



ABB HVAC WEBINARS

# Power quality in buildings

How ABB's solutions can help you to improve the power quality

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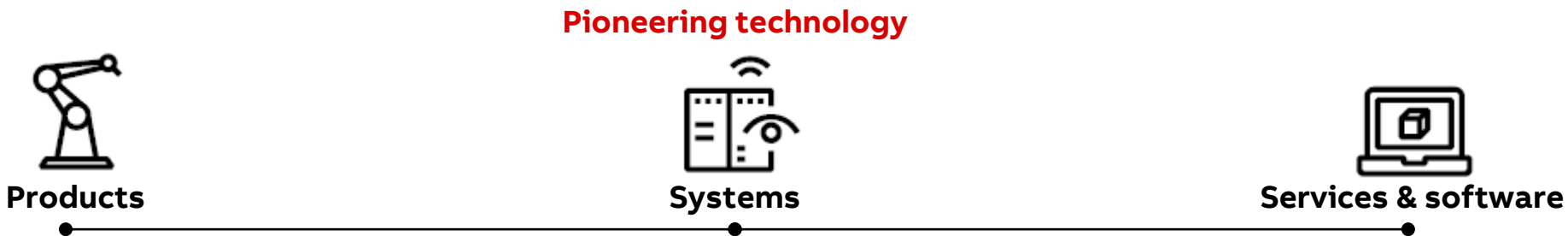


# ABB at a glance

## Facts and figures

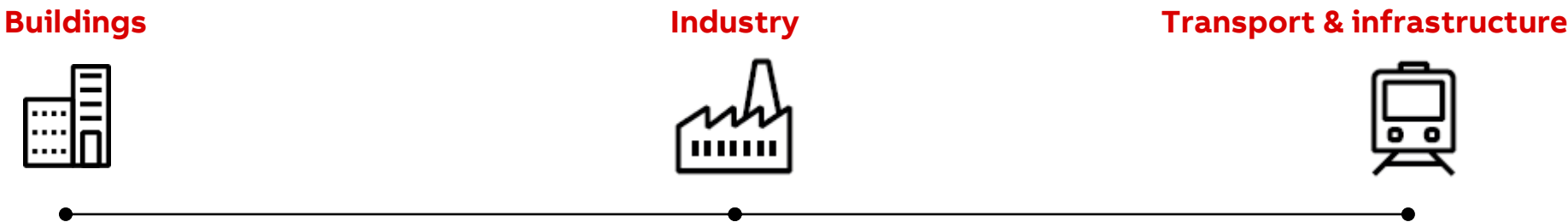
### What

Offering



### For whom

Customers



### Where

Geographies



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# Agenda

- Power quality aspects in buildings
- Power line harmonics
- Why do we care?
- Different ways to mitigate harmonics
- Harmonic standards and recommendations
- ABBs ultra-low harmonic drive for HVACR applications



# Power quality in a building

What aspects affect it

# Power quality in buildings

What is it?

Everything what makes the voltage and/or frequency deviate from the nominal conditions affects power quality.

- Voltage sags, voltage transients, notching, over- and undervoltage, power line harmonics, low power factor.

Common way to mitigate these problems is to overdimension equipment or add external components to protect the sensitive devices.

Could there be a better way?

In this presentation, we'll focus on the problems caused by the power line harmonics and low power factor.



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# Power line harmonics

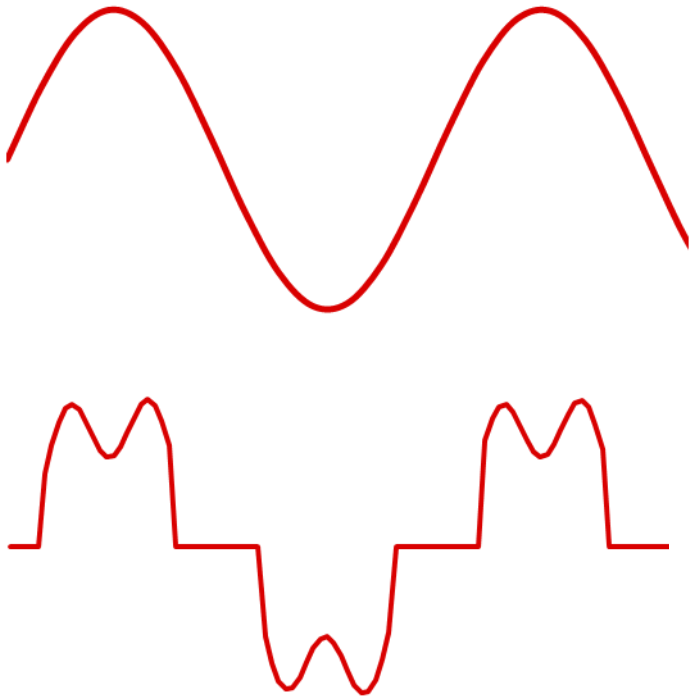
What are they and where they come from



# What are power line harmonics?

The effect they bring

## Ideal vs. distorted current waveforms



## Pure sinusoidal voltage

The **ideal supply network** voltage and current waveforms should be sinusoidal.

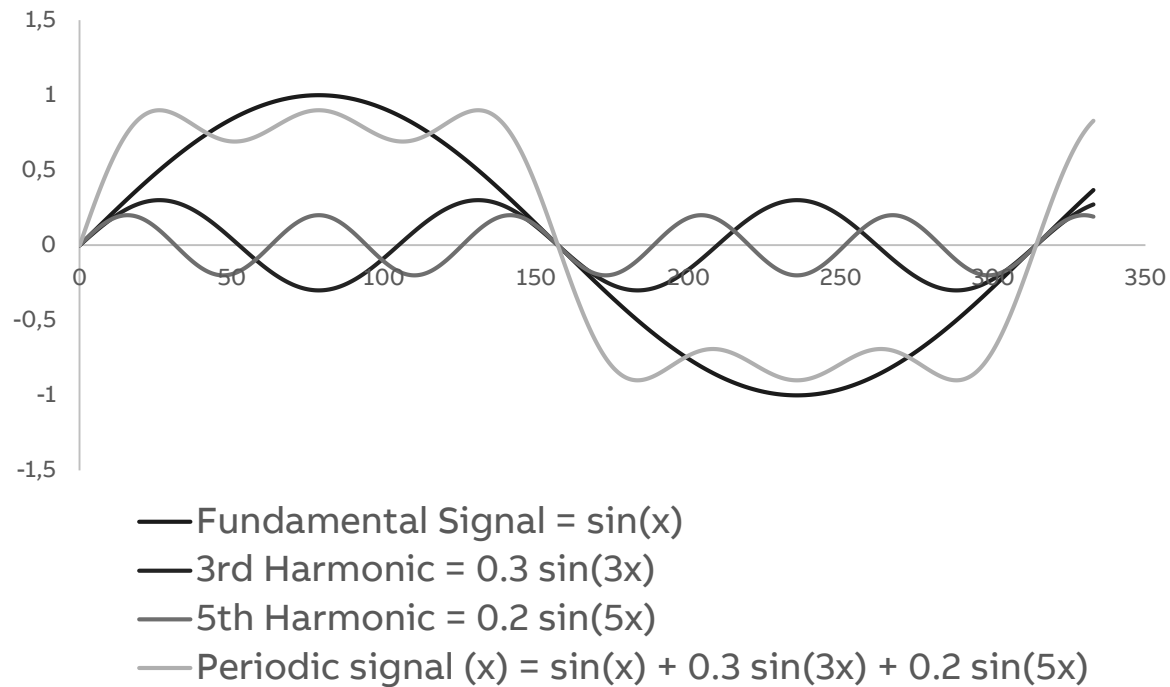
In reality, a range of power quality issues exists: e.g. dips, transients, voltage and frequency fluctuations etc.

## The effect of harmonics

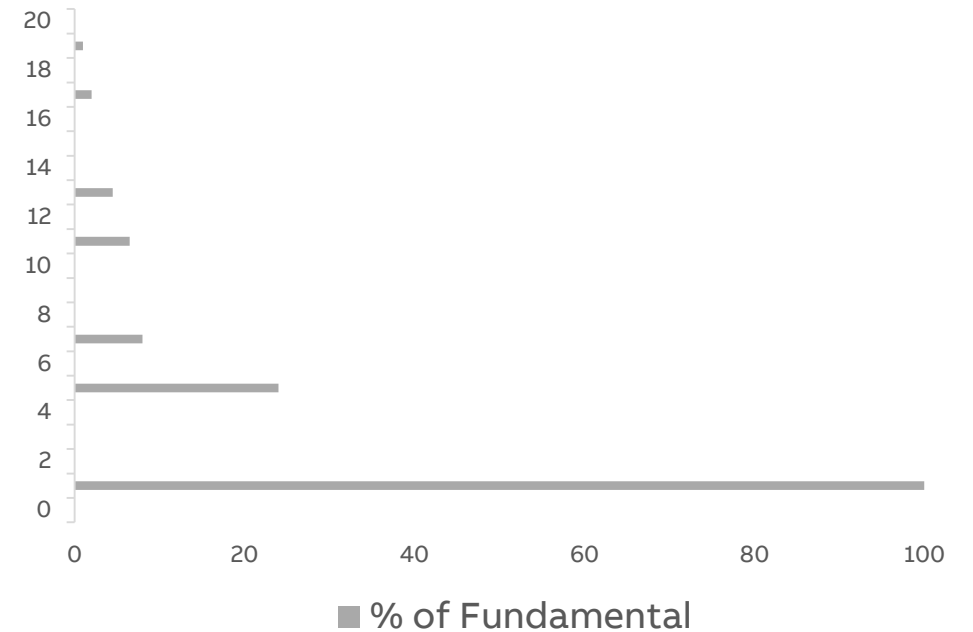
When a repetitive and predictable **non-sinusoidal** voltage or current distortion exists, this means the supply contains **harmonic distortion**.

# What are power line harmonics?

Example of distorted current



Representation of a spectrum analysis



All continuous periodic signals can be represented as a sum of sinusoidal components



# Power line harmonic causes

What is the source

## Non-linear loads in buildings

- In all buildings there are many loads that are susceptible to harmonics and that generate harmonics.
- Variable speed drives controlling motors of fans, pumps and compressors also produce harmonics.
- VSD harmonic performance must be considered as VSD load can be significant compared to total electrical load of the building.





# Power line harmonics

Why do we care?

# Power line harmonics

## Why to care

### Electronics sensitive to noise



- Medical equipment
- Airport navigation aids
- Security systems
- Communication equipment
- Laboratory equipment

### Interference in electronics having carrier signals



- Lighting systems
- Power meters

### Risk for emergency power systems

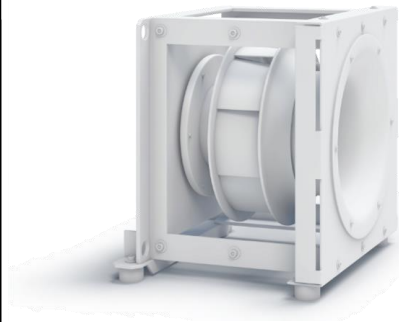


- Generators

# Power line harmonics

## Why to care

- Harmonic currents increase the total line current causing increase in cable and fuse sizes.
- “Extra current” is not active current – it is reactive current.
- Power plant has to deliver and invoice also the reactive current.
- EC motor current drawn from the network is about 25-40% higher than the load is.
- Reactive current lowers the total power factor.
- Many electrical utilities charge for the reactive current or low power factor.



### 6-pulse drive or typical EC motor

- true power factor ca. **0.78**
- line current ca. **128%**



### 6-pulse drive with a DC choke

- true power factor ca. **0.93**
- line current ca. **108%**



### AFE drive with DC bus caps

- true power factor ca. **1.0**
- line current ca. **100%**

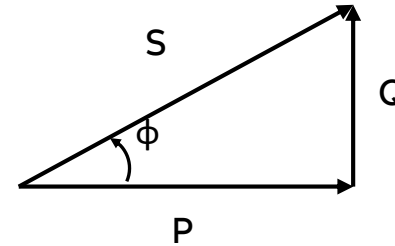
# Power line harmonics

## Effect on power factor

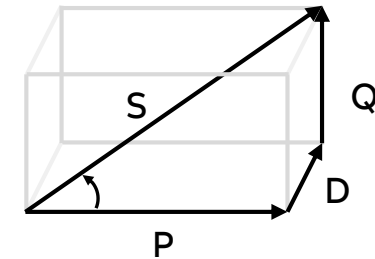
### Power factor (true, displacement, nominal, ..?)

$$PF_{\text{true}} = PF_{\text{displacement}} \times PF_{\text{distortion}} = \frac{P}{S} \times \frac{1}{\sqrt{1 + (THD^2)}}$$

- Reactive power  $Q$  affects  $PF_{\text{displacement}}$ . Inductive loads like motors consume reactive power.
- Harmonic reactive power or distortion reactive power  $D$  affects  $PF_{\text{distortion}}$ . Non-linear loads consume distortion reactive power.
- Both  $PF_{\text{displacement}}$  and  $PF_{\text{distortion}}$  have an effect on  $PF_{\text{true}}$ , which is the power factor that should be considered.
- When talking about power factors, it is important to understand, if one is  $PF_{\text{true}}$ ,  $PF_{\text{displacement}}$  or  $PF_{\text{distortion}}$ .



Linear resistive (P) and linear inductive (Q) loads present



Linear resistive (P), linear inductive (Q) and non-linear (D) loads present

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# Ways to mitigate harmonics

Comparing different solutions

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# Harmonics – what can I do?

## Mitigation techniques

### Basic mitigation techniques

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Reduction/abatement of particular harmonics at source or supply point

1. Reduction – correctly sized inductance (reactors, chokes)
2. Diversion – passive filters
3. Cancellation – 12/18/24 pulse rectifiers with special transformers or active harmonic filters
4. Managing – active rectifier (ultra-low harmonic drives)

### Less desirable solutions

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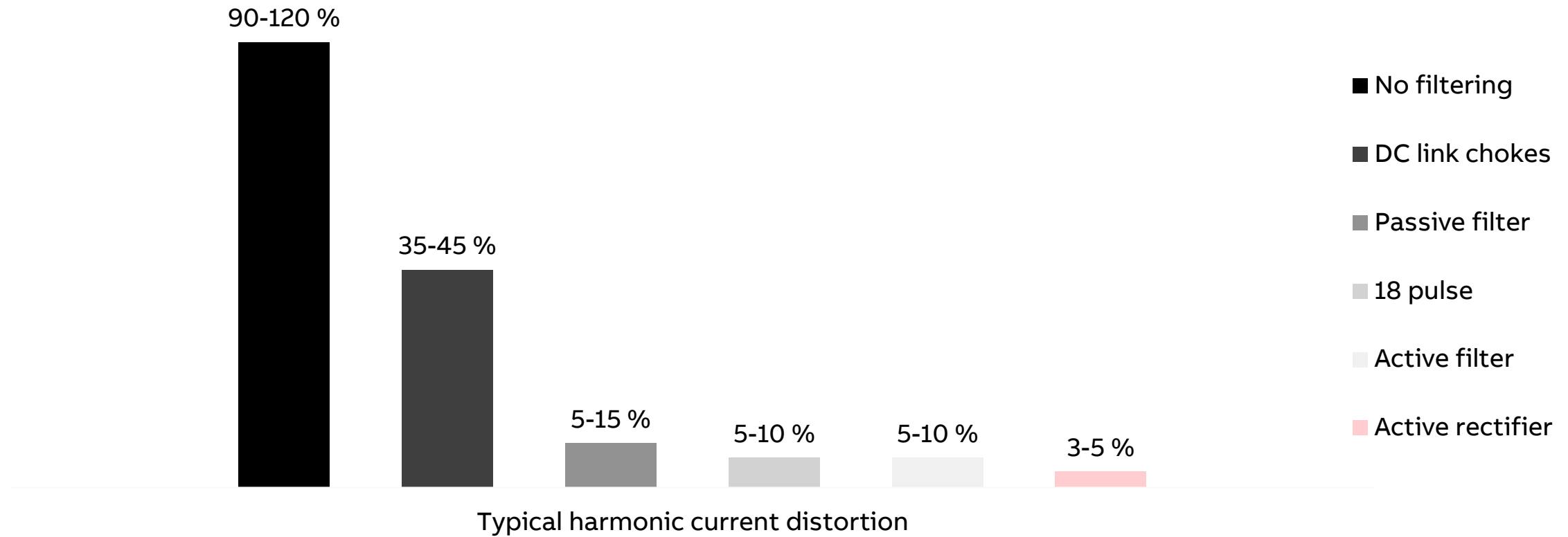
5. Low capacitive VFDs with no impedance (i.e undersized DC bus caps) – low current distortion, but higher voltage distortion
6. Matrix style VFD with no DC bus capacitors – unable to achieve full voltage to the motor

Both solutions provide some help with lower frequency current harmonics but with quite a big penalty with robustness, power loss capabilities and/or motor control capabilities.



# Methods of harmonic mitigation

Typical harmonic current distortion



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# Ways to mitigate harmonics

## Pros and cons

### AC line reactor/DC choke

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#### Pros

- Usually built-in the drive but also available as external option
- Reduces harmonics significantly but also protects the drive for voltage transients from the power line

#### Cons

- In some cases harmonic reduction is not enough
- Voltage drop over the AC line reactor, 5% line reactor causes 2.5% voltage drop

### Passive filter

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#### Pros

- Reduces harmonics efficiently on nominal conditions
- Can be retrofitted on to existing system

#### Cons

- External component that requires a separate panel to achieve proper IP class
- Need of disconnection of capacitors on partial loads, otherwise causes a leading power factor
- Risk of resonances if multiple filters in the same network
- Potential voltage drop over the passive filter

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# Ways to mitigate harmonics

## Pros and cons

### Active filter

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#### Pros

- Reduces harmonic current to 5% at PCC, also maintains good PF in the system
- Partial load performance is very good also on partial loads
- Can be retrofitted to existing system and can be used with multiple non-linear loads

#### Cons

- Large size and cost
- Requires external sensors to function
- In case of only one filter is installed, failure might cause overloading of the transformer

### Multi-pulse rectifier

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#### Pros

- 18-pulse and higher can significantly reduce harmonics
- Traditional way to reduce harmonics

#### Cons

- Large size and cost
- Requires special transformer
- Generates heat – means losses
- Existing line imbalance, transformer winding imbalance and/or excising harmonics reduce it's harmonic performance
- Can't be easily retrofitted in to existing system or even in an existing building

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## Ways to mitigate harmonics

Pros and cons

### Drive with active rectifier (active front end) and DC bus capacitors

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#### Pros

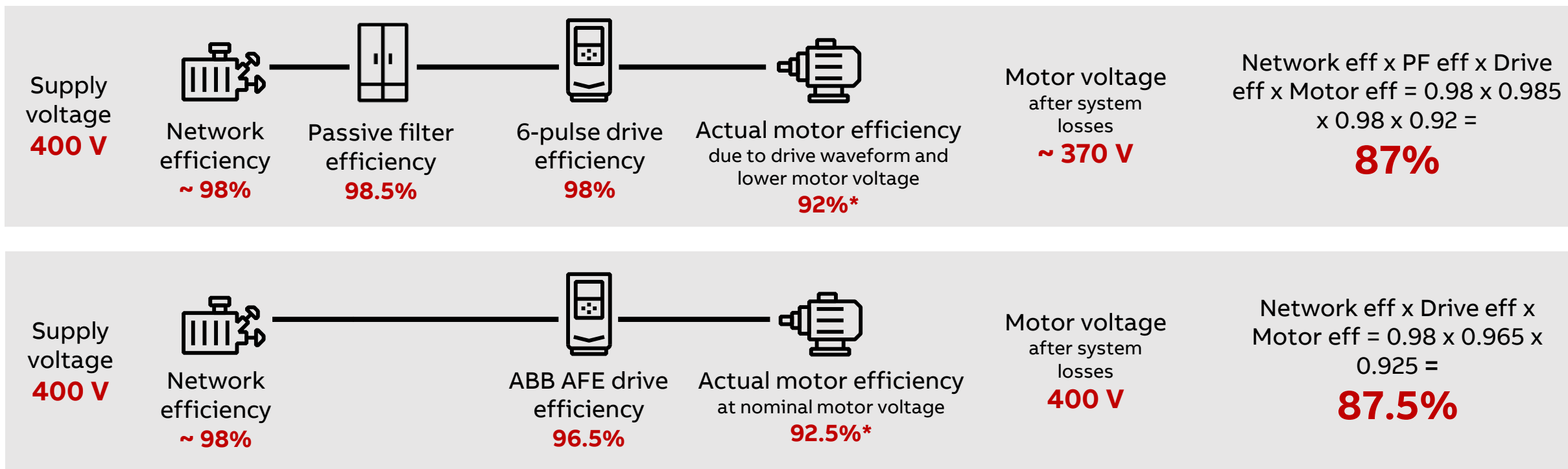
- Solution built in the drive
- Based on active supply unit and line filter
- Simple cabling
- Unity power factor
- Allows boosting up the DC (thus motor) voltage
- Typical full load THD (current) at drive input terminals below 5%, even less than 3%

#### Cons

- Slightly higher losses on the individual equipment level (minor impact on the system level)
- If designed poorly, active supply switching might cause higher frequency interference on the supply

# Ways to mitigate harmonics

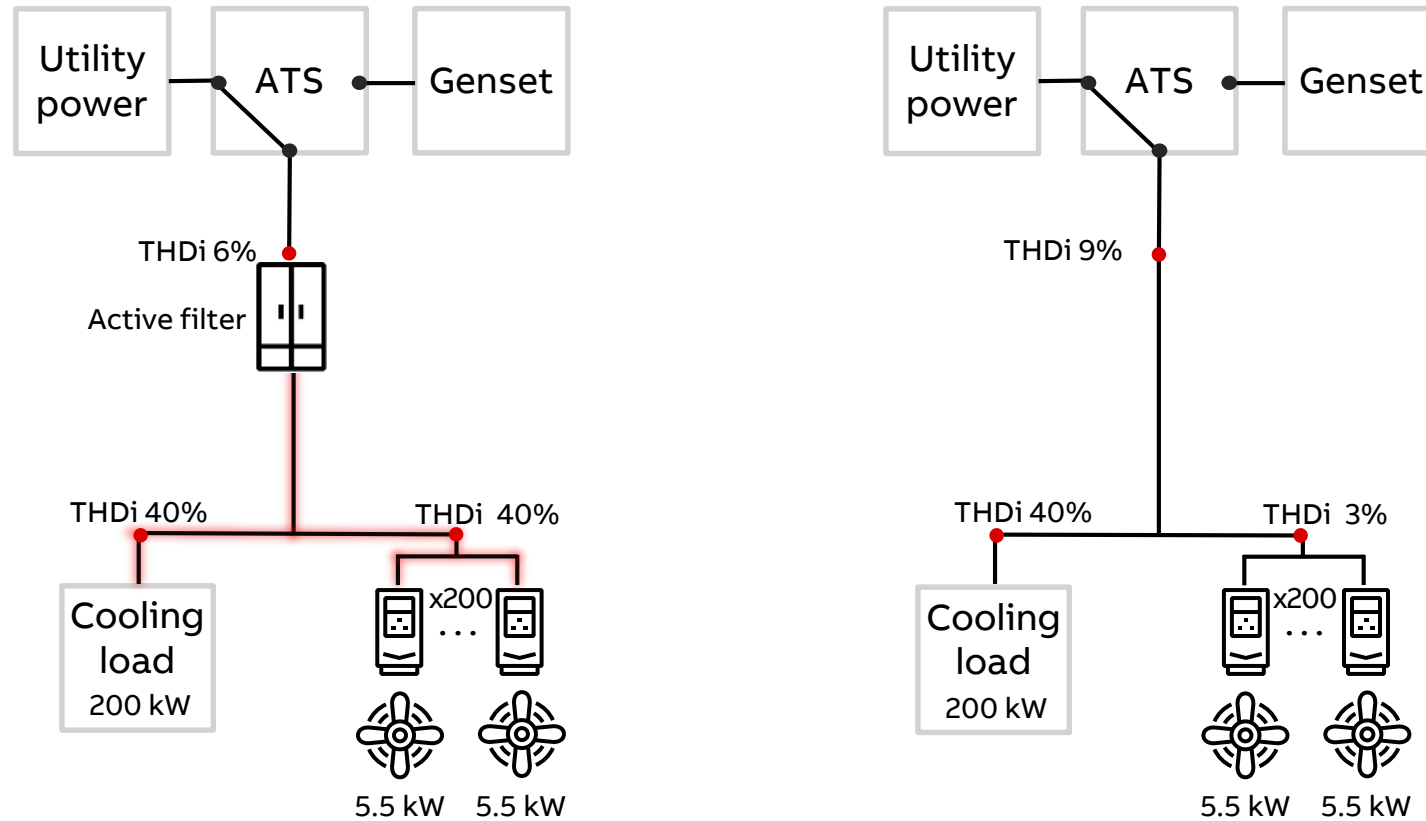
System efficiency over component efficiency



**Note:** Standard drive has higher efficiency than AFE, but the efficiency drop in the passive or active filter and the lower motor voltage make the system efficiency lower meaning higher operating costs.

# Ways to mitigate harmonics

## Centralized vs decentralized harmonics mitigation



- AFE drives is a decentralized harmonics mitigation solution solving the root cause issue
- Benefits of the decentralized harmonics management:
  - no overdimensioned cables and network components
  - no disruption in power network operation due to harmonics
  - no energy losses over the power network length including cables and network equipment
  - no risk of system overload in case of centralized active filter failure



# Harmonic standards and recommendations

Guidelines to follow



# Power line harmonics

## Main drivers for low-harmonic solutions

### End user's own needs

- 1 Weak network due to locations
  - Remote locations or old buildings with weak supply

### Authority regulations

- 2 Specified recommendations like IEEE519 and G5/4 in utility projects, standards like 61000-3-12
  - Adding anything might push over the limit

### Utility pricing scheme

- 3 Penalties
  - Excess harmonics might trigger e.g. 10 k€ extra fee every month!

### Consultant / supplier specification

- 4 12/18/24 pulse multi-pulse solution required
  - Consultant may require a multi-pulse – it is better to provide low harmonics

The need for low harmonic solutions comes from multiple directions

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# ABB ultra-low harmonic drives for HVAC

Product highlights and benefits

# Selecting a drive technology for buildings

Benefiting from ABB active front end ultra-low harmonic drives



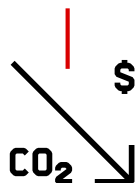
**ACH580 ultra-low harmonic drives**



**No need to oversize power network equipment to avoid overheating and downtime**



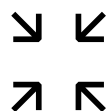
**Continuously clean and disturbance-free network for your critical applications**



**Effective use of energy both in HVAC and power network, no extra cost on the energy bill or utility penalties**



**Normal operation even in fluctuating network with no unexpected interruptions or downtime**



**The most compact solution in its class on the drives' market, with all components built-in**

# Selecting a drive technology for buildings

Benefiting from ABB active front end ultra-low harmonic drives

## Distribution transformer

6-pulse drives need transformer oversize by 1.35 x motor kVA. With AFE drives, the factor is 1.1.

**20%** cost  
down with AFE

## Cabling

Oversizing depends on the harmonics content in the grid.

TDD	Oversize
10%	1.00
50%	1.12
70%	1.22

**10%** cost  
down with AFE

## Generator

Generator supplying 6-pulse drives to be derated by 40-50%. Avoided if using AFE drives.

**50%** cost  
down with AFE

# ACH580-31 ultra-low harmonic drives for HVAC

Wall-mounted offering

## Power range and voltage range:

- 4kW to 110kW
  - 380 – 480 V
  - IP21/IP55; UL Type 1/UL Type 12 enclosures
  - 3 frame sizes
- 
- 6 DI, 2AI/2AO, 3RO, STO, +24V supply for the control unit, BACnet MS/TP or Modbus RTU built-in.
  - Two option slots to support wider range of I/Os and fieldbuses.
  - Hand-Off-Auto control logic on the panel, additional Bluetooth option for the control panel. DriveTune app development is made in-house at ABB.



# ACH580-34 ultra-low harmonic drives for HVAC

Module offering

## Power range and voltage range:

- 132 kW to 355 kW
- 380 – 480 V
- IP00 and IP20 enclosures
- Frame R11
- 6 DI, 2AI/2AO, 3RO, STO, +24V supply for the control unit, BACnet MS/TP or Modbus RTU built-in.
- Two option slots to support wider range of I/Os and fieldbuses.
- Hand-Off-Auto control logic on the panel, additional Bluetooth option for the control panel. DriveTune app development is made in-house at ABB.



R11  
132 – 355 kW



# Summary



# Power quality in buildings

## Summary



Excess harmonics in the power network cost money over the lifetime of the building.



There are multiple ways to manage harmonics, but some might cause problems, especially at part load operation, which is the case in HVAC applications.



Decentralized harmonics mitigation gives benefits also inside the building's network compared to centralized mitigation.



ABB has truly unique offering for HVAC – application support and ultra-low harmonics in the same package.



**ABB**