

# **Promoting reliable electricity supply: Options to address a harmonics issue**

## **Consultation paper**

19/05/2026

## Executive summary

The Electricity Authority Te Mana Hiko (Authority) is committed to promoting the security and resilience of New Zealand's power system, ensuring it is set up to deliver the best possible outcomes for consumers in a highly electrified future.

Through our multi-year Future Security and Resilience (FSR) work programme,<sup>1</sup> we are taking a forward-looking approach to enabling new and evolving technologies, addressing security and resilience risks and building a power system that is reliable, flexible and future-focused. A critical part of this programme is a review of the common quality requirements in Part 8 of the Electricity Industry Participation Code 2010 (Code).

'Common quality' means those elements of the quality of electricity conveyed across New Zealand's power system that cannot be technically or commercially isolated to an identifiable person or group of persons. An example is harmonics.

### What are harmonics?

Harmonics are electrical waveforms that have the form of a sine wave (ie, they are sinusoidal), with a frequency that is a multiple of the primary 50 Hertz alternating current sinusoidal waveform. Harmonics cause distortion of the primary 50 Hertz current and voltage sinusoidal waveforms.

Amongst other things, excessive levels of harmonics in electricity networks can lead to poor power quality and can cause problems in electrical equipment and appliances, including premature failure.

### Regulatory arrangements governing harmonics management are not fit for purpose

The Authority considers the regulatory arrangements governing the management of harmonics on New Zealand's power system are no longer fit for purpose.

At present, the main harmonics standard used in New Zealand is the New Zealand Electrical Code of Practice for Harmonics Levels (NZECP 36:1993). Two pieces of regulation currently refer to NZECP 36:1993:

- the **Code** – specifically **Schedule 12.6** (the *Default Transmission Agreement Template*). This requires Transpower (as a transmission network owner) and its customers to comply with NZECP 36:1993 (or equivalent) for harmonics at the customer's point(s) of connection to the transmission network.
- the **Electricity (Safety) Regulations 2010** – specifically **Regulation 31** (*Requirements relating to quality of supply*). This requires that the use of fittings and appliances must not unduly interfere with the satisfactory supply of electricity to a person or affect the safety or operation of other fittings or appliances. Compliance with this regulation can be achieved by complying with NZECP 36:1993.

The NZECP 36:1993 standard is widely considered to be outdated and unsuitable as the basis for managing power system harmonics. It was first published in 1993 and has not been updated since. It no longer reflects the realities of New Zealand's evolving power system and has been superseded by other harmonics standards, in particular by the IEC 61000 standard series and the AS/NZS 61000 standard series. Continued use of NZECP 36:1993 would mean a continuation of significant harmonic mitigation costs being imposed on affected parties. These costs may result in upward pressure on electricity prices faced by consumers.

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<sup>1</sup> [Future Security and Resilience programme](#).

## Options to update the regulatory arrangements governing harmonics management

The Authority seeks feedback from interested parties on three short-listed options for updating the regulatory arrangements governing the management of harmonics on New Zealand's power system.

- **Option 1:** Revoke NZECP 36:1993, mandate aspects of the AS/NZS 61000 standard series for transmission-level harmonics and mandate aspects of the Electricity Engineers' Association's (EEA's) Power Quality Guidelines for distribution-level harmonics.
- **Option 2:** Revoke NZECP 36:1993 and recommend, but not mandate, aspects of an expanded version of the EEA's Power Quality Guidelines that also covers harmonics on New Zealand's transmission network, and a preferred option for limiting and allocating total harmonic distortion.
- **Option 3:** Amend NZECP 36:1993 to address its shortcomings.

These options would support an approach to harmonics governance that is consistent across the electricity industry and with approaches followed overseas. Consumers would expect to benefit from this primarily through electricity suppliers facing harmonic mitigation costs that were lower than they would otherwise be. This would promote competition in, and the efficient operation of, the electricity industry for the long-term benefit of consumers.

A variation, or sub-option, of each of the three options would be to establish a database of harmonic measurements that is accessible to parties who have a legitimate use for the data. Among other things, the intent would be for this database to enable more efficient sharing of harmonics data between industry participants.

The Authority is considering the above options in collaboration with the Ministry of Business, Innovation and Employment and WorkSafe New Zealand, since these agencies are responsible for administering the Electricity (Safety) Regulations which, as noted above, also regulate harmonics.

### Your feedback is welcomed

The Authority welcomes feedback on this paper from interested parties. We have allowed a six week consultation period. During the consultation period the Authority will be available to hold individual and group briefings with interested stakeholders.

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# 1 Purpose of this consultation paper

- 1.1 The Electricity Authority Te Mana Hiko (Authority) seeks feedback from interested parties on three short-listed options for updating the regulatory arrangements governing the management of harmonics on New Zealand's power system.
- 1.2 This options paper follows on from two earlier Authority consultation papers:
  - (a) A 2023 issues paper,<sup>2</sup> which identified some ambiguity around—
    - (i) the applicability of harmonics standards for electricity industry participants, and
    - (ii) who manages harmonics (including the allocation of harmonics) on New Zealand's power system.
  - (b) A 2024 discussion paper,<sup>3</sup> which contained the Authority's thinking at the time on the governance and management of harmonics in New Zealand.
- 1.3 In summary, the Authority considers the regulatory arrangements governing the management of harmonics on the power system are no longer fit for purpose. This view was supported by submitters on our 2024 discussion paper. In particular, the New Zealand Electrical Code of Practice for Harmonics Levels (NZECP 36:1993), which is New Zealand's main regulatory standard for harmonics, is widely considered to be outdated and unsuitable as the basis for managing power system harmonics. NZECP 36:1993 has been superseded by other harmonics standards such as the AS/NZS 61000 standard series and the IEC 61000 standard series.
- 1.4 The Authority has settled on a short list of three options for updating the regulatory arrangements governing the management of harmonics:
  - (a) **Option 1:** Revoke NZECP 36:1993, mandate aspects of the AS/NZS 61000 standard series for transmission-level harmonics and mandate aspects of the Electricity Engineers' Association's (EEA's) Power Quality Guidelines for distribution-level harmonics.
  - (b) **Option 2:** Revoke NZECP 36:1993 and recommend, but not mandate, aspects of an expanded version of the EEA's Power Quality Guidelines that also covers harmonics on New Zealand's transmission network, and a preferred option for limiting and allocating total harmonic distortion.
  - (c) **Option 3:** Amend NZECP 36:1993 to address its shortcomings.
- 1.5 A variation, or sub-option of each option is establishing a database of harmonic measurements that is accessible to parties who have a legitimate use for the data.
- 1.6 In arriving at these three short-listed options, the Authority has:
  - (a) Researched approaches adopted in various overseas jurisdictions including, for some jurisdictions, engaging directly with people involved in regulating harmonics.
  - (b) Engaged with a number of subject matter experts on harmonics, including the Common Quality Technical Group, Transpower, WorkSafe New Zealand, and Professor Neville Watson from the University of Canterbury, who is an internationally renowned expert in harmonics. Together these parties represent a mixture of day-to-day operational involvement in harmonics-related matters, a

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<sup>2</sup> [Electricity Authority | Part 8 common quality requirements | Issues paper.](#)

<sup>3</sup> [Electricity Authority | The governance and management of harmonics in New Zealand's power system | Discussion paper.](#)

range of relevant commercial and technical experience, and extensive academic and institutional knowledge. Their insights have been most valuable to us.

- 1.7 We are seeking feedback on the three short-listed options, and/or other options you consider should be short listed for further consideration.

### **How to make a submission**

- 1.8 The Authority's preference is to receive submissions in a Word document in the format shown in Appendix B.
- 1.9 Submissions should be emailed to [fsr@ea.govt.nz](mailto:fsr@ea.govt.nz) with 'Consultation – Options to address a harmonics issue' in the subject line by 5pm, 30 June 2026.
- 1.10 If you cannot send your submission electronically, please email [fsr@ea.govt.nz](mailto:fsr@ea.govt.nz) or call (04) 460 8860 to discuss alternative arrangements.

### **Submissions will be published, can be requested under the Official Information Act, and may be shared with other organisations**

- 1.11 The Authority will publish all submissions received. If you consider we should not publish any part of your submission, please:
  - (a) indicate which part should not be published and explain why, and
  - (b) provide a version of your submission that we can publish (if we agree to not publish your full submission).
- 1.12 All submissions, including any parts the Authority does not publish, can be requested under the Official Information Act 1982. This means we would be required to release material not published unless good reason for not doing so existed under this Act.
- 1.13 In addition, please note we may share submissions or other information, including parts of submissions not published, with another public service agency, statutory entity, the gas industry body or an overseas regulator in accordance with section s47A of the Electricity Industry Act 2010. We would only do so if the submissions or other information could assist that organisation in the performance of its functions, and if we are satisfied that appropriate protections are in place for maintaining the confidentiality of anything provided (including information that is personal within the meaning of the Privacy Act 2020).

### **Next steps beyond this consultation**

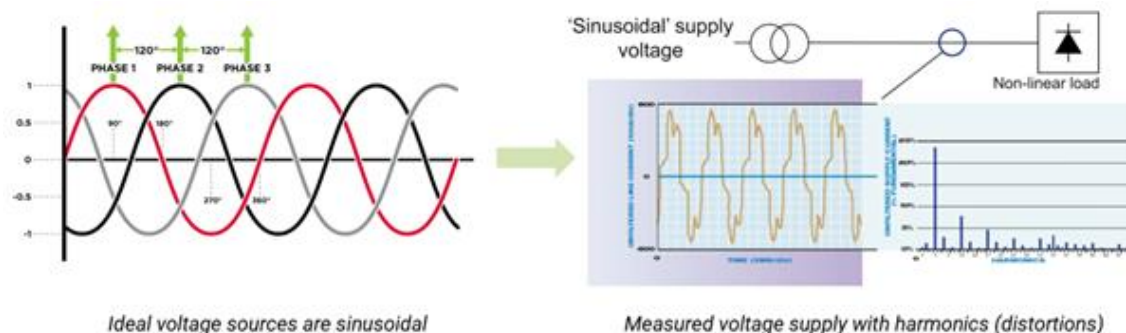
- 1.14 Following this consultation, the Authority will decide on our preferred option. This will determine whether we progress a Code amendment proposal.
- 1.15 If we decide to proceed with an option that requires amendments to the Code, we anticipate consulting on these amendments in the first half of 2027.

## 2 An overview of harmonics regulatory arrangements

### What are harmonics?

- 2.1 Harmonics are electrical waveforms that have the form of a sine curve (ie, they are sinusoidal), with a frequency that is a multiple of the primary 50 Hertz alternating current sinusoidal waveform.<sup>4</sup> Harmonics cause distortion of the primary 50 Hertz current and voltage sinusoidal waveforms, as shown by Figure 1.

**Figure 1: Effect of harmonics on voltage waveforms at a consumer installation**



- 2.2 Amongst other things, excessive levels of harmonics in electricity networks can lead to poor power quality and can cause problems in electrical equipment and appliances, including overheating, motor vibration, control equipment jitter, and premature failure.
- 2.3 Harmonics are typically caused by non-linear electrical loads, which are loads drawing current with a non-sinusoidal waveform (eg, computer power supplies, variable frequency drives, arc furnaces, and heat pumps). Another source of harmonics is any non-linear behaviour from generating units that are machine-based (ie, that convert mechanical energy to electrical energy).<sup>5</sup> Inverter-based resources, which contain power electronic components, can also cause excessive levels of (current and voltage) harmonics if the power electronic components are inadequately designed.
- 2.4 Inverter-based resources, such as wind generation, solar photovoltaic generation, and battery energy storage systems, are expected to become increasingly prevalent in New Zealand as various sectors of the economy electrify. For example, Transpower has estimated that approximately 3,900 megawatts of these three types of inverter-based resources may connect to New Zealand's power system by 2030.<sup>6</sup>
- 2.5 Care needs to be taken that the large uptake of inverter-based resources used in electrical loads and in electricity generation does not cause problems for New Zealand's power system and for consumers' appliances, through excessive harmonics. This necessitates a review of New Zealand's approach to managing harmonics, starting with the regulatory arrangements governing the management of harmonics.

### Regulatory arrangements governing harmonics management

- 2.6 Figure 2 sets out a conceptual framework for the governance and management of harmonics. When we refer to the management of harmonics, we are referring to the arrangements in place to set limits on the amount of harmonics on electricity networks and to maintain harmonics within those limits.

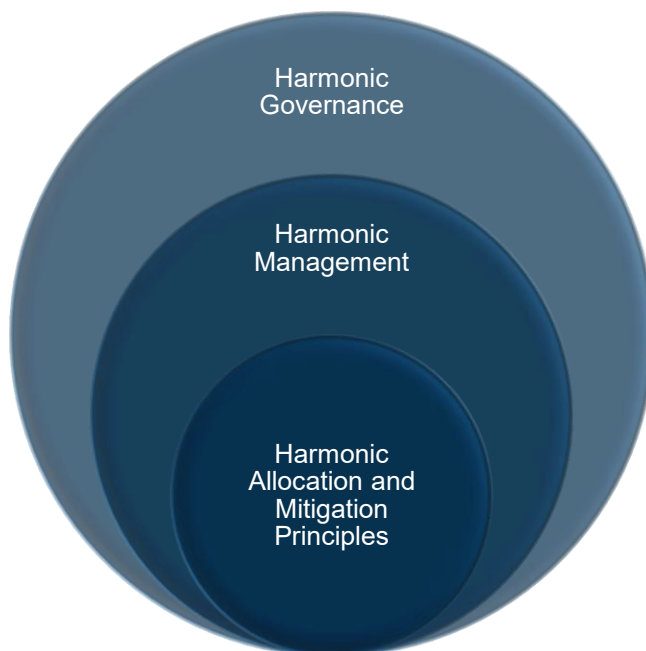
<sup>4</sup> For example, the 3rd harmonic is  $3 \times 50 = 150$  Hz. The 5th harmonic is  $5 \times 50 = 250$  Hz, and so on.

<sup>5</sup> [Preciado, V., et al., 2015, 'Harmonics in a wind power plant.' 2015](#)

<sup>6</sup> See Table 3-1 of Transpower's 2025 [Transmission Planning Report](#).

- 2.7 A standard for limiting harmonic levels and then maintaining harmonics within those limits was first introduced in New Zealand in 1981. This standard was based largely on recommendations from the United Kingdom over a decade earlier. Today, the Code and the Electricity (Safety) Regulations 2010 both contain harmonic standards that are intended to avoid harm associated with excessive harmonics.

**Figure 2: Conceptual framework for the governance and management of harmonics**



### **The regulation of harmonics by the Code**

- 2.8 The Default Transmission Agreement Template in Schedule 12.6 of the Code forms the basis for transmission agreements between Transpower and its customers (ie. generators, distributors and direct consumers). This default agreement template requires the parties to a transmission agreement to comply with:
- (a) NZECP 36:1993, as amended from time to time, or
  - (b) any other equivalent or similar Australian Standards and New Zealand Standards (AS/NZS) standard, International Electrotechnical Commission (IEC) standard, Institute of Electrical and Electronics Engineers (IEEE) standard, or
  - (c) any other requirements specified by Transpower (acting reasonably) that cover similar matters to those set out in NZECP 36:1993.<sup>7</sup>
- 2.9 In relation to these requirements, the Authority notes:
- (a) the NZECP 36:1993 standard applies only to harmonic voltages and harmonic currents emitted by consumer installations<sup>8</sup>
  - (b) the AS/NZS 61000 standard series is based on the IEC 61000 standard series
  - (c) IEEE standard 519 is relatively specialised compared with the other standards referred to in the Default Transmission Agreement Template. This standard describes IEEE recommended practices and requirements for controlling harmonics in power systems.

<sup>7</sup> Clause 4.7 of Schedule 8 (Connection Code) of Schedule 12.6 (Default Transmission Agreement Template) of the Code.

<sup>8</sup> See page 2 of NZECP 36:1993.

- 2.10 The Code does not require other persons connecting, or connected, to the power system to comply with a harmonics standard, with one exception. Small-scale distributed generation<sup>9</sup> applying for connection to a distributor's network using the simplified one-stage application process in Part 1A of Schedule 6.1 of the Code must incorporate an inverter that complies with the standard AS/NZS 4777.2:2020.
- 2.11 However, Part 6 of the Code does empower distributors to specify, via their connection and operation standards for distributed generation, a harmonics standard for distributed generation connecting, or connected, to their networks.<sup>10</sup> A relatively recent informal review of distributors' connection and operation standards for distributed generation found that several distributors cite a version of AS/NZS 4777.2:2020 for distributed generation of 10 kilowatts or less.
- 2.12 The Authority also notes that the EEA published an updated set of power quality guidelines at the beginning of 2024.<sup>11</sup> Amongst other things, these guidelines contain information on supraharmonics<sup>12</sup> and interharmonics.<sup>13</sup> Distributors are a key intended audience for these guidelines.

### **The regulation of harmonics by the Electricity (Safety) Regulations**

- 2.13 As with the Code, the Electricity (Safety) Regulations also contain harmonic standards that are intended to avoid harm associated with excessive harmonics.
- 2.14 The Electricity (Safety) Regulations require that the use of fittings and appliances must not unduly interfere with the satisfactory supply of electricity to any other person, or impair the safety of, or interfere with the operation of, any other fittings or appliances. In relation to interference from harmonics, this obligation is deemed to be complied with by complying with whichever of the following standards is applicable:<sup>14</sup>
- (a) NZECP 36:1993
  - (b) IEC 61000-3-2<sup>15</sup>
  - (c) IEC/TS 61000-3-4<sup>16</sup>
  - (d) IEC 61000-3-12.<sup>17</sup>

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<sup>9</sup> Being generating stations with a nameplate capacity of 10 kilowatts or less in total.

<sup>10</sup> See, for example, clauses 6.1(a), 6.2, 6.3(2) of the Code, clauses 1D, 3(2), 9F and 18(2) of Schedule 6.1 of the Code, and clauses 3 and 11 of Schedule 6.2 of the Code.

<sup>11</sup> [Electricity Engineers' Association, January 2024, Power Quality \(PQ\) Guidelines.](#)

<sup>12</sup> These are high frequency harmonics (>50<sup>th</sup> harmonic order).

<sup>13</sup> Interharmonics are waveform components that are at frequencies that are not a multiple of the supply frequency (being 50Hz in New Zealand). Interharmonics that are below the supply frequency are called subharmonics. See p. 58 of the Electricity Engineers' Association's 2024 Power Quality Guidelines.

<sup>14</sup> See regulation 31.

<sup>15</sup> See regulation 31.

<sup>16</sup> See regulation 31.

<sup>17</sup> 'Electromagnetic compatibility (EMC) - Part 3-12: Limits - Limits for harmonic currents produced by equipment connected to public low-voltage systems with input current >16 A and ≤ 75 A per phase'.

### 3 The problem with current regulatory arrangements

- 3.1 The regulatory arrangements governing the management of harmonics on New Zealand's power system have received relatively little attention in the Code and other regulatory instruments over the years. In part this has led to some challenges with the existing arrangements governing harmonics management.

#### **NZECP 36:1993 has limitations**

- 3.2 The harmonic emissions limits in NZECP 36:1993, which, as noted earlier, is New Zealand's main regulatory standard for harmonics, were developed in the 1960s and 1970s. These emissions limits do not account for modern inverter-based resources with power converters that transfer charge by frequently switching a conductor on and off. These power converters are becoming increasingly prevalent in New Zealand. They are used in wind generating stations, solar photovoltaic generating stations, battery energy storage systems, and industrial, commercial, and consumer electronic loads.
- 3.3 The high switching frequency of power converters used in inverter-based resources is a source of harmonics. As noted earlier, so too is any non-linear behaviour from machine-based generating units (see paragraph 2.3).
- 3.4 NZECP 36:1993 does not address, amongst other things,:
- (a) power quality disturbances such as supraharmonics and interharmonics, from new generation / non-linear load types
  - (b) the monitoring of harmonics
  - (c) roles and responsibilities in the management of harmonics
  - (d) the justification for the defined harmonic levels.
- 3.5 Regarding this last point, the restrictive compatibility limits of NZECP 36:1993 impose significant harmonic mitigation costs on affected parties. These costs are primarily in the form of equipment costs and conducting detailed engineering studies. Additionally, the equipment added to mitigate harmonic emissions may also introduce additional electrical losses, leading to higher operational costs for the asset owner.
- 3.6 Therefore, the continued use of NZECP 36:1993 may result in upward pressure on electricity prices faced by consumers.

#### **Ambiguity around applicability of harmonics standards**

- 3.7 As noted above, at present harmonic standards are located in the Electricity (Safety) Regulations and in Schedule 12.6 of the Code. In addition, Part 6 of the Code contains provisions that empower distributors to specify harmonic standards in their connection and operation standards for distributed generation.
- 3.8 The Code is subordinate to Acts and regulations,<sup>18</sup> so any harmonic standards in the Code, or authorised by it, are subordinated to the harmonic standards in the Electricity (Safety) Regulations should the Code and these regulations conflict. At present there is no such conflict as complying with the harmonics standards listed in regulation 31(2) of the Electricity (Safety) Regulations is just one way of meeting the obligation in regulation 31(1). Complying with the harmonics standards in the Code might be expected to also meet the obligation in regulation 31(1).

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<sup>18</sup> See section 33(2) of the Electricity Industry Act 2010.

- 3.9 However, the Authority considers there may be some ambiguity for industry participants around this interaction between the harmonic standards in the Electricity (Safety) Regulations and the standards in the Code. We believe this has the potential to cause confusion for participants.
- 3.10 A further source of potential ambiguity for harmonic standards is the Electricity (Safety) Regulations applying two different standards (NZECP 36:1993 and IEC 61000 3 2) to equipment covered by the AS/NZS 4777.2 standard in Part 6 of the Code and in distributors' connection and operation standards for distributed generation. Since NZECP 36:1993 applies to all consumer installations, it applies to the same inverter equipment as does AS/NZS 4777.2. So too does the standard IEC 61000 3 2, which applies to electrical and electronic equipment with a rated input current up to and including 16 amps per phase and intended to be connected to public low-voltage distribution systems.<sup>19</sup>
- 3.11 Lastly, the Electricity (Safety) Regulations refer to a standard that is in fact not to be regarded as an International Standard (IEC/TS 61000–3–4) according to the International Electrotechnical Commission.<sup>20</sup>
- 3.12 The absence of a nationally consistent set of harmonics regulations is causing ambiguity for various stakeholders including asset owners, developers, original equipment manufacturers and consultants.
- 3.13 In addition, the absence of a set of harmonics standards that are consistent across New Zealand's transmission and distribution networks creates considerable difficulty for distributors in developing an approach to managing harmonics within their respective networks. Consequently, approaches vary widely across the country.
- 3.14 This does not promote the efficient operation of the electricity industry, with higher-than-necessary costs on industry participants. These costs may result in upward pressure on electricity prices faced by consumers.

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<sup>19</sup> Arc welding equipment that is not professional equipment, with a rated input current up to and including 16 amps per phase, is included in IEC 61000-3-2. Arc welding equipment intended for professional use, as specified in IEC 60974-1, is excluded from IEC 61000-3-2 and can be subject to installation restrictions as indicated in IEC 61000-3-12.

<sup>20</sup> Correctly referred to as IEC TS 61000-3-4:1998.

## 4 Short-listed Option 1

- 4.1 Under the first short-listed option for updating the regulatory arrangements governing the management of harmonics, the Authority would amend the Code:
- (a) to remove the reference to the NZECP 36:1993 standard
  - (b) for transmission-level harmonics, to mandate aspects of the AS/NZS 61000 standard series, which is adopted from the IEC 61000 standard series
  - (c) for distribution-level harmonics, to mandate aspects of the EEA's Power Quality Guidelines, which are adopted from the AS/NZS 61000 standard series.
- 4.2 The Authority would also recommend to the Ministry of Business, Innovation and Employment that the Electricity (Safety) Regulations be amended to clearly say that complying with the harmonics standards in the Code would satisfy the obligation in regulation 31(1).<sup>21</sup> This would be to remove ambiguity around the applicability of the harmonics standards in the Code in relation to the Electricity (Safety) Regulations.

### Mandating aspects of the AS/NZS 61000 standard series

- 4.3 Under Option 1, the Code would be amended:
- (a) to include transmission harmonics planning levels from *AS/NZS TR IEC 61000.3.6:2012 Electromagnetic compatibility (EMC) – Part 3.6: Limits – Assessment of emission limits for the connection of distorting installations to MV, HV and EHV power systems* (refer to Table 2)<sup>22</sup>
  - (b) to require Transpower, as a transmission network owner, to adopt an approach to allocating total harmonic distortion that is based on best practice.
- 4.4 Planning levels are limits on harmonic disturbances permitted on a network. They are a critical part of managing harmonics, used by the network owner/operator to assist in achieving satisfactory power quality levels on the network.

### Mandating aspects of the EEA's Power Quality Guidelines

- 4.5 Under Option 1, the Code would also be amended:
- (a) to include distribution harmonics planning levels from the EEA's Power Quality Guidelines
  - (b) to require distributors to adopt an approach to allocating total harmonic distortion that is based on best practice (eg, the harmonics allocation methodology in the EEA's Power Quality Guidelines).
- 4.6 The EEA's Power Quality Guidelines provide a New Zealand-specific interpretation of relevant elements of the AS/NZS 61000 standard series, including planning levels. These guidelines are increasingly being used by distributors.

### Limited mandating of harmonics management requirements

- 4.7 Under Option 1, other than specifying harmonics planning levels, the Code would not place harmonics management requirements on distributors and Transpower, as a

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<sup>21</sup> Regulation 31(1) says the use of fittings and appliances must not unduly interfere with the satisfactory supply of electricity to any other person, or impair the safety, or interfere with the operation, of any other fittings or appliances.

<sup>22</sup> See Standards New Zealand (<https://www.standards.govt.nz/>) and the EEA's 2024 Power-Quality Guidelines.

transmission network owner. Instead, the Code would require these parties to apply industry best practice to their management of harmonics.

- 4.8 This would acknowledge that the management of harmonics is not easily codified – particularly matters such as the allocation of total harmonic distortion. On this point, the Authority notes the ‘voltage droop’ harmonics allocation method in the EEA’s Power-Quality Guidelines may not be appropriate for New Zealand’s transmission network due to assumptions about line length and capacitor detuning.<sup>23</sup> Under Option 1, distributors would apply this method where appropriate, but Transpower may not do so at higher voltage transmission network connection points (eg, those exceeding 66 kilovolts).
- 4.9 The Authority expects that requiring the adoption of industry best practice would result in network operators collaborating over the management of harmonics on their networks. We expect this to improve consistency of harmonics management across New Zealand’s transmission and distribution networks. An outcome of this collaboration might include, for example, Transpower and distributors having consistent and coherent methodologies for allocating total harmonic distortion.

### **Use of device standards versus installation standards**

- 4.10 To support implementation, the Code would clarify when a harmonics standard for devices applied (eg, AS/NZS 61000.3.2), and when a harmonics standard for an installation applied (eg, AS/NZS 61000.3.6). Currently, industry participants are unsure what to do in instances where both types of standard could apply, and the standards themselves provide limited guidance.
- 4.11 Device standards would be regulated under the Electricity Industry (Safety) Regulations. A question is how best to regulate installation standards. For example, the Electricity (Safety) Regulations could simply point to the Code’s requirements in this regard.
- 4.12 The Authority’s preliminary view is that the size of an asset’s point of connection to the network could be the basis for determining whether a device standard or an installation standard applies. In considering this issue the point of common coupling is important, and the location of interconnection transformers should also be taken into account.

### **Implementation considerations**

#### **Legacy clause arrangements**

- 4.13 The harmonics planning levels specified in AS/NZS TR IEC 61000.3.6:2012 differ from the levels specified in NZECP 36:1993. Therefore, the Authority considers it appropriate for AS/NZS TR IEC 61000.3.6:2012 to be mandatory for new equipment and any existing equipment that can comply, but to not be mandatory for existing equipment that cannot comply. This would be to accommodate instances where asset owners have purchased equipment (eg, capacitors) based on the planning levels in NZECP 36:1993. This would result in some planning levels remaining unchanged for a period of time (eg, those of Transpower, as a transmission network owner) before the higher planning levels in AS/NZS TR IEC 61000.3.6:2012 took effect.

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<sup>23</sup> See Neville Watson et al, June 2011, Development of PQ Guidelines for New Zealand, EEA Conference & Exhibition, p. 7.

## **Proportionate harmonics requirements**

- 4.14 The Authority considers it desirable for harmonics requirements to be proportionate to the scale and likely harmonics risk of the asset connecting to the network. Giving effect to this approach might include:
- (a) smaller / lower-risk connections having more streamlined requirements around harmonics studies
  - (b) more detailed/bespoke harmonics studies being required only where a credible and material harmonics risk exists
  - (c) harmonics mitigation requirements being proportionate to the scale and harmonics risk of the asset.

## **Implementation support**

- 4.15 The Authority understands that capability and familiarity with harmonics standards varies across distributors and other industry participants. Since Option 1 would introduce mandatory compliance with aspects of the AS/NZS 61000 standard series and the EEA's Power Quality Guidelines, the provision of support to some participants may be needed to ensure the Code's requirements are applied consistently. This support could be in the form of guidance material and, potentially, industry forums.

## **Tailoring of the AS/NZS 61000 standard series to New Zealand conditions**

- 4.16 The Authority also seeks submitters' views on whether aspects of the AS/NZS 61000 standard series should be substituted or adapted to New Zealand conditions—for example, to accommodate a lack of diversity in harmonic current phase angles of assets connected to New Zealand electricity networks.

## **Should the contractual framework for harmonics compliance remain?**

- 4.17 As noted above, at present the Code regulates harmonic standards via Part 6 and Schedule 12.6 of the Code. It does so primarily by making the establishment, monitoring and enforcement of harmonics requirements a contractual matter between electricity network owners and their customers.
- 4.18 The Authority is interested in submitters' views on whether this contractual approach is preferable to an alternative approach under which harmonics requirements are specified and enforced under the Code's compliance framework. In other words, the Authority would be responsible for monitoring and enforcing industry participants' compliance with harmonics requirements. The Authority notes this may require an amendment to the Electricity Act 1992 or the Electricity Industry Act 2010.
- 4.19 Lastly, the Authority seeks feedback on whether, under a continuation of the contractual approach to monitoring and enforcing harmonics requirements, the Code should be amended to require distributors to investigate and resolve harmonics issues within their respective networks. This would be consistent with the obligation in clause 7.2D of the Code for the System Operator to investigate and resolve security of supply or reliability issues caused by non-compliance with the harmonic levels specified in the Connection Code.<sup>24</sup>

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<sup>24</sup> The Connection Code forms part of the Default Transmission Agreement Template, which is incorporated by reference in the Code as Schedule 12.6.

## Key benefits of Option 1

4.20 Key benefits of Option 1 include:

- (a) Better alignment of New Zealand's harmonics arrangements with modern international standards and global best practice. This supports consistency of treatment of harmonics across all voltage levels and asset types. It also promotes competition amongst original equipment manufacturers, by enabling equipment designed to comply with internationally accepted standards to be supplied, rather than limiting the equipment manufacturer pool to providers of equipment designed to bespoke local specifications.
- (b) More modern requirements around harmonics planning levels. This should reduce the need for asset owners and developers to invest in harmonics mitigation measures (eg, harmonic filters).
- (c) Flexibility to use different harmonics allocation methodologies where justified. This will allow Transpower and distributors to adopt best practice approaches suited to their network characteristics. The aim should be for total harmonic distortion to be allocated in a manner that minimises overall harmonic mitigation costs faced by industry participants.

## Key costs of Option 1

4.21 Key costs of Option 1 include:

- (a) The AS/NZS 61000 standard series may be challenging to apply without adaptation. The standard series is technically complex and may not fully account for certain New Zealand-specific characteristics, such as limited diversity in equipment types or harmonic phase angles.
- (b) There is a risk of over-reliance on a standard series that may not fully address supra-harmonics or emerging technologies. Additional work may be needed to ensure appropriate treatment of supra-harmonics and other high-frequency harmonic emissions.
- (c) Variable capability across distributors may lead to inconsistent application of harmonics standards unless these are accompanied by clear guidance.

- Q1. Do you agree the Authority should be short listing Option 1 for further consideration? If you disagree, please explain why.
- Q2. Do you agree the Code should not mandate harmonics management requirements, other than harmonics planning levels? If you disagree, please explain why.
- Q3. What regulatory instrument (ie, the Code or the Electricity (Safety) Regulations) do you consider should be used to regulate installation standards for harmonics?
- Q4. Which, if any, aspects of AS/NZS 61000 do you consider need substituting or adapting in order to accommodate New Zealand conditions?
- Q5. Do you consider the establishment, monitoring and enforcement of harmonics requirements should be a contractual matter between electricity network owners and their customers, or a Code-enforceable matter? Please give reasons with your answer.

- Q6. Do you consider distributors should have a mandated responsibility to investigate and resolve security of supply or reliability issues caused by non-compliance with the harmonic levels specified for distribution networks?
- Q7. What guidance for industry participants do you consider would be necessary under Option 1?
- Q8. What do you consider to be the main benefits and costs associated with Option 1?

## 5 Short-listed Option 2

- 5.1 Under the second short-listed option for updating the regulatory arrangements governing the management of harmonics, the Authority would:
- (a) amend Schedule 12.6 of the Code so that it no longer mandated compliance with a harmonics standard
  - (b) adopt a guidance-based approach to governing the management of harmonics, using an expanded version of the EEA's Power Quality Guidelines.

### Expanding the EEA's Power Quality Guidelines to include transmission

- 5.2 The EEA's Power Quality Guidelines currently focus on distribution-level harmonics. Under Option 2, the guidelines would be expanded to include harmonics planning levels, allocation methodologies, and compliance processes for both distribution networks and New Zealand's transmission network.
- 5.3 The Authority notes that the voltage droop harmonics allocation method in the EEA's Power Quality Guidelines may not be fully suitable for New Zealand's transmission network. The method assumes short line lengths and detuned capacitors,<sup>25</sup> which may not reflect the configuration of the transmission network. Further work would be needed on an appropriate transmission-level harmonics allocation methodology.

### A recommended, rather than mandatory, compliance framework

- 5.4 Under Option 2, the Authority would recommend, but not require, that industry participants followed the amended EEA Power Quality Guidelines when assessing, planning and managing harmonics on their networks.
- 5.5 The aim of this approach would be to allow network owners and larger connecting parties to tailor harmonics requirements to their assets' characteristics.

### Use of device standards versus installation standards

- 5.6 As with Option 1, Option 2 would need to address ambiguity around the applicability of harmonics standards for devices and installations. Industry participants have indicated uncertainty about which type of standard applies in instances when both could be applicable.

### Resolving security of supply / reliability issues

- 5.7 Under Option 2, the System Operator would have a responsibility to investigate security of supply or reliability issues caused by non-compliance with the transmission network harmonic levels specified in the EEA's Power Quality Guidelines. However, clause 7.2D of the Code would no longer require the System Operator to resolve these issues. This would be a contractual matter between Transpower, as a transmission network owner, and Transpower's relevant customer(s).

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<sup>25</sup> See Neville Watson et al, June 2011, Development of PQ Guidelines for New Zealand, EEA Conference & Exhibition, p. 7.

## Interaction with the Electricity (Safety) Regulations

- 5.8 As noted earlier (see paragraph 3.8), complying with the harmonics standards listed in regulation 31(2) of the Electricity (Safety) Regulations is just one way of meeting the obligation in regulation 31(1).<sup>26</sup>
- 5.9 Therefore, complying with the harmonics requirements in the EEA's Power Quality Guidelines might be expected to also meet the obligation in regulation 31(1).

### Key benefits of Option 2

- 5.10 Key benefits of Option 2 include:
- (a) Industry participants having the flexibility to tailor harmonics requirements to their assets' characteristics and not be constrained by mandatory Code provisions, thereby reducing the risk of inefficient investments in harmonics mitigation measures.
  - (b) A smaller regulatory compliance burden, reducing operational costs for industry participants.
  - (c) The EEA's Power Quality Guidelines can be revised more easily than the Code, which enables a quicker adaptation to technological change, thereby reducing the potential for 'baking in' of costs associated with outdated harmonics standards.

### Key costs of Option 2

- 5.11 Key costs of Option 2 include:
- (a) The potential for inconsistent harmonics requirements across the electricity industry, which may lead to inconsistent outcomes for connecting parties, particularly asset owners / developers operating across multiple networks. It might also limit competition amongst original equipment manufacturers to providers of equipment designed to bespoke local specifications.
  - (b) A larger contractual compliance burden, including potentially higher transaction costs associated with the process of negotiating harmonics requirements and the process for monitoring and enforcing these.
  - (c) The potential for insufficient certainty for new connections / investment planning, which may lead to higher assessment costs for new connections and/or a higher risk of unexpected harmonics mitigation measures being required (eg, harmonic filters).

Q9. Do you agree the Authority should be short listing Option 2 for further investigation? If you disagree, please explain why.

Q10. What do you consider to be the main benefits and costs associated with Option 2?

<sup>26</sup> Recalling that regulation 31(1) says the use of fittings and appliances must not unduly interfere with the satisfactory supply of electricity to any other person, or impair the safety, or interfere with the operation, of any other fittings or appliances.

## 6 Short-listed Option 3

- 6.1 Under the third short-listed option for updating the regulatory arrangements governing the management of harmonics, the NZECP 36:1993 standard would be retained but amended to address its known technical and structural shortcomings.
- 6.2 These shortcomings include:
- (a) applying only to loads
  - (b) not accounting for modern equipment such as inverter-based resources, including power converters
  - (c) not addressing power quality disturbances such as supraharmonics and interharmonics, from new generation / non-linear load types
  - (d) not considering the size of the asset connected to the network and the capacity at the asset's point of connection
  - (e) covering only some voltage levels (ie, 66 kilovolts, 110 kilovolts, and 220 kilovolts)
  - (f) the absence of a methodology for allocating harmonics when there are multiple potential connections at a point on the network
  - (g) a failure to justify the defined harmonic levels
  - (h) incomplete background measurements
  - (i) not addressing roles and responsibilities in the management of harmonics, including the monitoring of harmonics.
- 6.3 A substantial revision to NZECP 36:1993 would be required to make it fit for purpose. This might include incorporating concepts and planning levels from the AS/NZS 61000 standard series.

### Key benefits of Option 3

- 6.4 Key benefits of Option 3 include:
- (a) Modernises harmonics requirements while keeping a familiar harmonics standard.
  - (b) Provides an opportunity to tailor a harmonics standard that reflects New Zealand's network characteristics, providing an opportunity to ensure the standard facilitates the lowest cost management of harmonics on New Zealand's power system.

### Key costs of Option 3

- 6.5 Key costs of Option 3 include:
- (a) Significant time, effort and cost to fully revise the harmonics standard. This would require extensive technical review, multi-agency coordination and broad industry engagement, which could take several years.
  - (b) Potential for reduced alignment with international harmonics standards and best practice over time (eg, due to competing resourcing priorities), as has occurred with NZECP 36:1993.

Q11. Do you agree the Authority should be short listing Option 3 for further consideration? If you disagree, please explain why.

Q12. What do you consider to be the main benefits and costs associated with Option 3?

## 7 Sub-option 1a / 2a / 3a

- 7.1 A variation of each of the three options is establishing a database of harmonics measurements that is accessible to parties who have a legitimate use for the data (eg, asset owners, developers, consultants, academics).
- 7.2 Currently there is limited visibility of harmonics levels across New Zealand's power system. A centralised repository could support clearer identification of emerging trends in harmonics across the power system. It could reduce transaction costs associated with asset owners / developers obtaining information on harmonics during the process of identifying where to connect new assets to the power system. Reducing costs such as these might be expected to benefit consumers in the long run, provided the costs associated with establishing and maintaining the database were lower.
- 7.3 Harmonics measurements in isolation are insufficient to draw meaningful conclusions. Their interpretation requires not only specialist expertise but also power system-related context (eg, network configuration and dispatch). Absent this context, there is a material risk of the measurements being misinterpreted, potentially leading to inefficient investment signals, or unnecessary concerns and avoidable inquiries that create additional workload across the industry.
- 7.4 Therefore, the purpose and scope of a harmonics measurement database would need to be clearly defined. Possible objectives include:
- (a) providing readily accessible information on background harmonics levels at key points on the power system, to support the owners of load and generation assets in their asset planning and in new connection assessments
  - (b) enabling more efficient sharing of harmonics data between industry participants, including reducing repeated, manual information requests to electricity distributors and Transpower, in its role of a transmission network owner
  - (c) improving compliance monitoring and investigation, to the extent that the database is used to identify harmonics-related compliance issues
  - (d) supporting long-term network planning and investment decisions, including identifying shifts in harmonic behaviour (eg, vector shifts or resonance phenomena).

### Current practice

- 7.5 Transpower, as a transmission network owner, currently provides harmonics data on request to parties looking to connect to the transmission network (or to any other parties whose request Transpower considers legitimate). Transpower makes harmonics data available to a party (and/or their engineering consultant) for the area(s) of the transmission network the party is looking at connecting to. These requests are relatively infrequent and relatively easy to service, with Transpower undertaking some 'curation' of the raw measurement data prior to its release.
- 7.6 Transpower usually provides the data alongside other contextual information. This includes harmonic impedance sectors and allocations to support harmonic compliance assessments and harmonic filter design (eg, for inverter-based resources). Transpower, as a transmission network owner, monitors transmission network-connected asset owner harmonic compliance in accordance with the transmission agreements in place between Transpower and its transmission customers.
- 7.7 Some stakeholders consider this approach to be sufficient. Others have expressed to the Authority a preference for direct access to raw harmonics measurement data (eg, 10-minute

total voltage harmonic levels; individual harmonics up to the 50<sup>th</sup> order). This is to support asset owners / developers undertaking their own analysis and developing their own tools or visualisations.

- 7.8 The Authority understands there is very limited harmonics measurement data available for distribution networks.

### **Data quality and measurement requirements**

- 7.9 A key design question is whether a harmonics measurement database should contain only data recorded using monitoring equipment that meets Class A measurement requirements under AS/NZS 61000.4.30. Requiring Class A equipment would ensure high-quality, standardised data but may limit the amount of data in the database due to this equipment being less common because of its relatively higher cost.
- 7.10 Consideration may need to be given to populating the database with voltage harmonics only – at least initially. The Authority understands harmonic current measurements at transmission network points of connection are typically incomplete, as power quality monitoring is not installed on each point at which electricity enters and leaves substations.
- 7.11 We also understand there are practical limitations on the measurement of harmonics arising from measurement transformers and installation arrangements. Care would be needed to avoid imposing accuracy or compliance expectations that are not technically achievable in practice or are disproportionate to the intended use of the data.

### **Privacy and cyber security considerations**

- 7.12 Consideration would need to be given to the form in which the data was published, to manage any privacy requirements and cyber security risks. For example, harmonic current data may be specific to individual parties connected to the network. Publishing such data risks the inadvertent disclosure of commercially or operationally sensitive information.

### **Compliance implications**

- 7.13 Establishing a harmonics measurement database may have implications for monitoring and enforcing compliance with harmonics planning levels. By enabling more people to look at harmonics data, the database may help network operators to be better informed about the level of harmonics on their networks relative to the harmonics planning levels. This would be if the additional parties looking at the data shared their findings / observations with the network operator.
- 7.14 This raises questions about the extent to which network operators would be expected to notify database users of gaps in the harmonics data, and respond to third party interpretations of the data. It also raises a question about the extent to which the database should form part of a formal monitoring and enforcement process.

### **Industry capability considerations**

- 7.15 Some distributors have limited technical understanding of harmonics requirements. Access to more data may be of limited value unless accompanied by guidance material or training, and clear explanations of assessment methods. Any harmonics database initiative may therefore require additional support for industry participants, further increasing its cost.

### **Hosting the database**

- 7.16 A question is who would host the harmonics measurement database. Although initially the content would primarily relate to harmonics data being collected by Transpower, over time

more distribution level harmonics data would be added as distributors' capability in this area improved. This might point to the Authority being the appropriate party to host the database.

### Implementation considerations

- 7.17 If a harmonics measurement database was to be implemented, a staged implementation may be desirable. This would be in acknowledgement of existing data limitations and to limit the risk of over-investment in functionality that turns out to be unnecessary.
- 7.18 A staged implementation might start with the database being populated with harmonics data from the transmission network and larger distribution networks. Additional harmonics data could then be added as monitoring capability and industry expertise and experience matured.
- Q13. What do you consider to be the benefits and costs of the current arrangements for obtaining harmonics data from distributors and from Transpower, as a transmission network owner?
- Q14. What do you consider to be the benefits and costs of a database of harmonics measurements?
- Q15. Would access to raw harmonics measurement data be useful for your organisation? If so, why?
- Q16. Who do you consider should host a database of harmonics measurement data? Please give reasons.

## Appendix A Feedback on the harmonics discussion paper

A.1 The Authority’s June 2024 harmonics discussion paper suggested a possible way forward for improving the governance of harmonics on New Zealand’s power system, but stopped short of doing so for the management of harmonics. Instead, the paper limited itself to:

- (a) summarising good industry practice in relation to a framework for the management of harmonics
- (b) examples of approaches to limiting harmonic emissions, with the following provided:
  - (i) an ‘open access’ approach
  - (ii) requiring connecting parties to be a net absorber of harmonic emissions
  - (iii) applying financial charges to the emitters of harmonics
  - (iv) pre-emptive installation of harmonics filters.

A.2 The Authority received 13 submissions on our discussion paper. Table 1 lists the submitters.

**Table 1: Submitters on June 2024 harmonics discussion paper**

	Generator/retailer	Generator	Lines company	Other
1.	Genesis Energy	Helios	Northpower	Electricity Engineers’ Association
2.	Mercury Energy	Lodestone Energy	Orion	Utilities Disputes
3.		Manawa Energy	Powerco	
4.		NewPower	Transpower	
5.			WEL Networks	

A.3 This appendix contains a collation of submitter feedback on the 2024 harmonics discussion paper. The submission summaries in this Appendix are not exhaustive, so we encourage you to review individual submissions for a comprehensive account of submitters’ views. Full submissions are available on our website.<sup>27</sup>

### The governance of harmonics in New Zealand is no longer fit for purpose

A.4 The governance framework for harmonics must account for all voltage levels (ie, including 220 kilovolts and above) within New Zealand’s power system, to ensure that compliance and adoption are feasible across the electricity sector.

A.5 The governance framework for harmonics must accommodate the growing technical complexities of New Zealand’s power system (eg, the generation of reactive power by harmonic filters), new technologies (eg, single stage and two-stage hydrogen electrolyzers), and harmonic currents on the power system that are introduced by some new technologies.

A.6 Standardise harmonic limitations, management, and allocation across all market participants. Consistency in how solar installations and other distributed energy resources are managed across different distribution networks is essential for effective and fair harmonics management throughout New Zealand.

<sup>27</sup> See [Electricity Authority | Future security and resilience | June 2024 The governance and management of harmonics in New Zealand’s power system.](#)

- A.7 NZECP 36:1993 is outdated – it needs to be replaced / phased out. The shortcomings of NZECP 36:1993 include:
- (a) it applies only to electrical loads
  - (b) it does not account for modern inverter-based resources, including power converters
  - (c) it does not address supra-harmonics
  - (d) it does not consider the size of the asset and the capacity at the asset's point of connection to a network
  - (e) it contains no method for dividing the allocation when there are multiple potential connections at or near a point on the power system
  - (f) it has incomplete background measurements.

### **Consistency is needed across regulations, Code and guidelines**

- A.8 Consistency is needed across the Electricity Governance (Safety) Regulations, the Code, and guidelines that promote good industry practice (eg, the Electrical Engineers' Association (EEA) Power Quality Guidelines).
- A.9 Also needed is consistency of application:
- (a) between electricity generation and load, and
  - (b) across electricity industry participants (eg, Transpower, as a transmission network owner, uses NZECP 36:1993 while some distributors use the EEA Power Quality Guidelines).

### **Implement a tailored version of AS/NZS 61000, or IEC 61000, or EEA's Power Quality Guidelines**

- A.10 Most methodologies impose harmonic current magnitude limits on harmonic sources (load/generation), while the network owner/operator has responsibility for managing the harmonic voltage.
- A.11 The EEA's Power Quality Guidelines, which are a local interpretation of the AS/NZS 61000 standards, which in turn are adopted from the IEC 61000 series of standards, offer greater flexibility/adaptability than the other two sets of standards.
- A.12 It is unclear how well the IEC 61000 standards work in relation to distributed energy resources connected at medium voltage.
- A.13 If a regulation-based approach is adopted, then this should be modelled on the Regulatory Systems (Immigration and Workforce) Amendment Act 2025, to allow the Authority to more quickly and easily update references to standards in the Code.
- A.14 Adopt only the planning and compatibility levels outlined in section 4.1 of AS/NZS 61000.3.6:2012. Other sections of AS/NZS 61000.3.6:2012 are informative, rather than prescriptive and should not be referenced or interpreted as a requirement, because:
- (a) some assessment techniques outlined in the standard are overly complex to implement
  - (b) some parts (eg, the general summation law), are unsuitable for assessing harmonic contributions from inverter-based generation, as their validity depends largely on the control algorithms implemented by the equipment manufacturer.
- A.15 A robust harmonics management process should first consider the likelihood of harmonics issues arising rather than saying network users 'should' conduct system studies, which are

often time consuming and expensive. For example, if the connecting party's load or generation is very small relative to the system strength in that part of the power system, harmonics would be unlikely to be an issue, and therefore no studies should be required.

- A.16 Further thought should be given to whether harmonics monitoring is mandatory for all network users or whether it is a staged process based on the size of the asset's connection relative to the network to which the asset is connecting.
- A.17 Simple processes / methods for assessing harmonics and connection risk (eg, the voltage droop method) can be easily understood and implemented by most network utilities in New Zealand. The voltage droop allocation methodology proposed by the University of Wollongong and discussed in the EEA's Power Quality Guidelines is a method that appears to strike a reasonable balance between compliance, complexity and risk.
- A.18 There needs to be a process to manage changes in a network's harmonic characteristics.
- A.19 There needs to be proportionality in the effort and costs for harmonic impact assessments that are required.
- A.20 There needs to be flexibility around, and pathways for, managing non-compliant plant – network utilities should take a pragmatic and constructive approach to working with connecting parties to resolve any identified harmonics issues without applying punitive measures.
- A.21 A blanket limit above the 50<sup>th</sup> harmonic should be implemented to address issues that could affect earthing system neutrals and the power system's overall performance.
- A.22 Currently there is a regulatory gap concerning frequencies between 2,500 Hertz and telecommunication bands, which should be addressed.
- A.23 Be cautious about including in the Code timeframes to manage harmonics or adopting timeframes found in harmonics standards.

## **Interaction between inverter-based resources and harmonics**

- A.24 Harmonics are not limited to inverter-based generation.
- A.25 Inverter-based resources will not necessarily make harmonics worse – see the 'Impact and Management of Harmonics' December 2023 study undertaken by the Australian Renewable Energy Agency (ARENA) and the University of Wollongong.<sup>28</sup>
- A.26 It is not a given that different inverter-based solutions constructively interfere with current and voltage waveforms. In many cases they can destructively interfere, reducing total harmonic distortion.
- A.27 Most existing transmission grid-scale inverter-based generation plant produce sufficiently low harmonics that, barring harmonic resonance or poor controller tuning, the generating plant is unlikely to cause harmonics issues immediately. It is the net effect of many inverters connecting to a network that eventually causes such issues.
- A.28 As increasing amounts of inverter-based generation and energy storage devices connect to the power system, harmonic emissions may cause problems with inverters, leading to a less stable power system.
- A.29 Inverter-based resource owners need certainty around the likely costs associated with harmonic mitigation that they will be required to pay.

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<sup>28</sup> Available at [University of Wollongong | Impact and management of harmonic distortion for large renewable generators project summary](#).

## Reasons for having a harmonics measurement database

- A.30 Data on harmonics measured at key locations on the power system and stored in a centralised database can be used to observe trends, assess the harmonic emissions from each connected asset, and forecast future changes in the levels of harmonics.
- A.31 A centralised database of harmonic data supports informed decisions, particularly understanding cost-benefit trade-offs on changes to the management of harmonics in New Zealand. For example, such a database could help inform whether it is more economically efficient to have harmonics standards based on the requirements of a more typical connected party or based on the requirements of the most sensitive parties affected by harmonics.
- A.32 A centralised database of harmonics data would reduce administrative burden across all stakeholders by removing the need to manually share harmonics data, while also allowing compliance with harmonics requirements to be monitored more effectively.
- A.33 The costs to implement a centralised database may be significant, but would be expected to be minimal compared to the savings obtained through minimising the need for additional harmonic filters.
- A.34 A centralised harmonics database is best hosted by the Authority via the Electricity Market Information (EMI) website, to maintain objectivity and prioritise the best outcomes for all stakeholders, including consumers.

## Reasons for not having a harmonics measurement database

- A.35 Concern was expressed about the value and practicality of measuring and publishing background harmonics data.
- A.36 Consideration needs to be given to expected measurement locations, data requirements and timeframes, and that network reconfigurations by Transpower can significantly impact harmonic levels at grid exit points.
- A.37 Consideration should be given to integrating harmonics measurement and publication requirements in distributors' information disclosure requirements.

## Allocation of total harmonic distortion

- A.38 Identifying the root source of harmonics can be very difficult, due to the constantly changing dynamics of the power system, as different loads, generating stations and circuits connect / disconnect / change their output. Even where clear daily patterns of harmonics are observed, the root cause may still be very difficult to identify and be unrelated to the apparently obvious change in the power system (eg, the commissioning of a wind farm).
- A.39 It would be more effective to substitute a harmonic allocation methodology with increased monitoring and a continuous automated assessment strategy. This is because a single upfront assessment is incapable of forecasting how a generating station's harmonic emissions will change over its lifetime.
- A.40 Allocating individual emission limits inadvertently promotes installation of harmonic filtering equipment, well before harmonic voltages approach their planning level limits.
- A.41 The AS/NZS 61000.3.6 standard and the EEA's Power Quality Guidelines allow for negotiation of allocated harmonic emission limits, but this is rarely done in practice. Typically, this is because there are limited people with sufficient expertise to guide each stakeholder through the negotiation process and there remains limited information about how the electricity network will change in the future.

- A.42 There is support for a ‘whole-of-system’ approach to allocating harmonics, designed with flexibility in mind to accommodate an evolving and more dynamic grid – allowing for future technological advancements that may influence harmonic generation or mitigation.
- A.43 It is desirable to have a similar harmonics allocation approach applied across New Zealand’s distribution networks:
- (a) so that developers have lower costs in managing harmonics issues, and
  - (b) to promote efficiency of connection of generation and load.
- But be cautious about mandating compliance to specific harmonic levels.
- A.44 A ‘whole-of-system’ approach is appropriate because the physics of harmonics do not respect commercial boundaries.
- A.45 The present framework allows some baseline harmonic planning levels to be exceeded. A new ‘whole-of-system’ approach would allow a more structured approach to allocating harmonics without exceeding established planning levels.
- A.46 The challenge with a ‘whole-of-system’ approach is its complexity, particularly when it comes to large harmonic models.
- A.47 Available harmonic headroom needs to be maximised.
- A.48 There is a need to properly account for local distribution network constraints as well as transmission system-wide needs.
- A.49 There is a need to provide clear guidance on key concepts such as ‘harmonic headroom’ and ‘harmonic allocation’.
- A.50 There is a need to have concrete evidence of any damage caused by higher level harmonics.
- A.51 Transpower's current method of allocating a fixed percentage of headroom to each user is not fair and equitable. At present, perverse outcomes occur where the first connecting party gets a larger percentage allocation, regardless of their project size.
- A.52 The fixed percentage method can result, and has resulted, in essentially no allocation of harmonic emissions at certain frequencies, which is not reflective of the risk of equipment problems, nor practical to achieve from a mitigation standpoint.
- A.53 At a minimum, any robust total harmonic distortion allocation method should consider the relative size of each connection compared to the capacity of the upstream connection point.
- A.54 All generation technologies should be treated equally.
- A.55 An abundance of small-scale projects in an area of a distribution network should not impose a potential cost on larger grid-scale projects in that same area.
- A.56 The Authority should not impose a harmonic allocation methodology on Transpower, as a transmission network owner, because the question of harmonic allocation is an active area of discussion internationally.
- A.57 Harmonic impedance polygons are not a way of allocating harmonic current, but rather a way of assessing harmonics compliance once an allocation has been provided.

### **Pros of the ‘open access’ approach to limiting harmonic emissions**

- A.58 The ‘open access’ approach warrants further investigation because it has some good benefits around connecting to a network (eg, removing compliance costs from the planning stage of investing in the connection of an asset) and responding to actual issues.

- A.59 When harmonics approach a threshold where they require mitigation, investment to assess, procure and implement the mitigation should be funded by the largest emitters, based on the extent to which they contribute to the issue. Mitigation costs should be socialised where there are no large emitters identified, or where all participants contribute equally to harmonic emissions.
- A.60 A centralised harmonic measurement database would be an essential component of an 'open access' approach.

### **Cons of the 'open access' approach to limiting harmonic emissions**

- A.61 The 'open access' approach is not a workable approach because it implies no harmonic allocations, which could then require real-time monitoring and curtailments to respect harmonic emissions limits. Electricity generators and loads would potentially be unmanageable and result in real-time problems for network management instead of problems in the planning process.
- A.62 While the costs of compliance are removed from the planning stage, they could be introduced at any stage of the project's life cycle. Given the potential costs, this could act like the 'Sword of Damocles' for projects, with uncertain costs becoming a barrier to investor backing.

### **The 'net absorber' approach to limiting harmonic emissions**

- A.63 Requiring connecting parties to act as net absorbers of harmonic emissions is impractical and could hinder progress by placing undue burdens on certain stakeholders.
- A.64 Requiring net absorption has a major flaw, in that it looks individually at generators, not holistically at the system. If similar inverter-based resources are used (New Zealand does not have the biggest range of products for items like central inverters), then they would be expected to have similar performance. There may then be certain harmonics well absorbed by these inverter-based resources, and certain harmonics that are exported. All generators may be compliant, but the overall system is suffering at the range that the similar inverter-based resources and technologies export at, and any 'easy win' ranges will have excess capacity – ie, the focus by each generator is to achieve the easiest, cheapest net absorption, not the best whole-of-power system performance.

### **The 'apply charges to emitters of harmonics' approach to limiting harmonic emissions**

- A.65 Charging emitters has some benefits, but as with the 'open access' approach, it could have issues in relation to identifying the emitters / causers and fairly allocating costs to them.

### **The 'pre-emptive installation of harmonic filters' approach to limiting harmonic emissions**

- A.66 Harmonic filters should be installed only where there is a demonstrated need.
- A.67 Harmonic modelling is very complex and often conservative – installing mitigation based on pre-commissioning modelling is likely to result in wasted investment, because post-commissioning measurements can be significantly different to pre-commissioning modelling.
- A.68 Harmonics emissions may include diversity between identical harmonic sources. If diversity is not considered, the harmonic modelling and pre-connection compliance assessment may include significant error, resulting in the installation of harmonic mitigation (eg, filters) that is not required and/or inappropriately designed.

- A.69 The pre-emptive installation of harmonic filters will act as a cost barrier to new investment in network-connected assets.
- A.70 Under the pre-emptive installation of harmonic filters, costs are disproportionate to the risks being mitigated. Often the connecting harmonic filters cause more problems than they solve (eg, they may interfere with existing ripple control systems), simply because they are designed when looking only at a single project rather than taking a more robust system view to harmonics mitigation.
- A.71 The pre-emptive installation of harmonic filters may be helpful in some situations but there are a number of issues with these filters that are starting to be identified in practice.
- A.72 Inverter manufacturers have some ability to tailor harmonic current emissions from their equipment. It is generally better to cancel harmonic currents (eg, by transformer vector group choices, or controls), than to filter them, as there is less chance for resonances (since harmonic filters alter resonance points, affecting the surrounding network(s)).

### **Combining elements of the 'open access' and 'apply charges to emitters of harmonics' approaches**

- A.73 Combining elements of the 'open access' and 'apply charges to emitters of harmonics' approaches could provide the necessary flexibility for adaptation to new technologies and changing network conditions, while also creating appropriate incentives for responsible harmonic management. This hybrid approach supports innovation by not imposing blanket restrictions yet maintaining network quality through financial mechanisms.

### **Another hybrid approach**

- A.74 An alternative hybrid approach would be to give loads some harmonic current allowance and give generation 'net zero' allocation (to treat synchronous and non-synchronous generation on the same basis). Under this hybrid approach:
- (a) Egregious potential harmonic issues would be identified using harmonic polygons and amplification factors, and assessed against some fixed limit (eg, 50%, or some function of generation megawatts, of the entire limit). Engineering judgment would be used to resolve any issues (as happens in practice now).
  - (b) The net emissions (eg, in real-power Watts) of the generation would be calculated. Generation should be encouraged to use harmonic phase cancellation, etc, where available, to reduce the amount of net harmonic current being created in the first place.
  - (c) C-type harmonic filtering would be installed at the highest background frequency (or whatever is requested by the network operator).
  - (d) Electrical loads are given harmonic current limits but these are adjusted for the cases where the load acts as a harmonic sink.

## Appendix B Submission form

[Name of consultation]

<b>Submitter</b>	
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Questions	Comments
Q1. Do you agree the Authority should be short listing Option 1 for further consideration? If you disagree, please explain why.	
Q2. Do you agree the Code should not mandate harmonics management requirements, other than harmonics planning levels? If you disagree, please explain why.	
Q3. What regulatory instrument (ie, the Code or the Electricity (Safety) Regulations) do you consider should be used to regulate installation standards for harmonics?	
Q4. Which, if any, aspects of AS/NZS 61000 do you consider need substituting or adapting in order to accommodate New Zealand conditions?	
Q5. Do you consider the establishment, monitoring and enforcement of harmonics requirements should be a contractual matter between electricity network owners and their customers, or a Code-enforceable matter? Please give reasons with your answer.	
Q6. Do you consider distributors should have a mandated responsibility to investigate and resolve security of supply or reliability issues caused by non-compliance with the harmonic levels specified for distribution networks?	
Q7. What guidance for industry participants do you consider would be necessary under Option 1?	
Q8. What do you consider to be the main benefits and costs associated with Option 1?	
Q9. Do you agree the Authority should be short listing Option 2 for further consideration? If you disagree, please explain why.	
Q10. What do you consider to be the main benefits and costs associated with Option 2?	
Q11. Do you agree the Authority should be short listing Option 3 for further consideration? If you disagree, please explain why.	
Q12. What do you consider to be the main benefits and costs associated with Option 3?	
Q13. What do you consider to be the benefits and costs of the current arrangements for obtaining harmonics data from distributors and from Transpower, as a transmission network owner?	
Q14. What do you consider to be the benefits and costs of a database of harmonics measurements?	
Q15. Would access to raw harmonics measurement data be useful for your organisation? If so, why?	
Q16. Who do you consider should host a database of harmonics measurement data? Please give reasons.	