

Harmonics Standards of the Present and the Future Electricity Networks

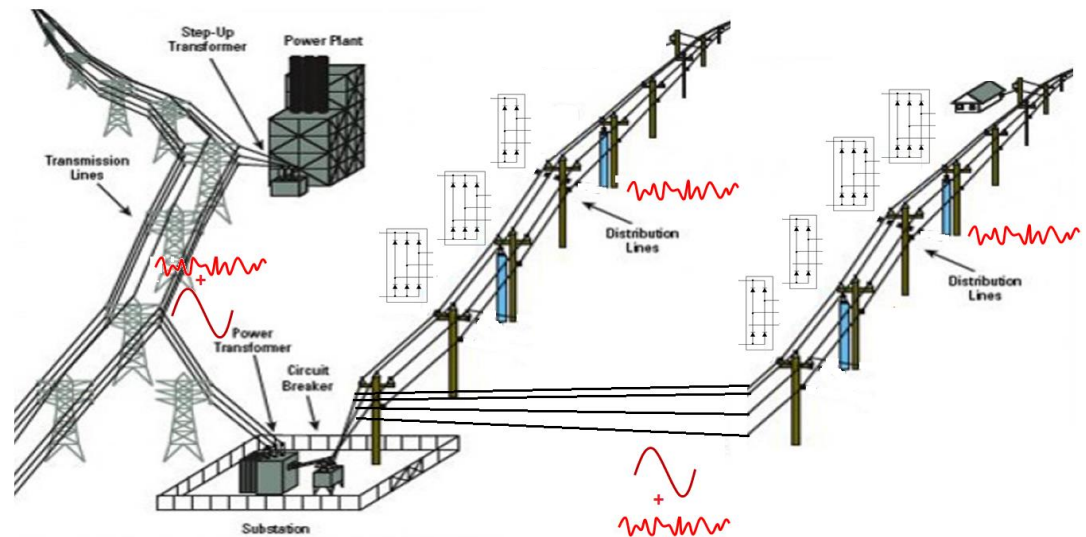
Dr. Firuz Zare
Danfoss Drives A/S
Global Research & Development Centre
Ulsnaes 1, DK-6300 Graasten
Email: fza@danfoss.com

Harmonic Issues in Distribution Networks: **Past**

Most important non-linear loads:

- Single phase rectifiers without PFC circuits
- Three phase rectifiers with passive solutions (DC or AC chokes, LC filters)
 - *Conventional chargers for electronic systems (AC-DC without PFC)*
 - *Lighting systems*
 - *Motor drive systems*
 - *Home appliances*

**Low Order Harmonics
(below 2 kHz)**



Harmonic Issues in Distribution Networks: **Past**

$0 < f < 2\text{kHz}$

IEEE 519
IEC 61000-3-2
IEC 61000-3-12



$150\text{kHz} < f$

CISPR

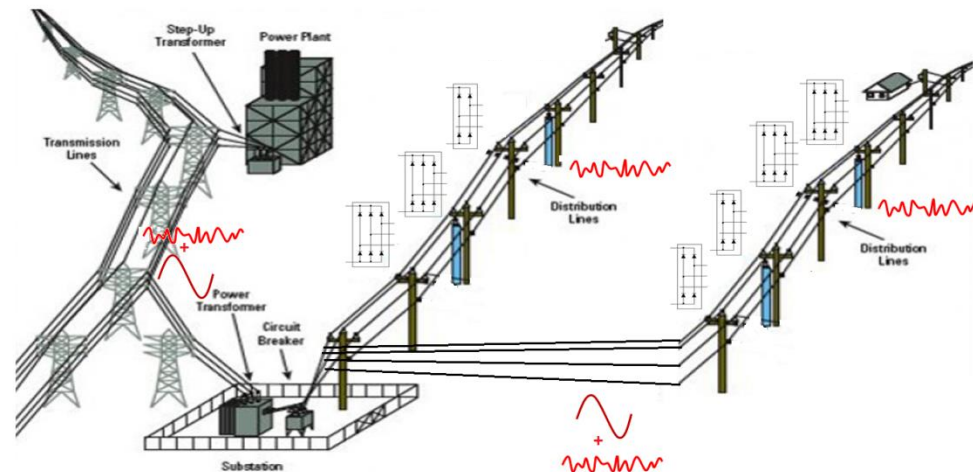


Main focuses were on:

- Harmonics (below 2 kHz)
- Electromagnetic Interferences (**EMI**) (above 150 kHz)

Harmonic Mitigation solutions?

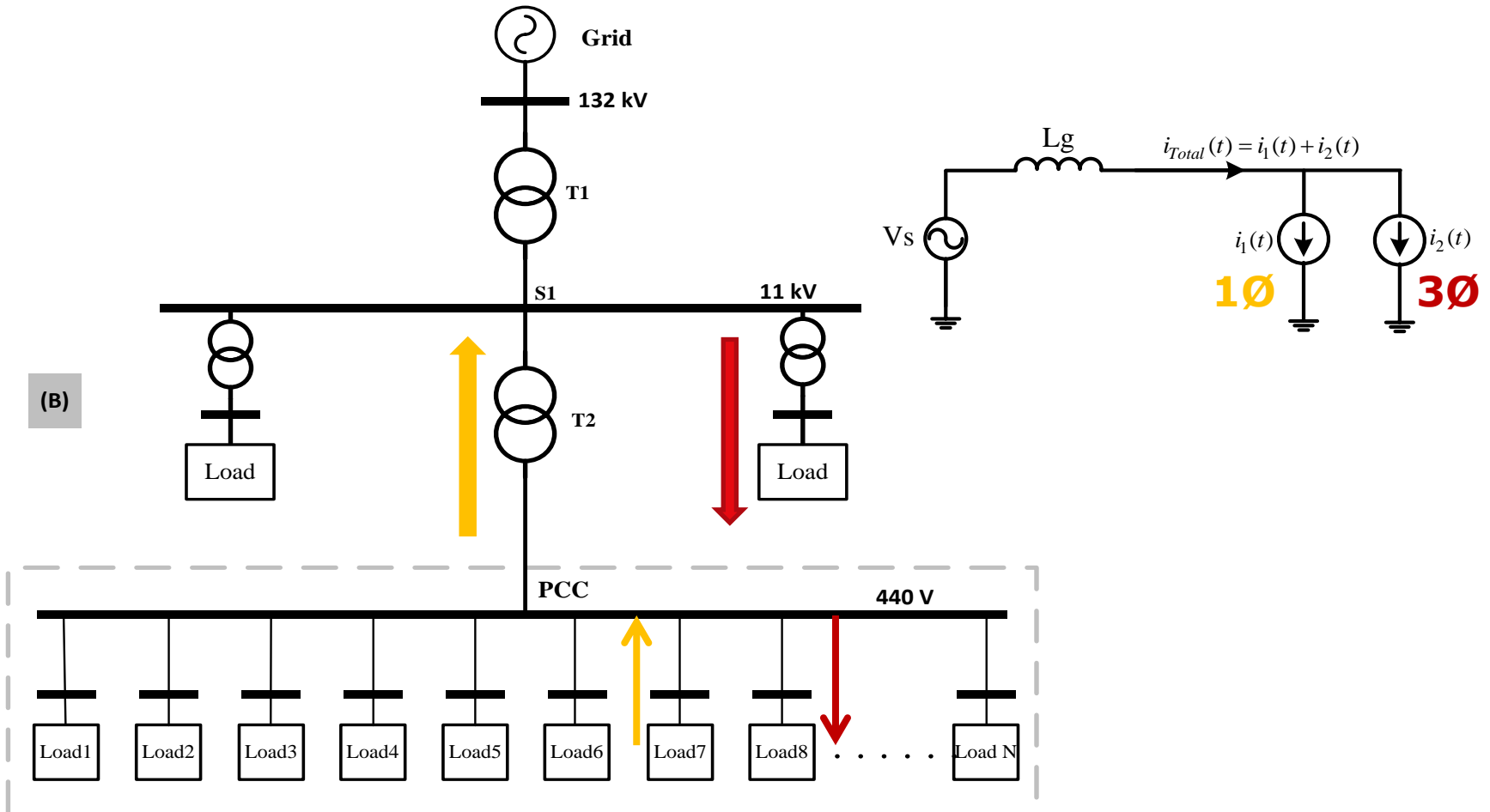
- 1: Regulations and standards
- 2: Active and passive filters both at product and system levels



Harmonic Issues in Distribution Networks: Past

The harmonic cancellation can happen at two different levels:

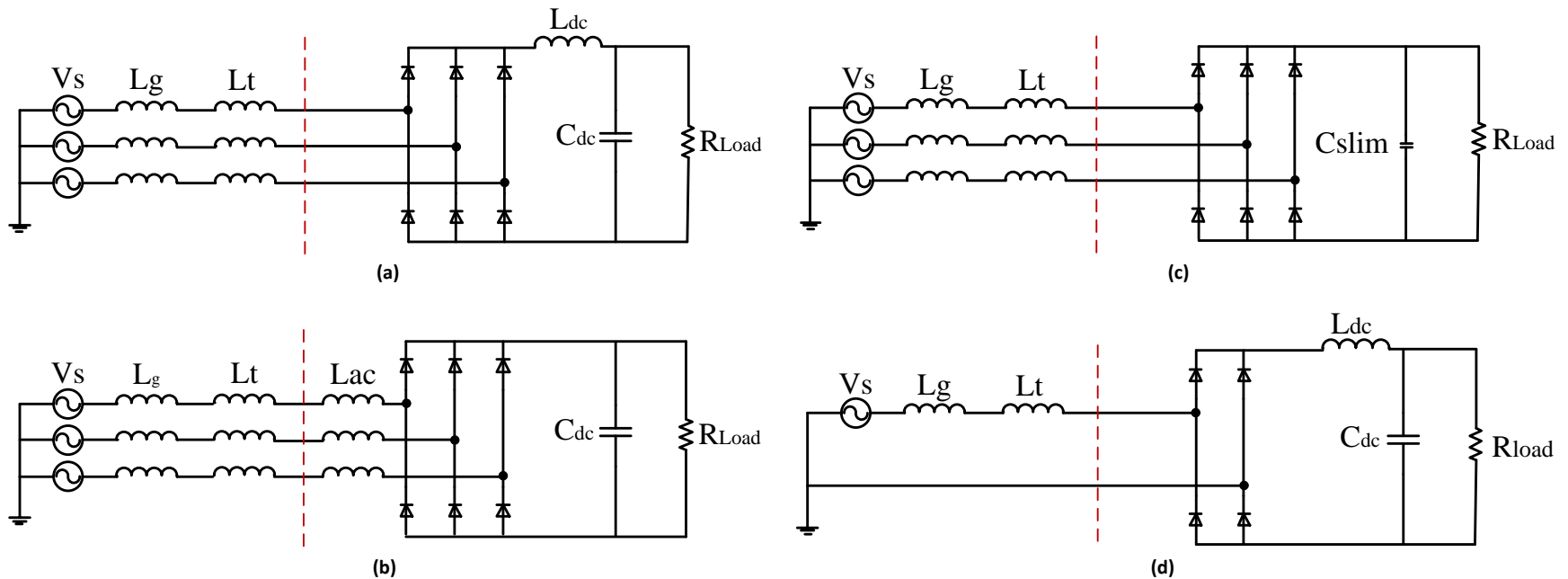
- 1: At low voltage networks between **1Ø** and **3Ø** power converters (non-linear loads)
- 2: At medium voltage networks



Harmonic Issues in Distribution Networks: **Past**

At a product level:

The phase angle differences between the 5th harmonics generated by single phase rectifiers **(without PFC)** and three phase rectifiers (with proper passive filters) can be close 180 degrees and therefore the effective magnitudes of these harmonics at the grid side are reduced.



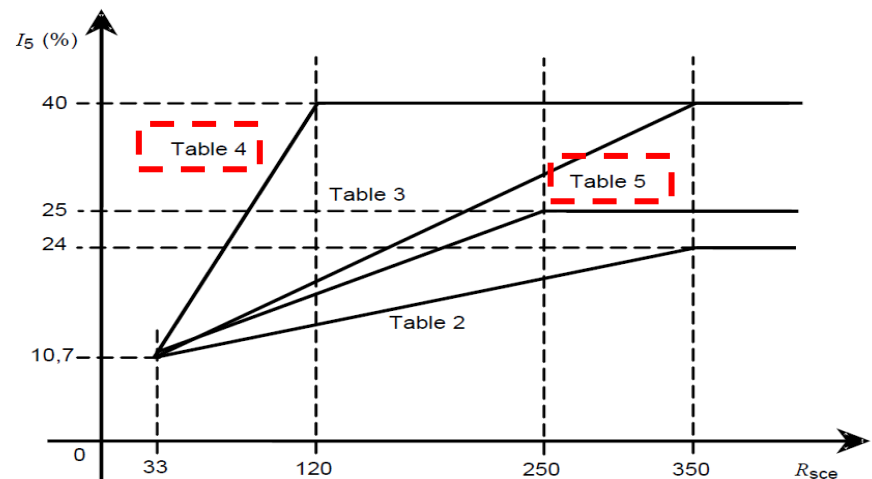
Harmonic Issues in Distribution Networks: **Past**

IEC 61000-3-12 ($16A < I_{load} < 75A$)

Current harmonic levels injected to the grid depend on the line impedance and short circuit ratio.

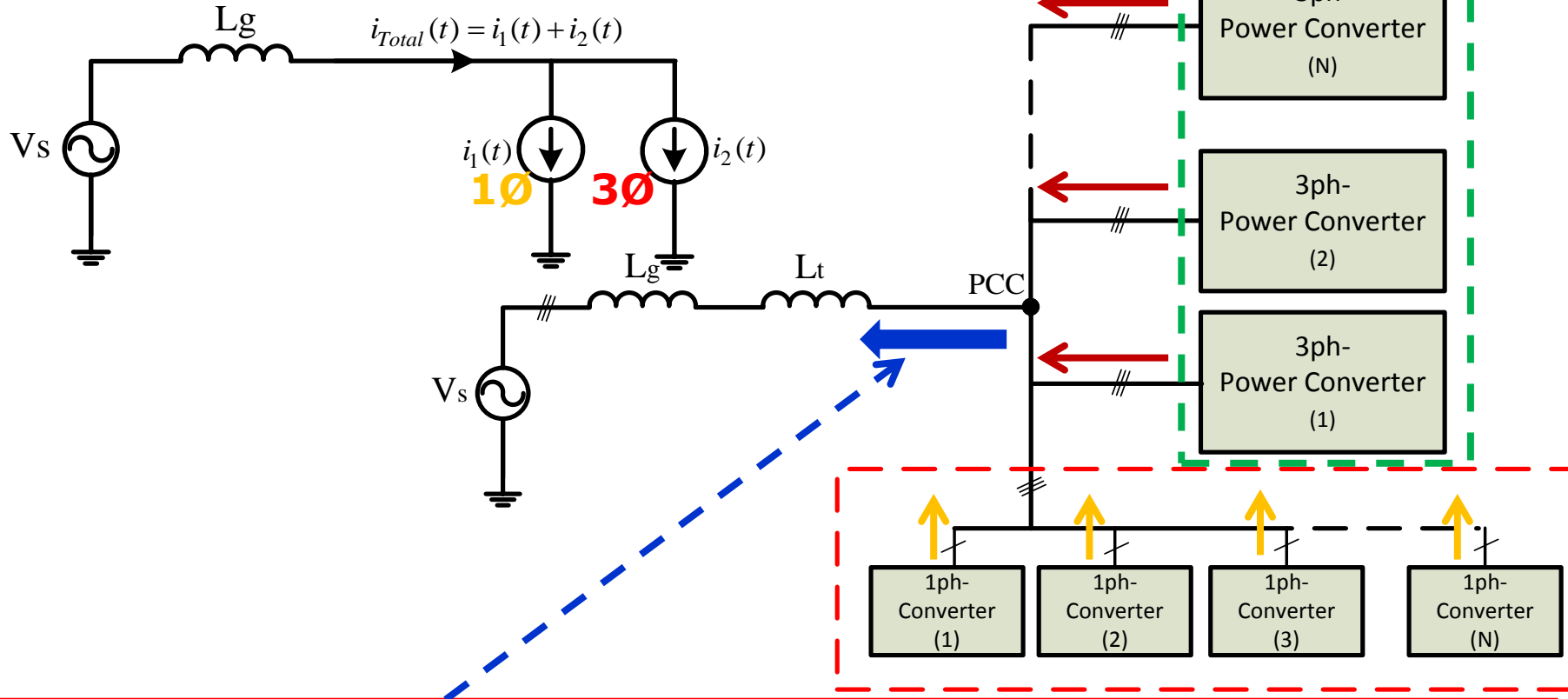
Minimum R_{sce}	Admissible individual harmonic current I_h/I_{ref} ^a %				Admissible harmonic parameters %	
	I_5	I_7	I_{11}	I_{13}	THC / I_{ref}	$PWHC / I_{ref}$
33	10,7	7,2	3,1	2	13	22
≥ 120	40	25	15	10	48	46

Phase angle values of Current Harmonics are important for harmonics cancellation at a system level.



Harmonic Issues in Distribution Networks: Past

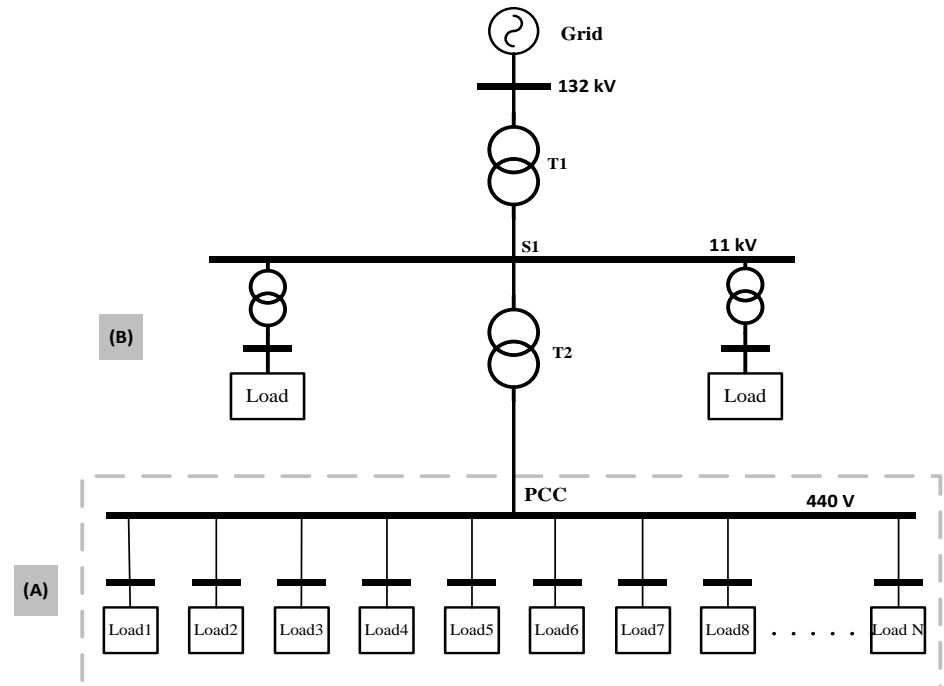
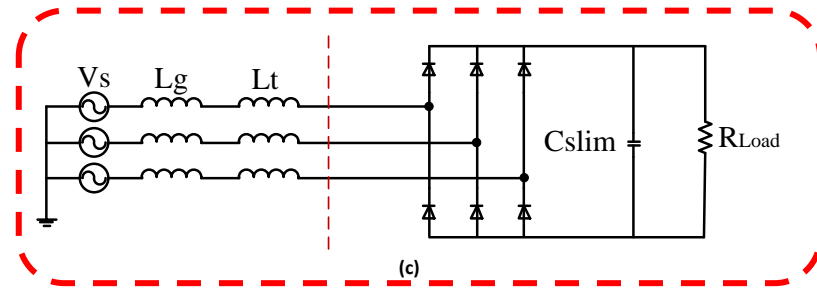
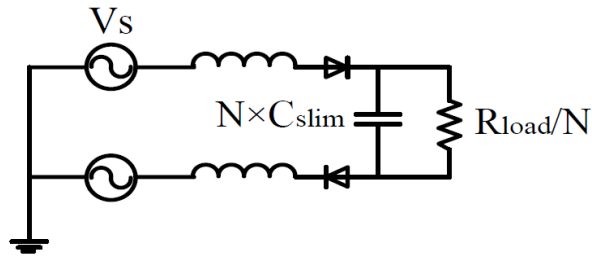
1. What types of loads we have?
2. How many single phase and three phase converters are there?
3. What is the ratio of single phase to three phase (power level)?
4. What is the dominant load configuration?



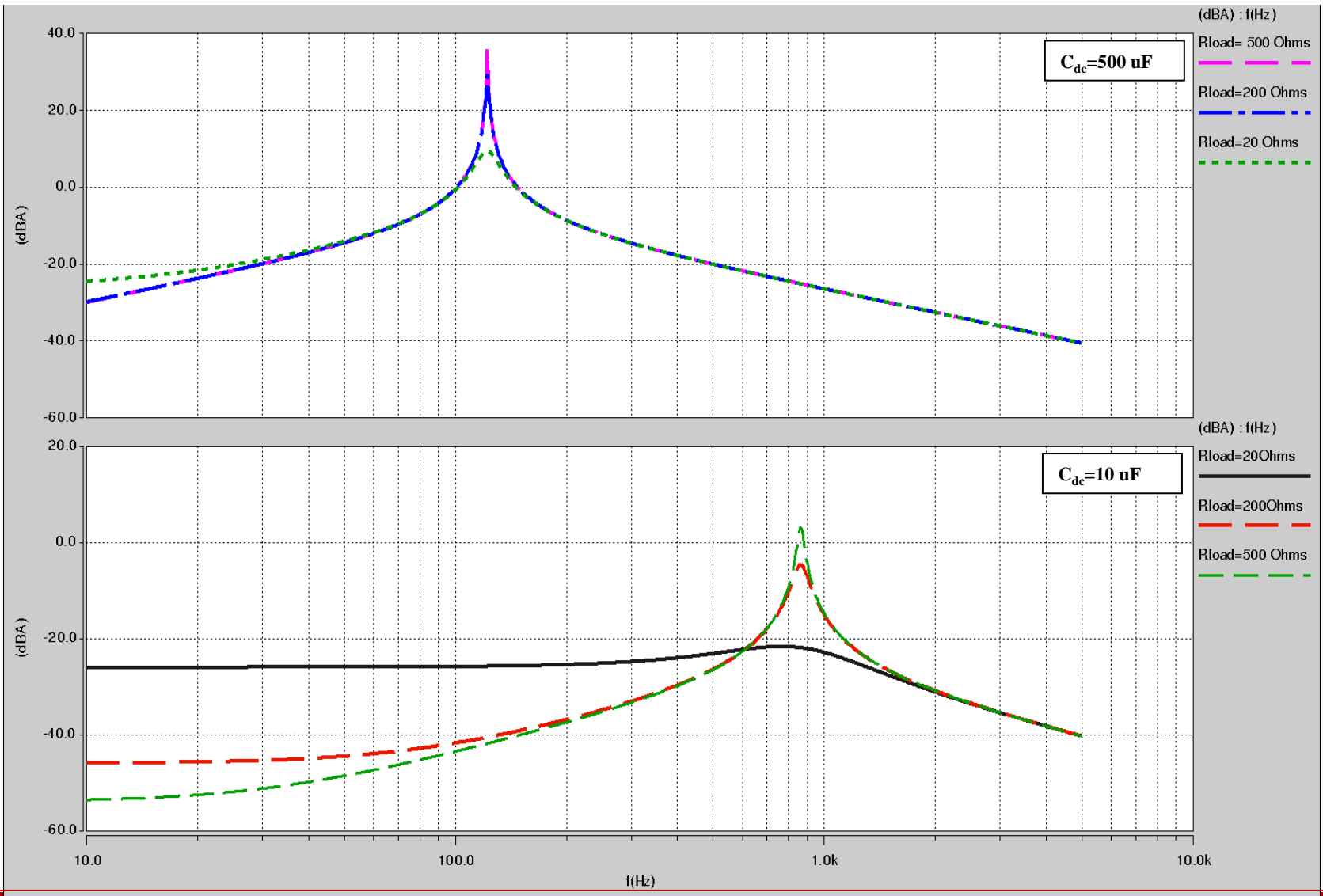
The effective value of the phase angle cannot be interpreted as the phase angle of the single or the three phase converters separately.

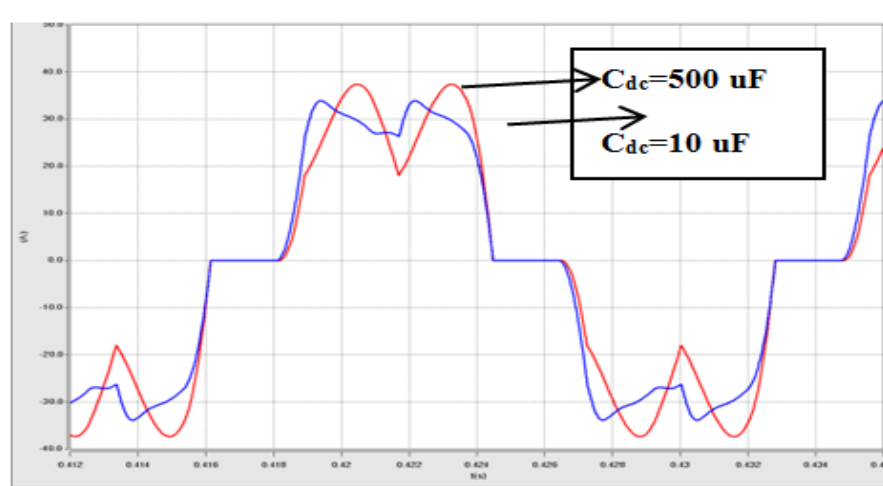
Harmonic Issues in Distribution Networks: **Past-Present**

Harmonics and Power Quality Issues of Three-Phase Diode Rectifiers with a Small DC Link Capacitor at a System Level

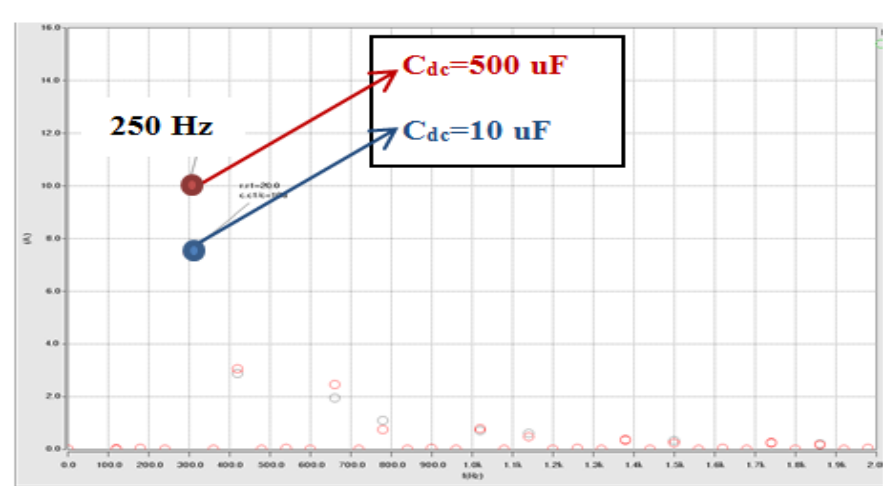


Harmonic Issues in Distribution Networks: Past-Present

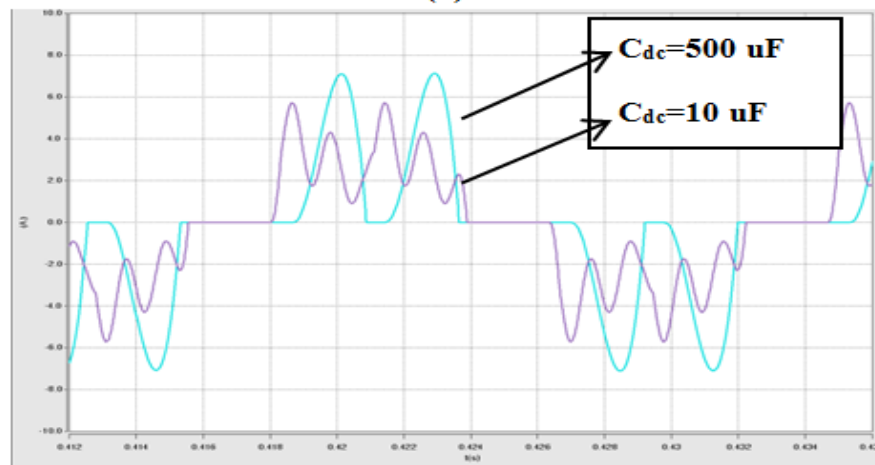




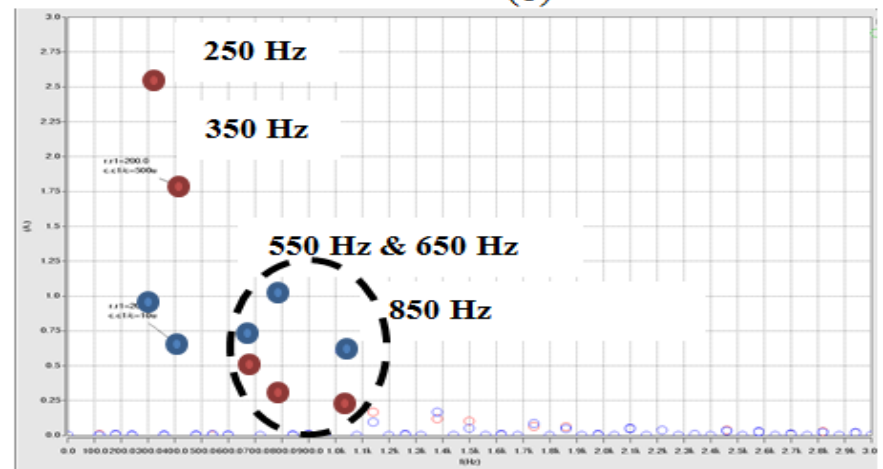
(a)



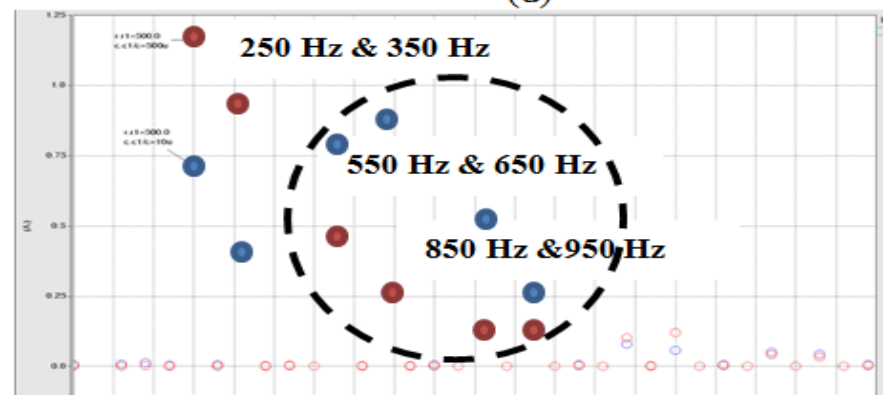
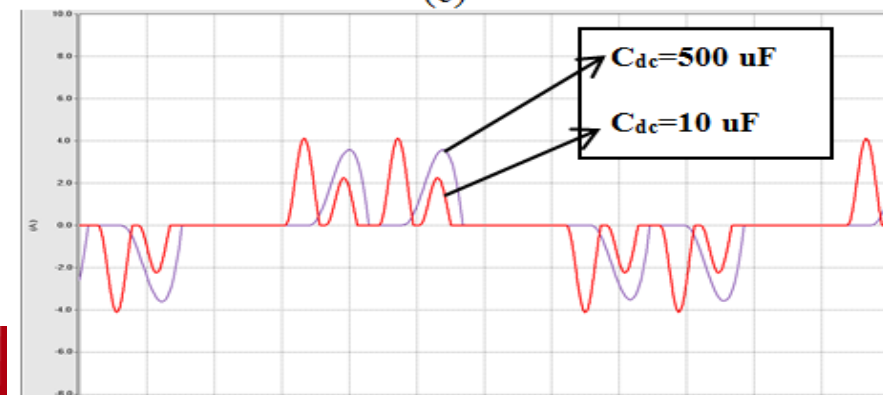
(b)



(c)

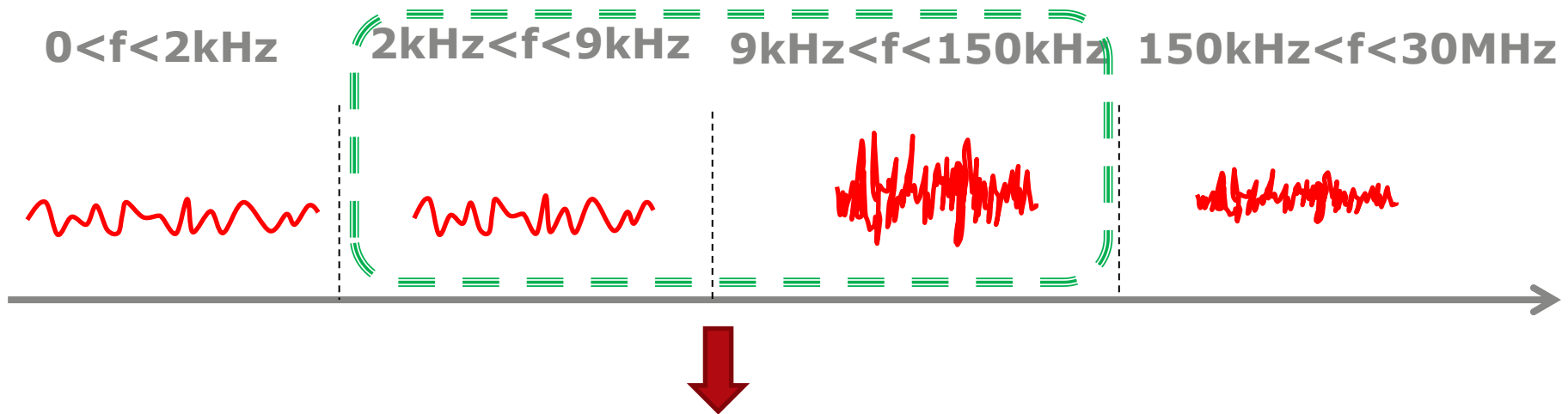


(d)



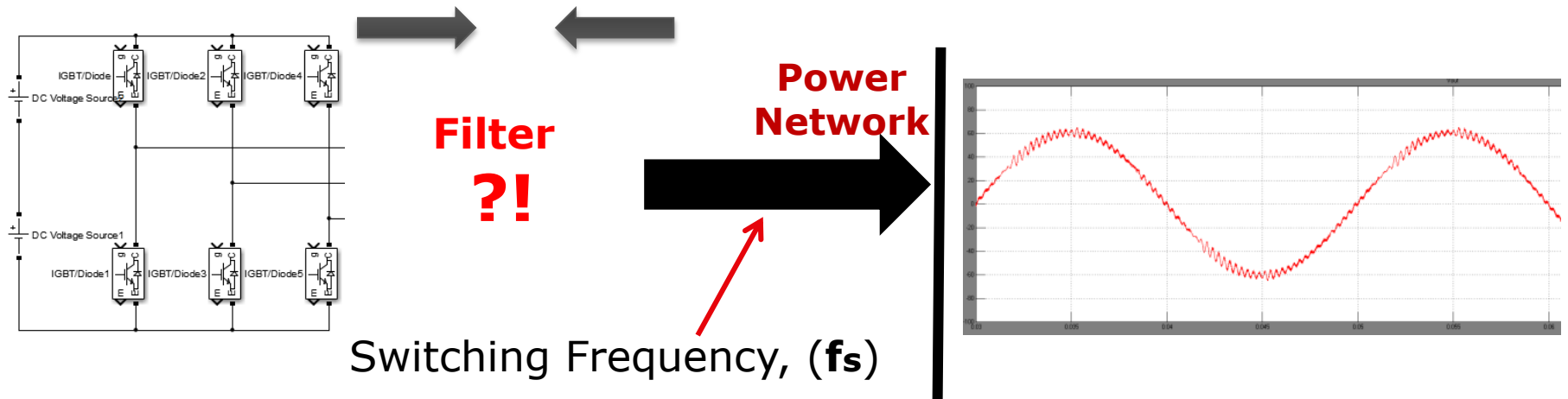
Harmonic Issues in Distribution Networks: **Present**

Harmonics and Interharmonics



- Active Front End converters for solar inverters and electric cars (*switching frequency ?!*)
- Increasing the penetration of single phase converters with PFC (*switching frequency ?!*)
- Compact Fluorescent Lamps (*switching frequency ?!*)
-

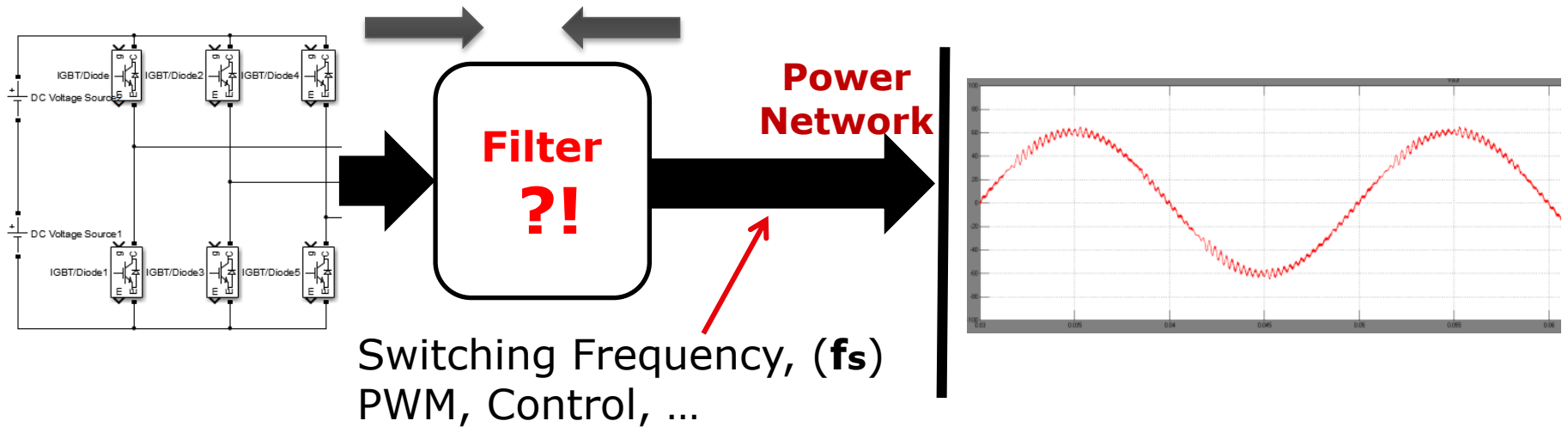
Harmonic Issues in Distribution Networks: Present



IEC technical Committee 77A, WG1, TF11: "Active Infeed Converters for Dispersed Generators"

- 1: Develop a new standard for the harmonic emission below 2 kHz.
- 2: The voltage harmonics within an existing network should not be affected by high penetration of dispersed generators.
- 3: Harmonic emission limits are very low for high order harmonics (different than IEC61000-3-2 or IEC61000-3-12)

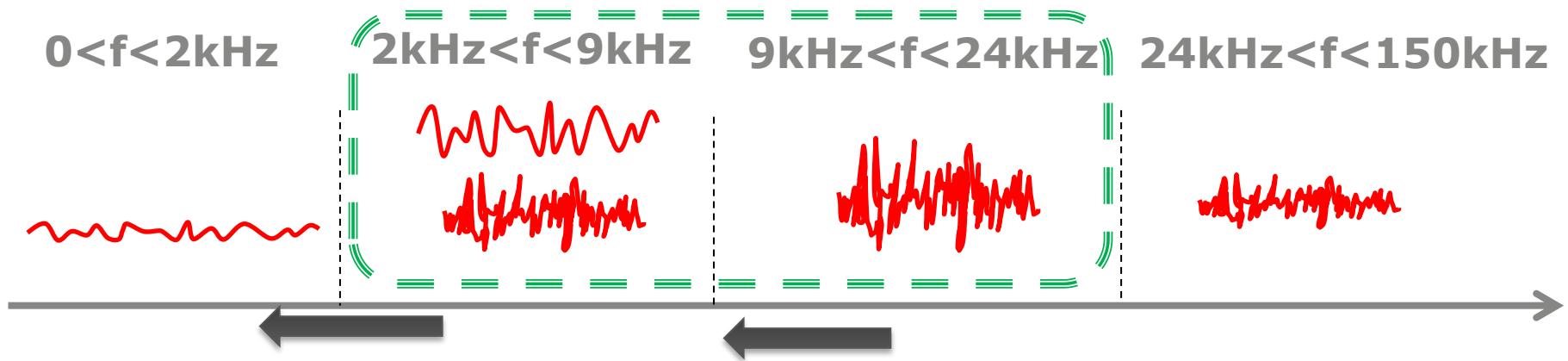
Harmonic Issues in Distribution Networks: Present Future



We need to consider two important effects:

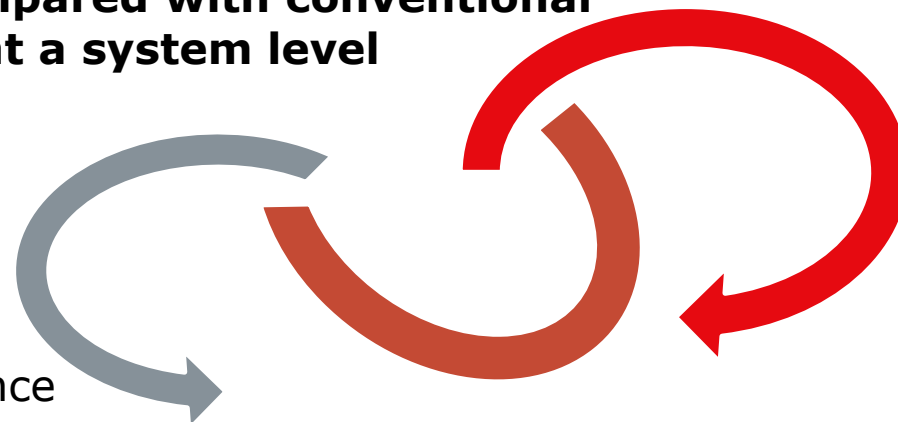
- *At a grid side when multi AFEs are connected to the grid*
- *At the converter side with respect to different grid types and emission levels*

Harmonic Issues in Distribution Networks: Present Future



AFEs cannot be compared with conventional rectifiers at a system level

AFEs:
Switching frequency
Filter characteristic
Modulation strategy
Control system
...



Low frequency resonance
(changing the line
impedance characteristics)

Thanks & Questions?



**ENGINEERING
TOMORROW**