Anonymised determination of connection charges payable under clause 4 of Schedule 6.3 of the Code

Executive summary

This is an anonymised version of a determination of connection charges payable under clause 4 of Schedule 6.3 of the Electricity Industry Participation Code 2010 (Code).

Part 6 of the Code provides the regulatory framework under which distributors may impose connection charges on distributed generators. Part 6 also provides a dispute resolution process for disputes between distributors and distributed generators.

For the purposes of this anonymised version of the determination, the distributor is called Electricity Distribution Limited (EDL) and the distributed generator is called Tūpararā Wind Farm Limited (Tūpararā).

EDL and Tūpararā have been in dispute. The dispute primarily related to various connection charges EDL imposed on Tūpararā.

To resolve the dispute, the Authority decided to apply the pricing principles in Part 6 and determine what connection charges were payable by Tūpararā to EDL.

The Authority determined that:

- EDL's charges to recover the costs of construction of assets connecting Tūpararā to EDL's network were consistent with the pricing principles. Tūpararā paid these costs in full, so there were no outstanding charges for these assets.
- EDL's charges for system operation and maintenance in relation to the assets required to connect Tūpararā to EDL's network would be consistent with the pricing principles. Charges should be based on the actual costs EDL had incurred to operate and maintain these assets since the connection of Tūpararā to EDL's network, and would incur in the future. Any charges to Tūpararā should take into account any reduction in EDL's distribution network costs resulting from the connection of Tūpararā.
- EDL's fixed daily charge and the uncontrolled energy charge it had invoiced Tūpararā had been inconsistent with the pricing principles. Accordingly, EDL should refund Tūpararā the full value of these charges paid by Tūpararā since its connection to EDL's network.
- All of the power factor charges on Tūpararā (i.e., applied when Tūpararā operated as load or operated as generation) were inconsistent with the pricing principles. Accordingly, EDL should refund Tūpararā the full value of these charges paid by Tūpararā since its connection to EDL's network.
- Any charge for the cost of a STATCOM installed by EDL at the substation near Timmins would be inconsistent with the pricing principles. Accordingly, Tūpararā would not be required to pay for the costs of the STATCOM, and EDL should bear the full costs of the STATCOM.

Contents

1 This is a determination of connection charges payable under clause 4 of Schedule 6.3 of the Code

The determination related to a dispute between Electricity Distribution Limited and Tūpararā

1.1 A dispute existed between Electricity Distribution Limited (EDL) and a distributed generator– Tūpararā Wind Farm Limited (Tūpararā) – connected to EDL's network.

1.2 The dispute primarily related to various connection charges EDL had imposed on Tūpararā.

1.3 Part 6 of the Electricity Industry Participation Code 2010 (Code) provides the regulatory framework under which EDL may impose connection charges on Tūpararā, as the owner of distributed generation connected to EDL's network. Part 6 of the Code also provides a default dispute resolution process for disputes between EDL, as a distributor, and Tūpararā, as a distributed generator.

1.4 After attempts by EDL and Tūpararā to resolve the dispute themselves, Tūpararā complained to the Authority.

1.5 The Authority considered that it was desirable that the dispute was resolved by the Authority applying the pricing principles in Part 6 and determining the connection charges payable by Tūpararā. The reasons for the Authority's view are set out in section 4 of this paper.

1.6 The rest of this paper is structured as follows:

(a) section 2 describes the regulatory framework that applied to the dispute

(b) section 3 summarises the background to, and the history of, the dispute

(c) section 4 provides the Authority's reasons why it considered it was desirable for the dispute to be resolved by the Authority applying the pricing principles in Part 6 and determining the connection charges payable by Tūpararā

(d) section 5 sets out the Authority's approach to applying the pricing principles

(e) section 6 sets out the Authority's determination, based on that approach.

2 Part 6 of the Code regulates the connection of distributed generation to a distribution network

An overview of Part 6

2.1 Part 6 of the Code regulates the connection of distributed generation to distribution networks. The purpose of Part 6 is to enable distributed generation to be connected to a distribution network, or to a consumer installation that is connected to a distribution network, if being connected is consistent with the distributor's connection and operation standards.[1]

2.2 Distributed generation is any form of electricity generation that is connected, or that is proposed to be connected, to:

(a) a distribution network;

1 Clause 6.2 of the Code.

(b) a consumer installation that is connected to a distribution network.

2.3 Distributed generators own and operate a variety of distributed generation throughout New Zealand, ranging from small-scale plant of a few kilowatts or less, to large power stations capable of generating megawatts of electricity.

2.4 Part 6 of the Code came into effect on 1 November 2010 and replaced the Electricity Governance (Connection of Distributed Generation) Regulations 2007 (DG Regulations). The DG Regulations are relevant to the dispute because Tūpararā was connected to EDL's network under the regulated terms in the DG Regulations.

The default dispute resolution process prescribes a staged approach for resolving a dispute

2.5 Under clause 6.8(1)(a) of the Code, the default dispute resolution process under Schedule 6.3 applies to an allegation that a party has breached the regulated terms under Schedule 6.2. Tūpararā connected its distributed generation to EDL's network under the regulated terms, which apply in the absence of the parties agreeing their own connection contract.

2.6 Under the default dispute resolution process in Schedule 6.3, the parties to a dispute must attempt to resolve the dispute with each other in good faith. If the parties are unable to resolve the dispute, either party may complain to the Authority.

2.7 Under clause 4 of Schedule 6.3 of the Code, the Authority may determine the connection charges a distributed generator must pay a distributor if in the opinion of the Authority it is necessary or desirable to resolve the dispute.

3 Background: the dispute related to EDL's requirements and charges for consuming reactive power

Tūpararā applied to connect to EDL's network

3.1 Tūpararā applied to connect a wind farm to EDL's network and used EDL's application form for connecting distributed generation for this purpose. EDL approved the application and Tūpararā was connected under the regulated terms in Schedule 2 of the DG Regulations.[2]

3.2 Tūpararā also entered into a construction contract with EDL to extend and reinforce EDL's network to connect Tūpararā. The construction contract to connect Tūpararā included the costs of installing poles, high voltage lines, underground cabling, and a transformer.

3.3 Tūpararā's generators are asynchronous induction generators that always consume reactive power, regardless of whether they are generating or operating as a motor, i.e., consuming electricity rather than generating it.

3.4 Tūpararā's application to connect to EDL's network:

(a) stated the generators were asynchronous induction generators

(b) stated the generators consumed reactive power

(c) provided the generators' nameplate information

---

[2] Under regulation 8(a) of the DG Regulations (now clause 6.6(2) of the Code), unless a distributor and distributed generator agree an alternative connection agreement within a set timeframe, the regulated terms in Schedule 2 of the DG Regulations (now Schedule 6.2 of the Code) become the default connection agreement for the two parties. On 1 November 2010, the regulated terms under Schedule 6.2 of the Code superseded, but did not materially change the content of, the regulated terms under Schedule 2 of the DG Regulations.

(d) provided engineering advice (based on EDL's network information) about the generators' simulated effect on EDL's network

(e) stated Tūpararā would use switched capacitors for power factor control, with a power factor of 0.96[3] when its turbines were generating at their rated full output.

3.5 Regulation 6 of the DG Regulations (subsequently, clause 6.3(2) of the Code) required a distributor to make certain information publicly available to enable connection of distributed generation where consistent with the distributor's connection and operation standards. The information the distributor had to make publicly available included the distributor's application forms and its connection and operation standards.

3.6 When Tūpararā applied to connect its distributed generation, EDL's application form and its connection and operation standards were set out in a single publicly available information pack.

3.7 Before approving an application to connect distributed generation, the DG Regulations required EDL to provide the following information to Tūpararā regarding any conditions, requirements, or charges relating to power factor (or otherwise) that EDL wished to impose on Tūpararā:[4]

(a) information about the extent to which the connection and operation of the distributed generation might result in a breach of the relevant standards for safety, voltage, power quality, and reliability of supply to other connected parties (regulation 12(b) of Schedule 1)

(b) information about any measures or conditions (including modifications to the design and operation of EDL's network, or to the operation of the Tūpararā's distributed generation) that might be necessary to address the matters referred to in paragraph (a), together with the approximate costs of those measures (regulation 12(c) and (d) of Schedule 1)

(c) information about any obligations to other parties that might be imposed on EDL and that could affect Tūpararā's distributed generation, such as obligations to Transpower, or the obligations under the Electricity Governance Rules 2003 at the time (regulation 12(f) of Schedule 1)

(d) a detailed description of any conditions that are conditions of connection, and what Tūpararā had to do to comply with such conditions, together with:

i. detailed reasons for the conditions

ii. a detailed description of the charges payable by Tūpararā (regulation 18(3)(a), (b) and (c) of Schedule 1).

---

3 In the context of <u>generating</u> electricity, the terms 'lagging' and 'leading' respectively describe whether reactive power is being produced or consumed. However, in the context of <u>consuming</u> electricity, the terms mean the opposite: 'lagging' means consuming reactive power, while leading means producing reactive power. Because Tūpararā's asynchronous induction generators consumed reactive power when generating, Tūpararā should have described the generators as 'leading' when generating. EDL has argued that this error in Tūpararā's applications led EDL to believe that Tūpararā would not consume reactive power when generating. Tūpararā acknowledged that it confused 'lagging' and 'leading' in its application form, but argued that its application form made it clear that its generators would consume reactive power when generating.

4 Part 6 of the Code specifies the same requirements at clauses 12 and 18 of Schedule 6.1.

3.8 The Authority understood that EDL approved Tūpararā's application orally. Before approval, EDL did not provide any of the required information to impose any specific conditions, requirements, or charges.

3.9 The application form and connection and operation standards from EDL's information pack stated:

(a) EDL did not currently apply a fee for assessing generation applications, or impose any ongoing charges in relation to distributed generation

(b) it was *preferable* for distributed generators not subject to despatch to export reactive energy (kVArh) whenever real energy (kWh) is exported onto the network. Subject to network voltage remaining within agreed limits, the *desired* power factor should be between 0.85 and 0.95, i.e. injecting reactive power and supporting voltage. [emphasis added].

3.10 During the application process for Tūpararā, EDL indicated that if, after connecting Tūpararā, EDL found voltage levels to be negatively affected, EDL retained the right to require Tūpararā to install a voltage regulator within 30 days of a written request from EDL. However, EDL advised that Tūpararā would not require installation of a voltage regulator.

EDL initiated power factor charging

3.11 After connecting Tūpararā, EDL imposed a requirement on Tūpararā to maintain a power factor of 0.95 or greater. Failure to maintain a power factor of 0.95 or greater attracted power factor charges, based on per kvar below the required power factor.

3.12 It was noteworthy that EDL's line pricing schedule power factor charge was described as applying to the power factor at the time of the six highest monthly demands at an installation when the power factor fell below 0.95. However, EDL applied the power factor charge at the time of the six highest monthly generation peaks at Tūpararā when the power factor was below 0.95.

3.13 To find an appropriate solution, Tūpararā sought advice from EDL on how EDL determined the power factor charges. Based on this advice, Tūpararā installed additional capacitors and control equipment.

3.14 However, despite Tūpararā adding the further capacitors and making further control system modifications, it continued to incur power factor charges.

3.15 Tūpararā asked EDL whether a joint solution was available, such as a shared STATCOM[5] at the substation. However, Tūpararā considered EDL's indicative pricing for a STATCOM to be uneconomic. This meant that the situation continued with Tūpararā maintaining and supplementing the existing capacitor-based system, and paying power factor charges when it did not achieve a power factor of at least 0.95.

EDL increased its power factor requirements

3.16 EDL then advised Tūpararā EDL would increase its minimum required power factor from 0.95 to 1.00 (unity) for Tūpararā's six highest monthly generation outputs. EDL also indicated that it would require all distributed generators on its network to adopt a higher power factor in the future. In effect, this would require distributed generators to actively export reactive power when exporting electricity into EDL's network.

---

[5] Static synchronous compensator.

3.17 Tūpararā added further capacitors and was able to achieve a power factor of 0.975. However, Tūpararā continued to incur power factor charges when its power factor fell below unity.

3.18 Tūpararā became concerned that EDL's increased power factor requirements had imposed additional costs. Tūpararā considered EDL had given insufficient reasons for the new requirements, and had not justified the power factor charges as a direct cost to EDL.

Tūpararā raised a dispute with EDL under Part 6 of the Code

3.19 Tūpararā initiated the dispute resolution process under clause 2 of Schedule 6.3 of the Code, and wrote to EDL, disputing the basis for the power factor charges under Part 6.

3.20 EDL responded that it considered that its information pack (see paragraph 3.9(b) above) specified EDL's power factor requirements. EDL considered this gave it the basis to increase its minimum required power factor, and charge for any failure to meet that minimum.

3.21 EDL further stated that its requirement of a power factor of 0.85 to 0.95 leading was more onerous than the unity power factor it based its current charges on.

3.22 EDL also referred to the regulated terms' requirement under clause 3(2)(b) of Schedule 6.2 of the Code that Tūpararā operated its equipment in accordance with EDL's connection and operation standards. In EDL's view, its connection and operation standards enabled EDL to specify power factor requirements such as the requirement to generate at unity or leading power factor.

3.23 EDL also considered that, after Tūpararā applied to connect to its network, its benchmark agreement with Transpower required EDL to maintain a unity power factor. EDL considered it fair and reasonable to require distributed generation on its network to assist in either maintaining a unity power factor on EDL's network, or paying the costs of supplying the required reactive power from elsewhere.

Tūpararā complained to the Authority

3.24 Tūpararā complained to the Authority under clause 2(3) of Schedule 6.3 of the Code, and alleged that EDL had breached Part 6 of the Code.

3.25 In Tūpararā's view:

(a) EDL's application form and connection and operation standards did not enable EDL to impose mandatory power factor requirements and associated charges. The words "preferable" and "desired" in EDL's connection and operation standards made EDL's power factor requirements optional; not mandatory or otherwise enforceable.

(b) The regulated terms and regulations 9 and 10 of the DG Regulations[6] did not allow EDL to impose requirements that it had not tabled with Tūpararā before Tūpararā connected its distributed generation. Consequently, EDL could not vary the regulated terms to impose such requirements without Tūpararā's agreement. Tūpararā did not at any point agree to any such requirements for its distributed generation.

(c) After Tūpararā connected its distributed generation, EDL could not amend its connection and operation standards to enable it to impose power factor requirements and associated charges (either retrospectively or going forward) on Tūpararā. The amendments EDL made to its connection and operation standards to this effect were

---

6 The equivalent clauses 6.6 and 6.7 of the Code applied from 1 November 2010.

not enforceable, because they did not reflect reasonable and prudent operating practice.[7]

(d) The regulated terms at regulation 20 of Schedule 2 of the DG Regulations[8] required that connection charges that were payable by Tūpararā be determined in accordance with the pricing principles set out in Schedule 4 of the DG Regulations.[9] Under pricing principle 2(a), a distributor may not recover costs that exceed the incremental costs of providing connection services to a distributed generator. EDL had not at any point provided evidence:

i. of the actual cost it incurred from the operation of Tūpararā's distributed generation

ii. that the power factor charges EDL imposed, and the costs Tūpararā had incurred in relation to EDL's power factor requirements, reflected EDL's incremental costs.

(e) EDL's lines pricing schedules for load did not specify that power factor charges would apply to distributed generation exported on EDL's network.

(f) When EDL introduced the power factor charges, Tūpararā assumed that EDL had the right to vary its power factor charges within reason. Tūpararā said it had tried to work cooperatively with EDL to meet EDL's changing power factor requirements. This required Tūpararā to invest in a custom-built, capacitor-based system and associated switching controls, together with upgrades to this equipment as EDL increased its power factor requirements. Tūpararā claimed that if EDL had been clear about these requirements at the time it applied to connect (as required under the DG Regulations at the time, and the Code now), Tūpararā would have had greater scope to select and install the most appropriate, cost-effective equipment at that time. EDL's unilateral changes to its power factor requirements after Tūpararā connected therefore undermined Tūpararā's original investment decisions.

(g) The requirement of a unity power factor in Transpower's benchmark agreement with EDL was a requirement on EDL, and not a requirement that bound Tūpararā or other distributed generators. In any event, the unity power factor requirement was introduced before Tūpararā connected to EDL's network. As a consequence, EDL would have known about the requirement before Tūpararā applied to connect. Despite this, EDL did not raise this requirement with Tūpararā in the application process.

3.26 Tūpararā requested the following outcomes to resolve the complaint:

---

7 Under regulation 5(1) of the DG Regulations, and subsequently clause 1(1) of the Code, 'reasonable and prudent operating practice', in relation to distributed generation, includes—
(a) the industry operating standards; and
(b) measures to avoid the injection of electricity from distributed generation that—
(i) exceeds the capacity of the distribution network at the point of injection; or
(ii) results in excessive power flow at feeder points or a significant adverse effect on voltage levels; or
(iii) results in a significant adverse effect on the quality and reliability of supply to other users of the distribution network; and
(c) the use or proposed use of reasonable and prudent measures to enable the connection of distributed generation.

8 The equivalent regulated term in clause 19 of Schedule 6.2 of the Code applied from 1 November 2010.

9 The equivalent pricing principles in Schedule 6.4 of the Code applied from 1 November 2010.

(a) a determination of the power factor requirements (if any) that applied to Tūpararā

(b) a determination of the methodology by which EDL calculated its power factor charges

(c) a refund of all power factor charges (including interest) that EDL did not have the right to impose

(d) a capital contribution from EDL reflecting the significant extra costs Tūpararā incurred in meeting EDL's escalating power factor requirements.

3.27 While still attempting to resolve the complaint, EDL installed a STATCOM on its network and applied a new approach of invoicing power factor charges based on Tūpararā's reactive power consumption when Tūpararā was not generating (i.e., when Tūpararā acted as a load).

3.28 EDL advised that it installed the STATCOM to resolve stability issues on its network caused by Tūpararā. However, Tūpararā said that EDL did not inform it of any stability issues before EDL installed the STATCOM.

3.29 Clause 13(1) of the regulated terms in Schedule 2 of the DG Regulations (subsequently, clause 13(1) of the regulated terms in Schedule 6.2 of the Code) requires a distributor to notify a distributed generator if the distributor considers the operation of a distributed generator's distributed generation may adversely affect the network service provided to other network customers, or cause damage to the network or other facilities. Tūpararā did not receive such a notice from EDL.

4 A determination of the connection charges payable is desirable to resolve the dispute

4.1 Under clause 4 of Schedule 6.3 of the Code, the Authority may determine the connection charges a distributed generator must pay a distributor, provided that:

(a) there is a dispute under Part 6 of the Code, and under clause 2(2) of Schedule 6.3, the parties to the dispute have attempted to resolve the dispute with each other in good faith

(b) under clause 4(2) of Schedule 6.3, determining the connection charges payable is necessary or desirable to resolve the dispute in question.

There was a dispute under Part 6 and the parties had attempted to resolve the dispute with each other in good faith

4.2 The Authority was satisfied there was a dispute under Part 6 and the parties had attempted to resolve the dispute with each other in good faith.

Determining the connection charges payable was desirable to resolve the dispute

4.3 The Authority considered it was desirable for the dispute to be resolved by the Authority applying the pricing principles set out in Schedule 6.4 and determining the connection charges payable by Tūpararā. This was because:

(a) the parties' attempts to resolve the dispute with each other broke down after EDL installed the STATCOM and commenced invoicing Tūpararā power factor charges based on when it acted as load

(b) the Authority's knowledge of the facts, and the key aspects of the dispute, made the Authority well-placed to determine the connection charges payable by applying the pricing principles under Schedule 6.4

(c) it provided the best approach for resolving the dispute in a timely and effective manner.

5 The determination of the connection charges payable was based on the pricing principles

5.1 To determine the connection charges payable, the Authority applied the pricing principles under Schedule 6.4 to the charges EDL had imposed on Tūpararā.

5.2 This section outlines the pricing principles relevant to the Authority's determination, and sets out the Authority's approach to applying the pricing principles.

Clause 2 of Schedule 6.4: *Charges to be based on recovery of reasonable costs incurred by distributor to connect the distributed generator and to comply with connection and operation standards within the distribution network, and must include consideration of any identifiable avoided or avoidable costs*

Clause 2(a) of Schedule 6.4: Connection charges in respect of distributed generation must not exceed the incremental costs of providing connection services to the distributed generation

5.3 Under clause 2(a) of Schedule 6.4, connection charges for distributed generation must not exceed the incremental costs of providing connection services to the distributed generation.

Part 1 of the Code defines 'incremental costs'

5.4 Under clause 1.1 of the Code, 'incremental costs' are the reasonable costs that an efficient distributor would incur in providing electricity distribution services with connection services to distributed generation, less the costs that the efficient distributor would incur if it did not provide those connection services.

5.5 For the purpose of this definition, an 'efficient distributor' is a distributor that provides distribution services consistent with the promotion of dynamic, allocative, and productive efficiency.[10] For example, an efficient distributor provides distribution services at least cost over time—consistent with dynamic and productive efficiency, in particular.

Incremental costs reflect reasonable costs an efficient distributor incurs in providing connection services to distributed generation

5.6 The first part of the above definition of 'incremental costs' recognises that a distributor incurs costs as a result of the connection and operation of distributed generation on its

[10] Dynamic efficiency is achieved by firms having appropriate (efficient) incentives to innovate and invest in new products and services over time. This increases their productivity, including through developing new processes and business models, and lowers the relative cost of products and services over time.

Allocative efficiency is achieved when the marginal value consumers place on a product or service equals the cost of producing that product/service, so that the total of individuals' welfare in the economy is maximised.

Productive efficiency is achieved when products and services that consumers desire are produced at minimum cost to the economy. That is, the costs of production equal the minimum amount necessary to produce the output. A productive efficiency loss results if the costs of production are higher than this, because the additional resources used could instead be deployed productively elsewhere in the economy.

network. These costs are in the form of capital expenditure and/or operating and maintenance expenditure, and must reflect the costs an efficient distributor would incur in providing distribution services.

5.7 This prevents a distributor from using the connection of distributed generation to its network as justification for 'gold plating' the network (in terms of capital investment and operation and maintenance), and passing on those costs to the distributed generator.

5.8 This also means a distributor cannot charge a distributed generator for historic (sunk) costs that are not the result of the connection of distributed generator's distributed generation, or for costs that exist in the distributor's business regardless of the connection of distributed generation.

Incremental costs must reflect reductions in a distributor's costs resulting from the connection of distributed generation

5.9 The second part of the definition anticipates that connecting distributed generation can also reduce some of the distributor's costs. For example, by operating at times of peak demand on the distribution network, distributed generation can defer or reduce the costs of upgrading the distribution network to bring more electricity to the area in which the distributed generation is located. Similarly, distributed generation can reduce losses on a distribution network, which can help defer or avoid future network costs.

The definition of "incremental costs" covers all reasonable costs and benefits associated with the connection of distributed generation

5.10 The above definition of 'incremental costs' therefore covers all of the reasonable costs (capital, operating, and maintenance) a distributor incurs in connecting distributed generation to its network, less any reduction in cost the distributor receives from the connection of the generation. Incremental costs do not include 'common costs', which are the costs that are common to all customers (such as head office costs and billing system costs), and do not result from any single connection.

5.11 Accordingly, the costs a distributor typically faces from the connection and operation of distributed generation on its network are:

(a) the capital cost of the lines and related equipment, such as transformers, to connect the distributed generation to its network

(b) the capital cost of any additional equipment the distributor must install as a result of the connection

(c) the operating and maintenance costs from operating the lines and related equipment connecting the distributed generation to its network

(d) any costs associated with determining the avoided costs to the distributor from the distributed generation being connected to its network

5.12 The incremental costs for a distributor are therefore the costs identified above, less any reduction in those costs the distributor receives as a result of the connection of the distributed generation.

Determining the connection charges payable centres on identifying a distributor's incremental costs

5.13 As outlined above, clause 2(a) of Schedule 6.4 prevents a distributor charging connection charges that exceed incremental costs. Determining the incremental costs a distributor incurs from the connection and operation of distributed generation on its network is therefore essential to determining the connection charges payable under clause 4(1) of Schedule 6.3.

Clause 2(b) to (f) of Schedule 6.4: Pricing principles guiding the calculation of incremental costs

5.14 Along with the requirements of the Part 1 definition of ‘incremental costs’, Schedule 6.4 sets out the following principles that guide the calculation of incremental costs, and the determination of connection charges payable under clause 4(1) of Schedule 6.3:

(a) *Costs may be estimated*: under clause 2(b) of Schedule 6.4, costs that cannot be calculated (e.g., costs a distributor may avoid due to the connection of distributed generation) must be estimated with reference to reasonable estimates of how the distributor's capital investment decisions and operating costs would differ, in the future, with and without the distributed generation.

(b) *Estimated costs may be adjusted ex post*: under clause 2(c) of Schedule 6.4, costs estimated under clause 2(b) may be adjusted ex post, if required. Ex-post adjustment involves calculating, at the end of a period, what the actual costs incurred by the distributor as a result of the distributed generation being electrically connected to the distribution network were, and deducting the costs that the distributor would have incurred had the generation not been electrically connected. If the actual costs differ from the costs charged to the distributed generator, the distributor must advise the distributed generator and recover or refund those costs after they are incurred (unless the distributor and the distributed generator agree otherwise).

(c) *Costs of distinct capital expenditure must be paid for in advance*: under clause 2(d) of Schedule 6.4, if costs include distinct capital expenditure, such as costs for a significant asset replacement or upgrade, the distributed generator must pay the connection charges attributable to its actions or proposals before the distributor commits to incurring those costs. When making reasonable endeavours to facilitate connection, the distributor is not obliged to incur those costs until it has received that payment.

(d) *Distributor must pay distributed generator if incremental costs are negative*: under clause 2(e) of Schedule 6.4, if incremental costs are negative, the distributed generator is deemed to be providing network support services to the distributor, and may bill the distributor for this service and, in that case, the distributed generator must comply with all relevant obligations (for example, obligations under Part 6 of the Code and in respect of tax).

(e) *Periodic operating expenses*: under clause 2(f) of Schedule 6.4, if a distributor incurs costs relating to ongoing or periodic operating expenses, such as costs for routine maintenance, the distributor may bill a distributed generator connection charges for the costs attributable to the distributed generator's actions or proposals in the form of a periodic charge.

Connection charges must reflect incremental costs a distributor incurs, or is reasonably likely to incur, in providing connection services

5.15 The effect of clause 2(b) to (d) of Schedule 6.4 is that a distributor can estimate incremental costs and bill a distributed generator for them, before incurring them.

5.16 Specifically, clause 2(b) allows a distributor to estimate incremental costs; clause 2(c) provides for a ‘wash up’ if, after incurring them, the costs differ from the connection charges imposed; and clause 2(d) requires a distributed generator to cover the costs of distinct capital expenditure attributable to its actions or proposals before the distributor commits to incurring those costs. Taken together, this allows a distributor to set ‘forward looking’ connection charges, provided that at the time the distributor imposes the connection charges the charges are directly linked to particular incremental costs that the distributor is reasonably likely to incur.

5.17 However, for the following reasons, the pricing principles do not allow a distributor to impose forward-looking connection charges for costs that the distributor is not reasonably likely to incur:

(a) The combined effect of clause 2(a) of Schedule 6.4 and the definition of ‘incremental costs’ is to limit the connection charges a distributor can impose to the reasonable costs that an efficient distributor would incur in providing distribution services to distributed generation, less the costs that the efficient distributor would incur if it did not provide those services. Connection charges that are not linked to costs the distributor is reasonably likely to incur in providing distribution services to distributed generation do not reflect reasonable costs that an efficient distributor would incur providing such services. This means these charges do not represent incremental costs, as defined. In particular, such charges do not take account of the distributed generator’s preferences, meaning the charges do not promote the efficient allocation of resources—allocative efficiency. Consequently, a distributor cannot charge a distributed generator for any capital, operating, or maintenance costs the distributor is not reasonably likely to incur as a result of the connection of the distributed generator’s distributed generation. To do so would be inconsistent with clause 2(a) of Schedule 6.4.

(b) The scheme and intent of clause 2(a) to (d) of Schedule 6.4 is that a distributed generator pays only for incremental costs a distributor incurs, or is reasonably likely to incur, in providing distribution services to the distributed generator. In particular, clause 2(c) requires a distributor to reimburse a distributed generator if the actual costs a distributor incurs are less than those estimated and charged in advance to the distributed generator. Similarly, clause 2(d) limits the connection charges a distributor may recover from a distributed generator for distinct capital expenditure by the extent to which the expenditure is attributable to the distributed generator's actions or proposals. The scheme and intent of these provisions is undermined if there are forward-looking connection charges that do not reflect costs that a distributor is reasonably likely to incur. This is because such charges do not reflect an increase in the distributor’s costs of providing the connection services (including because of an increase in the distributor’s service levels, sought by the distributed generator).

A distributed generator’s own expenditure was not within the scope of the determination under clause 4(1) of Schedule 6.3

5.18 The Authority’s approach to determining the connection charges payable under clause 4(1) of Schedule 6.3 did not include assessing Tūpararā’s own expenditure in seeking to meet EDL’s connection and operation standards.

5.19 This is because the pricing principles under Schedule 6.4 focus on the incremental costs a distributor incurs as the basis for imposing connection charges on a distributed generator.

6 Determination of the connection charges payable under clause 4(1) of Schedule 6.3

6.1 Based on the approach outlined in section 5, the Authority applied the pricing principles under Schedule 6.4 and determined the connection charges payable by Tūpararā to EDL.

The cost of the construction contract reflected EDL's incremental costs

6.2 There was no dispute between the parties concerning these costs.

The network and uncontrolled energy charges appeared to exceed EDL's incremental costs

6.3 As noted in paragraph 5.4, 'incremental costs':

(a) includes all of the reasonable costs (capital, operating, and maintenance) a distributor incurs in connecting distributed generation to its network, less any reduction in cost the distributor receives from the connection of the generation

(b) do not include 'common costs', which are the costs that are common to all customers (such as head office costs and billing system costs), and which do not result from any single connection to the distribution network.

6.4 This meant that under the Schedule 6.4 pricing principles, EDL was able to charge the capital costs of the connection *and* the ongoing costs for operation and maintenance arising from the connection, less any reduction in network costs resulting from the connection of the distributed generation. However, EDL was not able to charge for costs that were common to all EDL customers, such as head office costs.

6.5 Related to the issue of common costs, in its pricing disclosure, EDL stated that it had a number of geographical areas within its network that were uneconomic to service, and the costs of providing a supply to these remote locations were shared by all EDL's network consumers. However, the Schedule 6.4 pricing principles prevented EDL allocating a share of these costs to Tūpararā, because they were not incremental costs resulting from Tūpararā's connection to EDL's distribution network.

6.6 EDL had invoiced Tūpararā for the following three charges:

(a) fixed daily charge for connections of 31 to 45kVA, charged per day, per ICP

(b) uncontrolled energy charge for connections of 0 to 45kVA, charged per MWh on load

(c) power factor charge, charged per kvar.

6.7 The power factor charge is discussed further below. In relation to the fixed daily charge and the uncontrolled energy charge, for these charges to adhere to the pricing principles, the costs recovered by these charges had to only relate to incremental costs, could not include any common costs, and had to take into account any reduction in distribution network costs resulting from the connection of the distributed generation.

6.8 The fixed daily charge applied to Tūpararā was a standard charge for all non-residential 31 to 45kVA connections to EDL's network. The uncontrolled energy charge was a standard charge for connected loads of up to 45kVA. EDL's pricing disclosures indicated that these two charges collected revenue in relation to the following costs: transmission, system operation and maintenance, administration and overheads, depreciation, taxation, and return on investment. It was not clear from EDL's pricing disclosures what EDL's rationale was for charging Tūpararā these charges, but it appeared that EDL charged Tūpararā on the same basis as load of an equivalent size.

6.9 While Tūpararā drew load, this occurred during its operation as distributed generation, as the turbines drew electricity during start up and when wind speeds were low or variable. Since Tūpararā operated as distributed generation even when it drew load, the Schedule 6.4 pricing principles still applied. Any charges applied to Tūpararā, including the fixed daily charge and uncontrolled energy charge, must have therefore only been for recovery of incremental costs arising because of the connection of Tūpararā as distributed generation, not as load.

6.10 Because Tūpararā paid for the costs of connection to EDL's network, of the costs recovered by EDL through its fixed daily and uncontrolled energy charges, only system operation and maintenance appeared to relate to the incremental costs resulting from connection of Tūpararā, as distributed generation. Further, the charges did not appear to reflect any reduction in network costs resulting from the connection and operation of the distributed generation, e.g., reduced distribution network investment costs because of reduced losses.

6.11 Regarding the other costs that EDL recovered through its fixed and variable charges:

(a) *transmission costs* could potentially have been higher without Tūpararā, because Tūpararā reduced the amount of electricity that needed to be imported into EDL's network. This was reflected in the avoided costs of transmission payments EDL made to Tūpararā for its generation during the periods of regional coincident peak demand used by Transpower to calculate EDL's interconnection charges

At the same time, Tūpararā use induction generators and so drew reactive power. If this resulted in Transpower applying a kvar charge to EDL, this would have increased transmission costs, and it would have been consistent with the incremental cost requirement of the Schedule 6.4 pricing principles for EDL to charge Tūpararā for its share of this cost. While this issue is discussed further below, Transpower did not apply and does not apply a kvar charge. As a result, there was no increase in EDL's transmission costs from this source, as a result of Tūpararā's connection to EDL's distribution network

(b) *administration and overheads* were 'common costs' that were unlikely to vary with or without the connection of Tūpararā. Therefore, they should not have been included in the connection charges applied to Tūpararā, because they were not incremental costs

(c) given the incremental cost requirement, the only costs for which it would have been appropriate to charge *depreciation* and *a return on investment* would have been in relation to the additional costs EDL incurred as a result of connection of Tūpararā. Leaving aside for the moment the issue of reactive power, the only such additional costs were the costs of the connection assets, but these costs were incurred by Tūpararā rather than EDL. The Authority understood that certain assets continued to be owned by Tūpararā but were assumed by EDL to be part of its network. As a result, charging for depreciation and a return on investment on these assets would have been inappropriate. To the extent that Tūpararā gifted assets to EDL, charging for depreciation and a return on investment in relation to these assets would amount to double charging, so would also have been inappropriate.

6.12 Accordingly, the only costs recovered under the fixed daily and uncontrolled energy charges for which EDL was able to charge Tūpararā were incremental costs related to system operation and maintenance. EDL stated in its Pricing Methodology Disclosure that system operations and maintenance, depreciation, and return on investment were considered to be asset related and those costs were allocated based on the assets required to service the consumers in each group.

6.13 In the same document, EDL stated that its approach was to assign the value of assets to each ICP then summate these to get a total of each customer group. EDL used after diversity maximum demand (ADMD) to allocate the value (in replacement cost terms) of each asset across all of the ICPs supplied by the asset. EDL allocated assets to ICPs depending on an assessment of the extent to which the asset is shared across ICPs.

6.14 This indicated that EDL's allocation of system operation and maintenance costs was based on a proxy for actual system operation and maintenance costs in relation to each customer. In addition, the cost allocation appeared to rely on the value of all assets EDL assessed as being required to service a customer group, not just incremental operation and maintenance costs incurred because of the connection of a customer, such as Tūpararā. Accordingly, the portion of the fixed daily charge and the uncontrolled energy charge that EDL attributed to system operation and maintenance appeared to exceed the incremental cost requirement for charges to Tūpararā. This is because the allocation appeared to include costs relating to system operation and maintenance of assets other than those required to connect and maintain the connection of Tūpararā.

6.15 Consistent with the Schedule 6.4 pricing principles, the Authority noted that charges for system operation and maintenance in relation to the assets required to connect Tūpararā to EDL's network[11] should be the actual costs EDL incurred to operate and maintain these assets since the connection of Tūpararā. As noted in paragraph 5.14(a)above, under clause 2(b) of the Schedule 6.4 pricing principles charges may be based on estimated costs but clause 2(c) provides for a 'wash up' of charges if actual costs exceed estimated costs.

6.16 EDL would need to identify and itemise these costs, with supporting documentation. The Authority noted that ownership of at least some of these assets was retained by Tūpararā, and it was not clear to the Authority whether Tūpararā or EDL maintained these assets. Clearly, charges would only be appropriate for maintenance of these assets undertaken by EDL.

6.17 The Authority's starting assumption was that, since the time of connection of Tūpararā to EDL's network, EDL incurred little or no cost operating and maintaining the assets required to connect Tūpararā to its network. This assumption was based on the assets being new.

6.18 The Authority noted that, as the assets age, EDL would be expected to incur operating and maintenance costs related to those assets.

6.19 Further, any charges that EDL applied to Tūpararā had to take into account any reduction in distribution network costs as a result of the connection and operation of Tūpararā. For example, if the connection and operation of Tūpararā reduced losses on EDL's network, and therefore future investment costs, this should be reflected in the charges EDL applied to Tūpararā.

Power factor standards and charges can reflect incremental costs

6.20 Power factor standards and associated charges are primarily used to incentivise voltage support and increase real power conveyance on transmission and distribution networks

---

11 To reiterate, this is only the system operation and maintenance costs in relation to those assets used to connect Tūpararā to the network, and only those assets operated and maintained by EDL It does not include costs in relation to the reactive support equipment installed by EDL since the connection of Tūpararā, as the costs in relation to this equipment are discussed in the next section.

during periods of peak demand. In New Zealand, it is standard practice for a distributor to set a minimum power factor threshold of 0.95 lagging for large load customers.[12]

6.21 Power factor charges would be consistent with the Schedule 6.4 pricing principles if the charges related to costs that the distributor incurred, or was reasonably likely to incur, as a result of the connection of the distributed generation connecting to the distributor's network. Accordingly, the issue for determination was whether the power factor charges applied to Tūpararā related to costs actually incurred by EDL or that EDL expected to incur as a result of the connection of Tūpararā to EDL's network. The charges would have been inconsistent with the pricing principles if the main purpose of the charge was to provide an incentive on Tūpararā to curtail consumption of reactive power in instances where EDL did not incur, or expect to incur, any costs because of the consumption of reactive power.

6.22 As outlined in paragraph 5.6 and reflecting clause 1.1 of the Code, the costs must be costs that an efficient distributor would incur in providing the connection service, and so cannot include costs that would imply 'gold-plating' of the distribution network. This meant that, if EDL undertook or expected to undertake investment on its network because of the connection of Tūpararā, the pricing principles would only allow EDL to charge Tūpararā for those costs if the investment was, or would be consistent with, what an efficient distributor would have done. This means the distribution investment solution chosen must reflect the engineering need identified through appropriate analysis, and must be the least cost option for addressing that need.

6.23 As with other charges, the Schedule 6.4 pricing principles mean that if Tūpararā was not generating, but was drawing load, charges would still be limited to incremental costs if the costs arose because of the Tūpararā's operation as distributed generation. Tūpararā operates as a load when its turbines start up or during periods of low or variable wind speed. Any power factor charges applied to Tūpararā during these periods would have to be on the same basis as for reactive power during periods when Tūpararā did generate, i.e., incremental costs. This is because any reactive power costs EDL would incur when Tūpararā operated as a load only would arise as a result of Tūpararā operating as distributed generation. EDL would not incur these costs if Tūpararā was not distributed generation connected to EDL's network.

6.24 EDL initially charged Tūpararā the EDL price schedule power factor charges that applied to load, but charged according to peak generation rather than peak demand. In particular, power factor charges were applied to Tūpararā when its power factor during periods of peak monthly generation was below the power factor standard EDL had chosen to apply to its network, ie, 0.95 lagging (with the term 'lagging' as applied to loads – reflecting the operating state in which reactive power exported from the network is consumed by the load).

6.25 EDL then changed the basis for calculating power factor charges for generators, including Tūpararā. In particular, a power factor charge applied to peak generation when generators were importing reactive power from the distribution network and was invoiced on the basis of reactive power imported from the network.

---

12 As outlined in footnote 3, in respect of load, the term 'lagging' applies where reactive power is being consumed or exported from the network, while the term 'leading' applies where reactive power is being generated or imported into the network. A 0.95 lagging standard incentivises large load customers to manage reactive power consumption to below approximately one third of their real power consumption. A distributor usually calculates this charge by multiplying the power factor rate (expressed as a $/kvar charge) with the peak periods in which the load customer's worst breach exceeded the distributor's power factor threshold for any given month.

6.26 EDL sought to recover from Tūpararā the costs of the STATCOM that EDL installed. EDL and Tūpararā discussed several options for Tūpararā to pay for the STATCOM but did not reach agreement on payment for the STATCOM.

6.27 After EDL and Tūpararā failed to agree on the STATCOM costs, EDL changed the basis for charging Tūpararā power factor charges. EDL's changed basis was to apply kvar charges at times when Tūpararā was consuming active and reactive power and was not exporting active power at the same time. EDL applied this charge to Tūpararā's peak imports of reactive power demand.

6.28 As stated above, to meet the requirements of the Schedule 6.4 pricing principles, the power factor charges and the recovery of the costs of the STATCOM:

(a) had to relate to incremental costs that EDL incurred, or expected to incur, as a result of the connection of Tūpararā to the distribution network

(b) had to reflect the costs that an efficient distributor would incur in providing the connection service.

The power factor charges were inconsistent with the pricing principles

6.29 Taking first the power factor charges, neither the power factor charges on Tūpararā when it was operating as generation, nor the power factor charges on Tūpararā when it operated as load, related to costs that EDL incurred or expected to incur because of the connection of Tūpararā.

6.30 EDL's Pricing Methodology Disclosure stated that a charge for reactive energy, where power factors were below 0.95, would be levied to encourage investments in improving power factors and it had observed payback periods for some customers investing in equipment to correct their power factor of 12-24 months.

6.31 EDL's justification for the power factor charges specifically applying to generation was to reflect the requirement under EDL's benchmark agreement with Transpower to maintain a unity power factor.

6.32 The power factor charges applied to Tūpararā did not appear to reflect the requirement under the Schedule 6.4 pricing principles for charges to distributed generation to relate to incremental costs that EDL incurred or expected to incur as a result of the connection of Tūpararā to EDL's network.

6.33 In the case of the power factor charge on load, EDL's justification for the charge was not to recover costs of equipment it had to install because of the connection but to encourage installation of reactive support equipment by loads subject to the charge. While this was not unreasonable in or of itself, it was inconsistent with the Schedule 6.4 pricing principles applying to distributed generation. Accordingly, the Authority considered EDL was unable to apply the power factor charge applying to load to Tūpararā.

6.34 The unity power factor requirement on EDL could potentially have necessitated EDL installing reactive support equipment to address the reactive power demands of Tūpararā and other consumers of reactive power. However, correspondence between Transpower and EDL indicated that Transpower had entered into non-compliance agreements for different power factor requirements when requested. This indicated that EDL had the option of seeking an agreement with Transpower for a different power factor requirement if the unity power factor requirement was problematic. EDL did not appear to have sought such an agreement with Transpower. Further, as far as the Authority was aware, Transpower had not sought to enforce the unity power factor requirement on EDL. This is likely to be because the power factors at the grid exit point supplying the relevant area were approaching unity. Accordingly, the unity power factor requirement did not appear to be imposing a cost on EDL. Even if it did, the least cost option was likely to be for EDL to seek Transpower's agreement to an alternative power factor requirement.

6.35 One further point to note regarding EDL's justification for the unity power factor charge on generation is that if EDL was genuinely concerned about the unity power factor requirement under the benchmark agreement, it would have been reasonable to expect EDL to place the same requirement on load. However, the power factor charge on load continued to be for consumption of reactive power below a power factor of 0.95, rather than unity.

6.36 Accordingly, the Authority considered that EDL had not demonstrated that the connection of Tūpararā imposed a cost on EDL that necessitated EDL applying a power factor charge, based on a unity power factor, on Tūpararā.

The charge seeking to recover the costs of the STATCOM was inconsistent with the pricing principles

6.37 EDL decided to install the STATCOM at the substation to allow the power factor at the substation to be corrected. EDL further explained that the STATCOM was only installed to provide the reactive support required by the network as a consequence of Tūpararā. Accordingly, EDL sought to charge Tūpararā for the full cost of the STATCOM.

6.38 In terms of the Schedule 6.4 pricing principles, the STATCOM was a cost borne by EDL that in the view of EDL:

(a) would not have been incurred except for the connection of Tūpararā to EDL's network

(b) would not have been incurred if Tūpararā had installed, operated and maintained the equipment necessary to improve the power factor at the substation.

6.39 The correspondence between EDL and Tūpararā indicated that the capacity of the STATCOM exceeded that required to correct the power factor to the level targeted by EDL. In particular, EDL noted that Tūpararā used approximately 50% of the capacity of the STATCOM when operating as a load and approximately 60% when running as generation; therefore the STATCOM had some spare capacity, however the marginal cost of the additional capacity was low, as a significant part of the costs were fixed.

6.40 Accordingly, while the STATCOM could have potentially met the Schedule 6.4 incremental cost requirement, if it did meet this requirement, the full cost of the STATCOM was likely to exceed incremental costs.

6.41 The next consideration was whether the charge for the STATCOM reflected costs that an efficient distributor would incur in providing the connection service. The key issue for determining whether Tūpararā should bear a proportion of the costs of the STATCOM was whether it was necessary to correct the power factor at the substation by installing that equipment.

6.42 The Authority investigated whether there was a power quality problem at Timmins that necessitated installation of the STATCOM. This is discussed in the engineering analysis (Appendix A). In that analysis, it is noted:

(a) Sometime before Tūpararā connected to EDL's distribution network, EDL upgraded the substation from 11 kV to 33 kV. This strengthened the distribution network at Timmins by reducing its source impedance (i.e., the impedance of the circuit(s) supplying Timmins from the grid). This increased the network's capacity to host distributed generation without imposing incremental costs on EDL.

(b) Since Tūpararā first connected:

i. EDL provided no evidence of current, voltage or power quality problems resulting from the Tūpararā's connection and operation of its distributed generation.

ii. Tūpararā improved the power factor of its generation by installing control equipment and a number of capacitors, and modifying the control systems. In addition, EDL strengthened the substation by upgrading its two transformers.

6.43 In terms of addressing current, voltage or power quality problems, the engineering justification for requiring any of this investment was unclear.

6.44 In conclusion, while the operation of Tūpararā caused a relatively poor power factor at the substation, prior investments by EDL had strengthened (i.e., reduced the impedance of) the network to the extent that there were no current, voltage or power quality problems necessitating installation of the STATCOM. That is, while the power factor from Tūpararā may have been relatively poor, the strength of the network meant this did not cause voltage or power quality problems for other users, requiring correction by the STATCOM. Accordingly, installation of the STATCOM was not a cost that an efficient distributor would incur in connecting the Tūpararā. Therefore, charging Tūpararā to recover the costs of the STATCOM would be inconsistent with the Schedule 6.4 pricing principles.

Conclusion

6.45 In conclusion, the Authority determined that:

(a) Charges to recover the costs of construction of the assets connecting Tūpararā to EDL's network were consistent with the Schedule 6.4 pricing principles. The Authority understands Tūpararā paid these costs in full, so there were no outstanding charges for these assets.

(b) Charges for system operation and maintenance in relation to the assets required to connect Tūpararā to EDL's network would be consistent with the Schedule 6.4 pricing principles. Charges should be based on the actual costs EDL has incurred to operate and maintain these assets since the connection of Tūpararā to EDL's network, and will incur in the future. Any charges to Tūpararā should take into account any reduction in EDL's distribution network costs resulting from the connection of Tūpararā.

(c) The fixed daily charge and the uncontrolled energy charge that EDL invoiced to Tūpararā were inconsistent with the Schedule 6.4 pricing principles. Accordingly, EDL had to refund Tūpararā the full value of these charges paid by Tūpararā since its connection to EDL's network.

(d) All of the power factor charges on Tūpararā (i.e., applied when Tūpararā operated as load or operated as generation) were inconsistent with the Schedule 6.4 pricing principles. Accordingly, EDL should refund Tūpararā the full value of these charges paid by Tūpararā since its connection to EDL's network.

(e) Any charge for the cost of the STATCOM installed by EDL at the substation would be inconsistent with the Schedule 6.4 pricing principles. Accordingly, Tūpararā would not be required to pay for the costs of the STATCOM, and EDL should bear the full costs of the STATCOM.

Appendix A Engineering analysis

A.1 This analysis first summarises the general role of power factor standards on a network, and then analyses whether EDL had good engineering reasons for the power factor standards and charges it sought to apply to Tūpararā.

The role of power factor standards on networks: encouraging voltage support during periods of peak demand

A.2 Power factor standards and associated charges are primarily used to incentivise voltage support and increase real power transmission on transmission and distribution networks during periods of peak demand. In New Zealand, it is standard practice for a distributor to set a minimum power factor threshold of 0.95 lagging for large load customers.[13]

A.3 While it is standard practice for a distributor to set power factor standards for load customers (and apply charges if a customer's reactive power import from the network exceeds a set limit), it is questionable for a distributor to set such standards and charges for distributed generation on its network. This is because, compared with load customers, most types of distributed generators are able to control local network voltage dynamically.[14] This ability to control voltage means the generator automatically varies its power factor in accordance with what is required to maintain voltage on the local network. It also improves real power transmission into a local region and helps manage dynamic voltage fluctuations (improving power quality). For these reasons, power factor standards are generally not required or used for most types of distributed generation.

A.4 However, some types of distributed generation cannot support voltage. In this case, Tūpararā's "Type A" wind generators use simple induction machines that cannot directly control voltage. These generators also consume relatively high levels of reactive power (especially at maximum generation output) and can have poor power factor at low generation levels. As the power systems analysis section in this report illustrates, operating such distributed generation can reduce the voltage on a network during both peak demand and/or peak generating periods. In principle, this means that there may be good engineering reasons to set minimum power factor standards or thresholds and associated charges if doing so encourages distributed generators with this type of generation to better manage the impact of their generation on network voltage.

---

13 The term 'lagging' applies where reactive power is being consumed or exported from the network, while the term 'leading' applies where reactive power is being generated or imported into the network. A 0.95 lagging standard incentivises large load customers to manage reactive power consumption to below approximately one third of their real power consumption. A distributor usually calculates this charge by multiplying the power factor rate (expressed as a $/kvar charge) with the peak periods in which the load customer's worst breach exceeded the distributor's power factor threshold for any given month.

14 Being able to control voltage dynamically requires a generator (typically a synchronous machine) with an Automatic Voltage Regulator (AVR) that enables the generator to produce or consume reactive power to maintain voltage.

Were there good engineering reasons for EDL to set and apply power factor standards and associated charges to Tūpararā?

A.5 In terms of encouraging Tūpararā to manage the impact of its generation on network voltage, there was arguably some engineering justification for EDL to set the initial 0.95 power factor standard (and associated charges). The 0.95 power factor standard was also consistent with the standard EDL applied to load on its network.

A.6 However, there were several issues:

(a) Under the pricing principles in Part 6 of the Code, EDL could only charge Tūpararā for power factor (or any other charge) if EDL had incurred incremental distribution costs to connect the distributed generation. EDL had invested in a STATCOM and two transformers at the substation following the installation of Tūpararā. These investments did not appear to have been made for good engineering reasons. They should therefore not have been considered as incremental distribution costs under the pricing principles as they were not required.

(b) There were several other important issues related to the current methodology applied by EDL when calculating power factor charges for Tūpararā. These were:

(i) EDL charged power factor at an ICP level. As power factor is usually used to incentivise better voltage within an electrical region, it was more relevant in this case to aggregate Tūpararā's real and reactive power consumption and use this aggregate to calculate power factor. The reason for this was that all of the turbines are electrically close.

(ii) At all times, a power factor charging approach incentivises improved power factor in over-voltage network conditions. This can exacerbate over-voltage conditions. For this reason choosing peak generation periods (or peak generation and peak demand periods) for the purposes of charging would make better engineering sense, incentivising better voltage regulation.

A.7 EDL raised its minimum required power factor from 0.95 to 1.00 (unity) for Tūpararā's six highest monthly generation outputs. However, for the following reasons, EDL did not, and does not, have good engineering reasons for this:

Before Tūpararā connected:

(a) EDL upgraded the substation from 11 kV to 33 kV, strengthening the network at Timmins.[15] This increased the network's capacity to host distributed generation without imposing incremental costs on EDL.

Since Tūpararā first connected:

(b) EDL had not provided evidence related to any engineering problems associated with Tūpararā's operation. For example, there had been no evidence provided, to the Authority or Tūpararā's, by EDL of any voltage or power quality problems resulting from Tūpararā's installation and operation of its distributed generation on EDL's network.

15 .

(c) Tūpararā had improved the power factor of its generation by installing control equipment and a number of capacitors, and modifying its systems. In addition, EDL had since strengthened the substation by upgrading its transformers and installing a STATCOM. In terms of addressing voltage or power quality problems, it is unclear what EDL's engineering justification was for requiring any of this investment.

(d) EDL's stated justification for increasing the 0.95 power factor standard to unity was that EDL considered its benchmark agreement with Transpower required it to maintain a unity power factor. EDL considered it fair and reasonable to require distributed generation on its network to assist in either maintaining a unity power factor on EDL's network, or paying the costs of supplying the required reactive power from elsewhere. However, the following points indicate that there was little to no relationship between Transpower's unity power factor requirement and EDL's unity power factor requirement:

(i) Transpower's unity power factor requirement applied to the 100 highest regional peak demand periods across the whole Upper South Island region over a pricing year. Most of these 100 peak demand periods occurred in the morning and evening peaks in winter. In contrast, because the windy periods comprising Tūpararā's six highest monthly generation outputs could occur at any time during the day or night, EDL's unity requirement applied to Tūpararā's generation at all times. In practice, this resulted in Tūpararā's highest monthly generation outputs occurring outside the winter months when the highest regional peak demand periods occurred. This would have made EDL's unity power factor requirement ineffective in assisting EDL to meet Transpower's unity power factor requirement.

(ii) unlike EDL, Transpower did not charge its customers for failing to meet its unity power factor requirement.

(iii) EDL's unity power factor standard could potentially have had the perverse effect of inadvertently causing over-voltage conditions during times of high export from Tūpararā and low demand on the network.

(e) As connection and operation standards under the Code, EDL's power factor requirements had to reflect or be consistent with 'reasonable and prudent operating practice', which is defined in Part 1 of the Code. Applying that definition, EDL had not shown that the power factor requirements were measures to avoid the injection of electricity from distributed generation that:

(i) exceeded the capacity of the distribution network at the point of injection;

(ii) resulted in a significant adverse effect on voltage levels; or

(iii) resulted in a significant adverse effect on the quality and reliability of supply to other users of the distribution network.

A.8 Taken together, this indicated that the engineering justification that supported a power factor standard of 0.95 did not apply to the higher (unity) power factor standard.

Power systems analysis of voltages at the substation

A.9 This section illustrates the general theory behind improving power factor, and how this is applied to Tūpararā's inductive Type A wind generators. This analysis uses simple voltage phasor diagrams to illustrate the concept of how voltage magnitude at the receiving end of the network (in this case, at Timmins) can change when compared to the voltage magnitude at the sending end of the network (in this case, at Salinas) with different network operating conditions.

A.10 This section provides the general theory of power factor correction and voltage regulation, an illustrative example with a weak network impedance and then applies this theory specifically to the Timmins region of EDL's network by interpreting data from measurements made by Tūpararā.

General theory of power factor correction and voltage regulation with reference to inductive Type A wind generators

A.11 The important operating states are the extreme states that bound all other operating states. The difference in the receiving end voltage at Timmins against the sending end voltage at Salinas is important.

A.12 In this case, these conditions are:

(a) high wind, high/low demand periods (where problems can arise from low voltage)

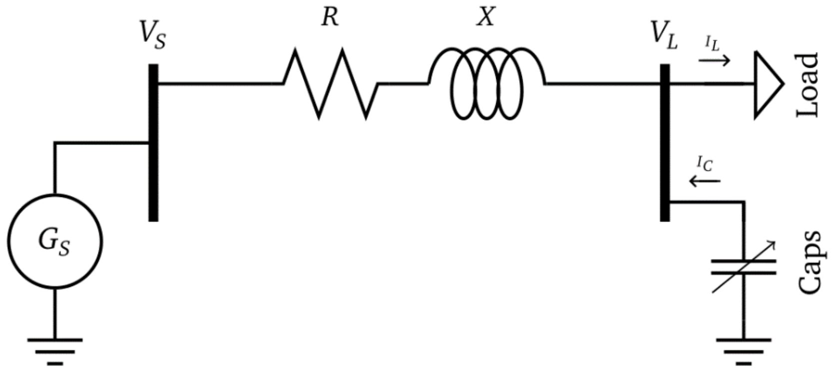
(b) low wind, low demand periods (where problems can arise from high voltage).

A.13 The 2-bus power system model can be used in many aspects of power system engineering and analysis to help understand underlying problems and issues. The model simplifies the connected network into an equivalent impedance, representing a simple inductance and resistance between two buses.

A.14 In this case, the model symbolises EDL's network between Salinas and Timmins, with 'Vs' representing Salinas and 'VL' representing Timmins. 'Load' represents the combination of Tūpararā and local load at Timmins. 'Caps' can represent power factor correction, or in this instance, the STATCOM that EDL had installed at Timmins.

A.15 'R' and 'X' represent resistance and inductance, respectively, which together comprise the equivalent network impedance, including lines and transformers, between Salinas and Timmins.

Figure 1 Simple 2-bus power system model



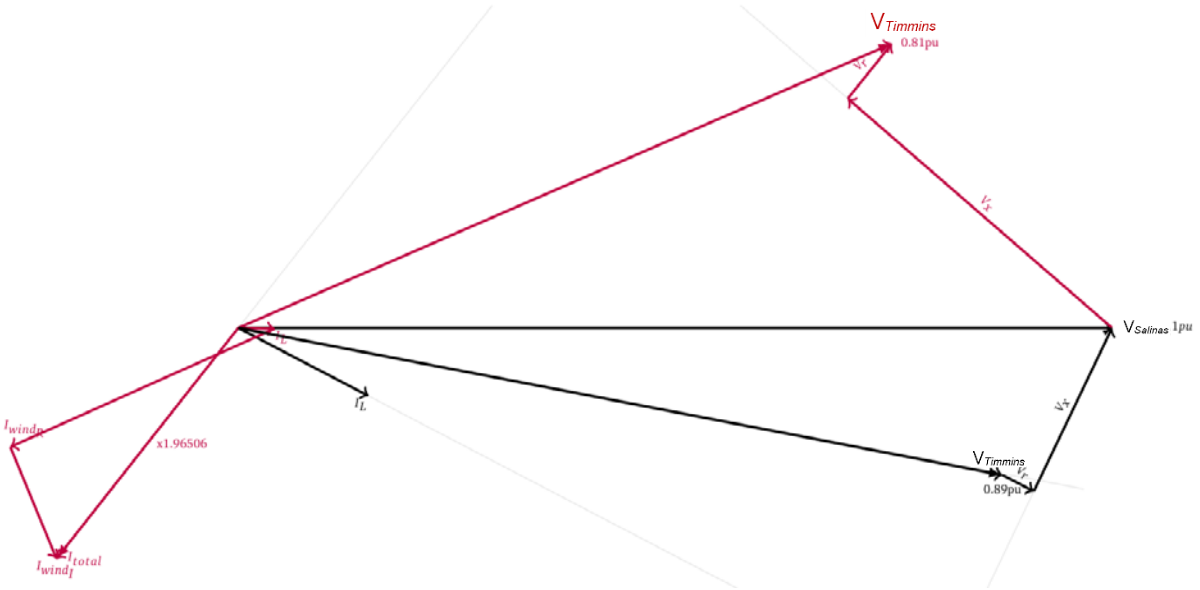
A.16 While simplified, this type of model illustrates the underlying voltage issues that result from poor power factor.

A.17 Strong networks can host a lot of generation (or demand) and have small network impedance (small values of R and X), and corresponding small voltage drops across their network. In contrast, weak networks have high network impedance and large voltage drops. This is significant in this case as EDL progressively upgraded the network at Timmins before and after Tūpararā connected its distributed generation, which progressively lowered network impedance, and reduced the scale of voltage drops on the network as a result of different network conditions.

Weak network impedance example

A.18 The following phasor diagram in Figure 2 provides a hypothetic illustrative example, assuming weak (high) network impedance and the problems associated with voltage magnitude (in p.u.[16]) at the receiving end for two different operating states.

Figure 2 Hypothetical and exaggerated phasor diagram illustrating potential voltage issues at Timmins, assuming a high network impedance, low demand, and high wind generation drawing reactive power from the network at 0.93 power factor.



Maximum wind generation, low/high demand:

A.19 The red phasors represent conditions of high wind generation and low demand. When is producing maximum real power, the total Timmins load and generation consists of the combinations of the real and imaginary parts of the wind generation (I_{windL} and I_{windR}) and demand (I_L) at Timmins. This is illustrated by the red I_{total} phasor. For simplicity it is assumed that the remainder of EDL's network behind Salinas is strong with the voltage at Salinas fixed at 1p.u.

A.20 The voltage drops across EDL's network between Salinas and Timmins are represented by the red voltage phasors V_X and V_R. The magnitude of these voltage

16 Per unit, abbreviated p.u. is used in power systems analysis to indicate the percent of the local voltage of the network. This is a more convenient way to represent voltage when base voltage levels are different. Common distribution base voltage levels in New Zealand are 11 kV, 33 kV, 66 kV and 110 kV.

drops is primarily dependent on the impedance of the network along with the total current flowing between Salinas and Timmins. The angle of the voltage drops, i.e., whether the voltage lowers or increases receiving end voltage, is primarily dependent on reactive power consumption/injection at Timmins. Power factor thresholds and standards are generally used to help dis-incentivise reactive power consumption which in turn helps increase local voltage. In this example, the voltage at Timmins (0.81p.u.) is equal to the set 1p.u. voltage phasor at Salinas, minus the voltage phasors that represent the voltage drops across the resistance and reactance of the network. In this case real power is flowing from Timmins to Salinas, while reactive power can be thought as flowing from Salinas to Timmins.

A.21 High wind generation combined with high demand results in a similar phasor diagram with the receiving end voltage at Timmins being around 0.8p.u.

No wind, high demand:

A.22 The black phasors similarly represent conditions with little or no wind generation and high demand.

A.23 The voltage difference (or regulation) between these two network operating conditions can therefore vary between the red line to $V_{Timmins}$ with a length/magnitude of 0.81p.u voltage and the black line with a magnitude of 0.89p.u. At very low load levels, the voltage drops V_X and V_R become small and the Timmins voltage approaches Salinas's voltage of 1p.u. Such analysis is usually conducted with power flow software and for a range of operating points. This is then used to inform lines companies whether network investment is required or not.

A.24 This example assumed that the network impedance between Timmins and Salinas was high (i.e., a weak network) and may be representative of the case had Tūpararā connected its distributed generation at Timmins prior to the network upgrades EDL carried out.[17]

A.25 The analysis also illustrates the potential voltage regulation issues on weak networks caused by inductive Type A wind generators with poor power factor. For this reason it is likely that either:

(a) network standards are upgraded to ensure that distributed generation is able to control voltage, which would equate to a ban on induction Type A wind generators unless they were installed with appropriate voltage control equipment; or

(b) if induction generators are allowed onto the network, enforce strict power factor requirements as necessary.

Applying this analysis specifically to the EDL dispute case

A.26 While Tūpararā has a poor power factor, the network in which they are connected was upgraded before Tūpararā connected (as outlined in the section on recent network upgrades below). This means the network had relatively low impedance and

---

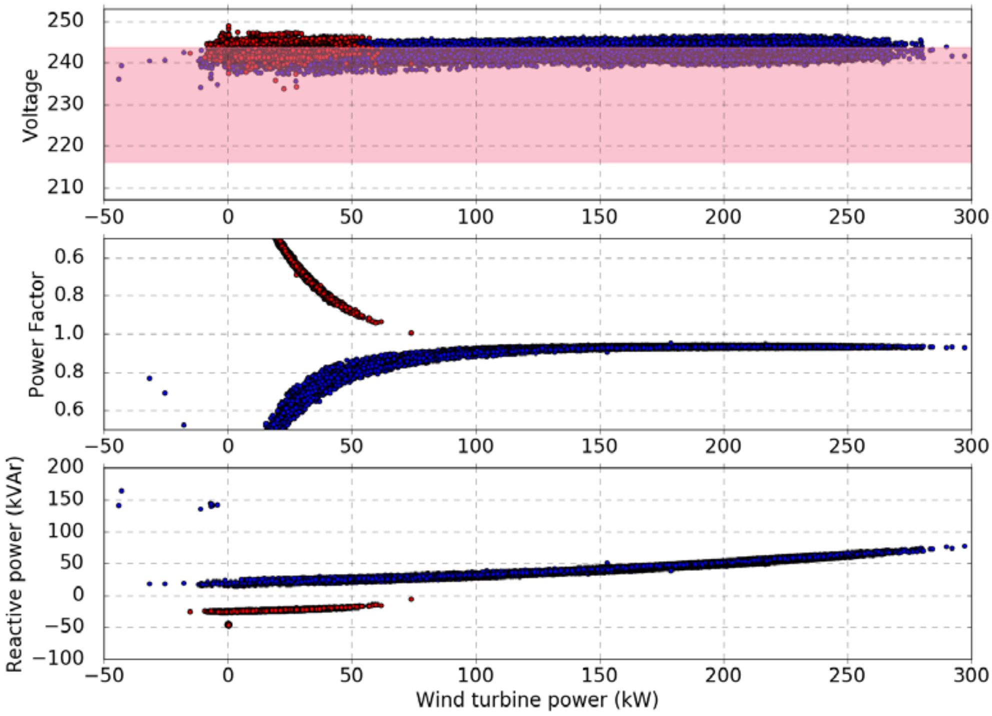
[17] Lines companies are required to maintain voltages within 6% of the low voltage standard set out in the Electricity (Safety) Regulations 2010, i.e., between 0.94 p.u. and 1.06 p.u. voltage. This hypothetical case would therefore likely require additional network investment to achieve this. Had voltage regulation at Timmins looked similar to this prior to and/or following the installation of the wind turbines then this would present good evidence for the need to upgrade the local network and charge this to the wind farm as an incremental cost under the pricing principles in Part 6 of the Code.

was able to host the wind generators without significant voltage fluctuation or any incremental network investment.

A.27 Since Tūpararā measured the voltages, there has been no evidence that voltages at Timmins have been overly affected by Tūpararā connections.[18] Therefore it appears likely that any investment at Timmins since then is over and above what is required to host Tūpararā, or, in other words, there does not appear to be any engineering justification to warrant charging the cost of the STATCOM or any other network upgrades (including the installation of two transformers) at the substation as incremental costs.

A.28 Data supplied by Tūpararā and illustrated in Figure 3 shows that, despite poor power factors of the wind generators, voltages remain tightly regulated within a narrow voltage range and are all generally high. This is illustrative of a strong network with low impedance. Although only measured for select days in most months over a year, the data clearly shows tight voltage regulation. In addition to this, the red dots appear to illustrate situations where Tūpararā is supplying reactive power to the local network.

Figure 3 Tūpararā voltage, power factor and reactive power for selected days during most months over a year (red dots indicate a leading power factor, or reactive power flowing from the wind turbines to the network)



A.29 This data can be used, through small signal analysis, to provide an estimate of the connected network impedance. This is achieved by taking the voltage and current differences in each 10 second measurement period (as a result of the changing wind

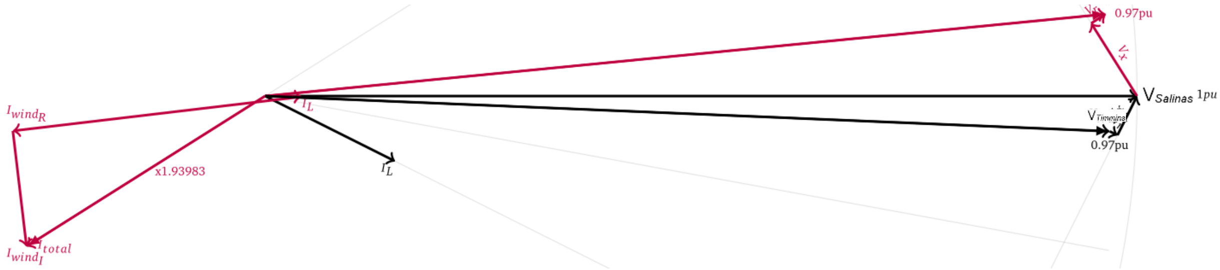
18 For example, although on the high-side (due to the measurement point) voltages measured over a year show tight voltage regulation over a range of different operating conditions.

generation) and using this to derive an estimate of the connected network impedance using Ohm's Law.

A.30 Dividing the resulting change in voltage with the change in wind generator current for each 10 second period we see an approximate network impedance of around 0.05 p.u for most operating states. In other words, a shift of 10 Amps in current would cause a 0.5 V difference in voltage. This network impedance is around four times lower than the impedance that was used in the hypothetical example illustrated in Figure 2.

A.31 Figure 4 illustrates a more accurate phasor diagram that tends to more closely match the tight voltage regulation seen at Tūpararā's terminals over a year using this smaller network impedance.

Figure 4 More accurate phasor diagram illustrating more realistic voltages at Timmins as a result of Tūpararā.



A.32 These results show that voltage regulation at Timmins was very good prior to the investment made at Timmins by EDL to improve power factor.

A.33 The combination of the measured voltage by Tūpararā, and the power system analysis provided here demonstrate that the poor power factor of Tūpararā does not result in any major engineering or operating issues. Therefore, the investment made by EDL to improve power factor does not appear to have been made for good engineering reasons.