Harmonics and Solution for Port Cranes

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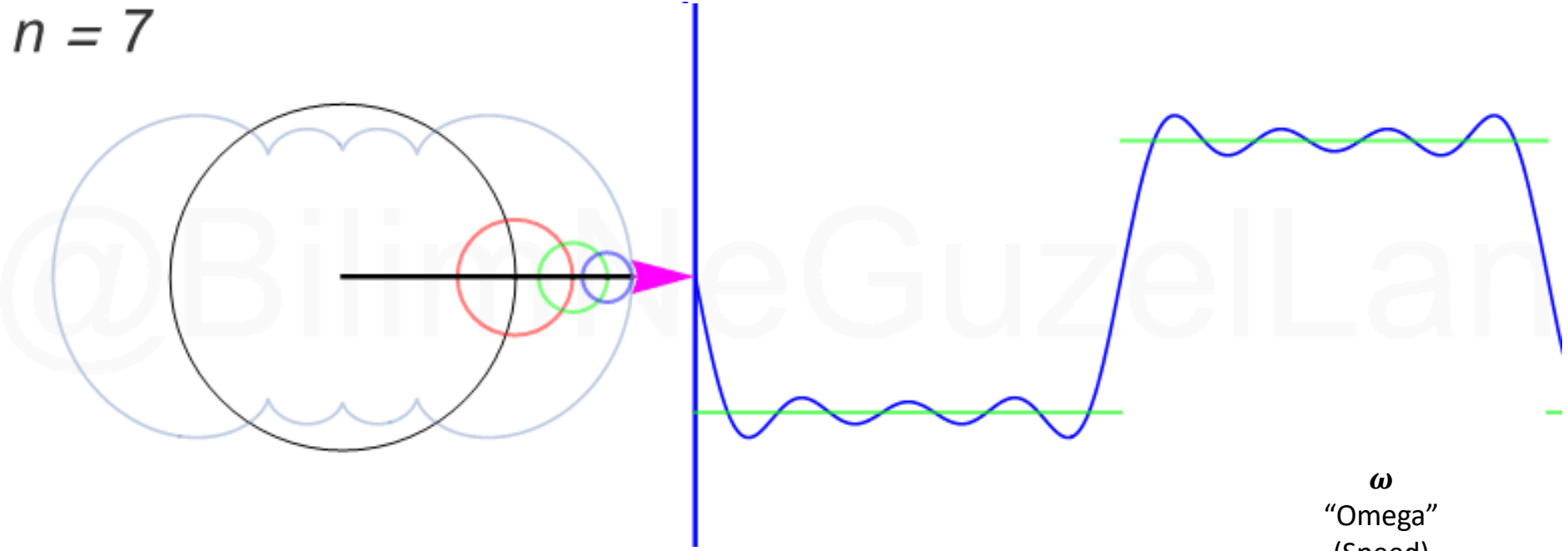
Presentation Outline:

1. What are Harmonics?
2. Harmonics in Port System
3. How bad can it get?
4. How to fix it?

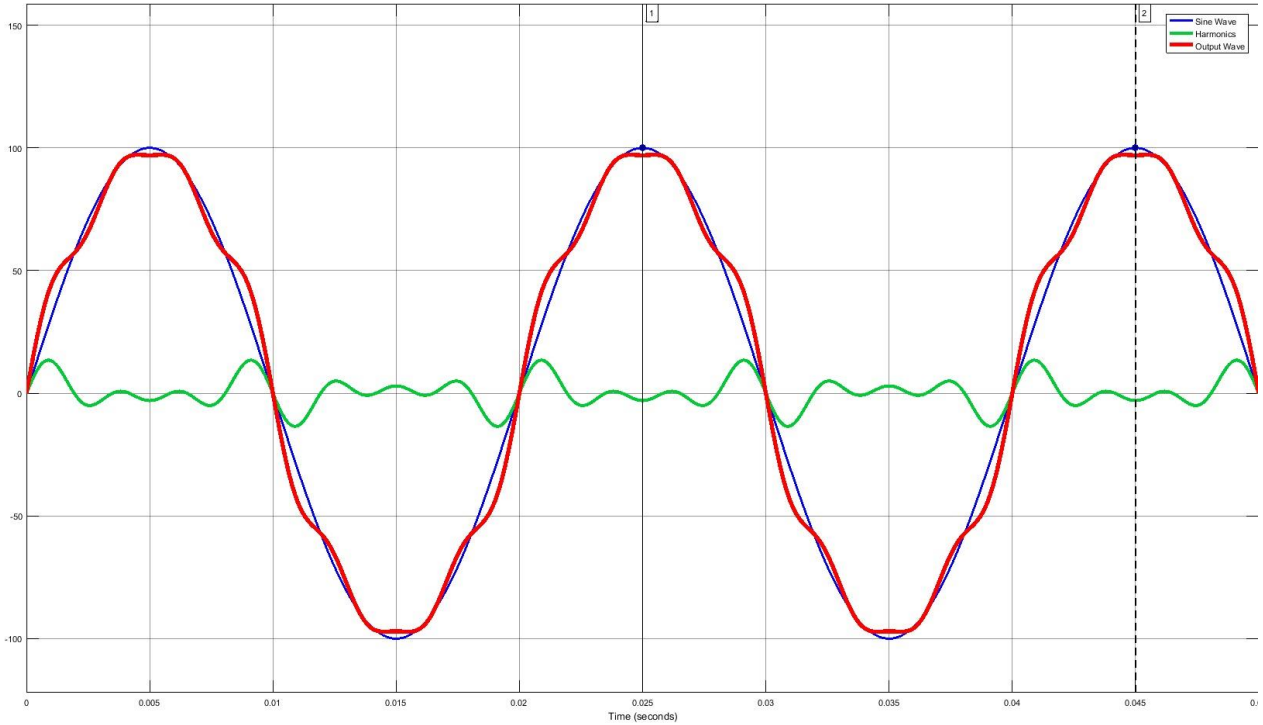
What are Harmonics?

Let’s understand using a circle



7th **harmonic wave** Sine wave

No perfect sine wave in reality

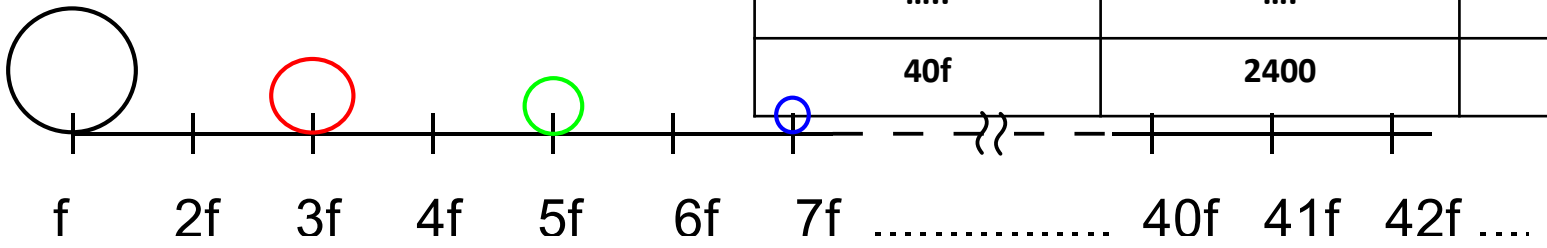


Harmonic Spectrum

$$\omega = 2\pi f$$

Harmonic Spectrum

Spectrum	(Hz)	n
f = 60 Hz	60	1
2f	120	2
3f	180	3
5f	300	5
7f	420	7
.....	....	....
40f	2400	40

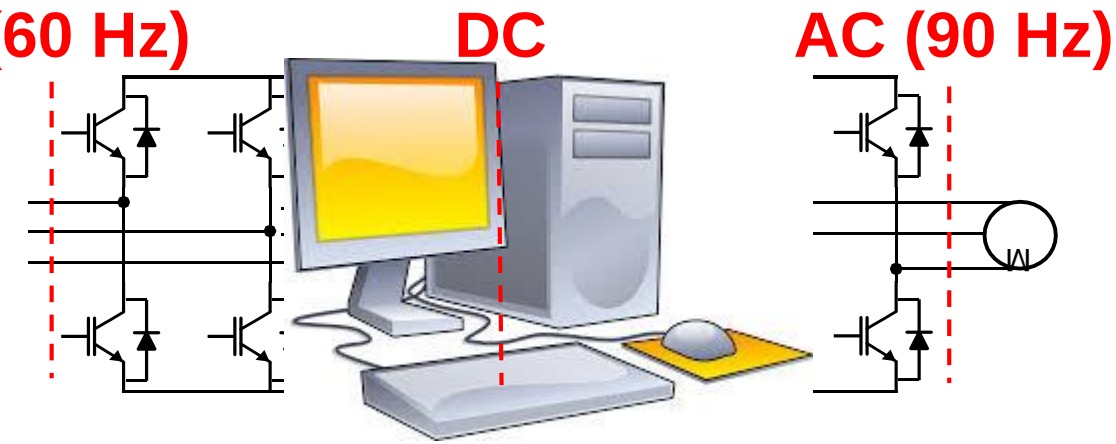


Port & Harmonics

Where do Harmonics come from?

Sources of Harmonics on a crane

1. Variable Frequency AC Drives
2. DC Drives
3. UPS
4. Computers
5. Non-Linear Auxiliary loads



Negative Impacts of harmonics

Negative Impacts of harmonics:

1. **Heating**
    1. **Bigger equipment - more cost**
    2. **Wasted energy**
    3. **Premature equipment failure**
2. **Poor power quality and penalties from Utilities.**

Negative Impacts of harmonics (cont.):

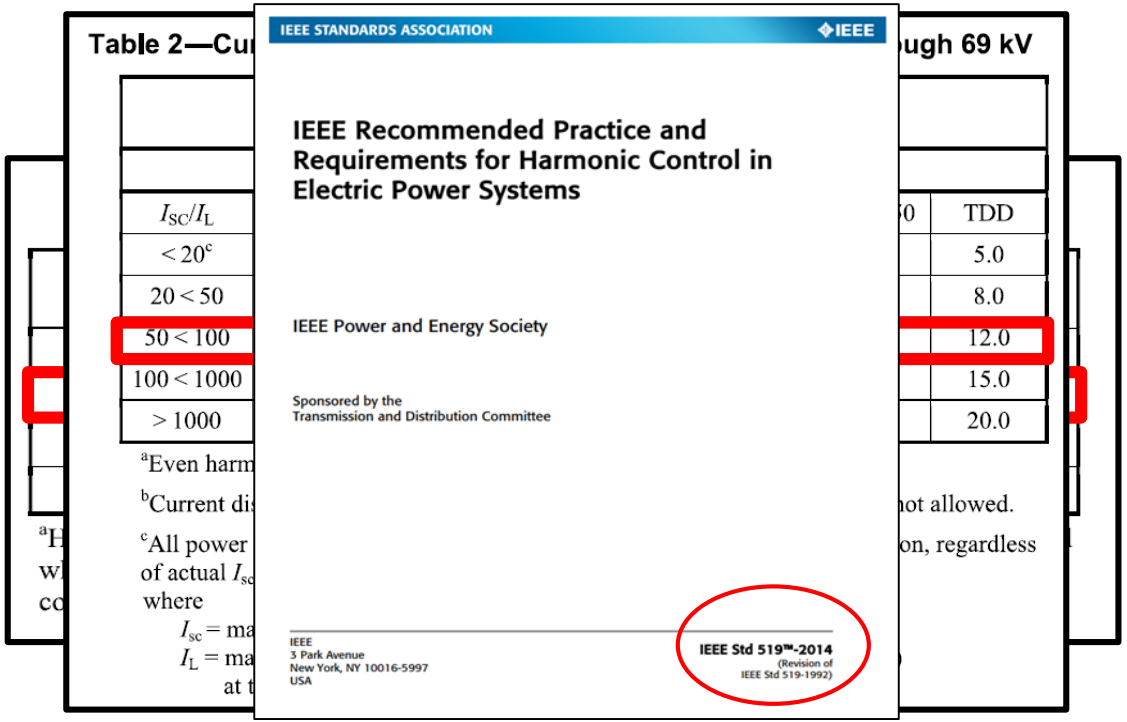
3. Premature failure of Aux equipment including near by office equipment such as AC, lights, Computers, Printers etc.

4. Interferes with crane control circuits.

How much is too much?

IEEE Standard 519 - 2014

IEEE Standard 519 - 2014



IEEE STANDARDS ASSOCIATION

IEEE

IEEE Recommended Practice and Requirements for Harmonic Control in Electric Power Systems

IEEE Power and Energy Society

Sponsored by the
Transmission and Distribution Committee

IEEE
3 Park Avenue
New York, NY 10016-5997
USA

IEEE Std 519™-2014
(Revision of
IEEE Std 519-1992)

Table 2—Cu

ugh 69 kV

I_{SC}/I_L	TDD
$< 20^c$	5.0
$20 < 50$	8.0
$50 < 100$	12.0
$100 < 1000$	15.0
> 1000	20.0

[a]Even harm

[b]Current di

[c]All power

of actual I_{sc}

where

I_{sc} = ma

I_L = ma

at t

ot allowed.

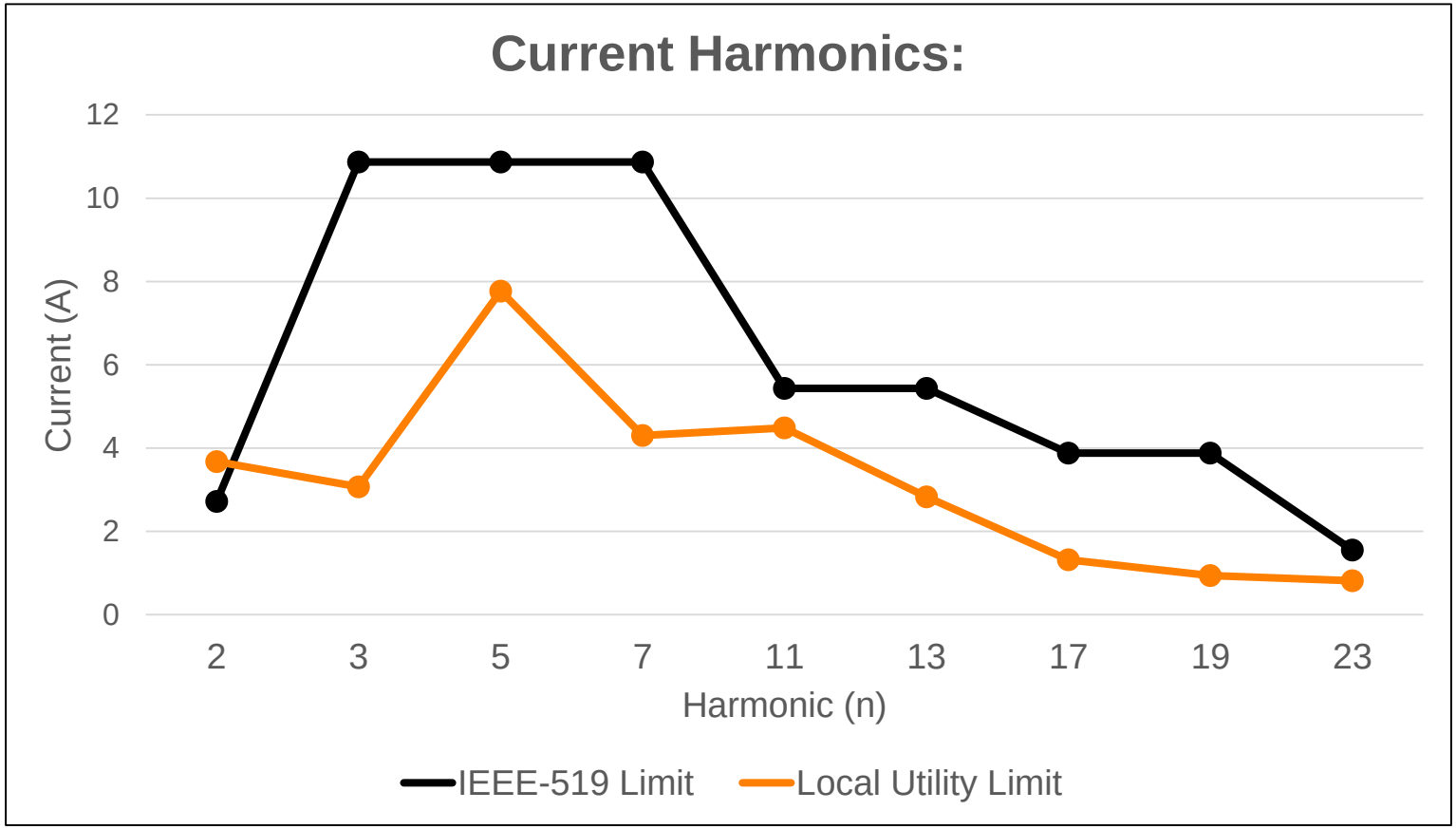
on, regardless

Local Harmonics Limit can be different…

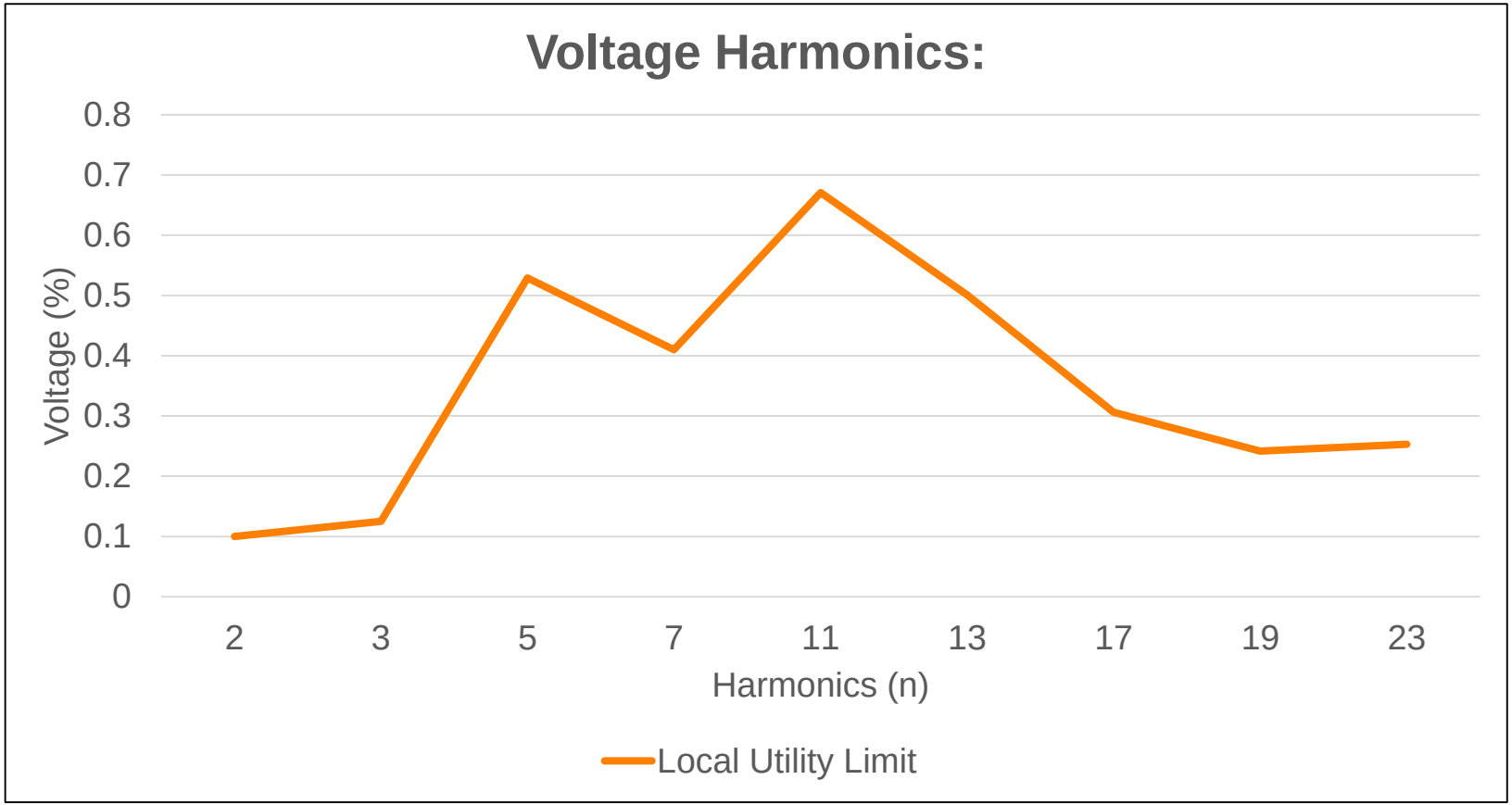
What about Local Utility?

Harmonic (n)	Voltage Limit (%)	Current Limit (A)
2	0.100	3.67
3	0.125	3.07
4	0.100	1.84
5	0.529	7.77
6	0.100	1.22
7	0.410	4.30
…	…	…

Comparison: IEEE vs Local Limits



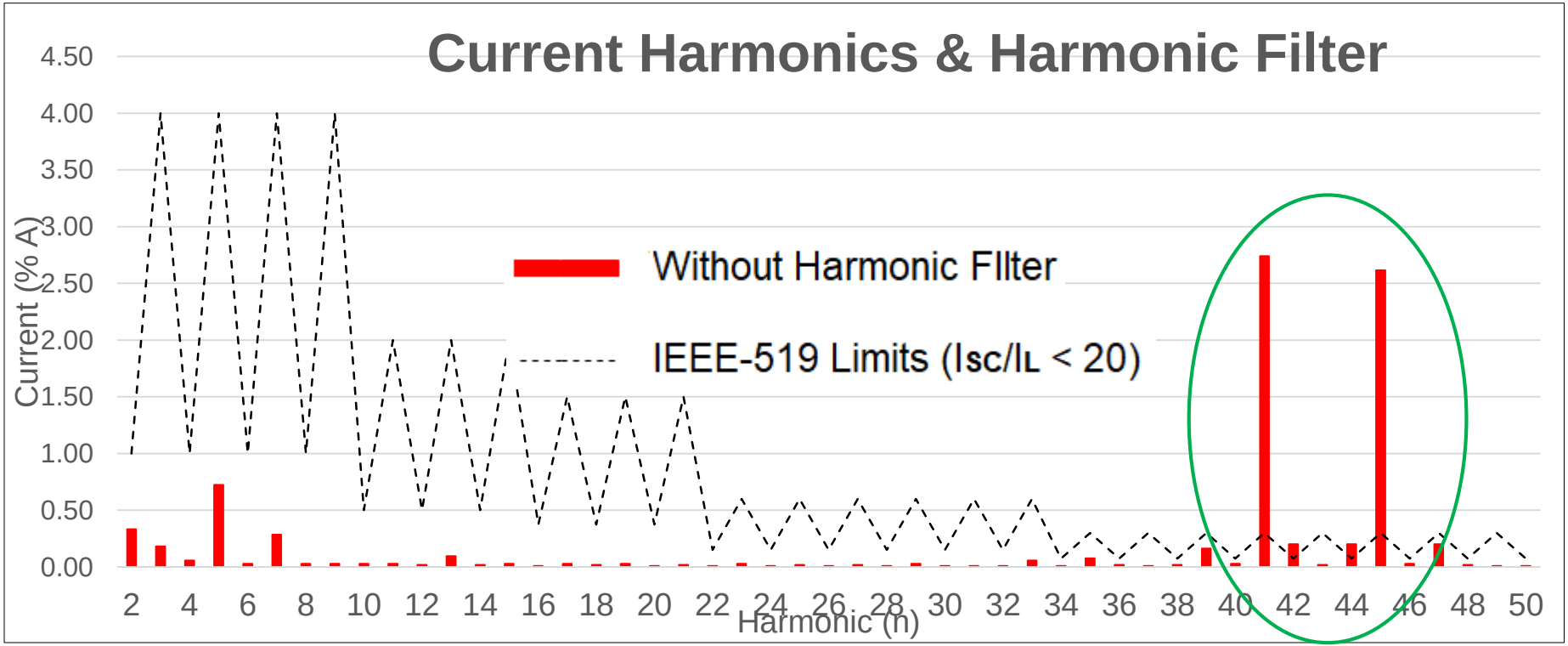
Voltage distortion - Local Limits



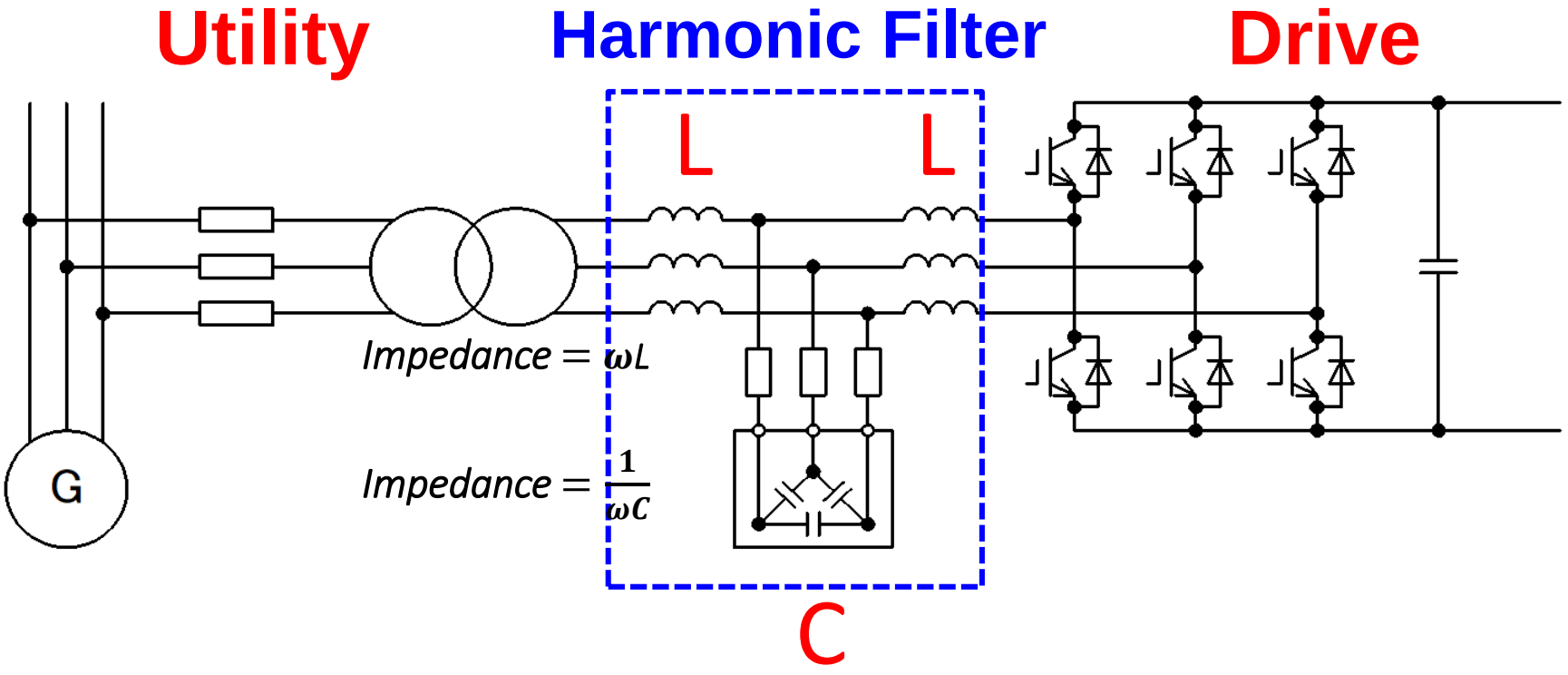
Solution

Harmonic Filter

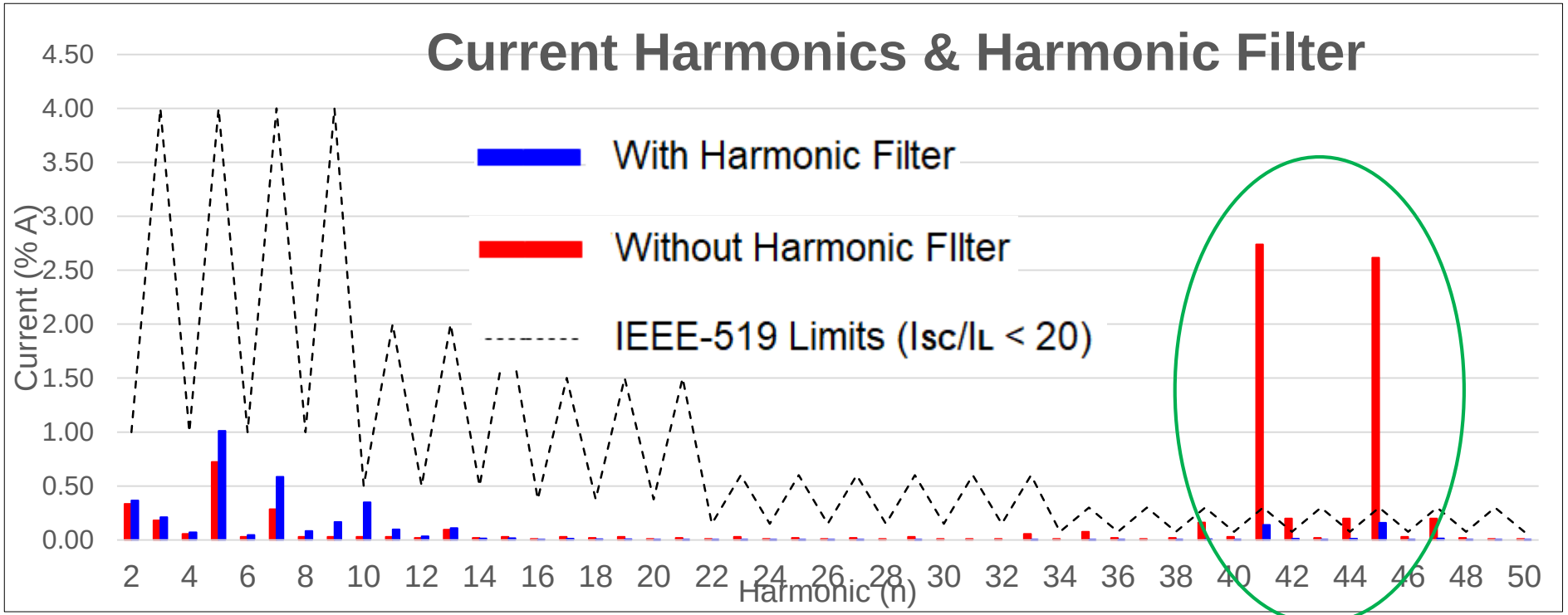
Harmonics from Drives …



Harmonic Filter



With Harmonic Filter …



Harmonic Filter

Is IEEE Std. 519 filter sufficient?

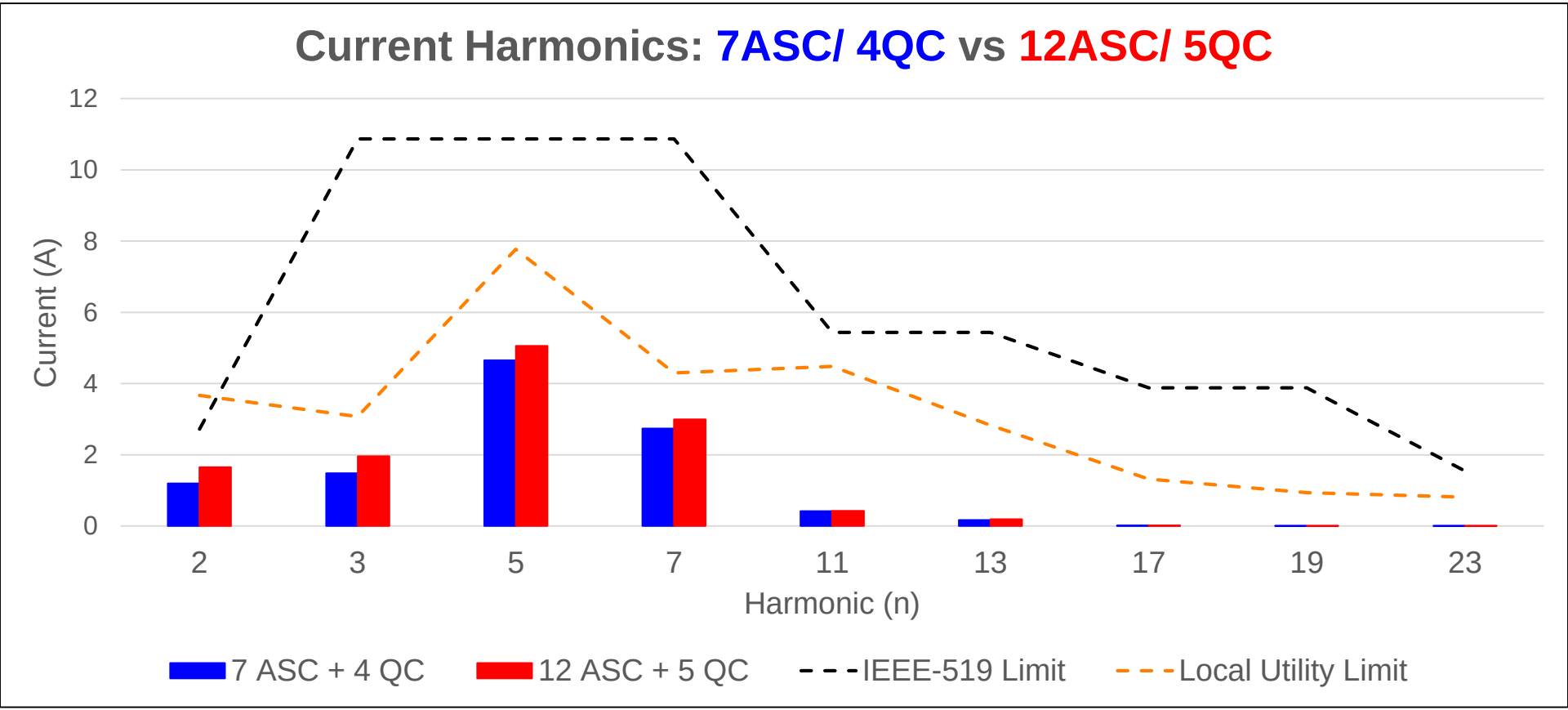
Case 1:

7 ASC + 4 QC vs 12 ASC + 5 QC

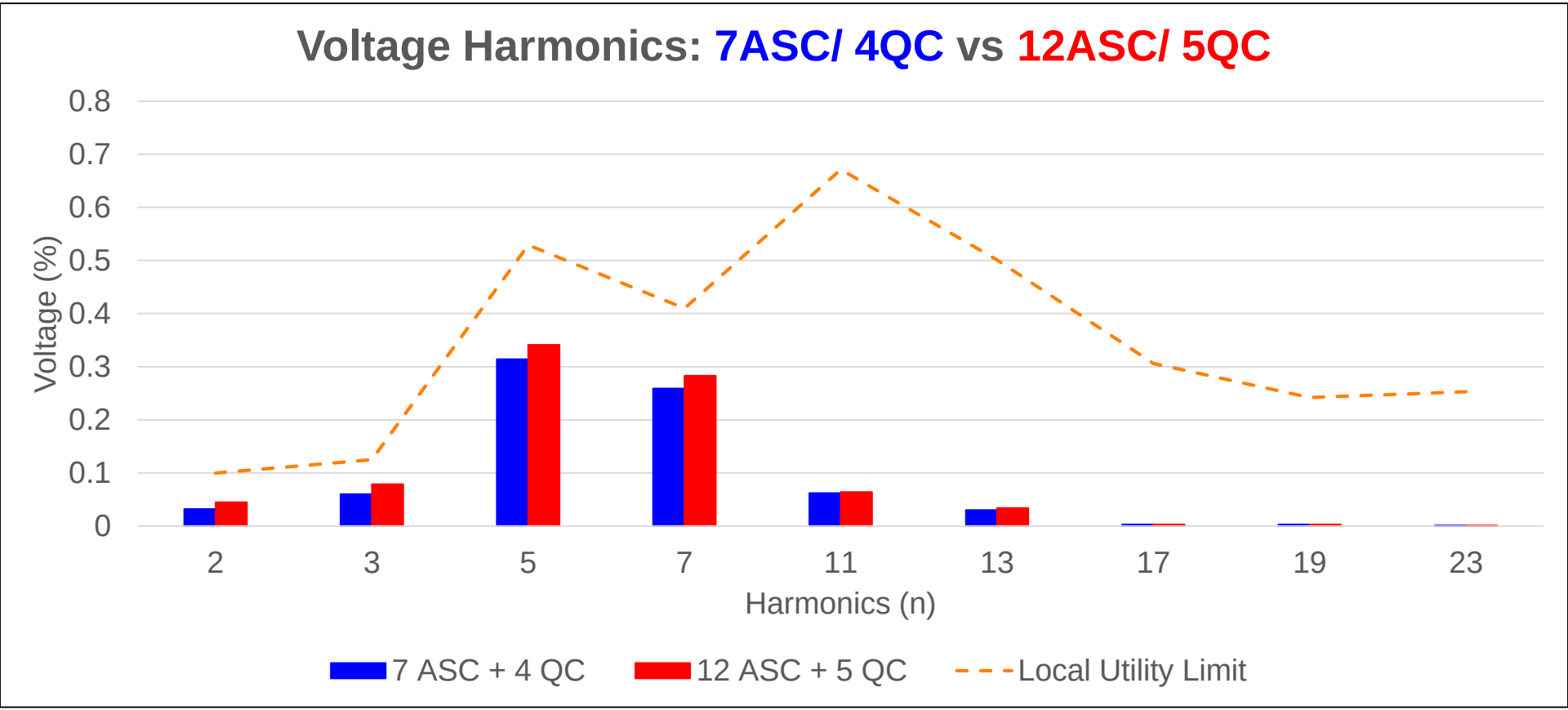
(Scenario 1) (Scenario 2)

- Impacts of increasing # cranes
- Each crane contributes

Less Cranes v/s More Cranes



Less Cranes v/s More Cranes



Scenario 3:

Critical # of cranes

(Scenario 3): 22 ASC + 7 QC

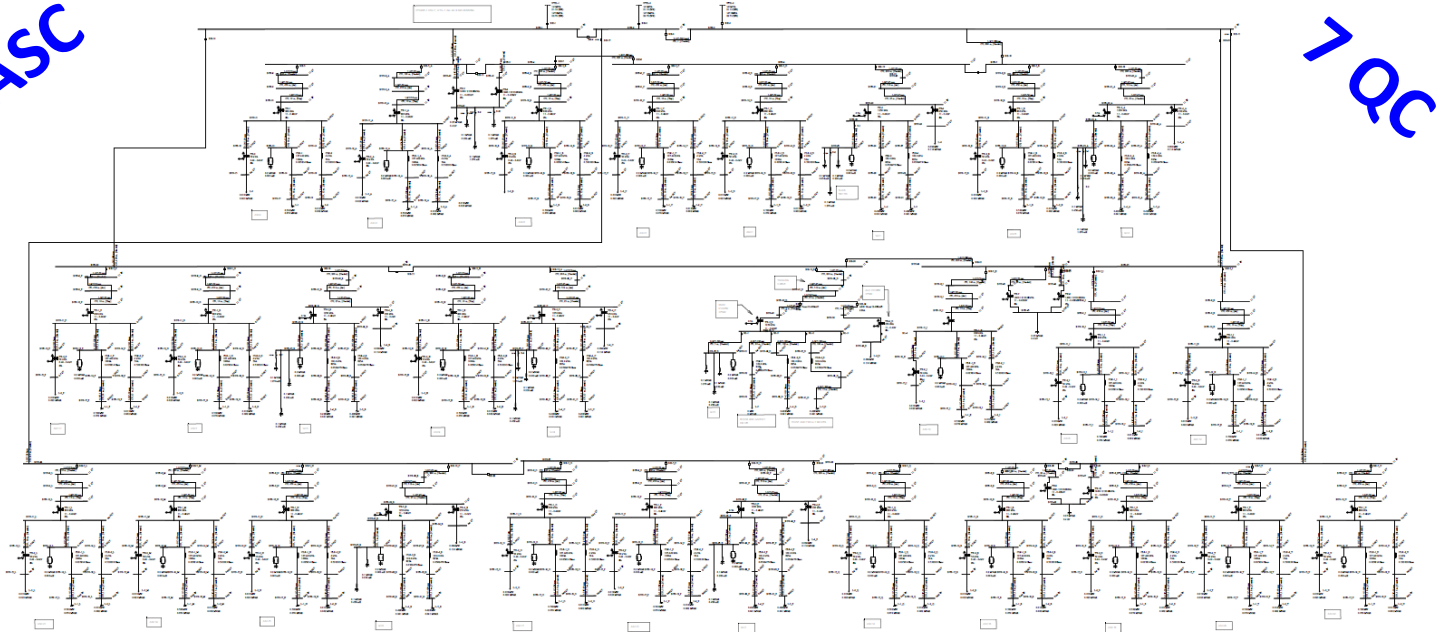
- 5^{th} , 7^{th} harmonics exceeded
- Standard v/s Custom Design

With Port Expansion …

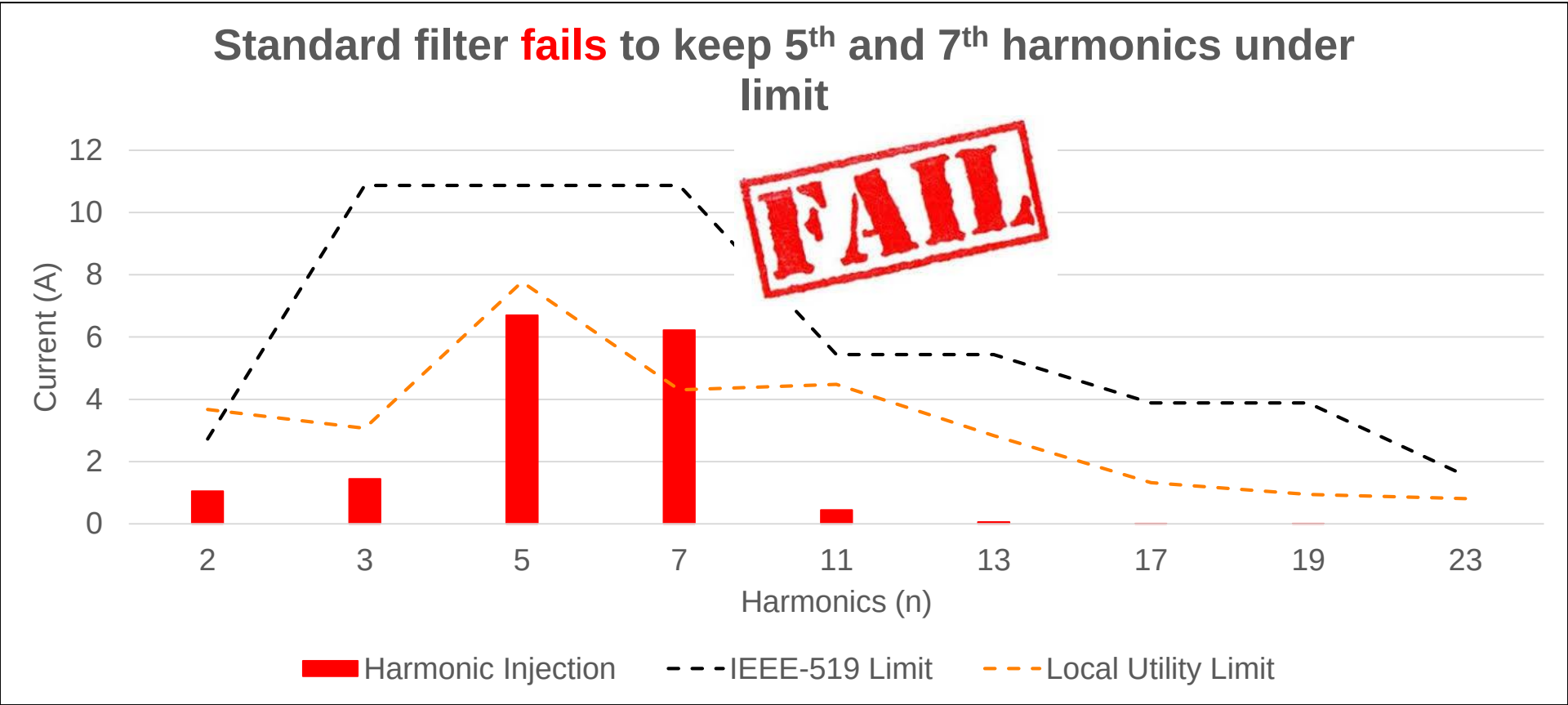
More cranes operating at the same time, increase harmonic injection !

22 ASC

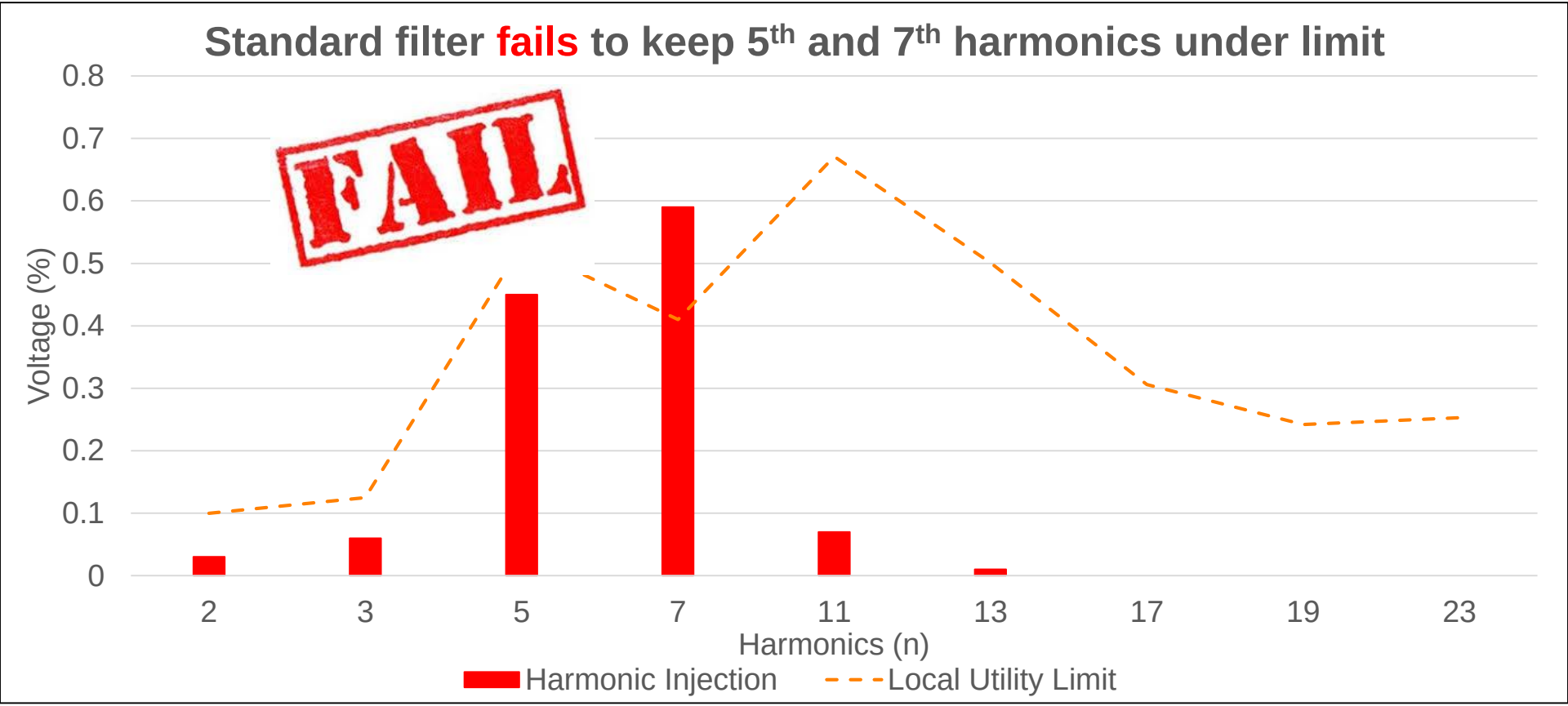
7 QC



Problem: 5th and 7th harmonics

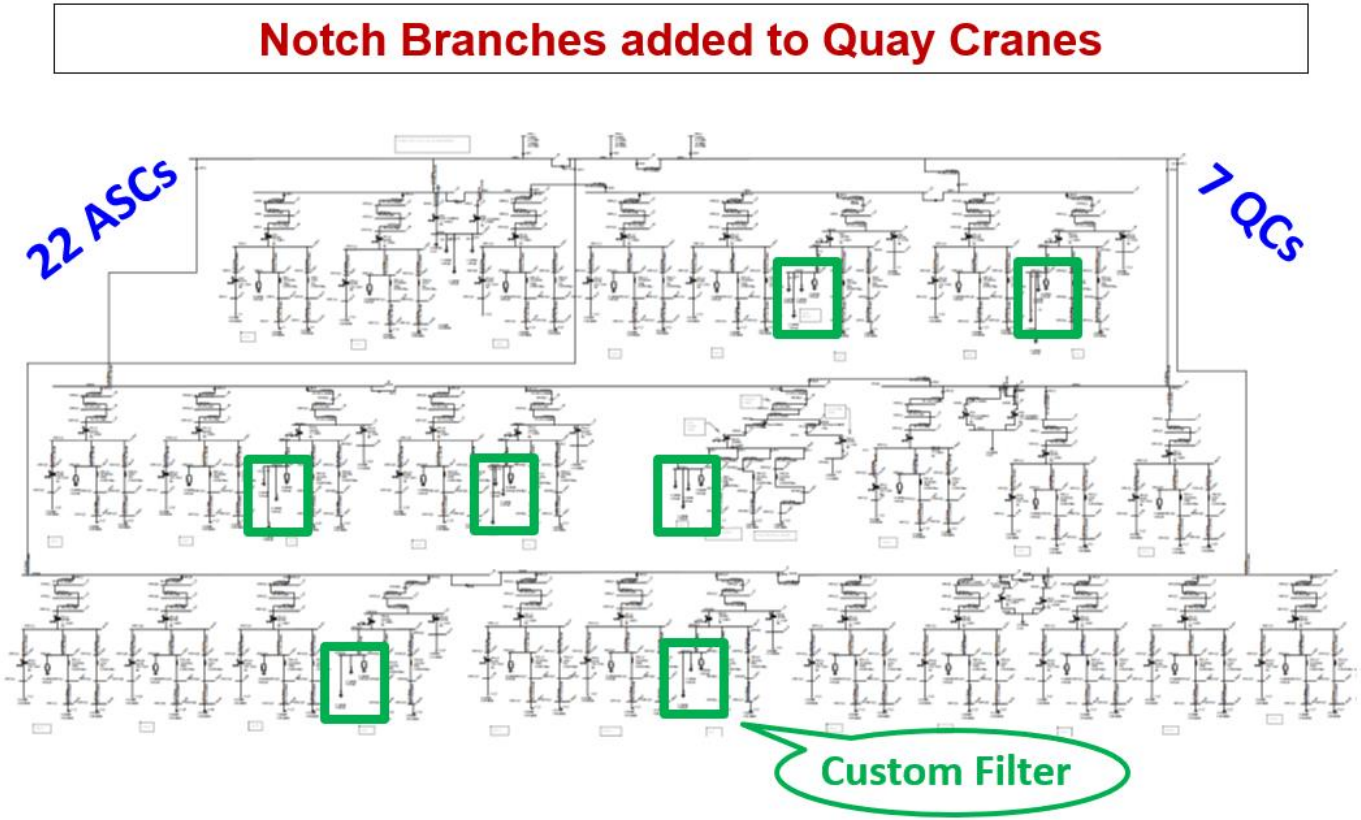


Problem: 5th and 7th harmonics

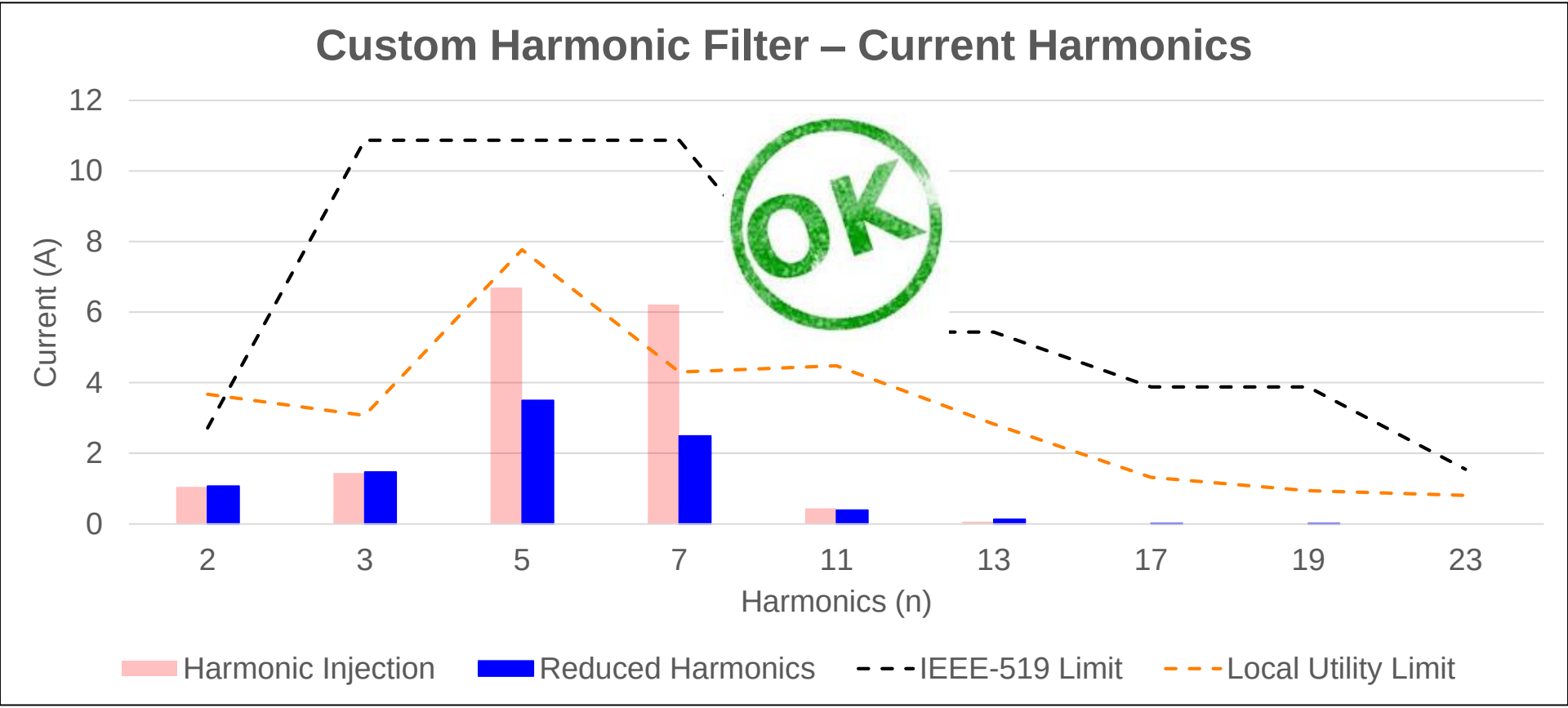


What about Custom Harmonic Filter?

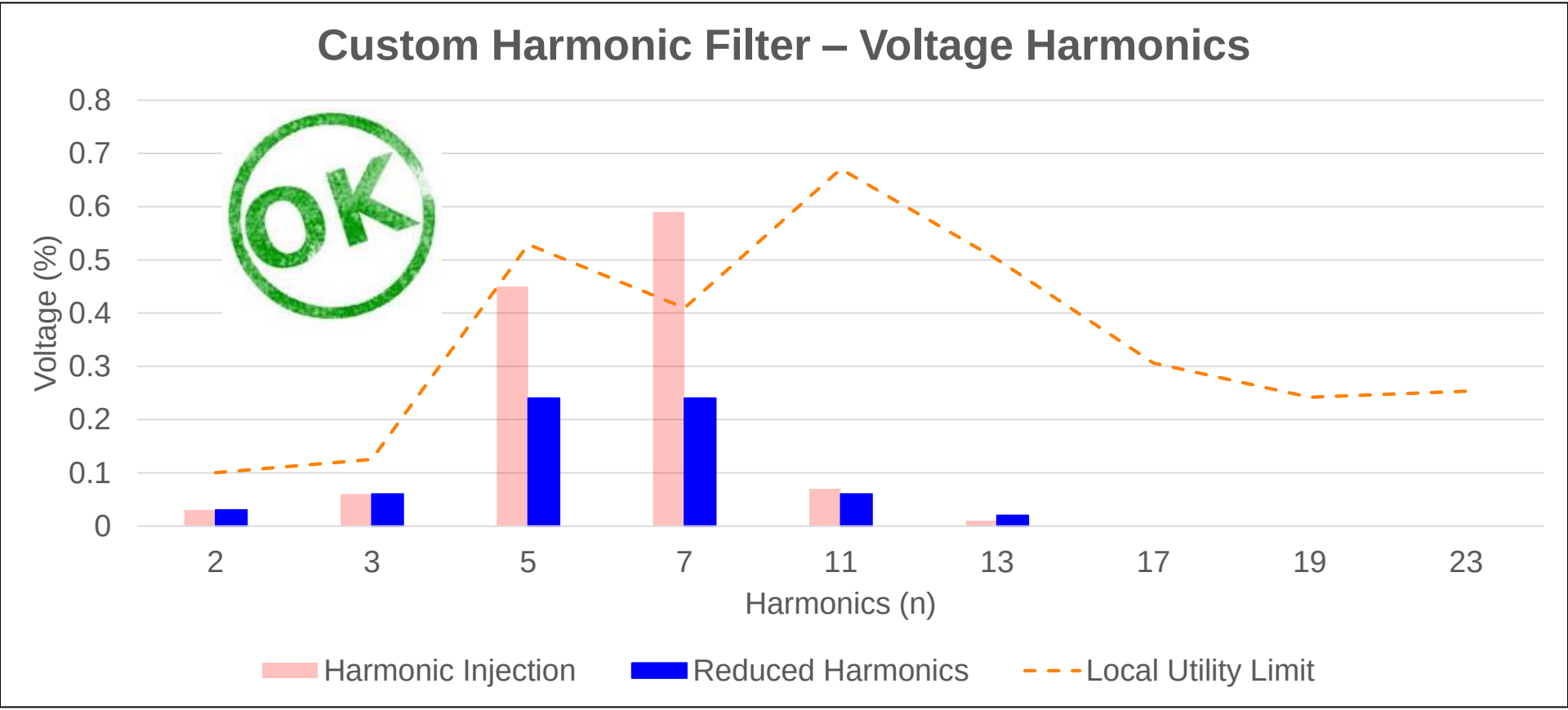
After adding Custom Filter …



5th and 7th harmonics are suppressed



5th and 7th harmonics are suppressed



Summary

- **Local Utility Limits may be more stringent than IEEE-519.**
- **Harmonic distortion at PCC increases as more cranes are operated.**

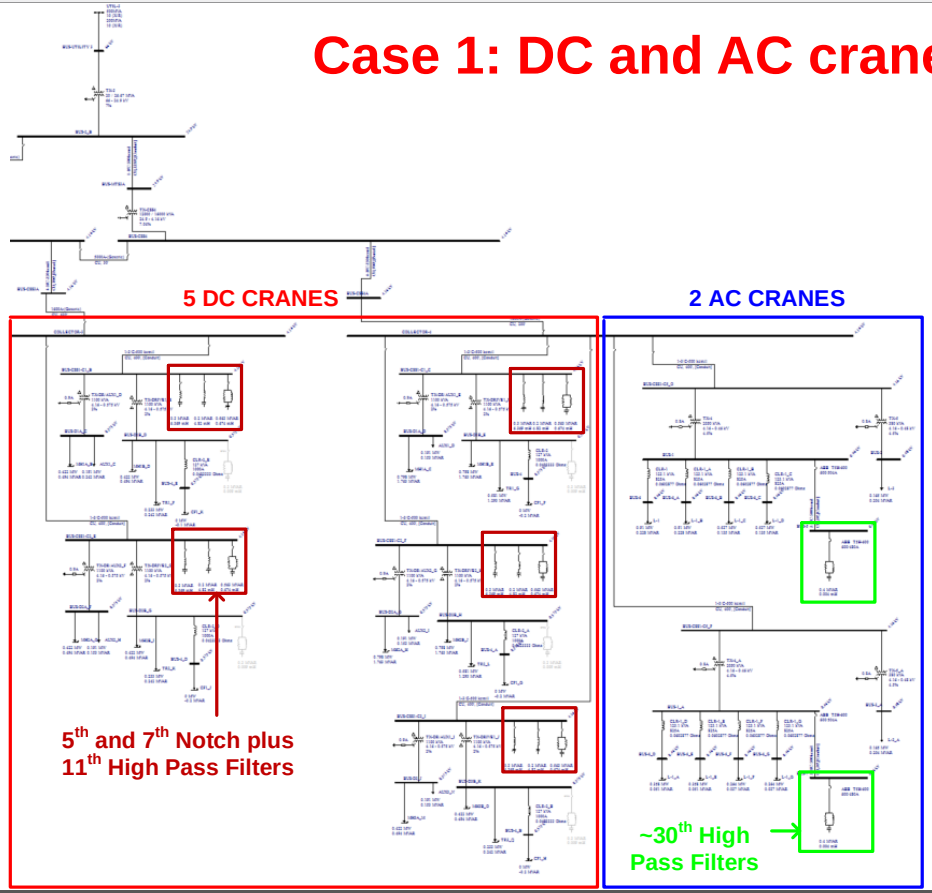
A custom filter based on the model of entire port including future expansion meets IEEE std. 519 and local utility requirements at PCC.

Summary (cont.)

A custom filter based on the model of entire port including future expansion meets IEEE Std. 519 as well as applicable local utility requirements at PCC.

DC Cranes and AC Cranes. Case 1

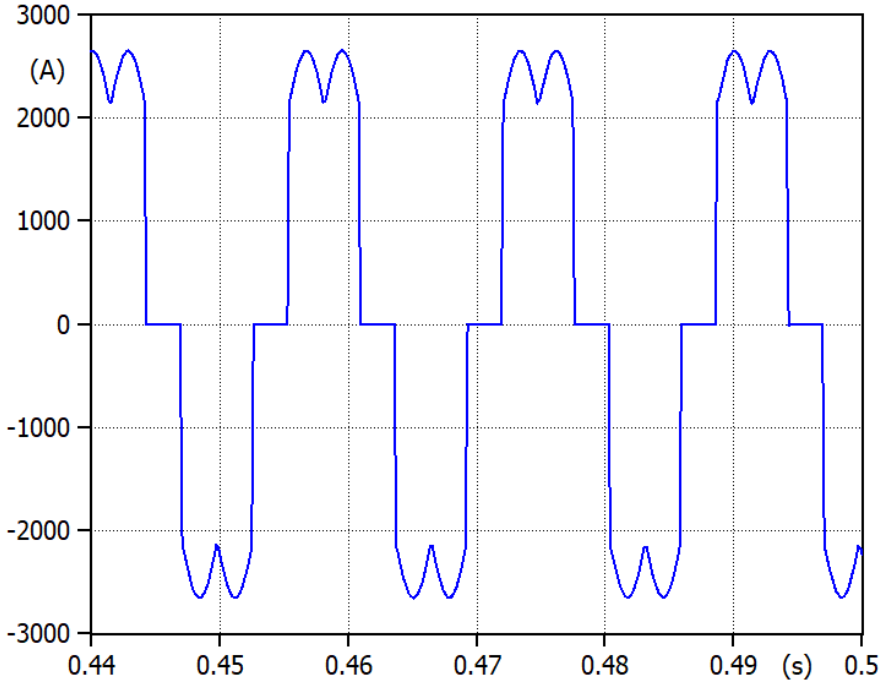
Case 1: DC and AC cranes with Filters.



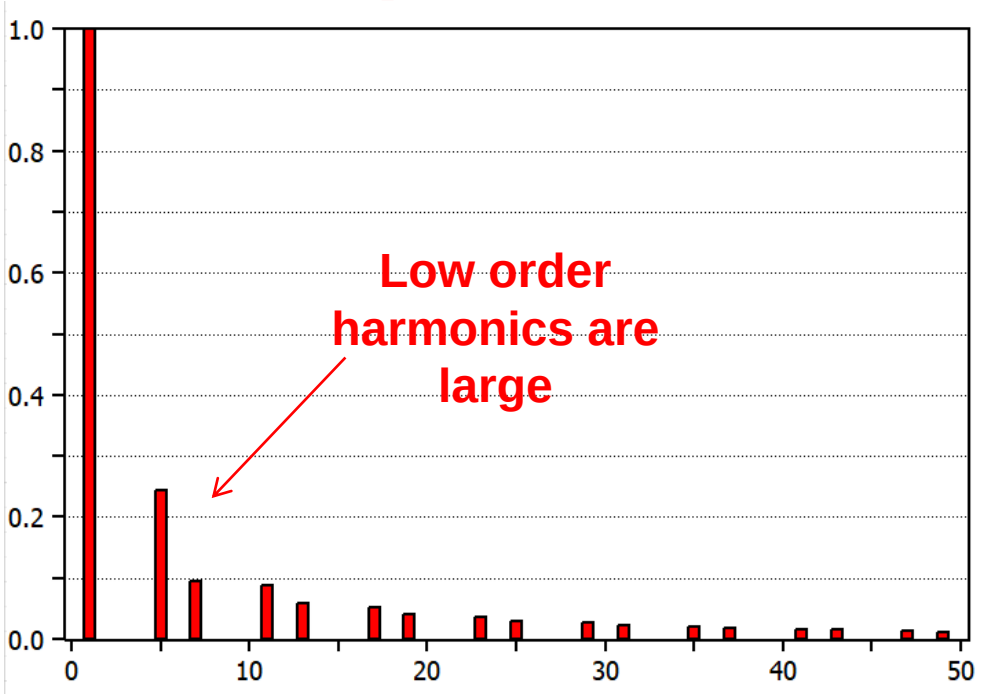
DC and AC cranes inject harmonics with substantially different spectrums

6 Pulse DC Drive Current

Waveform

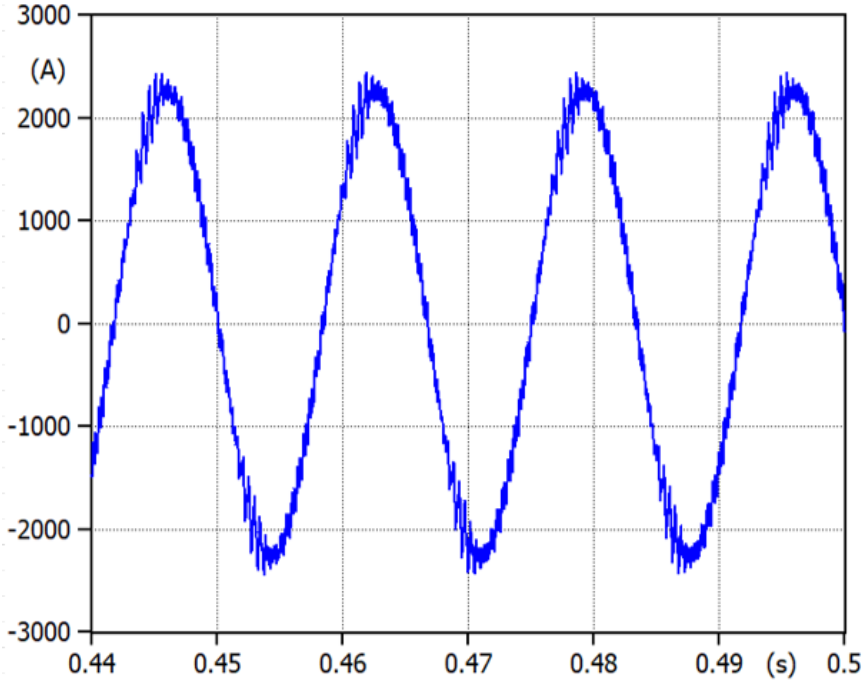


Spectrum

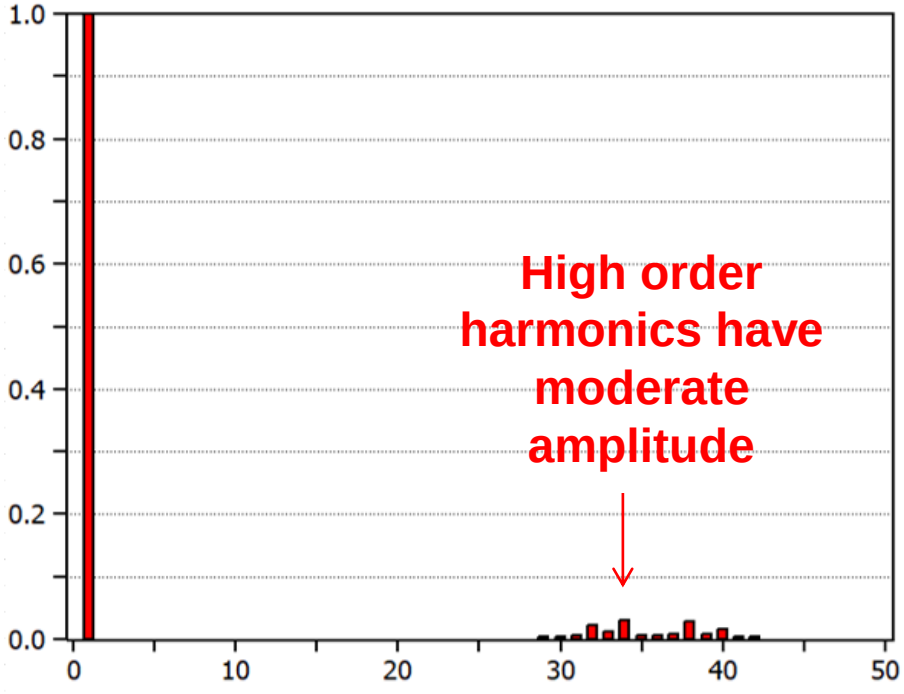


2 Levels IGBT Drive Current

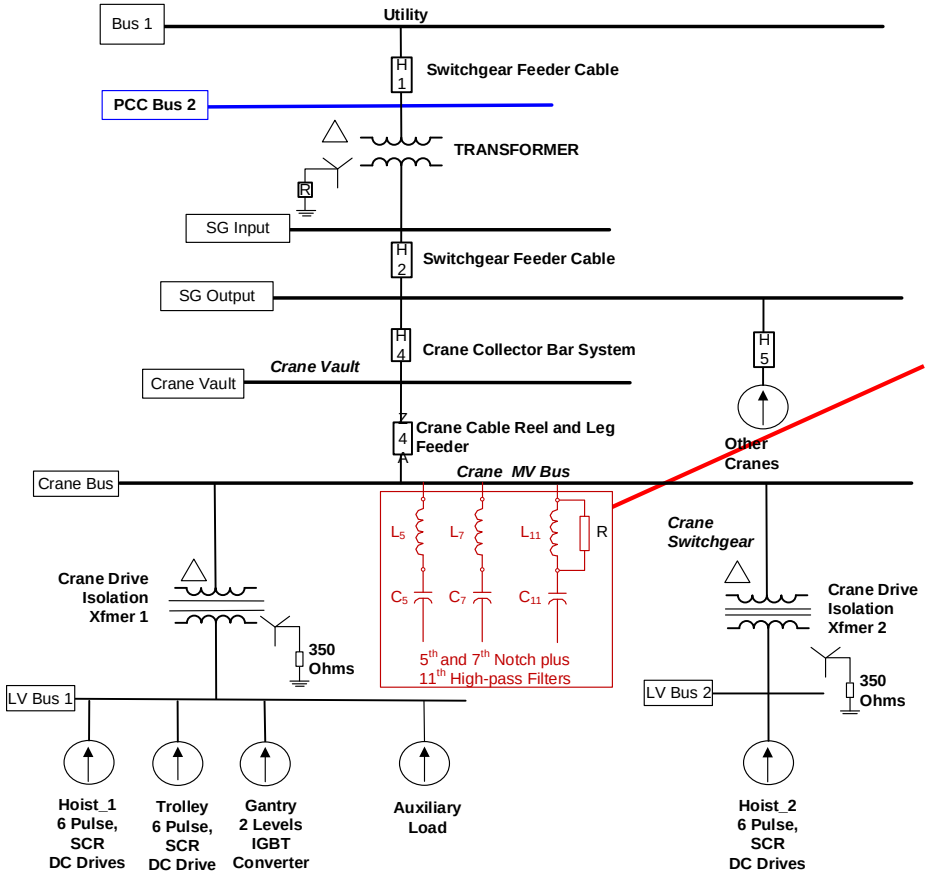
Waveform



Spectrum

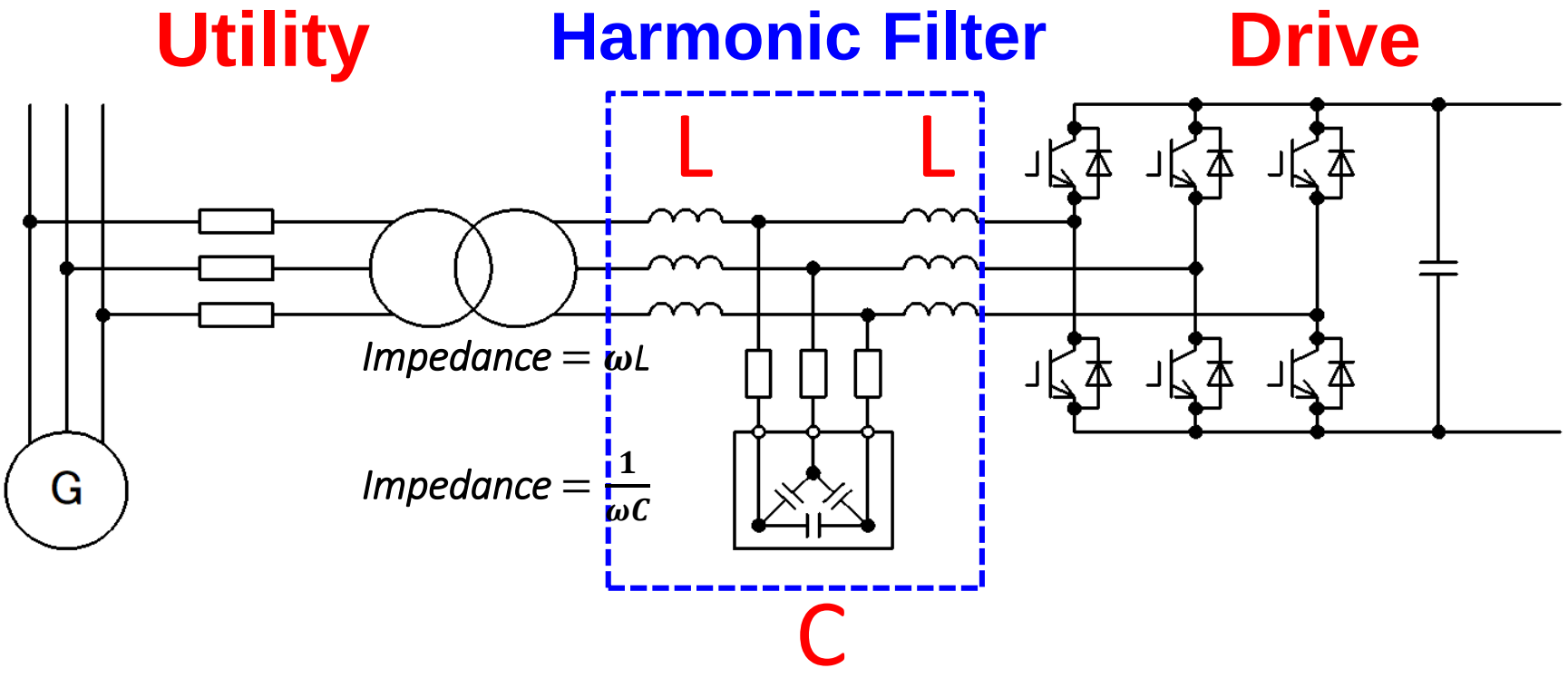


DC Cranes Filter

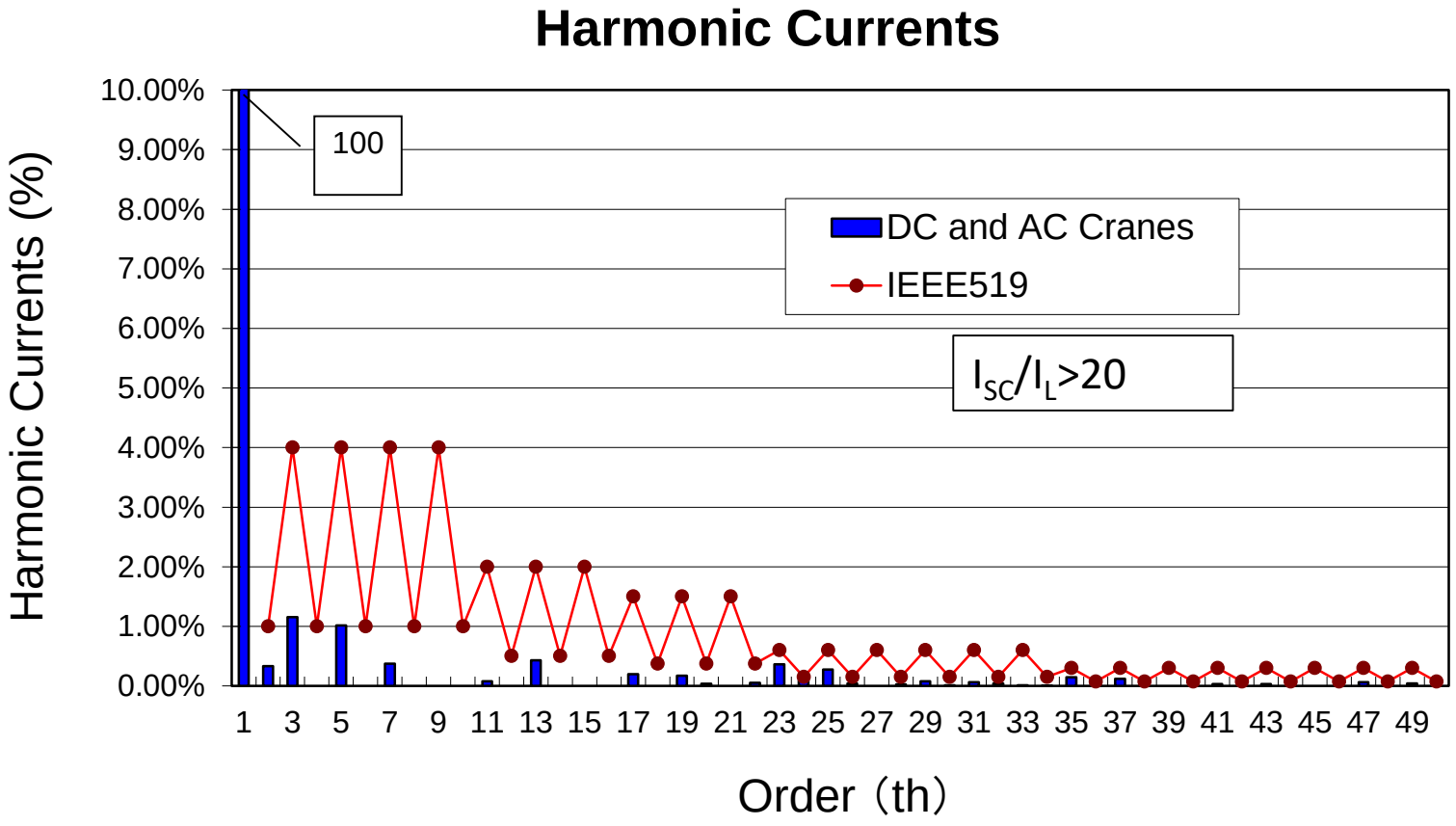


Filters at the MV Bus

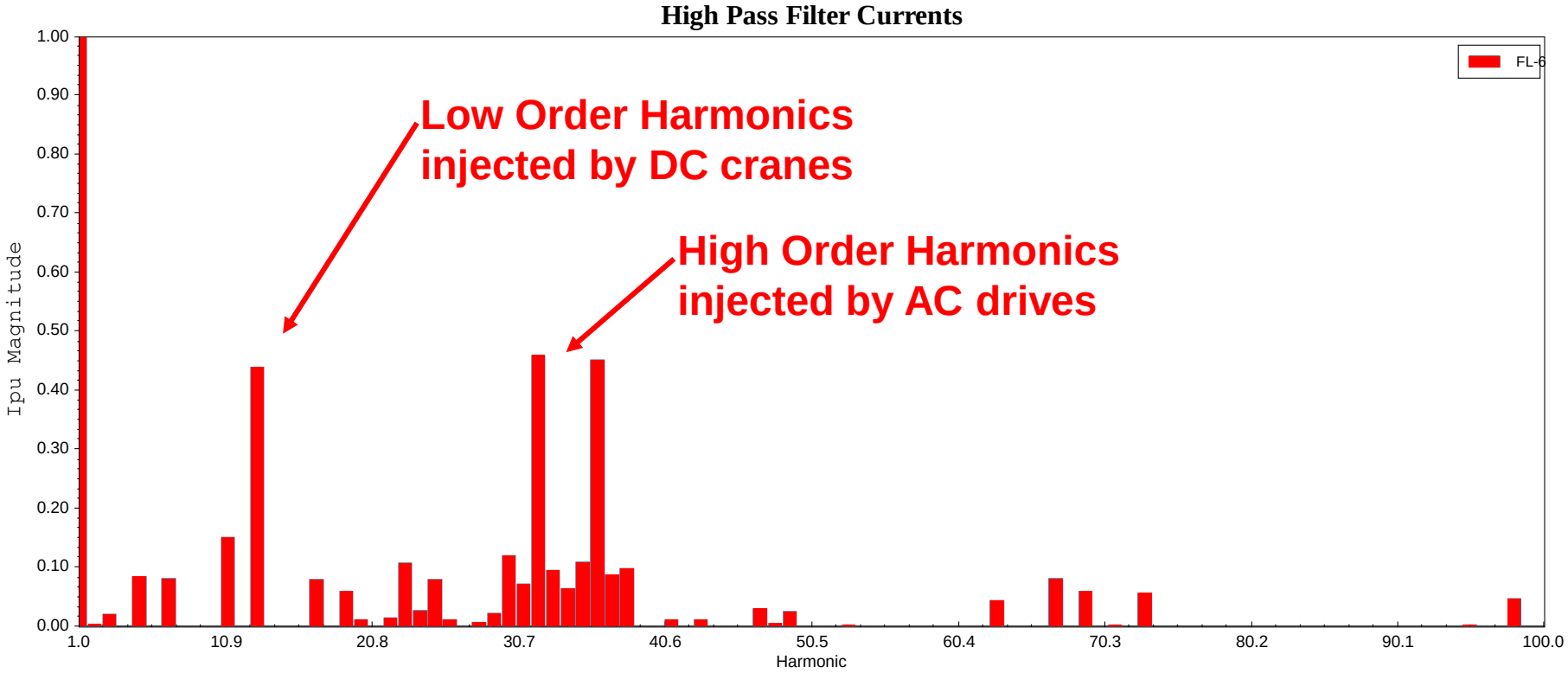
AC Cranes Harmonic Filter



Harmonic Spectrum at the PCC



AC Crane, High Pass Filter Currents

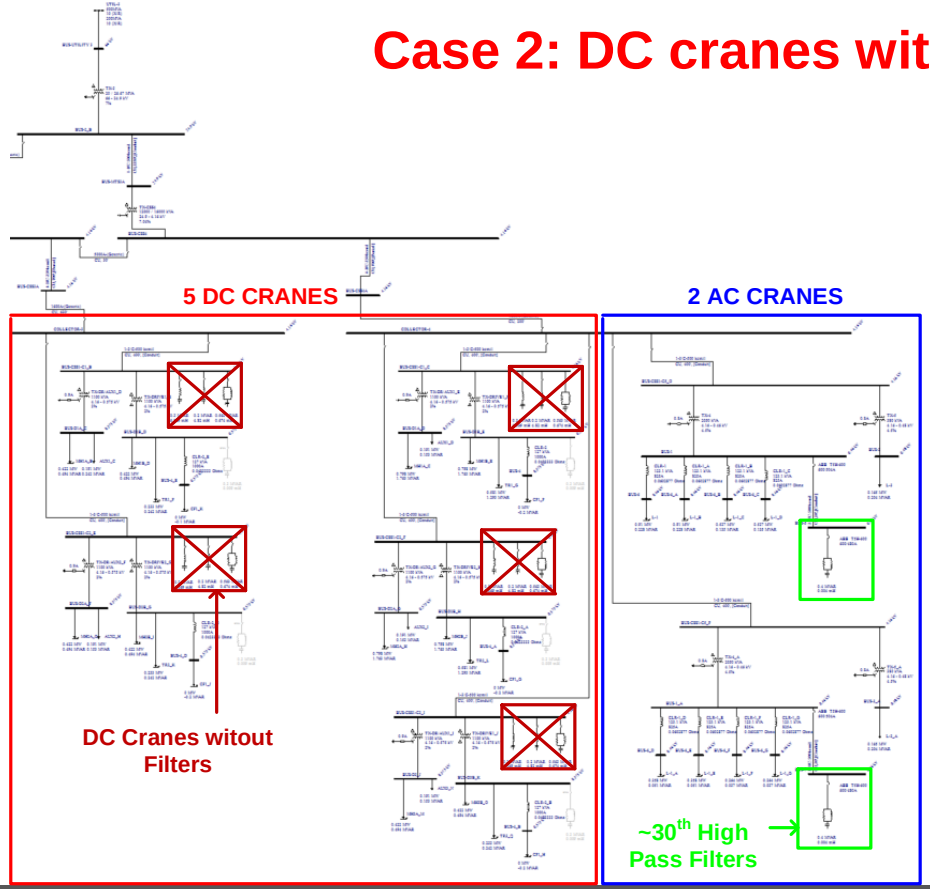


Summary

- DC drives inject low order harmonic currents with high amplitude.
- AC drives inject high order harmonic currents with moderate amplitude.
- Cranes with DC drives require Low harmonic order notch filters and a High Pass section, all connected at the MV bus.
- Cranes with AC drives require High Pass filter to attenuate high frequency harmonics
- Combination of these filters ensure compliance with IEEE std. 519 at the PCC.

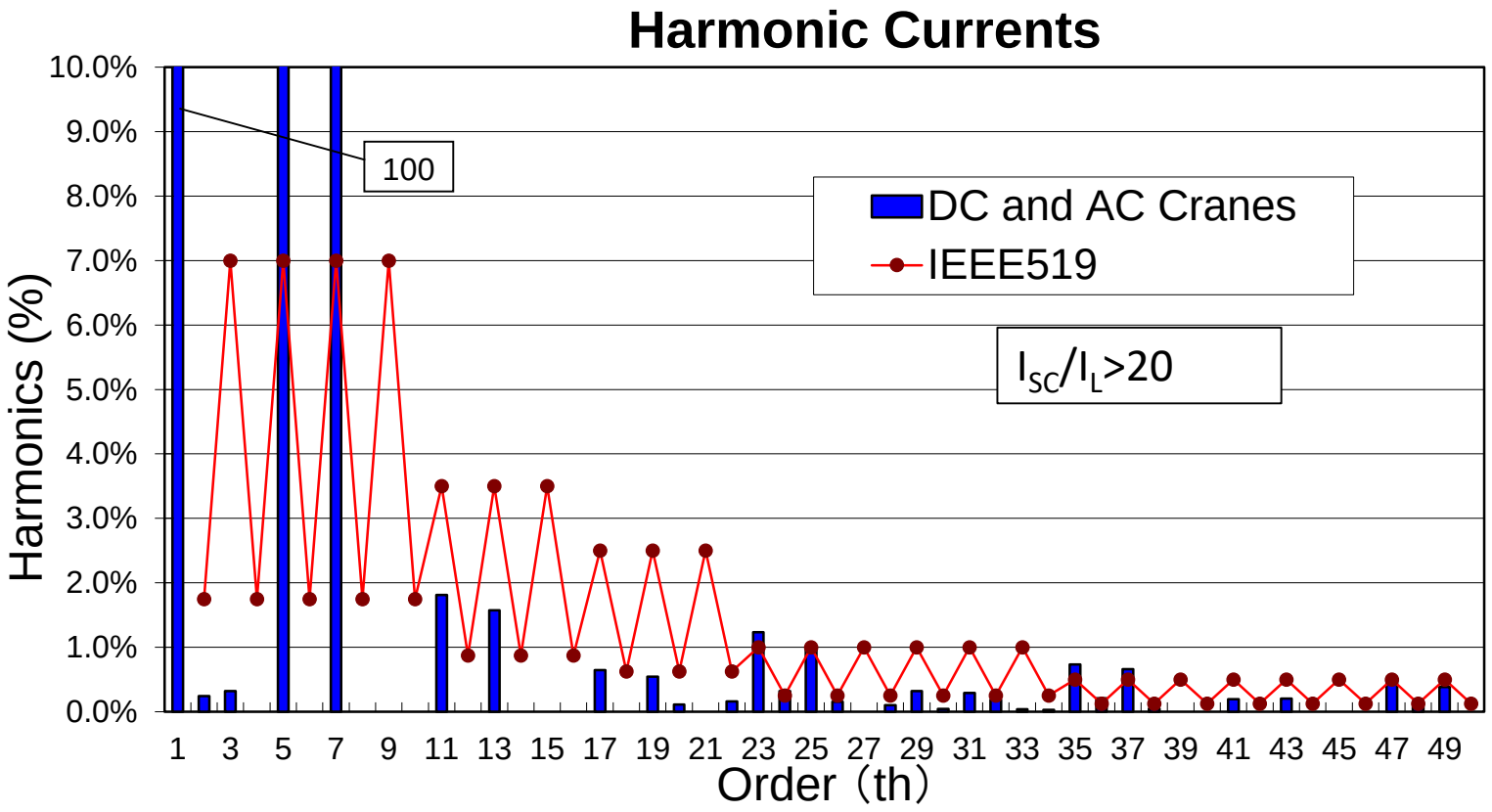
DC Cranes and AC Cranes. Case 2

Case 2: DC cranes without MV Filters.

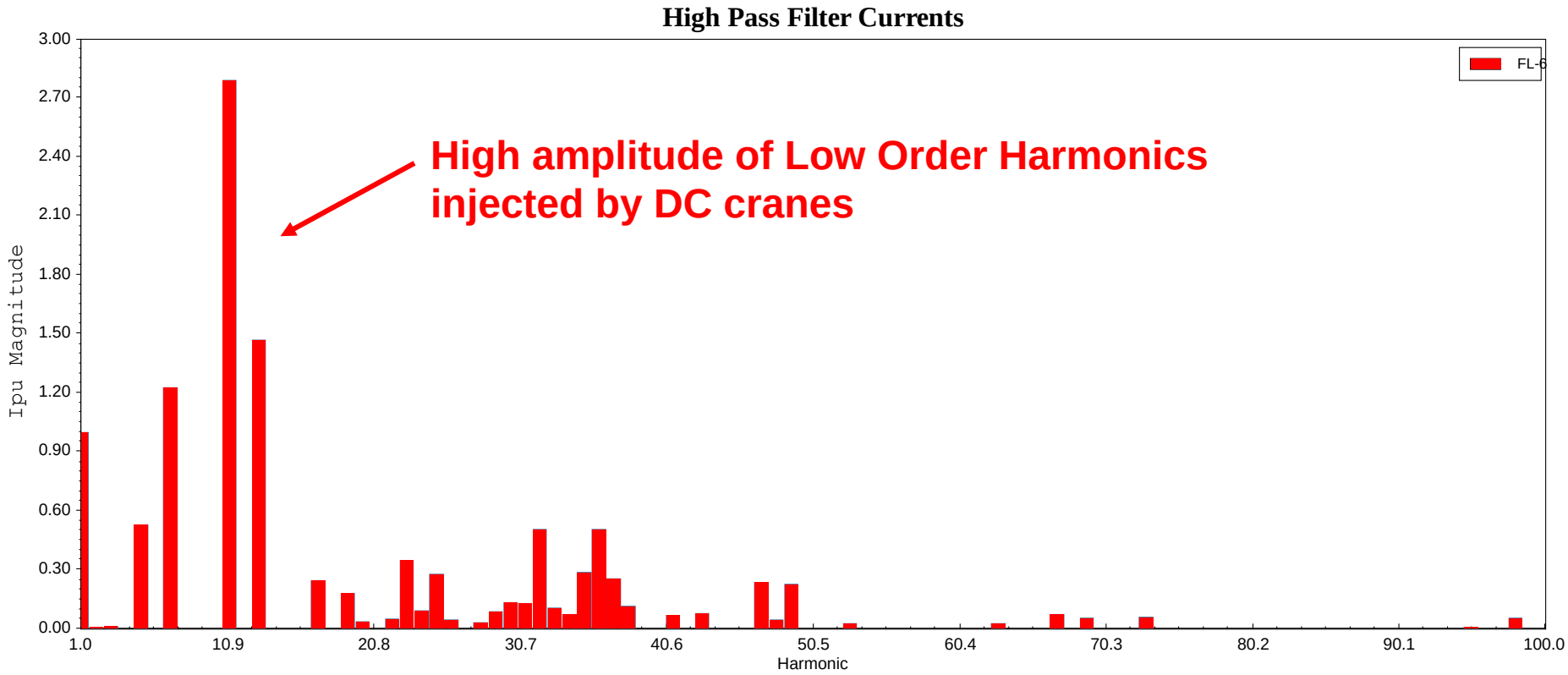


Notch and High Pass filters for DC cranes are disconnected.

Harmonic Spectrum at the PCC



AC Crane, High Pass Filter Currents



Summary

- When DC cranes operate without MV notch and high pass filters, the low frequency harmonics injected by the DC drives exceed the IEEE std 519 limits.
- Some of the low frequency harmonics injected by the DC drives are absorbed by the LV High Pass filters installed in the AC Cranes.
- In this example, the 11^{th} harmonic current on the AC cranes filters is approximately 6 times higher when the DC cranes filters are disconnected.
- Due to high harmonic currents in the AC crane filters, protection devices will trip.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