3M's Comments on North Island Grid Upgrade Project Amended Proposal

Application for Approval

November 22, 2006

3M™ Aluminum Conductor Composite Reinforced (ACCR)

A Technology Solution to Quickly Enhance Transmission Capacity Using Existing Infrastructure

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I. Introduction

In June of 2006, 3M submitted comments to the Electricity Commission (the Commission) on its draft decision regarding upgrades to the transmission system serving Auckland, New Zealand. In its comments, 3M described two alternative scenarios to resolve the capacity needs of the system using 3M™ Aluminum Conductor Composite Reinforced (ACCR) and respectfully asked the Commission to include 3M's approach its short list of options for further consideration by Transpower.

Potential benefits of 3M's proposal included:

- Economic savings because 3M ACCR's light weight and low sag properties allow for installation on existing structures, and its higher ampacity would provide transmission capacity equivalent to the other options;
- Less disruption to both the community and the environment than other alternatives because 3M ACCR can be installed on the existing structures;
- Ultimately, a more robust and reliable system as part of a future 400kV core grid, a need that Transpower apparently recognizes, as evidenced by the list of "Common Augmentation Projects" that appear in Transpower's **North Island Grid Upgrade Project Amended Proposal Application for Approval** (the Amended Proposal) (pp. 30-31);
- A quick solution to the more immediate capacity problems;
- Resolution of the thermal issues, as well as improved voltage and dynamic stability performance;
- A solution proven in stringent and extensive testing and commercial applications similar to the Auckland transmission system;
- A solution backed by a local presence, combined with 3M's global technological resources;
- 3M's well-established reputation as one of the most innovative corporations in the world across its numerous businesses.

After reviewing the Amended Proposal, filed with the Commission on October 20th, 3M asserts that those benefits still apply.

Although Transpower claims to consider 3M ACCR, and apparently other high temperature conductors, as "non-qualifying" (p. 25, ¶ 113), this conclusion appears to be based solely on Rule 19.3, which states that a "qualifying" option must be "…reasonably likely to proceed if neither the proposed investment nor any other alternative project proceeds and unlikely to proceed if the proposed investment does proceed…". 3M believes a thoughtful consideration of the various ways 3M ACCR can be used on the system will demonstrate that it can satisfy the capacity needs through 2033 or beyond economically, meeting the requirements for a "qualifying" option, including:

> *19.1 technically feasible;*
> *19.2 reasonably practicable having regard to the matters set out in clauses 8.1 to 8.4;*
> *19.3 reasonably likely to proceed if neither the* ***proposed investment*** *nor any other* ***alternative project*** *proceeds and unlikely to proceed if the* ***proposed investment*** *does proceed;*

> *19.4 reasonably expected to provide similar benefits, in type but not necessarily in magnitude, to relevant nodes, as the* ***proposed investment****; and*
> *19.5 reasonably expected to enable the deferment of investment of the type contemplated by the* ***proposed investment*** *for a period of 12 months or more."*

In the Amended Proposal, Transpower looks at only one option – bundled high temperature conductor equivalent to duplexed Goat conductor in size and concludes, based on their initial analysis, that the additional mechanical loads introduced on the structures may require substantial rebuilding of the line. What they do not appear to take into consideration is the ability of 3M to optimize line design to mitigate concerns related to the existing structures, available capacity, sag clearance, losses, reactive compensation requirements and other aspects.

Given these considerations, 3M asserts that the proposed 3M ACCR options still warrant consideration. Specifically, 3M respectfully requests the Commission to:

- Consider the 3M proposal a "qualifying option".
- Launch an independent technical evaluation of the 3M proposal and the other qualifying alternatives to ensure assessment on a level playing field by a qualified evaluator and including optimization of the total solution, based on the characteristics of the system and 3M ACCR specifically.

Given the changes Transpower assumed in its discount rate, demand forecast and planning horizon, 3M requests that the Commission direct that this independent evaluation use low and medium demand forecasts and the discount rate and planning horizon originally established by the Commission, as well as Transpower's assumptions. Such an analysis would eliminate information asymmetry, make transparent to all parties the data and analysis methods used, provide a "second source" for critical review and competing projects, and provide an objective and more robust perspective to the analysis. Given such an analysis, 3M believes the merits of its proposal will become evident to all parties.

II. Summary of 3M's Original Proposal

In the original comments, 3M proposed two alternate scenarios. The first scenario involved upgrading OTA-WKM A, B and C in two stages. In stage 1, the A and B lines would be upgraded with duplexed 3M ACCR, uprating them from 200 MVA to 1,000 MVA each. In stage 2, OTA-WKM C would be upgraded to 1,000 MVA each circuit, also using duplexed 3M ACCR. The total resulting summer N-1 path rating could be 3,500 MVA, equal the path rating of the Incremental Upgrade Package.

Scenario 2 achieves the same results, but uses the intermediate step of replacing OTA-WKM A and B with 3M ACCR Goat simplex, deferring the need to duplex the line until 2021. The purpose of this step was to postpone acquiring easements if it was determined they were needed to install duplex conductor. In fact, in Appendix D of Attachment I of its Amended Proposal, Transpower estimates cost savings for installing simplex HTC of between $7.4 and $27.4M for a combination of duplex Goat and simplex HTC, with little risk of injurious affection. (p. 39).

III. Discussion of Transpower's Analysis

As stated in 3M's original comments, 3M recognizes the need for upgrades and fully supports improving the reliability of power supply to Auckland. In fact, in its original comments, 3M proposed upgrading the existing 220 kV lines, deferring the need for the 400 kV line, similar to Transpower's preferred Option 2.

In addition, 3M appreciates Transpower's analysis of an alternative that would utilize high temperature conductor (HTC). 3M is also encouraged that Transpower acknowledges that HTC's enable higher power transfer, that 3M's proposal to duplex OTA-WKM A and B and OTA-WKM C is a technically feasible option, that the installation is no more complex than conventional ACSR (Appendix G, p. 7), and that the EMF associated with this option is equivalent to the conventional duplexed option and within ICNIRP guidelines (p. 25). 3M also acknowledges that Transpower has in other situations been able to use existing towers and foundations to duplex conventional conductors, such as the ROX-ISL- A line, and has done so without the need to significantly rebuild the line.

However, Transpower, in its Amended Proposal, raises a number of issues that do not appear to take into consideration the unique properties and benefits of 3M ACCR, distinct from conventional conductors, as well as other HTC's.

A. Structure concerns and associated costs

The main body of the Transpower analysis (Appendix G – High Temperature Conductors) focuses on the economics surrounding this alternative and, in particular, the significant degree to which the line would need to be rebuilt due to concerns over the adequacy of the steel structures or the foundations. As acknowledged by Transpower, the conclusions were based on "desktop studies only" (p. 7). Yet, despite the nature of the analysis, Transpower makes three arguments supporting a relatively high estimate of structure and property costs that would be incurred to use HTC's. 3M counters that, while those arguments may apply to some HTC's, their applicability to 3M's options is questionable.

First, on page 38 of Appendix D of Attachment I, Transpower states, "Some varieties of HTC would have increased sag, which may require tower raising or earthworks in some spans." Yet one of the differentiating characteristics of 3M ACCR is its low thermal expansion, resulting in less sag than other conductors of the same size at the same operating temperature. Therefore, this argument and the associated costs do not apply to the 3M options.

Second, Page 57, in paragraph 264, states that considerations for requiring easements include conductor diameter, conductor swing, electric and magnetic fields, temperature and conductor sag and tower heights. Yet, the advantages of 3M ACCR mitigate most of those issues. In fact, Transpower estimates, on page 21 of the Supplementary Information, that using HTC would save approximately $83 million in property costs.

Third, in Attachment I, Transpower states that an initial engineering assessment indicates that the towers used on the WKM-OTA A and B lines were not designed to support the same loads as the towers used on the ROX-ISL- A line, which was recently successfully upgraded to duplex "Goat" ACSR conductor (p. 6). Therefore, Transpower's cost estimates for duplexing these lines include a substantial budget for tower reinforcement and replacement. If, after a thorough technical-economic study is complete and given the lower weight and improved sag characteristics specific to 3M ACCR, it is finally concluded that these structures have insufficient structural capacity to support the 3M ACCR equivalent of twin Goat, then 3M can offer several options that could mitigate the need for structure replacement, substantially reducing the cost of this alternative. These options include modifying the installation tension of the conductor; changing the rated operating temperature; using compact constructions, in which each strand is trapezoidal in shape rather than round, to reduce transverse wind loads on the structures; or simply reducing the tower loads by reducing the conductor size. Because of its unique properties, even at a reduced diameter, a high performance 3M ACCR conductor can deliver a very large current capacity improvement over the existing ACSR goat conductor. 3M would welcome the opportunity to optimize its solution as required to minimize total system costs and optimize performance.

B. Line losses and reactive compensation

In paragraph 258 on page 57, Transpower states "A significant cost for this option is attributable to the relatively high losses incurred on the line… due to the increase in current." 3M agrees that running more current through the conductor will increase losses on the line. However, total losses on the system are usually evaluated based upon the line loads during normal, not N-1 operating conditions, and are sensitive to the dispatch pattern assumed. Since losses, as Transpower points out in the same paragraph, quadruple when current doubles, a small reduction in loading on one path can result in a large reduction in losses on that path, while the corresponding increases caused on the other paths may be fairly small if those paths were lightly loaded. And, during emergencies, when the line is running at higher loads, the short-term impact on losses is far exceeded by the improvement in system reliability.

In regard to the need for shunt and series compensation, 3M agrees that increasing the power transfer without increasing voltage results in the need for additional reactive power supply. However, as noted in the original comments, the loadability of the 220 kV system is limited by three issues:

- the thermal ratings of the individual circuits,
- voltage stability performance, and
- dynamic stability performance.

These limitations are relevant whether or not a 400 kV line is added to the transmission system; they simply arise in varying combinations, at different times.

Reconductoring the OTA-WKM A and B 220 kV lines with higher-capacity single conductors, as appears to be the assumption Transpower uses in Section 6 of Attachment G, page 20 for the high temperature conductor, would address only the thermal limits. In contrast, reconductoring the A and B lines with duplexed conductor, whether standard or high temperature conductor, would address all three of these limiting considerations:

Voltage Stability would be enhanced because duplexed conductors would reduce the series inductive reactance of the circuit by approximately 25 to 30%. This is of great consequence during heavy loading conditions, as experienced during N-1 episodes, since it is the series reactance (X) that determines both the reactive power consumption (I^2X) and the reactive voltage drop (IX).

Dynamic Stability would also be enhanced if the series inductive reactance were reduced by installing duplexed conductors. Reducing the series reactance reduces the voltage phase angle displacement required across the circuit (and related network) to transfer a given amount of power. As a result, the dynamic power transfer limit is increased.

An important advantage of duplexed conductors on the A and B lines is that after installation of a parallel 400 kV line, the A and B circuits' lower series reactance will improve the load sharing amongst the four 220 kV OTA-WKM circuits. This helps delay the need for a future reconductoring of the two C line circuits.

The higher line loadings achievable with high-temperature conductors result in higher reactive power consumption (reactive losses) on the lines. Duplexed conductors, series compensation, and shunt compensation are all well-established options to address part or all of the increased reactive losses. Series compensation and duplexing also permit increased utilization of existing generator reactive capability; this typically reduces the amount of new shunt compensation required.

C. Transpower's lack of experience with 3M ACCR

Transpower's analysis of an alternative that would utilize high temperature conductor concludes that this alternative is "non-qualifying" (p. 25, ¶ 110). 3M believes this conclusion is unsupported, particularly given that the duplexing of OTA-WKM A & B with conventional conductors is considered a "qualifying" alternative. The reasoning appears to be related to Transpower's concerns surrounding commercial maturity, product performance and economic competitiveness. Yet, evidence indicates HTC's actually meet these criteria.

In terms of commercial maturity, Transpower acknowledges that there are multiple suppliers of HTC (Appendix G, p. 3). The first use of HTC's dates to the late 1970's. Since that time, thousands of kilometers of HTC's have been put to use in Japan, Korea and the United States. These conductors are used widely in applications similar to Auckland's system, and their benefits are independent of the length of the transmission line, making Transpower's conclusion that there are no applications of equivalent length irrelevant.

In terms of product performance, while Transpower may not have experience with such conductors, 3M believes the conclusion that using them heightens the risks of conductor failure is unsubstantiated. (p. 25, ¶ 111) As with other manufacturers of such products, 3M recognizes the critical role of the conductor. 3M specifically designed the conductor to provide a reliable solution, has extensively tested the conductor in the laboratory and in the field, and has installed it in commercial applications similar to Auckland's system. As a result, 3M ACCR has never failed in the field and has performed as expected, including in commercial use in critical applications providing power to major metropolitan cities.

Therefore, 3M submits that Transpower's lack of experience with reconductoring and with 3M ACCR specifically is irrelevant to this discussion and should not be used as evidence that 3M ACCR does not meet criterion 19.3 to be considered a "qualifying" option. 3M points out that New Zealand had no experience with HVDC lines until it built one. Also, Transpower has limited experience building 400 kV lines or with series compensation, both of which are included in its qualifying alternatives. However, Transpower is rightly relying on the experience of others in the electric industry with these technologies to enable it to implement innovative options. 3M suggests this is also the right approach to take with reconductoring in general and with use of 3M ACCR in particular.

Specifically, 3M ACCR has been installed in commercial installations, including one serving the city of Phoenix that includes significant sections with underbuilt residences, commercial buildings, highways, and distribution and telecommunication facilities. 3M ACCR was chosen for this application because its unique light weight, low sag properties made it possible to achieve the necessary capacity increases without having to remove buildings or disrupt populations or businesses, while reducing expected construction outage times. Today that line provides a critical path into downtown Phoenix, an area experiencing 10% annual load growth and extreme ambient temperatures, and that includes the airport, two sports arenas and many downtown businesses. In this, and all its other installations, 3M ACCR has never experienced a failure. In addition, the conductor has undergone extensive and thorough laboratory and field tests, including running at high temperatures for extended periods of time. Detailed reports on all testing are available, and a summary is included in Appendix C of 3M's original proposal. 3M is pleased to offer this extensive experience to benefit the Auckland area.

D. 3M Offers The Ability To Optimize Line Design

The third argument that Transpower raises regarding its categorization of HTC's as "non-qualifying" options relates to their economic competitiveness with other options. In particular, as previously noted, Transpower has expressed concerns regarding the impact of using duplexed conductor, including high temperature conductor, on its aging structures. Given these concerns, 3M points out that the properties of 3M ACCR, the availability of the conductor in both round and trapezoidal strand configurations, and the variety of core and conductor sizes available, combined with the 3M team's knowledge and experience, make it possible to optimize the line design around these parameters. In other words, 3M can provide Transpower with options that vary the capacity, sag parameters and weight of the conductor to optimize the total system design for performance and economics.

Figure 1 summarizes three example scenarios for increasing the capacity of the Auckland system to similar levels, based on a simplified power flow analysis[1].

The first scenario is Transpower's original proposal and includes building a double circuit 400 kV line, resulting in 2,250 MVA.

The second scenario is Transpower's preferred option, Option 2[2], and includes:

- constructing two new 2,462 MVA 400 kV transmission lines,

[1] The path ratings in Figure 1 are based on 3M's power flow model.
[2] In Transpower's Amended Proposal, 3M notes the discount rate, demand forecast and planning period have all been changed.

- providing 55% series compensation for the two new lines,
- installing twelve new 220/400 kV transformers,
- constructing a new receiving station at Ormiston Road,
- installing four new 220 kV cables connecting Ormiston Road with Otahuhu and Pakuranga substations, and
- installing 20 ohm series reactors in the Otahuhu-Whakamaru A & B lines to limit power flows over these lines.

Transpower's analysis of this scenario shows about 3,100 MW of capacity to the Upper North Island under the N-1 contingency limit in the year 2033, when the two new 400 kV lines are converted to 400 kV service. The result is a significant economic investment for no more gain than the competing options.

The next scenario is based on 3M's Scenario 1 from the original proposal, but uses smaller diameter ACCR than originally proposed. This options includes:

- providing 25% series compensation,
- looping the A&B lines into the new Huntly East substation,
- installing duplexed 300 kcmil Ostrich 3M ACCR conductor (600 MVA) between Whakamaru and Huntly East, and
- installing duplexed 477 kcmil Hawk 3M ACCR conductor (800 MVA) in all four lines between Huntly East and Otahuhu.

This could result in an Upper North Island transmission delivery capacity from the south of 3,400 MVA based on the N-1 contingency limit for the year 2033[3]. In this scenario, the use of smaller conductor than was assumed by Transpower will minimize the amount of tower modifications needed to accommodate the bundled high capacity 3M ACCR conductor. The 300 kcmil ACCR conductor is less than half the weight and cross-section of the Goat conductor assumed in Transpower's HTC option, while providing adequate capacity to support the Upper North Island.

If the choice were to install simplex conductor, the last scenario on the graph, and again assuming 25% series compensation, reconductoring the Whakamaru to Huntly East segments of the A and B lines with 795 kcmil Drake ACCR conductor (600 MVA), and the four Huntly East to Otahuhu lines with 1,272 kcmil Pheasant ACCR conductor (800 MVA), the resulting Upper North Island transmission delivery capacity (from the south) could be 3,500 MW's based on the N-1 contingency limit for the year 2033.

Both of the 3M ACCR options provide essentially the same N-1 transfer capacity to the Upper North Island while using smaller conductors than were studied by Transpower in its assessment of the viability of using HTC. An unbiased detailed assessment of the use of 3M ACCR could identify additional options that would provide even greater transmission grid transfer capacities by optimizing the conductor and series compensation characteristics. These two options, plus the two options identified in 3M's original proposal, are examples only, but are indicative of the results that could be achieved by optimizing the line design using 3M ACCR.

[3] The estimated path ratings for lines A and B are for the north. The ratings for the south will be 600 MVA per line.

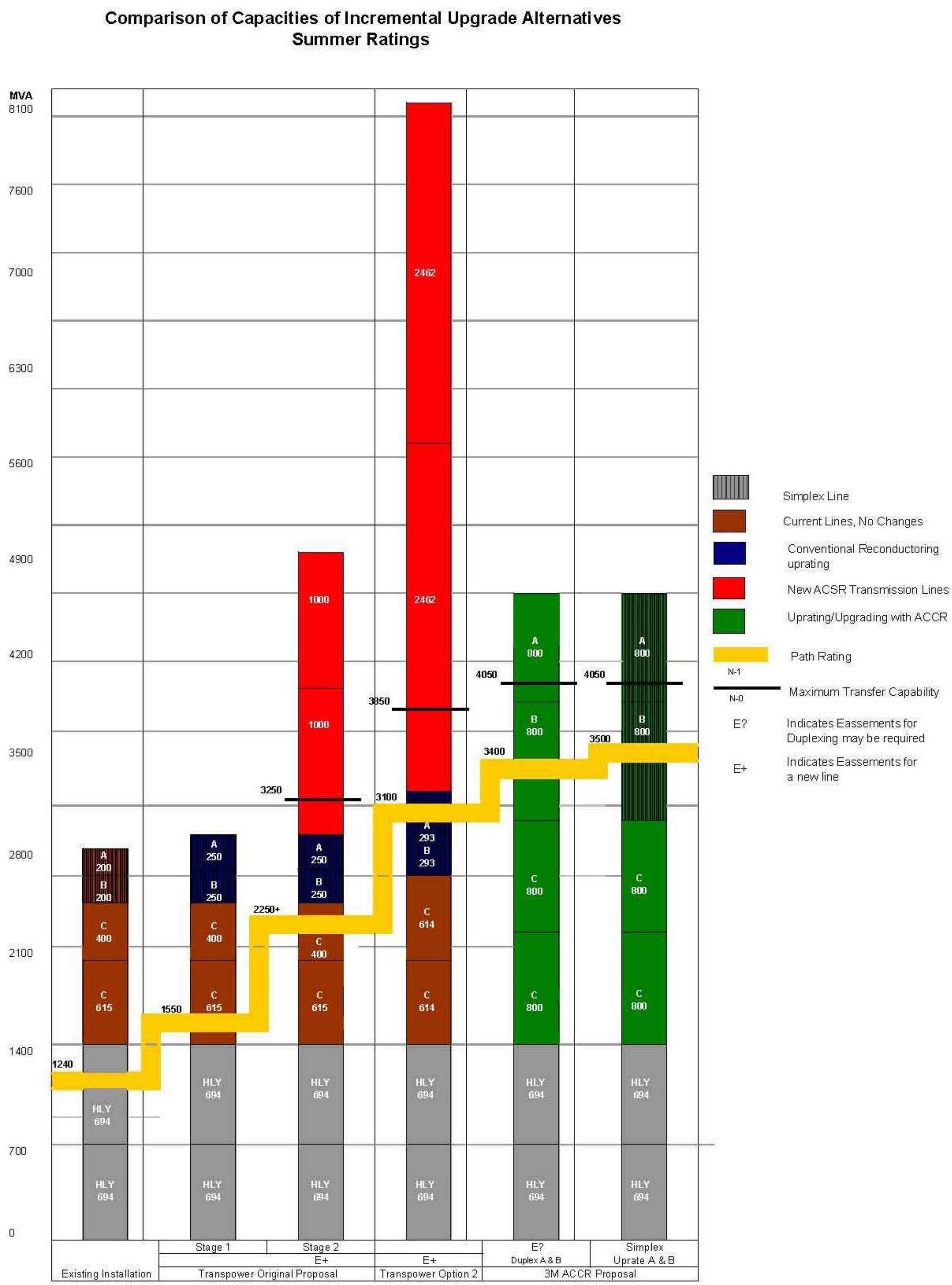
Comparison of Capacities of Incremental Upgrade Alternatives
Summer Ratings
MVA
8100
7600
7000
6300
5600
4900
4200
3500
2800
2100
1400
700
0
Simplex Line
Current Lines, No Changes
Conventional Reconductoring uprating
New ACSR Transmission Lines
Uprating/Upgrading with ACCR
Path Rating
N-1
N-0
Maximum Transfer Capability
E? Indicates Eassements for Duplexing may be required
E+ Indicates Eassements for a new line
1240
1550
2250+
3250
3100
3850
3400
4050
3500
4050
Stage 1
Stage 2
E+
E+
E?
Duplex A & B
Simplex
Uprate A & B
Existing Installation
Transpower Original Proposal
Transpower Option 2
3M ACCR Proposal

Figure 1

In addition, 3M ACCR can help with the issue of load balancing on the upgraded system. In the Transpower preferred option, the high transfer limits are achieved by dispatching up to 2,600 MW from Whakamaru, but less than 500 MW from Huntly. However, as the Huntly generation increases, the Whakamaru generation will have to be backed off to prevent overloading of the lines north of Huntly, as some portion of the Whakamaru power will still flow up the 220 kV lines. To attempt to manage some of those power flows, the Transpower case includes a 20-ohm series reactor in each of the A and B lines. Although this strategy helps prevent overload of the A & B circuits, the resultant increased circuit impedances cause degradation in system voltage stability and dynamic stability performance.

However, if the A and B lines were upgraded using 3M ACCR and looped into Huntly East, high simultaneous deliveries from both Whakamaru and Huntly are possible. Therefore, while there may not be enough generation in the Whakamaru area to fully utilize the transmission capacity provided by the Transpower proposal, and while the Transpower proposal does little to accommodate additional generation in the Huntly area, the 3M options can better balance the transmission grid to accommodate power from either direction.

IV. Conclusion

3M acknowledges that a 400 kV double circuit line, backed by a strong underlying 220 kV system, addresses security and supply needs and may, ultimately, be needed. However, incorporating 3M ACCR could provide substantial economic savings and be less intrusive to both the community and the environment than other alternatives. Particularly, it could avoid significant easement costs, delays, and uncertainty well into the future, consistent with the Commission's evaluation framework and screening criteria for a "qualifying" option.

Although 3M notes that Transpower's base plan has changed since the original filing, including changing the terminating substation, 3M's approach could result in an equivalent N-1 path rating to the comparison approaches. In addition, as Transpower's new base plan appears to recognize, robust support by the rest of the network is necessary for a new 400 kV line to provide the results required. Any of 3M's scenarios could provide robust support for this expansion. In addition, the conversion to a duplex conductor design on the A and B lines could help address all three of the system's issues: thermal limits, voltage stability, and dynamic stability.

3M's approach could achieve all this while saving time and money. Although 3M cannot determine the exact amount given the new parameters for discount rates, demand forecast, terminating substation and planning horizon adopted by Transpower, as well as the lack of data and detailed information available on Transpower's analysis, 3M's original estimates were millions less than building a new double circuit 400 kV line. The approach could also save significant indirect costs, including installation time, disruption to Auckland's businesses and residents, land and, through the resulting robustness of the system, the risk of expensive outages.

3M ACCR is an extensively tested, commercially available, proven technology well suited for the demands of a growing transmission system serving a major urban hub such as the Auckland area. The product is backed by the full range of design assistance, accessories, and installation expertise of 3M and its partners. Our local presence can offer the Commission and the electricity sector the benefits of the corporation's global technological resources. The Commission can also rely upon 3M's well-established reputation as one of the most innovative corporations in the world across its numerous business lines.

For these reasons, 3M presents the scenarios in this submission as "qualifying options" -- fully viable; economically, environmentally, and technically attractive alternatives, consistent with GEIP, GRS and GIT. As summarized in 3M's previous comments, it meets all of the criteria for a "qualifying option" adopted by the Commission and detailed in section 6.13.25 of the Draft Decision (p. 51).

Given the benefits of 3M ACCR, the issues identified in these comments, and the commercial standing and viability of 3M's proposal, 3M respectfully requests that the Commission:

- Consider the 3M proposal a "qualifying option".
- Launch an independent technical evaluation of the 3M proposal and the other qualifying alternatives to insure assessment on a level playing field by a qualified evaluator and including optimization of the total solution, based on the characteristics of the system and 3M ACCR specifically.

Such an analysis would eliminate information asymmetry, make transparent to all parties the data and analysis methods used, provide a “second source” for critical review and competing projects, and provide an objective and more robust perspective to the analysis. Given such an analysis, 3M believes the merits of its proposal will become evident to all parties. 3M is pleased to offer its assistance with this type of evaluation and appreciates the Commission’s continued serious consideration of the Company’s proposals.

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3M’s Comments on North Island Grid Upgrade Project Amended ...
22 Nov 2006 ... acknowledges that HTC’s enable higher power transfer, that 3M’s ... 3M agrees that running more current through the conductor will increase ...
www.electricitycommission.govt.nz/pdfs/submissions/pdfstransmission/revised...