Study Committee C4

System Technical Performance

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Critical Review of Harmonic Assessment Procedures for Transmission Customers and Renewable Generators

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Motivation

- Network transformation sees increased proliferation of harmonic sources across the grid
- Increasing power electronic penetration increases the impact of harmonic compliance approaches
- The paper reviews transmission customer harmonic compliance assessment principles and procedures
- IEC/TR 61000-3-6 is taken as a starting point
- Basis is the authors' experience in Australia, but the work is not limited to Australian conditions
- Recognises proliferation of new connections requiring harmonic assessments

Objectives of harmonic limits

- Existing limits have evolved from historical measurements, per IEC TR 61000-1-4 and are not necessarily based on rigorous coordination between emissions and immunity
- Limits can only manage the effects of harmonic distortion, predominantly long-term

Ideal compliance assessment

- Technically robust
- Equitable (in some sense)
- Simple:
  - Able to be applied without extensive computer simulations
  - Industry workload commensurate with the magnitude of the problem
  - Small number of defined outputs to be compared against corresponding limits
- Repeatable: 10 power quality engineers making the same assessment will make the same conclusion
- Minimises costs of mitigation
- Compliance is within customer's control

Scope

a) Review principles and practices in harmonic compliance methodology for three-phase transmission customers, both load and generation

b) Review the relationship between allocated harmonic voltage limits and compliance quantity, and reduce ambiguities in the definition of emission level

c) Consider the role of harmonic current limits in compliance assessment

d) Review key challenges in harmonic compliance assessment

Conclusions

a) Review of harmonic limits is timely, with a focus on compressing individual limits into indices

b) Harmonic voltage emission allocation E_{Uhi} requires explicit definition – consider further developing the 'Global' approach

c) Harmonic current emission level E_{Ihi} is of little value for assessing compliance

d) Treatment of varying network operating scenarios warrants much more attention

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Validity of harmonic models

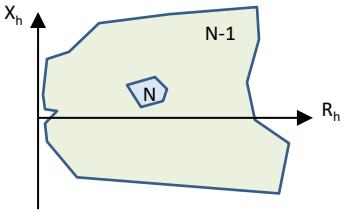
- Load models based on historical heuristic assessments
- Resistive damping sets resonant peak magnitudes
- Higher-order harmonic measurement is challenging
- Power electronic harmonic equivalent circuit parameters can be highly variable
- How to reliably determine harmonic model parameters for inverters?

THD

- IEC/TR 61000-3-6 gives THD indicative planning levels
- But no guidance on THD allocation among individual customers
- Measurement standards for 95th percentile of THD are ambiguous
- Circuit theory does not offer a solution
- What happens if a customer complies with individual harmonic limits but fails on THD?

Impedance polygons

- Key input to filter decision, but customer is given limited knowledge of network conditions considered
- Filter may be required on basis of an obscure network condition which may never eventuate
- N vs N-1 vs N-2 – can they be decoupled?



Statistical assessment quantities

- Some confusion exists within the industry as to which index is applicable:
  - 95% of 10-minute measurements?
  - 99% of 3-second measurements?
- No distinction between non-compliances which are marginal and occur only briefly and non-compliances where limits are breached by (for example) an order of magnitude for almost 5% of the time
  - Consequences for equipment are different
- Rolling intervals? Or start each Sunday midnight?
- Which measurements? Single line-line voltages? Average or worst case of three line-line or line-neutral voltages?

Diversity and summation law

- IEC/TR 61000-3-6 indicative exponents are proposed in the absence of further information, but have evolved into typical practice
- α = 1.4 dates at least as far back as 1976
- Summation law was intended for use across different plants, but finds use within a single plant, where exponent choice may easily dictate whether a filter is required
- Is there a better solution?

Accumulation of worst cases

- Customer limits determined conservatively
  e.g. via onerous impedance polygons
- Customer emission levels also determined conservatively
  e.g. worst-case customer equivalent circuit parameters and worst-case points on impedance polygons
- Small violations of conservative limits may result in plant being deemed non-compliant and thus requiring a harmonic filter
- This approach is not necessarily consistent with the intent of 95% / 99% quantities in IEC/TR 61000-3-6

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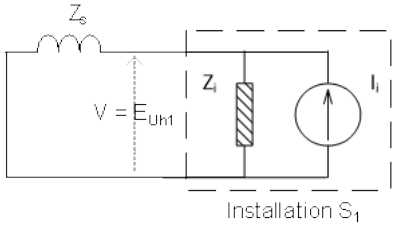
Interpreting allocated voltage E_{Uhi}

- What physical or calculated quantity should be compared against E_{Uhi} when assessing customer compliance?

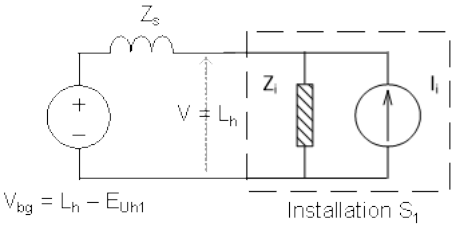
'Individual' approach

- Typical 'Individual' approach uses the connection point harmonic voltage with background sources deactivated
- Requires separate assessment of customer impact on background sources



'Global' approach

- 'Global' approach compares the difference between planning and background voltage levels against E_{Uhi}
- Here the background voltage level is that when all other customers – existing and future – are injecting at full allocation



Interpreting allocated current E_{Ihi}

- Usual practice is to compare the customer line current against E_{Ihi}
- But changes on the network side can then move the customer from compliance to non-compliance → terminal current is not a robust compliance measure
- Which impedance points should be used when determining E_{Ihi}?

Comparison

Quantity	Interpretation	
	Individual	Global
Power system voltage source	Zero	$L_h - E_{Uhi}$
Power system impedance	Impedance of network elements	Impedance of network elements
Test for compliance	$V \le E_{Uhi}$	$V \le L_h$

Conclusions

- Review of harmonic limits is timely, with a focus on compressing individual limits into indices
- Harmonic voltage emission allocation E_{Uhi} requires explicit definition – consider further developing the 'Global' approach
- Harmonic current emission level E_{Ihi} is of little value for assessing compliance
- Treatment of varying network operating scenarios warrants much more attention