

Illustrative photo: a power quality analyser at drive cabinets.

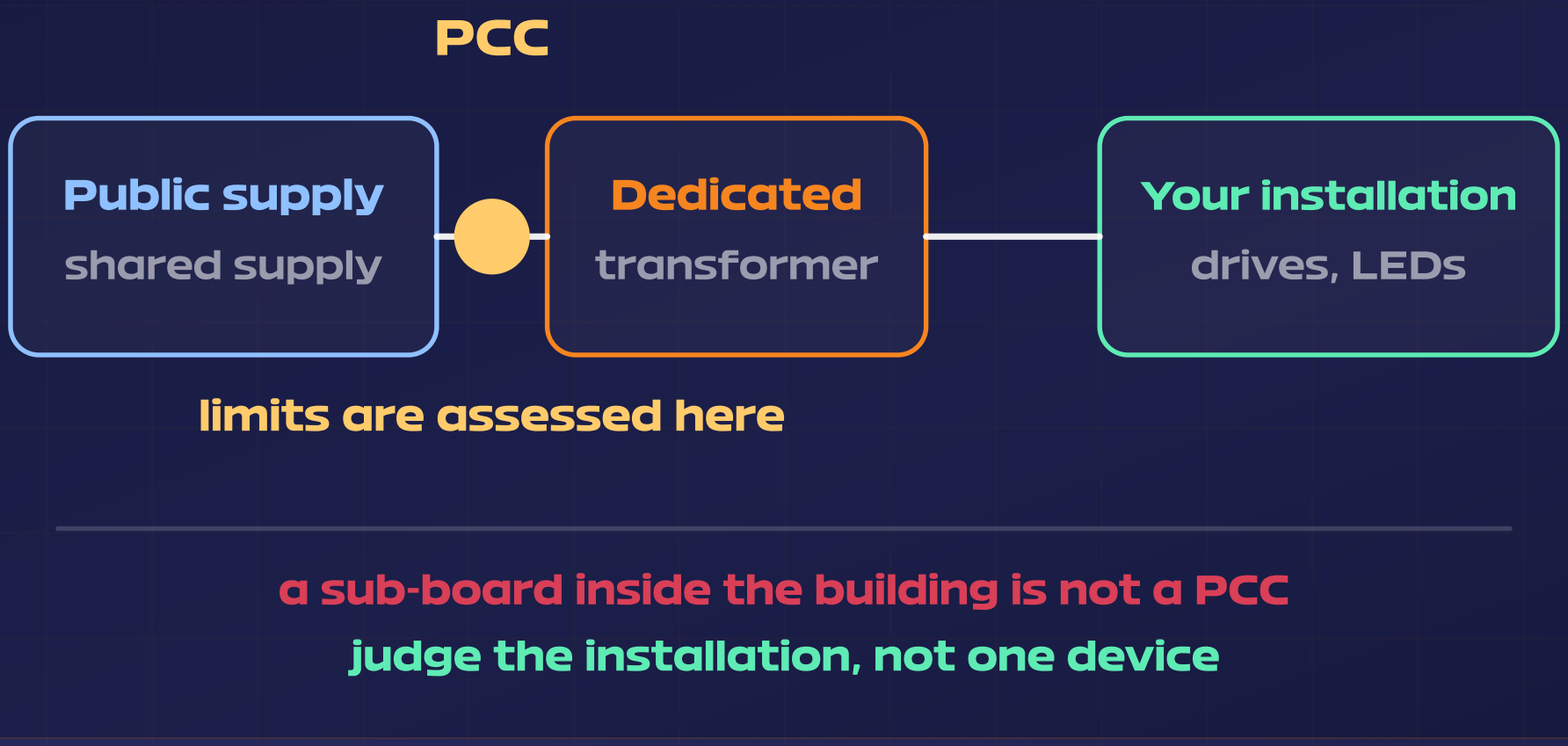
NLC ACADEMY · EPISODE 36

Harmonics, and where the limits apply.

Under IEEE 519, harmonic limits are assessed at the point of common coupling (PCC) for the whole installation, not one nonlinear device. Which limits bind a site depends on the regulator, connection agreement, contract or project specification.

WHERE THE LIMIT SITS

Assess the installation at the PCC



a sub-board inside the building is not a PCC

judge the installation, not one device

1. In IEEE 519-2022 the PCC is a point on the public supply where other customers are, or could be, connected. A distribution board inside the building is not one. [2]
2. IEEE 519 states that its limits are not binding in all cases. Whether they bind a site depends on the regulator, connection agreement, contract or project specification. [2]

A limit checked on one drive or one luminaire is not an IEEE 519 installation-level assessment. [2]

ORDER, SEQUENCE, FREQUENCY

Triplens are zero-sequence: balanced phases add them in the neutral

order	1st	3rd	5th	7th	9th	11th	13th
sequence	pos	zero	neg	pos	zero	neg	pos
50 Hz	50	150	250	350	450	550	650
60 Hz	**60**	**180**	**300**	**420**	**540**	**660**	**780**

the highlighted orders are the triplens

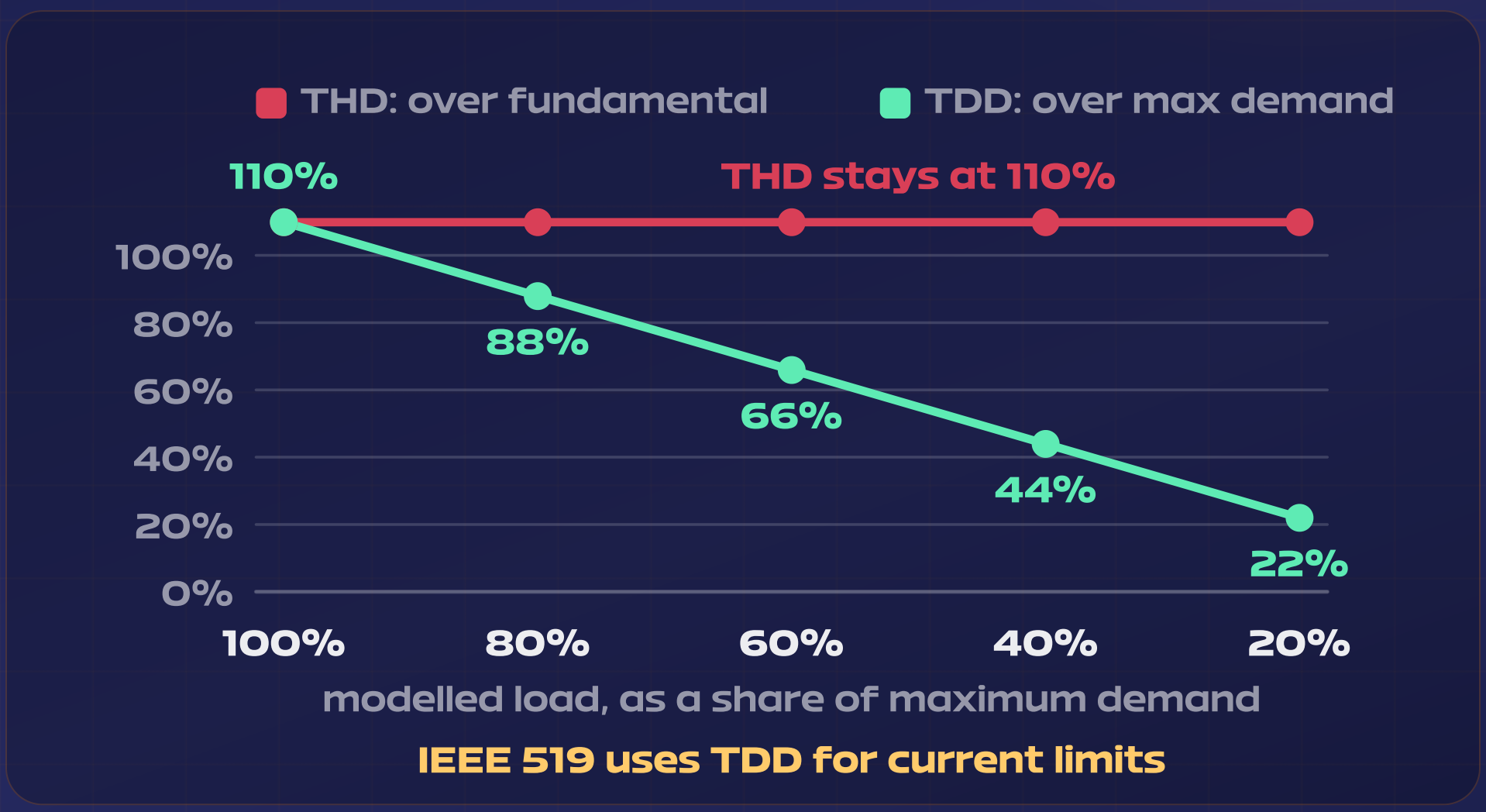
balanced phases arrive together, so they add in the neutral

Saudi Arabia runs at 60 Hz: the 5th is 300 Hz

1. On the Saudi 60 Hz grid the 5th is 300 Hz and the 7th is 420 Hz, not 250 and 350. [1]
2. In a balanced three-phase, four-wire system, triplens (3rd, 9th, 15th) are in phase on all three phases, so in the neutral they add instead of cancelling.

THD IS NOT TDD

In this modelled example, THD stays constant while TDD falls with load



IEEE 519 uses TDD for current limits

1. THD divides by the fundamental actually flowing. TDD divides by maximum demand, the base IEEE 519 uses for current. [2]
2. One harmonic shape at every load: THD stays at 110%, TDD = THD × load share, so 44% at 40% of maximum demand. High THD alone is not a limit breach. [4]

In real installations THD changes with load, because the harmonic currents and the operating point change.

THE NEUTRAL

Triplens and imbalance both load the neutral; THD alone does not predict it



amber bars are triplens: 3rd, 9th, 15th

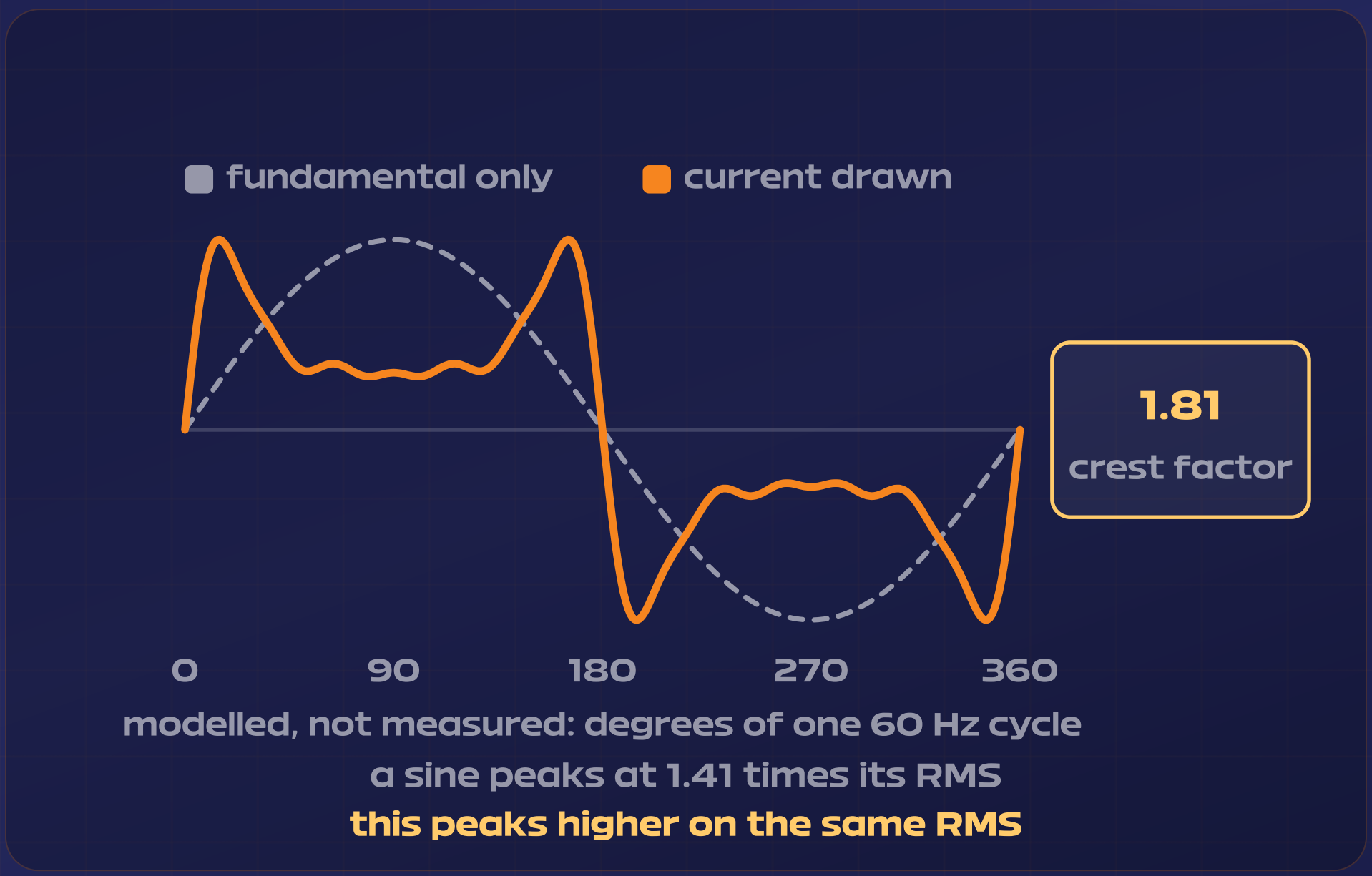
modelled spectra, balanced supply, not measured

1. In a balanced three-phase, four-wire system, triplens add in the neutral at three times the per-phase value. The modelled 3rd is 81% of the fundamental. [4]
2. Load imbalance also produces neutral current. The modelled six-pulse drive has no triplens and zero neutral current, at about a quarter of the switch-mode THD. [4]

Do not put neutral heating down to one cause without measurement or analysis.

THE WAVEFORM

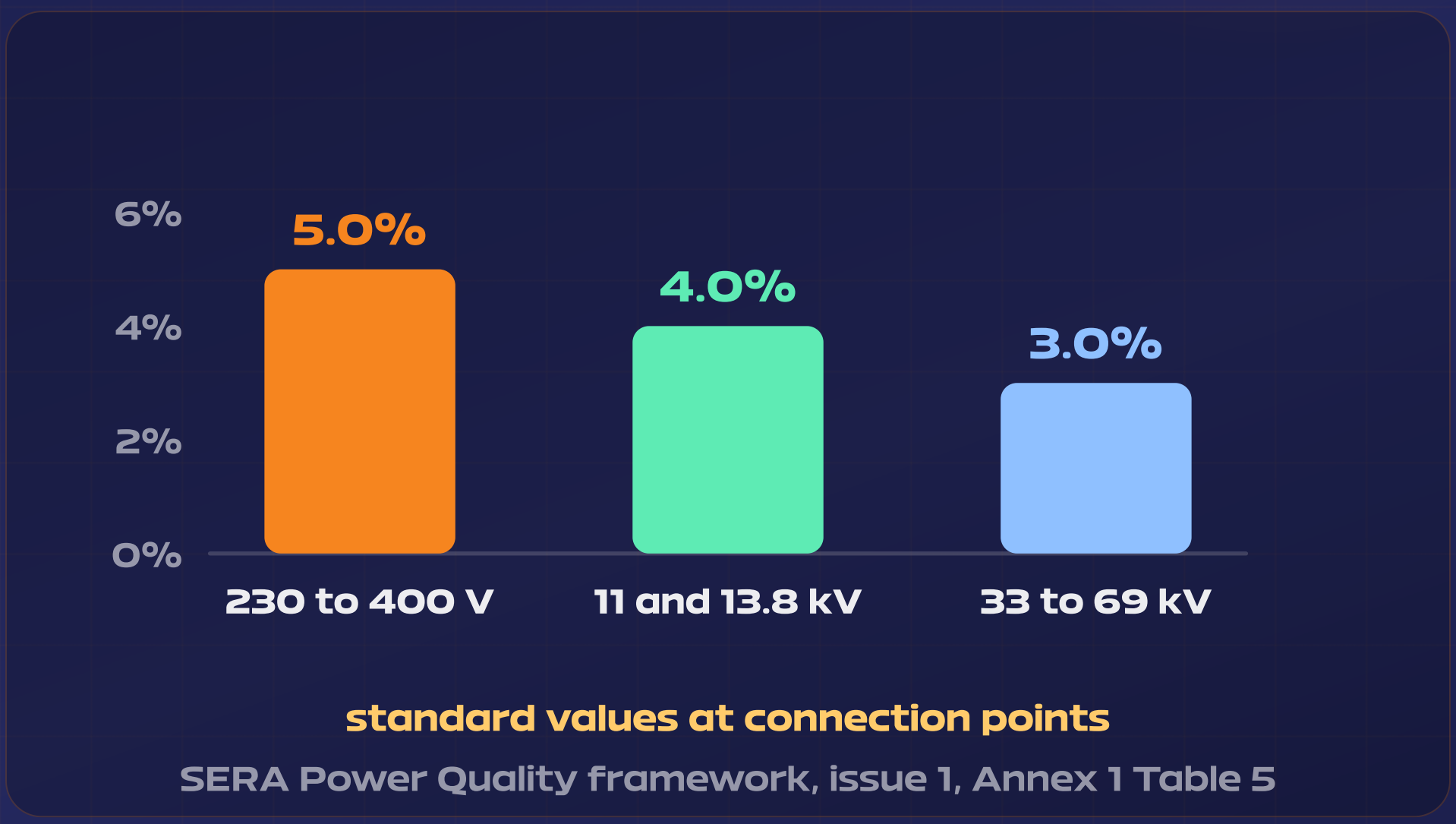
The current is a narrow pulse, and its peak is the number to check



1. The modelled switch-mode current is a narrow pulse, not a sine. [4]
2. The modelled peak is 1.81 times the RMS, against 1.41 for a sine, assuming all harmonics are zero-phase. Equipment rated on peak current, such as a UPS inverter, may see that peak. [4]

THE SAUDI FRAME

Saudi Arabia runs at 60 Hz, with its own THD values



standard values at connection points

SERA Power Quality framework, issue 1, Annex 1 Table 5

1. SERA Power Quality framework, issue 1, Annex 1 Table 5: voltage THD 5.0% at 230 to 400 V, 4.0% at 11 and 13.8 kV, 3.0% at 33 to 69 kV. [1]
2. Applied at all connection points, measured to IEC 61000-4-7 in 10-minute intervals over at least one week. [1]

The framework does not reference IEEE 519 or IEC/TR 61000-3-6. [1]

THREE NUMBERS

THD, neutral current and crest factor each answer a different question



1. THD is harmonics over the fundamental, the neutral ratio is In over phase current in a balanced model, and crest factor is peak over RMS. [4]

2. Quote the number your question needs. A THD figure alone does not answer the other two. [4]

REFERENCE TABLE

IEEE 519 and SERA voltage limits, side by side

Bus at or below 1 kV IEEE 519-2022, Table 1 [2]	**8.0% THD** **5.0% single**
230 to 400 V SERA, Annex 1 Table 5 [1]	**5.0% THD**
Above 1 kV up to 69 kV IEEE 519-2022, Table 1 [2]	**5.0% THD** **3.0% single**
11 and 13.8 kV SERA, Annex 1 Table 5 [1]	**4.0% THD**
33 to 69 kV SERA, Annex 1 Table 5 [1]	**3.0% THD**
Where IEEE 519 applies the PCC, IEEE 519-2022 clause 3 [2]	**not a sub-board**

SERA's values are tighter than IEEE 519 at every level shown. Use the values the connection agreement or specification adopts. For current, IEEE 519-2022 sets TDD limits by the short-circuit ratio at the PCC. [2]

WHERE THE METRICS SIT

Three terms on every site, each with one job



Illustrative photo: a power quality analyser on a switchboard, showing three-phase waveforms.

PCC	TDD	THD
where the limit applies	**IEEE 519 current metric**	**IEEE 519 voltage metric**
public supply side, not a board	over maximum demand	over the fundamental

CRITICAL SITES

A stricter target for a critical site is set in the specification

IEEE 519	SERA	critical site
Table 1	Annex 1 Table 5	state the target
by bus voltage	by voltage level	in the spec
at the PCC	connection points	with its metric

state a stricter target in the specification

1. IEEE 519-2022 Table 1 sets voltage limits by bus voltage at the PCC. [2]
2. A hospital, data centre or airport that needs a tighter target writes it into the specification, with the value, the measurement point and the metric.

Do not assume a stricter target from the site category. Write it into the specification.

THE MISTAKE: A K-RATED TRANSFORMER

A K-rated transformer tolerates harmonics. It does not remove them

K-rated transformer

changes: heating margin inside the transformer

harmonics: not reduced

Filter, active front end or multi-pulse rectifier

changes: what the site injects into the grid

reduces the injection

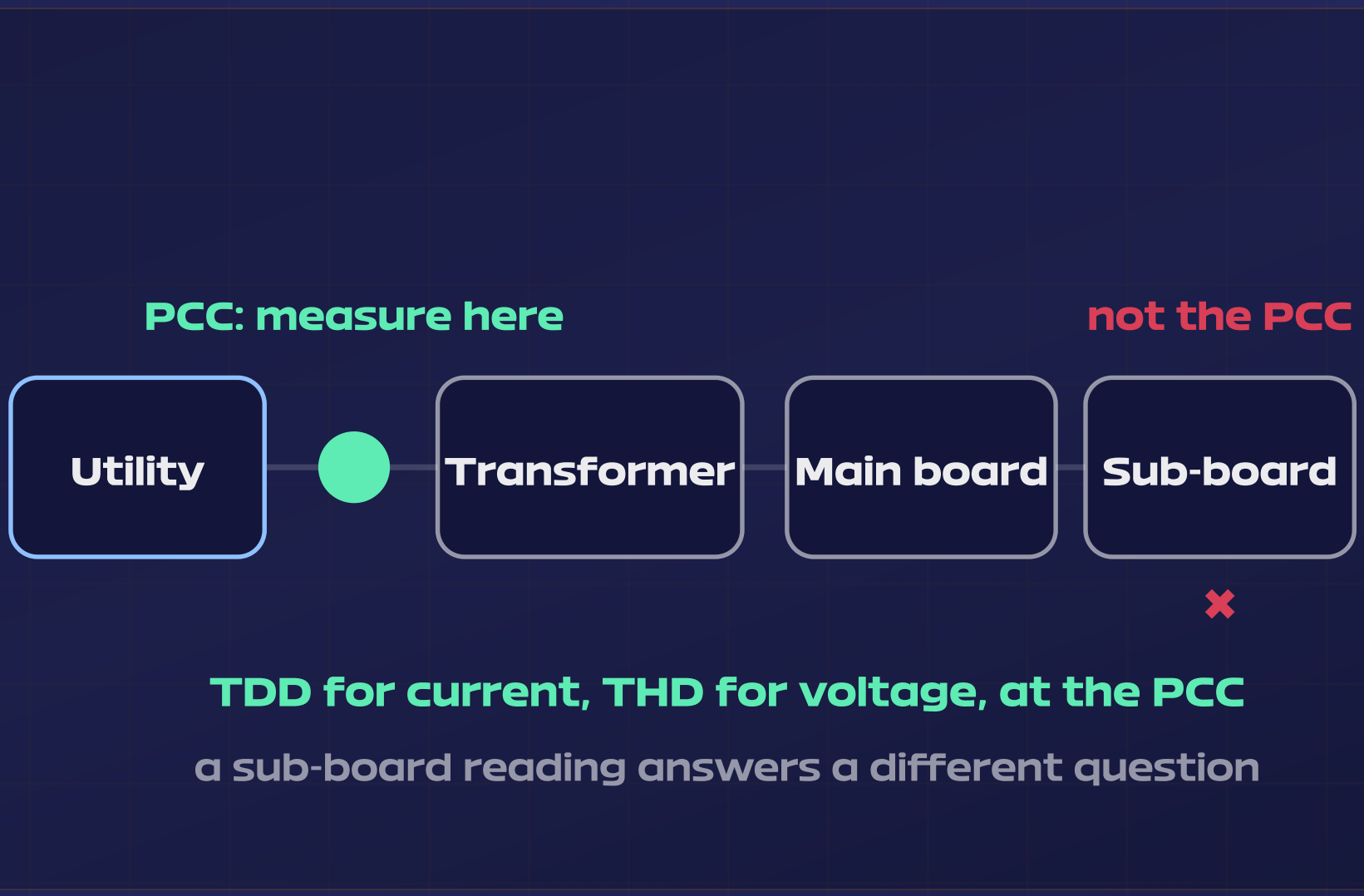
K-rating protects the transformer, not the grid

1. K-rating gives the transformer extra thermal headroom for harmonic heating. [3] It does not reduce the harmonic current the installation injects into the network.
2. Reducing what the installation injects takes a different measure: a filter, an active front end or a multi-pulse rectifier.

Name the fix for the problem you have: heating, or injection.

THE CORRECTION: MEASURE AT THE PCC

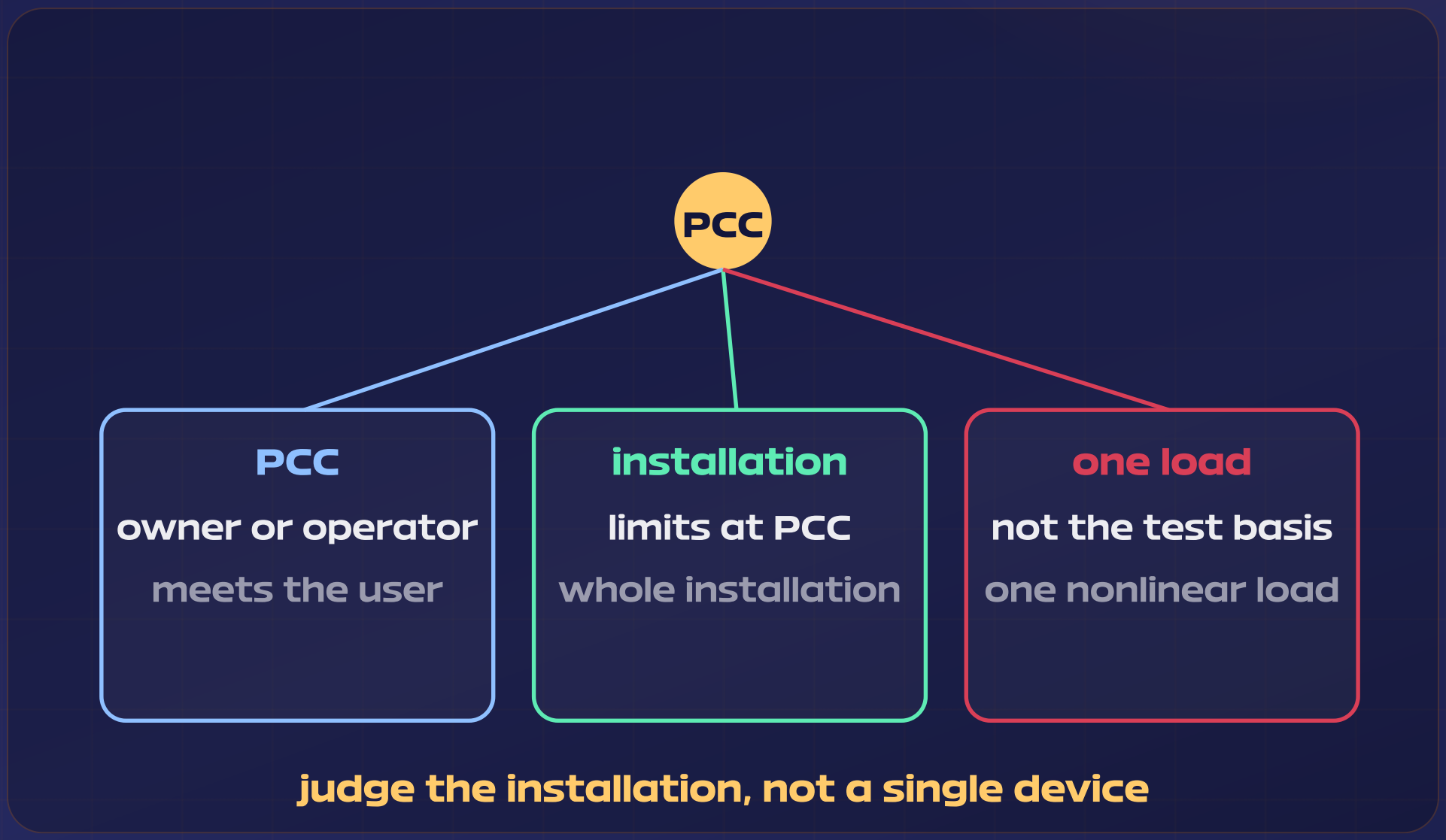
Measure at the PCC, against the right metric



1. A THD reading at a sub-board does not answer the PCC question that IEEE 519 frames. [2]
2. Under IEEE 519-2022, current is compared with the TDD limits at the PCC, and voltage with the THD and individual harmonic limits at the same point. [2]

THE CORRECTION: WHO CARRIES THE DUTY

Judge the installation, not one nonlinear load



1. IEEE 519-2022 shares the duty at the PCC: the system owner or operator for voltage distortion, the user for the harmonic current the whole installation injects. [2]
2. IEEE 519 limits are not meant for one piece of equipment. [2] Equipment emission limits come from product standards such as IEC 61000-3-2 and IEC 61000-3-12. [5]

The limits bind a site once a regulator, utility, connection agreement or project specification adopts them. [2]

THE CLAUSE TO COPY

Write the limit in five parts, each one checkable

Point	PCC on the public supply
Current metric	TDD over maximum demand
Voltage metric	THD and singles at the PCC
Scope	whole installation, not one load
Basis	60 Hz: 5th at 300 Hz, 7th at 420 Hz

cite the IEEE 519-2022 edition and the clause used

A template for one project specification: check each part against drawings or a measurement report.

CHECKLIST

Before the spec goes out

- [x] Point of common coupling named in the spec
- [x] TDD for current, THD for voltage
- [x] limits judged on the installation, not one device
- [x] frequency basis 60 Hz, orders at 300 and 420 Hz
- [x] edition and clause cited and checked

Every item traces to a source on the next slide.

SOURCES

Where every claim in this carousel comes from

- **SERA, issue 1**
  Saudi voltage THD, 60 Hz, measurement method
- **IEEE Std 519-2022**
  PCC and TDD (clause 3), voltage limits (Table 1)
- **K-factor reference**
  transformer heating margin under harmonics
- **NLC illustrative model**
  spectra, THD, neutral ratio, crest factor, TDD

[1] SERA Power Quality framework, issue 1, Annex 1 Table 5
[2] IEEE Std 519-2022, clause 3 and Table 1
[3] Power Monitors, Power Transformer K-Factor (whitepaper)
[4] NLC illustrative model (modelled spectra)
[5] IEC 61000-3-2 and IEC 61000-3-12, equipment emission limits

Standards are cited by number, edition and table or clause. Values marked [4] come from an NLC illustrative model, not from measurements.

Practical electrical engineering

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Read the full episode article

https://nlc.com.sa/academy/harmonics-thd.html

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