

Table 4 – Tower Steel Supply rate - ROX-ISL A				
Option	**Description**	**Base Cost Estimate $ m**	**Revised Costs $ m**	
			-20%	**+20%**
1	Modify Existing line with 100% Outages	70.7	70.6	70.9
2A	Modify Existing with Bypasses & Outages	99.1	98.9	99.2
2B	Modify Existing with Bypasses & Live Work Outages	99.3	99.2	99.5
3	New 330 kV Single Circuit	92.7	87.9	97.5

As expected the variation for option 1, 2A and 2B are minimal as these options use only small quantities of imported tower steel (mainly for totally replaced towers). For option 3, the overall costs changes by about 5%.

It is very unlikely that the price of steel will increase when exposed to competitive tendering. Most probably the price will be lower which makes the new line build more attractive.

The sensitivity analysis shows that option 3 remains attractive even if the tower steel price increases by 20%.

7.3 Variation in the extent of Strengthening

This is probably the single item that could vary within wide limits, as the weights have been estimated based on a very high level analysis. It is unlikely that the estimated strengthening steel to be lower. The table below shows the sensitivity based on the assumed weights increasing by 10% and 30 %. The analysis clearly demonstrates how the relativity can change with even a moderate increase in the extent of strengthening. It is possible that increases in excess of 30% to be needed when subjected to detailed structural analysis.

Table 5 – Tower Strengthening Steel - ROX-ISL A				
Option	**Description**	**Base Cost Estimate $ m**	**Revised Cost- Weights up by 10% $ m**	**Revised Cost- Weights up by 30% $ m**
1	Modify Existing line with 100% Outages	70.7	72.4	75.7
2A	Modify Existing with Bypasses & Outages	99.1	100.7	104.1
2B	Modify Existing with Bypasses & Live Work Outages	99.3	101.0	104.3
3	New 330 kV Single Circuit	92.7	92.7	92.7

For 10% to 30% variations in tower steel weight, the overall costs increase by about 2% and 7% respectively.

However, as the new line build is not subjected to this variation, option 3 becomes more attractive.

7.4 General Comment on Sensitivity Analysis

The sensitivity of most of the aspects on estimated costs vary between 2 and 7%, which is within the accuracy of the estimates. However, the single item that can significantly affect the relativity between conversion and new build options is the extent of strengthening of existing towers. This will have a major influence on the cost of the conversion options but not on the new build option.

Even though the sensitivity analyses has been done only for ROX-ISL A line, similar comparisons can be drawn for OTA-WKM A line as well.

Depending on the extent of variations in the individual items, it is possible for the conversion costs with total outages to exceed that of new line costs.

8. Conversion of SFD-TMN A and HLY-TMN A lines to 330 kV

These two lines form part of the 220 kV double circuit line from Stratford to Huntly commissioned during 1987-1988. The lines were designed and built for carrying single Zebra conductors per phase with a designed maximum operating temperature of 120 ^{o}C.

A major part of SFD-TMN section runs through extremely rugged terrain, which presented several challenges during construction. Most tower sites are perched on very narrow edged ridge tops

As 330 kV operation requires heavier conductors and larger electrical clearances, the conversion of these lines to 330 kV double circuit require major alterations to the upper part of the tower body. A high level comparison of the tower design loads for the most common tower types with loadings that would be imposed even with twin Zebra conductors indicate excessive overloading.

The extent of overloading is illustrated in table 6.

Table 6 – Comparison of Tower Design Loads

	Transverse Load		Vertical Load	
Tower Type	**Tower Design**	**Site specific for 2xZebra**	**Tower Design**	**Site specific for 2xZebra**
	kN	kN	kN	kN
C806 Type 0	11.7	23.7 (202%)	21.6	13.2
C806 Type 1	11.7	31.4 (268%)	32.4	16.9

A high level check was also done on the loading of main members below the waist. This indicates approximately 135% loading for Type 0 and 120% for Type 1, confirming that significant strengthening would be required even to install twin Zebra conductors.

To comply with RFI and Noise limits, double circuit 330 kV requires triple conductors with diameters bigger than 30 mm (existing conductor is single Zebra with a diameter of 28.6 mm) per phase. The overloading levels in table 6 indicate that practically the whole tower would need to be replaced for upgrading the lines to 330 kV double circuit.

Some parts of the line runs through very rugged terrain with towers located on very narrow ridge tops. The use of existing easement on such sections will be difficult if not impossible.

From this high level analysis it appears that the conversion of SFD-TMN A and HLY-TMN A line for 330 kV double circuit is neither feasible nor economic.

9. Conclusions

Based on this high level investigation on practicality aspects and costs, it is concluded that for ROX-ISL A and OTA-WKM A lines:

- Option 1 (conversion with full outages) is not worth pursuing due to inevitable system constraints and the outage requirements being not practical and its inability to provide bare hand live line maintenance capability.

- Option 3 (new line construction) is preferred to Option 2A or 2B (conversion with bypasses) as this option is about 4 to 7% cheaper than options 2A or 2B.
- In the event that any of the conversion options (1, 2A or 2B) become a preferred option after an overall economic analysis, then it is considered essential to revisit the cost estimates with a more detailed engineering analysis to ensure that the relativity of costs between various options remain unchanged.

The conversion of SFD-TMN A and HLY-TMN A line for double circuit 330 kV operation is neither feasible nor economic. It may be feasible to convert this line to 330 kV single circuit line, but this option has not been fully investigated as the thermal capacity will be lower than that for the existing 220 configuration.

APPENDIX A

References

1. Transpower Draft Standard - Design and Performance Criteria for 330 and 400 kV Transmission lines – Revision 1, 7 July 2003

2. Teshmont Consultants Preliminary Investigations Summary Report – March 2003

3. Conductor Selection Report -Rev 2 , July 2003, Meritec LTD

4. Internal Memo on Load curve for Canterbury Region and North dated 8 Aug 2003 – Carmen Yip to Mohamed Zavahir

APPENDIX B

SCOPE OF WORK PROVIDED TO POWER LINE SOLUTIONS

As part of a high level assessment of the impact on the above issues, Transpower has completed a preliminary structural analysis on one representative tower type (standard suspension) on each of the following lines.

(a) ROX-ISL A

(b) OTA-WKM A

The structural analysis has identified the structural components that need to be modified for 330 kV operation. The combined weights of these components have also been estimated. On some locations it may be necessary to raise the towers by about 2 to 3.0 m and erect the modified tower on new foundations to meet the required ground clearances.

The 330 kV conversion also requires the conductors to be replaced with new duplex conductors of at least 33 mm in diameter and new 330 kV insulators. ACSR BUNTING has been used in the structural analysis. (Tower out line drawings showing the modifications is attached).

Please investigate and report on the constructibilty, outage durations and rough order costs (erection only) for completing the following activities on each section of the above lines.

1. Strengthen and modifying the tower with out any body extensions
2. Strengthen and modifying the tower with a 3 m body extension and erecting on new foundations adjacent to existing one.
3. Re-insulating and installing new conductors on approximately 10 km section on terrain representative of the line. It may be assumed that the line section consist of all standards suspensions and two strain towers. All strain towers can be assumed to be replaced with new towers and foundations. Costs should be assessed for two scenarios: building with outages as required for various activities and building with a temporary by pass line constructed to minimise outage durations.
4. The cost of building a new line of the same length and number of structures as in (3), adjacent to the existing line. Tower weights can be assumed to be similar to the existing ones.
5. Order of magnitude costs for any modifications required on existing structures to provide live line maintenance facility.

400 kV Line Costs

Please provide material and erection costs new 400 kV single and double circuit lines based on overseas utility experiences with recently installed lines customised for New Zealand situation.

APPENDIX C

Preliminary Conductor Selection and Conductor Configurations used in the Analysis

Nominal Voltage (kV)	Circuit Configuration	Conductor and Configuration	Conductor Diameter (mm)
330	Single Circuit	Duplex Moose	31.77
	Double Circuit	Triplex Cardinal	30.38
400	Single Circuit	Duplex Chukar	40.68
	Double Circuit	Quad Goat	25.97

Tower Weights used in the Analysis for new 330/400 kV Towers

Nominal Voltage kV	Circuit Configuration	Tower Type	Tower Weight (Tonne)
330	Single Circuit	Suspension	10
		Angle	18
		Strain	22
	Double Circuit	Suspension	14
		Angle	22
		Strain	30
400	Single Circuit	Suspension	12
		Angle	20
		Strain	25
	Double Circuit	Suspension	16
		Angle	25
		Strain	35

APPENDIX D

PLS Report on 330/400 kV Line Upgrade Study

Version: Final

22 August 2003