Options to help address the harmonics common quality-related issue – Next steps

Common Quality Technical Group meeting – 17 October 2024

Contents

1. Harmonics discussion paper feedback

1.1. The Authority received 13 submissions on our June 2024 harmonics 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	

1.2. Appendix A contains a collation of submitter feedback.

1.3. The Authority considers the key points raised in submissions may be summarised as follows.

Governance of harmonics

(a) The governance of harmonics in New Zealand is no longer fit for purpose.

(b) Consistency is needed across the instruments that regulate harmonics in New Zealand.

(c) NZECP 36:1993 (New Zealand Electrical Code of Practice for Harmonics Levels) should be replaced with:

i. a version of the AS/NZS 61000 or IEC 61000 standards, tailored for the New Zealand electricity sector, or

ii. the Electricity Engineers' Association (EEA) January 2024 Power Quality Guidelines, with 220kV and above voltage levels included.

Management of harmonics

(a) It is not a given that inverter-based resources (IBRs) always make harmonics worse.

(b) There are two views on a centralised database of harmonics on the power system:

i. The cost to implement and operate the database would be less than the savings from reduced investment in harmonic filters, and reduced costs associated with sharing background harmonics data and monitoring industry participants' compliance with harmonics requirements

ii. It is unclear whether the database's benefits would outweigh the costs, noting that network reconfigurations can have a material impact on harmonics.

(c) There is support for a 'whole-of-system' approach to allocating harmonics, to get consistency across distribution networks. However, Transpower considers a harmonic allocation methodology should not be imposed upon it, as a transmission network owner, because harmonic allocation is being actively discussed internationally.

(d) There are two views on an 'open access' approach to limiting harmonic emissions:

i. It warrants further investigation because it removes costs from the planning stage of a new connection to a network

ii. Costs are shifted from the planning stage of a new connection to the real-time operation of the network (eg, identifying harmonics emitters).

(e) The 'net absorber' approach to limiting harmonic emissions looks only at an individual generator's harmonics emissions and does not look at how multiple generators' harmonics affect the power system/network.

(f) The 'apply charges to emitters of harmonics' approach may face challenges identifying emitters.

(g) The 'pre-emptive installation of harmonic filters' approach is likely to result in unnecessary investment in harmonic filters, which would act as an unnecessary barrier to investment in new connections.

(h) Two hybrid approaches were put forward in submissions:

i. Combine elements of the 'open access' and 'apply charges to emitters of harmonics' approaches

ii. Give loads some harmonic current allowance and give generation 'net zero' allocation (to treat synchronous and non-synchronous generation the same), and encourage generation to use harmonic phase cancellation. Install C-type harmonic filtering as requested by the network operator (eg, at the highest background frequency).

2. Suggested short-listed options to address the harmonics issue

2.1. Following our consideration of submissions, the Authority has identified three short-listed options to help address the harmonics common quality-related issue:

(a) Option 1: Revoke NZECP 36:1993, mandate aspects of the AS/NZS 61000 series of standards, and recommend, *but not mandate*, a preferred option for limiting and allocating total harmonic distortion.

(b) Option 2: Revoke NZECP 36:1993 and mandate aspects of the EEA Power Quality Guidelines, and recommend, *but not mandate*, a preferred option for limiting and allocating total harmonic distortion

(c) Option 3: Revoke NZECP 36:1993 and recommend, *but not mandate*, aspects of the EEA Power Quality Guidelines and a preferred option for limiting and allocating total harmonic distortion.

2.2. A variation, or sub-option, of each of the three options would be to establish a publicly available database of harmonic emissions.

2.3. We seek the CQTG's feedback on these options.

2.4. We are open to recommendations from the CQTG on other options the CQTG considers should be short-listed in addition to, or possibly in place of, these three options.

Option 1 – Notes

2.5. The Code would be amended to require industry participants to comply with aspects of the following AS/NZS 61000 series of standards (eg, planning and compatibility levels):[1]

(a) AS/NZS IEC 61000.3.2:2023 Electromagnetic compatibility (EMC), Part 3.2: Limits for harmonic current emissions Harmonic current emission limits for equipment input current ≤16 A per phase[2]

(b) AS/NZS 61000.3.4:2007 Electromagnetic compatibility (EMC) - Limits - Limitation of emission of harmonic currents in low-voltage power supply systems for equipment with rated current greater than 75 A

(c) 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

(d) AS/NZS IEC 61000.3.12:2023 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

(e) AS/NZS 61000.4.7:2012 Electromagnetic compatibility (EMC) - Part 4.7: Testing and measurement techniques - General guide on harmonics and interharmonics measurements and instrumentation, for power supply systems and equipment connected thereto

(f) AS/NZS 61000.4.15:2012 Electromagnetic compatibility (EMC) - Part 4.15: Testing and measurement techniques - Flickermeter - Functional and design specifications

(g) AS/NZS IEC 61000.4.30:2023 Electromagnetic compatibility (EMC), Part 4.30: Testing and measurement techniques - Power quality measurement methods.[3]

2.6. The Authority would publish a guideline that recommended, but did not mandate, a preferred option for limiting and allocating total harmonic distortion.

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1 See Standards New Zealand (https://www.standards.govt.nz/) and the EEA 2024 Power-Quality Guidelines.

2 This standard, published on 9 June 2023, supersedes AS/NZS 61000.3.2:2013 Harmonic current emission limits for equipment input current ≤16 A per phase.

3 This standard, published on 24 March 2023, supersedes AS/NZS 61000.4.30:2012 Electromagnetic compatibility (EMC) - Part 4.30: Testing and measurement techniques - Power quality measurement methods.

2.7. Might it be necessary to substitute aspects of the AS/NZS 61000 standards (eg, to accommodate a lack of diversity in the harmonic current phase angle of assets connected to New Zealand electricity networks)?

Options 2 and 3 – Notes

2.8. The voltage droop harmonics allocation method in the EEA Power-Quality Guidelines may not be appropriate for New Zealand's transmission network, as it requires that all transmission lines are sufficiently short and that all capacitors are detuned.[4]

2.9. The EEA Power-Quality Guidelines could be amended to include a recommended method for limiting and allocating total harmonic distortion across New Zealand's transmission network, or the Authority could publish a guideline that recommended a preferred option for limiting and allocating harmonics on the transmission network.

Option 1a / 2a / 3a – Notes

2.10. The purpose of a publicly available database of harmonics emissions would need to be clearly defined. Is it to enable trends in harmonic emissions to be readily accessible for network connection purposes, including the connected party's compliance with harmonic limits? Is it to be used for network planning purposes?

2.11. Would the database be populated with harmonic emission measurements from only monitoring equipment that complies with the measurement methods for Class A equipment set out in AS/NZS 61000.4.30?[5]

2.12. One approach would be to not require monitoring equipment to be installed for the purpose of populating the database but rather to simply let the database be a data receptacle for any monitoring equipment installed on the power system. The intention of this approach would be to keep downward pressure on the cost of the database and its associated processes. However, a drawback of this approach would be geographic gaps in harmonic emissions data for New Zealand's distribution networks.[6]

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4 See Neville Watson et al, June 2011, Development of PQ Guidelines for New Zealand, EEA Conference & Exhibition, p. 7.

5 See section 25.1 of the EEA 2024 Power-Quality Guidelines.

6 This stated drawback assumes Transpower's transmission-connected harmonics monitoring equipment provides a good geographical coverage of the transmission network.

Appendix A – Summary of feedback on the discussion paper on harmonics

This appendix contains a collation of submitter feedback on the Authority's June 2024 harmonics discussion paper.

1. Governance of harmonics in NZ is no longer fit for purpose

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

1.2. The governance framework 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 electrolysers), and harmonic currents on the grid that are introduced by some new technologies.

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

1.4. NZECP 36:1993 is outdated – it needs to be replaced / phased out. NZECP 36:1993:

(a) applies only to loads

(b) does not account for modern inverter-based resources (IBRs), including power converters

(c) does not address supra-harmonics

(d) does not consider the size of the asset and the capacity at the point of connection

(e) contains no method for dividing the allocation when there are multiple potential connections

(f) has incomplete background measurements.

2. Need consistency across regulations, Code, and guidelines

2.1. Need consistency across the Electricity Governance (Safety) Regulations 2010, the Code, and guidelines that promote good industry practice (eg, the Electrical Engineers' Association (EEA) Power Quality (PQ) Guidelines).

2.2. Also need consistency of application:

(a) between generation and load, and

(b) across electricity industry participants (eg, Transpower, as a grid owner, uses NZECP 36:1993 while some distributors use the EEA PQ Guidelines).

3. Implement a tailored version of AS/NZS 61000, or IEC 61000, or the EEA PQ Guidelines

3.1. Most methodologies impose harmonic current magnitude limits on harmonic sources (load/generation), while the network owner/operator has responsibility for managing the harmonic voltage.

3.2. The EEA PQ Guidelines offer greater flexibility/adaptability than the other two sets of standards, and are a local interpretation of the AS/NZS 61000 standards.

3.3. How well do the 61000 standards work for medium voltage-connected DERs?

3.4. If a regulation-based approach is adopted, then model this on MBIE's proposed Regulatory Systems (Immigration and Workforce) Amendment Bill, to allow the Authority to more quickly and easily update references to standards in the Code.

3.5. Adopt only the planning and compatibility limits outlined in AS/NZS 61000.3.6:2012, Section 4.1. 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.

3.6. A robust harmonics management process should first consider the likelihood of there being harmonics issues 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, then it is unlikely that harmonics would be an issue, and no studies should be required.

3.7. 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 connection relative to the network.

3.8. 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 PQ Guidelines is a method that appears to strike a reasonable balance between compliance, complexity and risk.

3.9. Needs to be a process to manage changes in a network’s harmonic characteristics.

3.10. There needs to be proportionality in the effort and costs for required harmonic impact assessments.

3.11. 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.

3.12. Implement a blanket limit above the 50^{th} harmonic to address issues that could affect earthing system neutrals and overall performance.

3.13. Currently there is a regulatory gap concerning frequencies between 2500Hz and telecommunication bands, which should be addressed.

3.14. Be cautious about including in the Code timeframes to manage harmonics or adopting timeframes found in harmonics standards.

4. Interaction between IBRs and harmonics

4.1. Harmonics are not limited to inverter-based generation.

4.2. IBRs 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.

4.3. It is not a given that different inverter-based solutions constructively interfere – in many cases, they can destructively interfere, reducing total harmonic distortion (THD).

4.4. Most existing grid-scale inverter-based generation plant produce sufficiently low harmonics that - barring harmonic resonance or poor controller tuning – the generator is unlikely to cause immediate issues. It is the net effect of many inverters connecting that eventually causes harmonic issues.

4.5. 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.

4.6. IBR owners need certainty around the likely costs associated with harmonic mitigation that they will be required to pay.

5. Reasons for a harmonics measurement database, with harmonics measured at key locations

5.1. Harmonic data in a centralised database can be used to observe trends, assess the emissions from each participant, and forecast future changes in harmonic levels.

5.2. 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 – eg, is it 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?

5.3. A centralised database of harmonic data would reduce administrative burden across all stakeholders by removing the need to manually share harmonics data, while also allowing compliance to be monitored more effectively.

5.4. 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.

5.5. A centralised harmonic 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.

6. Reasons for not having a harmonics measurement database

6.1. Concern about the value and practicality of measuring and publishing background harmonic data.

6.2. 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 (GXPs).

6.3. Consider integrating measurement and publication requirements in distributors' information disclosure requirements.

7. Allocation of THD

7.1. Identifying the root source of harmonics can be very difficult, due to the constantly changing dynamics of the power system, as different loads, generators 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 system (eg, the commissioning of a wind farm).

7.2. More effective to substitute a harmonic allocation methodology with increased monitoring and a continuous automated assessment strategy, because a single upfront assessment is incapable of forecasting how a generator's harmonic emissions will change over its lifetime.

7.3. Allocating individual emission limits inadvertently promotes installation of harmonic filtering equipment, well before harmonic voltages approach their planning limits.

7.4. The AS/NZS 61000.3.6 standard and the EEA PQ Guidelines allow for negotiation of allocated 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.

7.5. 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.

7.6. 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.

7.7. A 'whole-of-system' approach is appropriate because the physics of harmonics do not respect commercial boundaries.

7.8. The present framework allows some baseline harmonic planning level limits to be exceeded. A new 'whole-of-system' approach would allow a more structured approach to allocating harmonics without exceeding established planning level limits.

7.9. The challenge with a ‘whole-of-system’ approach is its complexity, particularly when it comes to large harmonic models.

7.10. Maximise available headroom.

7.11. Need to properly account for local distribution network constraints as well as transmission system-wide needs.

7.12. Need to provide clear guidance on key concepts such as ‘harmonic headroom’ and ‘harmonic allocation’.

7.13. Have concrete evidence of any damage caused by higher level harmonics.

7.14. 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.

7.15. 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.

7.16. At a minimum, any robust THD allocation method should consider the relative size of each connection compared to the capacity of the upstream connection point.

7.17. All generation technologies should be treated equally.

7.18. 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.

7.19. The Authority should not impose a harmonic allocation methodology on Transpower, as a grid owner, because the question of harmonic allocation is an active area of discussion internationally.

7.20. Harmonic impedance polygons are not a way of allocating harmonic current, but rather a way of assessing harmonic compliance once an allocation has been provided.

8. Pros of the ‘open access’ approach to limiting harmonic emissions

8.1. 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 a connection investment) and responding to actual issues.

8.2. 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.

8.3. A centralised harmonic measurement database would be an essential component of an ‘open access’ approach.

9. Cons of the ‘open access’ approach to limiting harmonic emissions

9.1. 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 limits. Managing the network, generators and loads would potentially be unmanageable and result in real-time problems rather than problems in the planning process.

9.2. 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.

10. The ‘net absorber’ approach to limiting harmonic emissions

10.1. Requiring connecting parties to act as net absorbers of harmonic emissions is impractical and could hinder progress by placing undue burdens on certain stakeholders.

10.2. Requiring net absorption has a major flaw, in that it looks individually at generators, not holistically at the system. If similar IBRs are used (New Zealand does not have the biggest range of products for items like central inverters), then it is expected they will have similar performance. There may then be certain harmonics well absorbed by these IBRs, and certain harmonics that are exported. All generators may be compliant, but the overall system is suffering at the range that the similar IBRs 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 system performance.

11. The ‘apply charges to emitters of harmonics' approach to limiting harmonic emissions

11.1. Charging emitters has some benefits, but as with the ‘open access’ approach, could have issues in identifying the emitters / causers and fairly allocating costs to them.

12. The ‘pre-emptive installation of harmonic filters’ approach to limiting harmonic emissions

12.1. Harmonic filters should be installed only where there is a demonstrated need.

12.2. 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.

12.3. 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.

12.4. Pre-emptive installation of harmonic filters will act as a cost barrier.

12.5. Under 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.

12.6. May be helpful in some situations but there are a number of issues with these filters that are starting to be identified in practice.

12.7. 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)).

13. Combining elements of the 'open access' and ‘apply charges to emitters of harmonics' approaches

13.1. 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.

14. Another hybrid approach

14.1. Give loads some harmonic current allowance and give generation ‘net zero’ allocation (to treat synchronous and non-synchronous generation on the same basis).

14.2. Identify egregious potential harmonic issues. Using harmonic polygons and amplification factors, assess against some fixed limit (eg, 50%, or some function of generation MW, of the entire limit). Engineering judgment is used to resolve any issues (as happens in practice now).

14.3. Calculate net emissions (eg, in real-power Watts) of the generation. 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.

14.4. Install C-type harmonic filtering at the highest background frequency (or whatever as requested by the network operator).

14.5. Loads are given current limits but clarified for the cases where the load acts as a harmonic sink.