Thank you to the Special Reporter for the opportunity to provide a contribution addressing the question

> *"On the subject of management of power quality disturbances in evolving power systems, what are the difficulties/drawbacks with the existing approaches which require focus/development ensuring that the regulatory mechanisms, engineering methodologies and solutions are practical, robust and cost-effective?"*

Confining this contribution to harmonics and neglecting other power quality disturbances, we see three key areas where attention is warranted:

1. definition and interpretation of the customer emission level;
2. methodology for incorporating multiple network operating conditions via harmonic impedance polygons; and
3. structure of harmonic limits.

1. Definition and interpretation of the customer harmonic emission level

The h^{th} harmonic voltage emission level E_{Uhi} for customer i is a key concept for the principles and processes in IEC/TR 61000-3-6. However, E_{Uhi} is not formally defined. In the process of assessing an individual customer's pre-connection compliance with harmonic limits, it is common practice for this quantity to be based on harmonic sources only on the customer side of the point of connection – that is, E_{Uhi} represents the harmonic voltage at the point of connection when background sources are deactivated. This interpretation neglects the impact of the customer plant shunt impedance (including capacitor banks and passive filters) upon background harmonic sources. No guidance is given in IEC/TR 61000-3-6 for this assessment.

It would be desirable for customer compliance to be determined in a robust manner that takes full account of the customer's impact on the network

2. Methodology for incorporating multiple network operating conditions via harmonic impedance polygons

Whilst CIGRE Technical Brochure 766 provides guidance on determination of harmonic impedance polygons for aggregating multiple network operating conditions, the impact of decisions made in setting impedance polygons warrants further attention.

In the allocation process, IEC/TR 61000-3-6 is largely silent on how network operating conditions should be selected. The allocated customer emission level will be determined from a single operating condition, which may or may not reflect typical network characteristics.

For compliance assessment, at any given harmonic order, pre-connection compliance assessment decisions are typically derived from the worst-case combination of polygon impedance point and customer Norton equivalent impedance. This worst-case combination may never eventuate in practice, or may occur only rarely. The customer's allocated emission

level – derived from a single operating condition – will still apply under all operating conditions, potentially imposing unduly onerous restrictions on the customer.
Further work to provide guidance on judgment to be applied in the development and application of impedance polygons for harmonic management is thus suggested.

3. Structure of harmonic limits

Current typical practice sees each individual harmonic order, up to the 40^{th} or 50^{th}, being prescribed a limit. For any given three-phase customer plant, this practice may require assessment of 297 individual quantities against corresponding limits, when accounting for the three individual phases and for the assessment of both 10-minute and 3-second measurements. In our opinion, this limit structure creates unnecessary complexity; slavish adherence to each limit individually creates the risk of imposing disproportionately onerous filtering requirements on customers or networks.

A renewed focus on managing the long-term effects of harmonics on network and customer equipment is advocated. A simple step towards achieving this would be to permit the acceptance of harmonic emission levels at one harmonic order in return for reduced limits at other harmonic orders, recognising that the long-term effects of – for example – high 46^{th} harmonic voltages will be comparable to those of 44^{th} harmonic voltages. Ultimately, development of a much simplified limit structure – for example, reducing harmonic management to only a few indices[1] – has the potential to simplify harmonic requirements for utilities and customers.

[1] R. Barr, V. Gosbell, "Power system harmonic limits for the future", *Proc. ICHQP*, 2014.