ABB HVAC WEBINARS

Improving data center efficiency with VSDs for cooling

Making the right choice for efficient, continuous and cost-effective operation
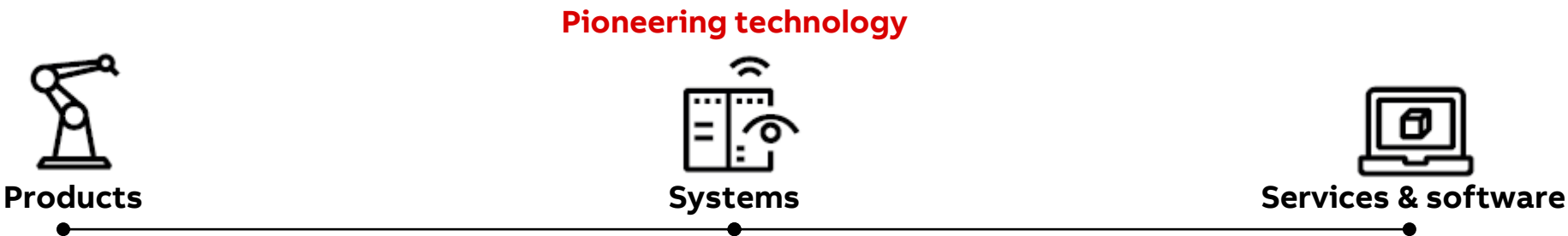
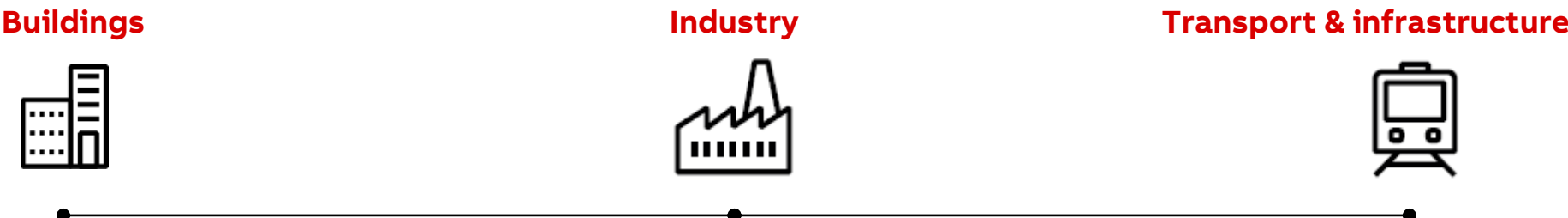Maria Fedorovicheva – Global HVACR Product Marketing Manager, ABB Motion

ABB at a glance

Facts and figures

Pioneering technology

What Offering	**Products**	**Systems**	**Services & software**

Buildings **Industry** **Transport & infrastructure**

For whom Customers			

Globally

Where Geographies	**Asia, Middle East and Africa**	**Americas**	**Europe**

Revenue ~$28 bn   Countries ~100   Employees ~110,000*

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Agenda

- Energy use by data centers nowadays

- How to save energy in data center cooling applications

- Variable speed solutions for cooling and power quality aspects

- Industry standard EN 50600 Information technology – Data center facilities and infrastructures

- Active front end drive technology with DC bus capacitors and its benefits

- System approach towards component selection

- Saving project costs with active front end drives

- Where to find the information
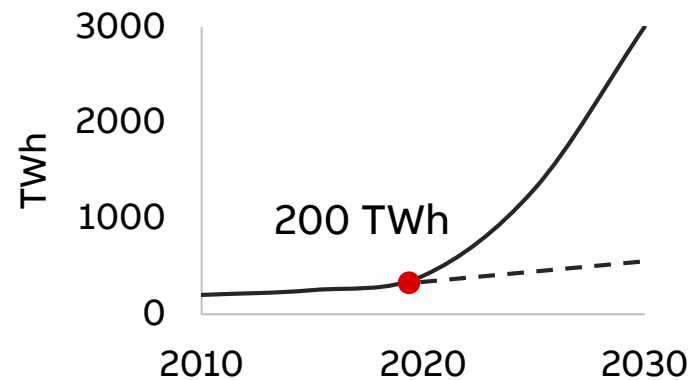
Energy use in data centers
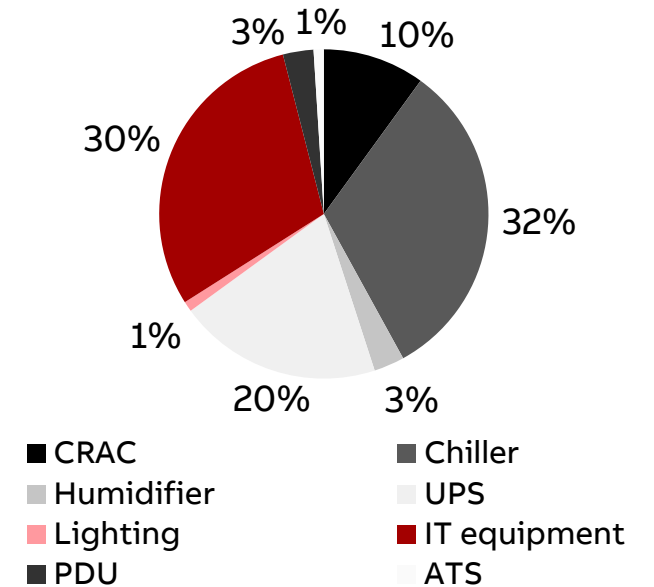
Why bother

Global energy consumption

20 000 TWh
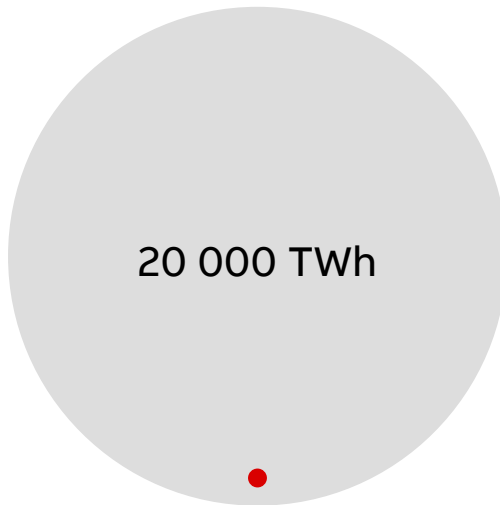
1% of world energy is consumed by data centers[1].

Data centers energy demand

200 TWh

8 times is how much data center energy demand may increase by 2030[2]. Trends 2010–2020 show a flat growth[1].

Typical data center energy use

3% 1% 10%
30%
32%
1%
20% 3%

- ■ CRAC
- ■ Chiller
- ■ Humidifier
- ■ UPS
- ■ Lighting
- ■ IT equipment
- ■ PDU
- ■ ATS

2/5 of energy consumed by a data center is used for cooling[3].

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Energy use in data centers

Load profile

- Data center cooling systems are designed for peak loads at worst cooling conditions.

- Data centers do not operate at design loads most of the time.

- The challenge is to make a data center efficient <u>at part loads</u>.

- Cooling system should be able adjust to a data center's load profile as well as to environmental conditions, and maintain high efficiency even at part loads.

Normalized 2 day data center load*

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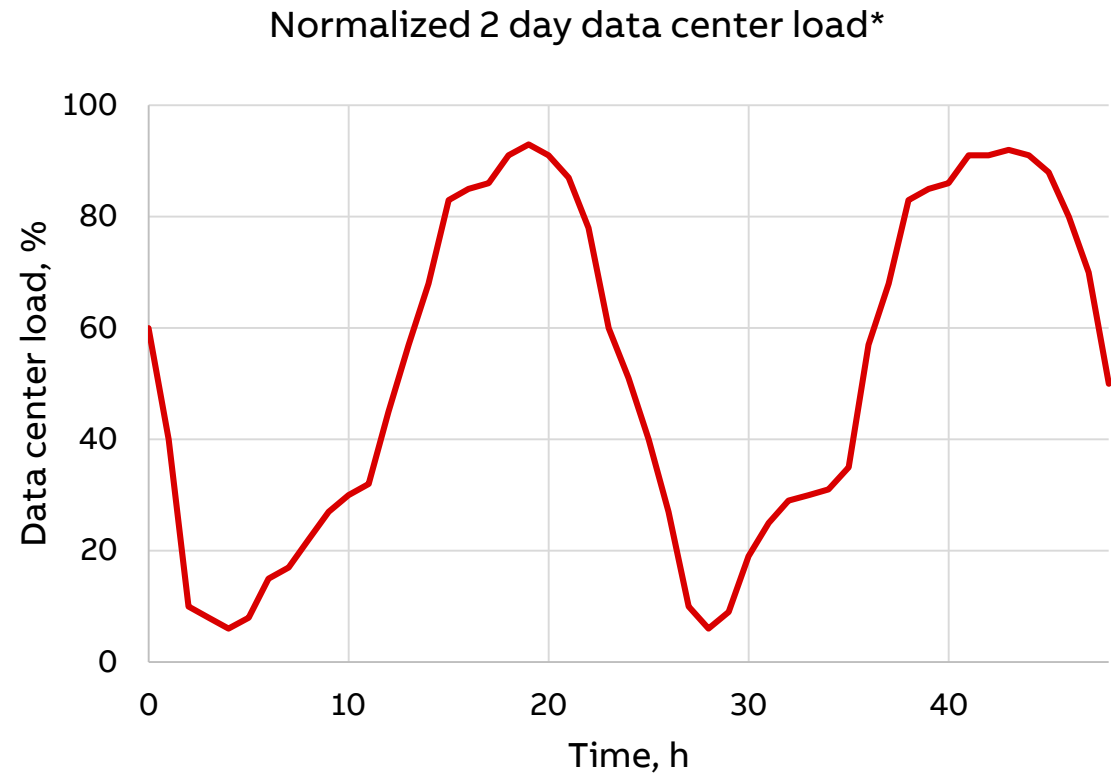
Saving energy in cooling by common means

High efficient motors, variable speed solutions and application-specific control

- IE4 and IE5 motors bring 5 to 15% energy savings in comparison to IE2 and IE3. <u>Attention to part load efficiency to be paid!</u>

- Motor variable speed drives adjust motor speed in accordance to a current need decreasing energy use by 20-60%.

- Drives' ability to optimize motor magnetic flux in accordance to the load type (centrifugal for HVAC) brings additional 1…20% savings.

- Cooling optimization using system analysis brings up to about 30% energy savings.

Drive + motor efficiency along the load profile

SynRM FA IE5
ECM IE4
IM IE3

Efficiency

Motor speed

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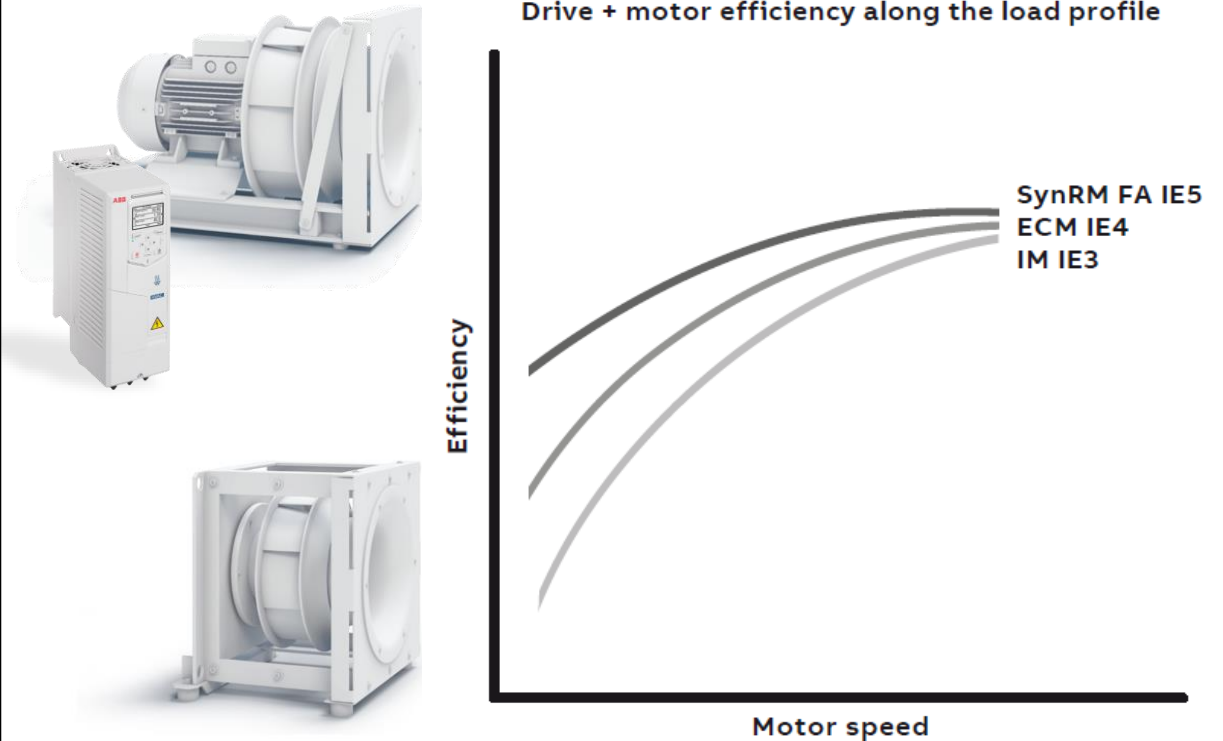
Variable speed solutions for data center cooling

Harmonics as a power quality aspect

- Majority of data centers use variable speed motor control solutions allowing to save much energy.

- However, variable speed controls distort current and voltage waveform resulting in harmonics in the network.

- Excessive harmonics decrease system reliability and energy efficiency, increase capex and opex:

  - power losses on motors, transformers and cables

  - risk of equipment malfunction or failure, reduced equipment lifetime

  - constant maintenance of malfunctioning devices or expensive mitigating measures

  - penalties from electrical utilities for high harmonics content in the network
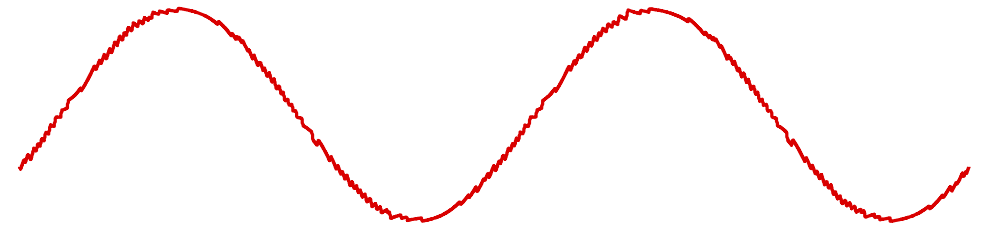
Ideal current wave form
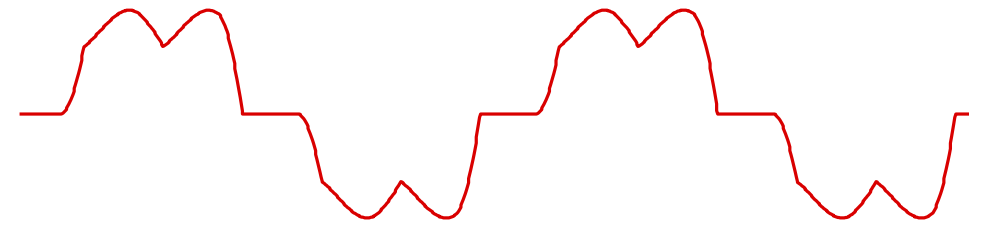
Current distortion caused by non-linear loads in the network

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Variable speed solutions for data center cooling

System losses due to harmonic currents in conductors

The passage of an electric current through a conductor produces losses resulting in heat:

$$P = I^2 \cdot R$$

The transmitted active power is a function of the fundamental current I1.
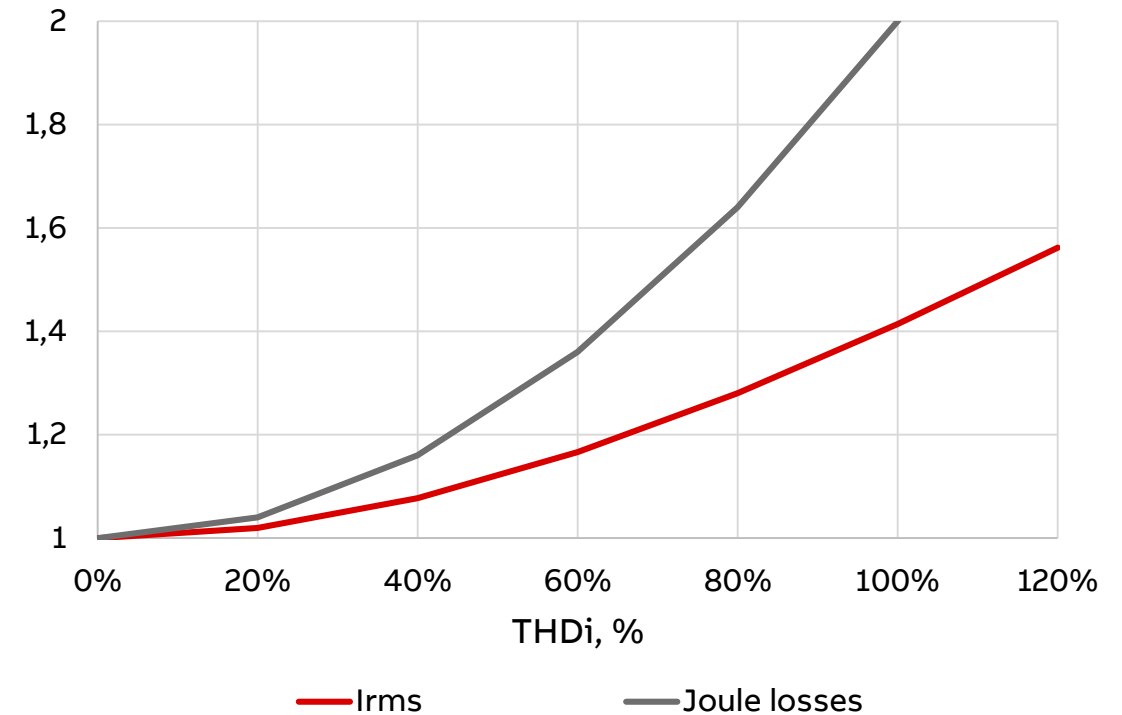
When the current contains harmonics, its total value Irms is greater than the fundamental current I1.

$$Irms = I_1 \cdot \sqrt{1 + THDi^2}$$

The harmonic currents cause increased Joule losses in all conductors they flow through.

Example: 40% THDi results in 16% higher energy losses!

Irms and Joule losses as a function of THDi

THDi, %

— Irms   — Joule losses

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Variable speed solutions for data center cooling

Power factor as a power quality aspect

- Cooling equipment has large inductive loads being a source of reactive power.

- Big content of reactive power results in:

  - increased line current and power losses

  - overdimensioned power lines and line equipment

  - generator operation at risk

  - penalties from electrical utilities for reactive power consumption / poor power factor

- VSDs with DC bus significantly improve displacement power factor.

- AFE drives with DC bus caps deliver unity power factor, but can also compensate reactive power in the network.
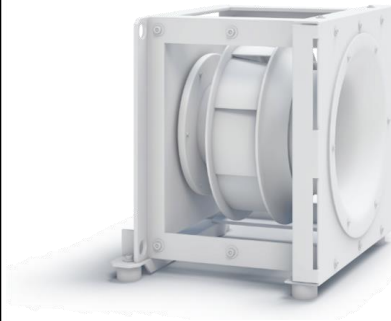
6-pulse drive or typical EC motor

- 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%**

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Efficient energy use in data centers

Why PUE doesn't tell the whole story

- Power usage effectiveness is one of the performance indicators for data centers.

$$PUE = \frac{P_{Total}}{P_{IT\ load}} = \frac{P_{Total}}{P_{Total} - P_{Cooling}}$$

- The closer PUE to 1, the more efficient a data center is?

- PUE considers only active power ignoring harmonic losses introduced by variable speed motor controls and cooling system reactive load!
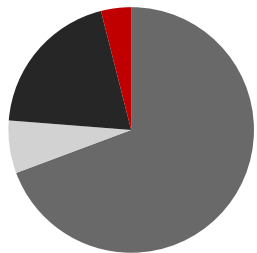
- Active (fundamental) current
- Fundamental current heat losses
- Reactive current
- Reactive current heat losses

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Industry standards

EN 50600 Information technology – Data center facilities and infrastructures

The series of standards EN 50600 "Information technology - data center facilities and infrastructures" includes:

EN 50600-1 General concepts

EN 50600-2-1 Building construction

EN 50600-2-2 Power supply and distribution

EN 50600-2-3 Environmental control

EN 50600-2-4 Telecommunications cabling infrastructure

EN 50600-2-5 Physical security

EN 50600-3-1 Management and operational information

EN 50600-4-1 Overview of and general requirements for KPIs

EN 50600-4-2 Power usage effectiveness (PUE)

EN 50600-4-3 Renewable energy factor (REF)

EN 50600-4-4 IT equipment energy efficiency for servers (ITEEsv)

EN 50600-4-5 IT equipment energy utilization for servers (ITEUsv)

EN 50600-4-6 Energy re-use factor (ERF)

EN 50600-4-7 Cooling efficiency ratio (CER)

EN 50600-4-8 Carbon Usage Effectiveness (CUE)

EN 50600-4-9 Water usage effectiveness (WUE)

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Industry standards

EN 50600-2-2: Power distribution

6.2.4.1 Requirements

The loads, power factors and harmonics presented to the supply(s) shall remain within the boundaries of any contract of supply and/or be compatible with any local generated and additional supplies.

6.2.4.2 Recommendations

The following aspects should be taken into account when planning the capacity of the supply with respect to the load;

a) Critical loads:

    1) the input power factor and harmonic current spectrum of the chosen UPS (as indicated in Figure 2 and Figure 3, UPS or DC supplies are required in order to ensure adequate power quality to protected sockets feeding the IT, and other critical loads - as a result the load presented to the utility is dominated by the power input stage of the chosen UPS);

    2) the input power factor and harmonic current spectrum of the critical load when the UPS is in bypass or other off-line mode.

b) Non-critical loads: the input power factor and harmonic current spectrum of the loads fed by unprotected, short-break and locally protected sockets such as cooling system compressors, pumps and fans - especially if variable speed drives are used.

Improving power quality in cooling

Why harmonics mitigation techniques matter

- Nobody wants a data center to run into problems due to excessive presence of harmonics.

- Variable speed solution for cooling and harmonic mitigation technologies should be considered carefully.

- It is not only about decreasing harmonic content in the system, but also decreasing it in the right part of the system using right technologies.

- Besides efficient energy use, it results in network and connected equipment stability, significant operating and capital cost savings.

Active filter

AFE drive

6-pulse drive with DC choke

EC motor

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Improving power quality in cooling

Techniques to reduce harmonics

- There are different technologies of harmonics mitigation with a different complexity level, cost and effect on the power quality.

- An optimal harmonic mitigation solution is defined by the project type (brownfield/greenfield), grid and load.

- One of the project requirements <u>must be</u> solution analysis on a cost/performance basis.

- AFE drives is a superior technology mitigating harmonics to a minimum over the load profile without installation complexity and massive footprint.
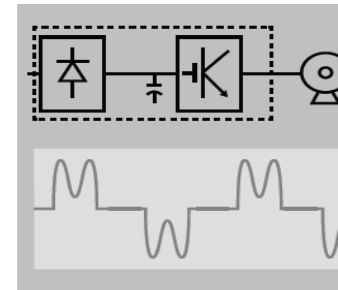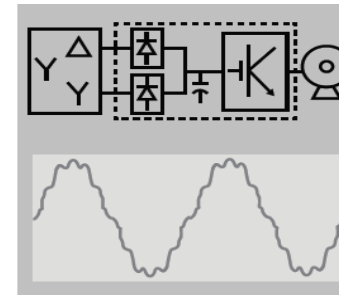
6-pulse drive, no
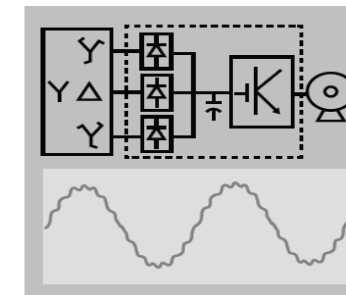harmonic reduction
THDi = 40 to 120%
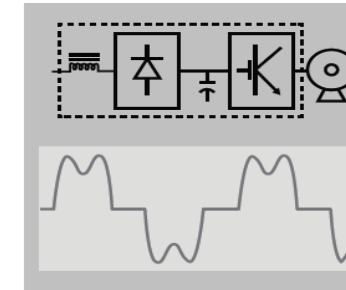
6-pulse drive,
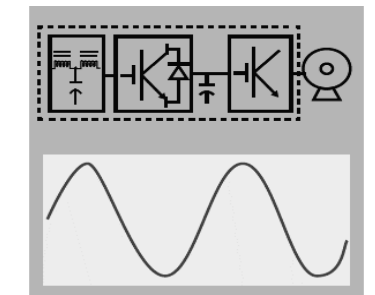input reactor
THDi = 32 to 48%
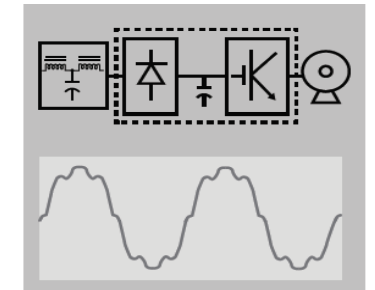
6-pulse drive,
input passive filter
THDi = 6 to 12%

12-pulse drive
THDi = 8 to 12%

18-pulse rectifier
THDi = 4 to 8%

Active front end
drive THDi ≤ 3%

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Variable speed solutions for data center cooling

What is an active front end technology by ABB

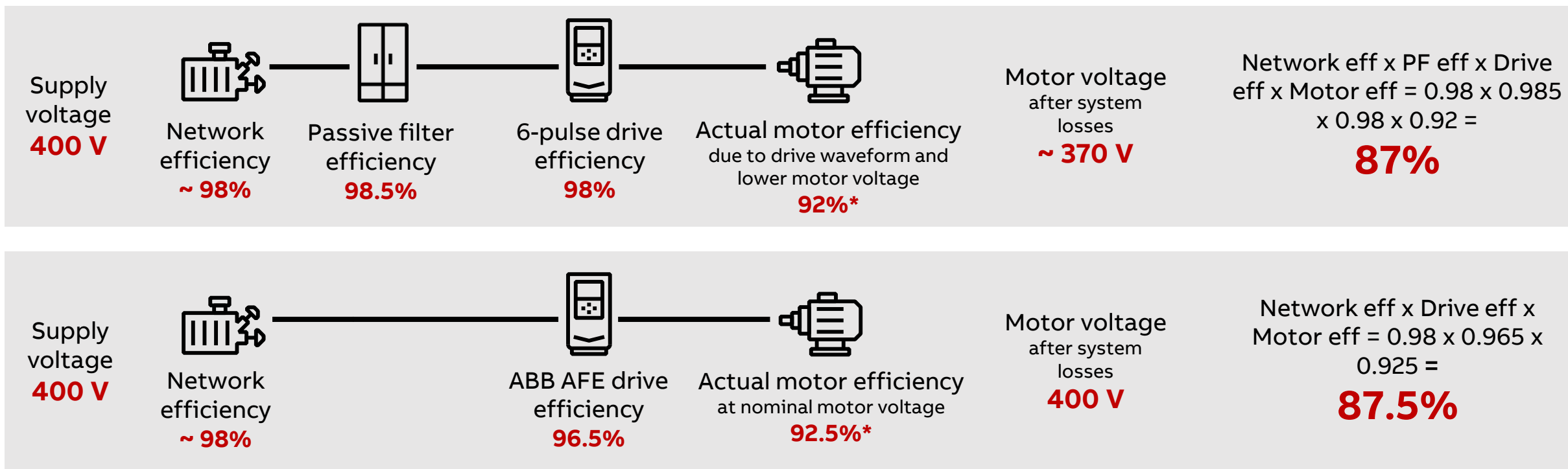### Design highlights

- IGBTs replace a traditional diode-based rectifier to create a smooth AC current waveform into the drive

- An LCL circuit is installed before the front end IGBTs to clean up high frequency noise caused by the IGBTs

- DC bus capacitors allow the AFE to achieve maximum output voltage

AFE drive

LCL filter   IGBTs

Difference to a 6-pulse drive   DC bus capacitors

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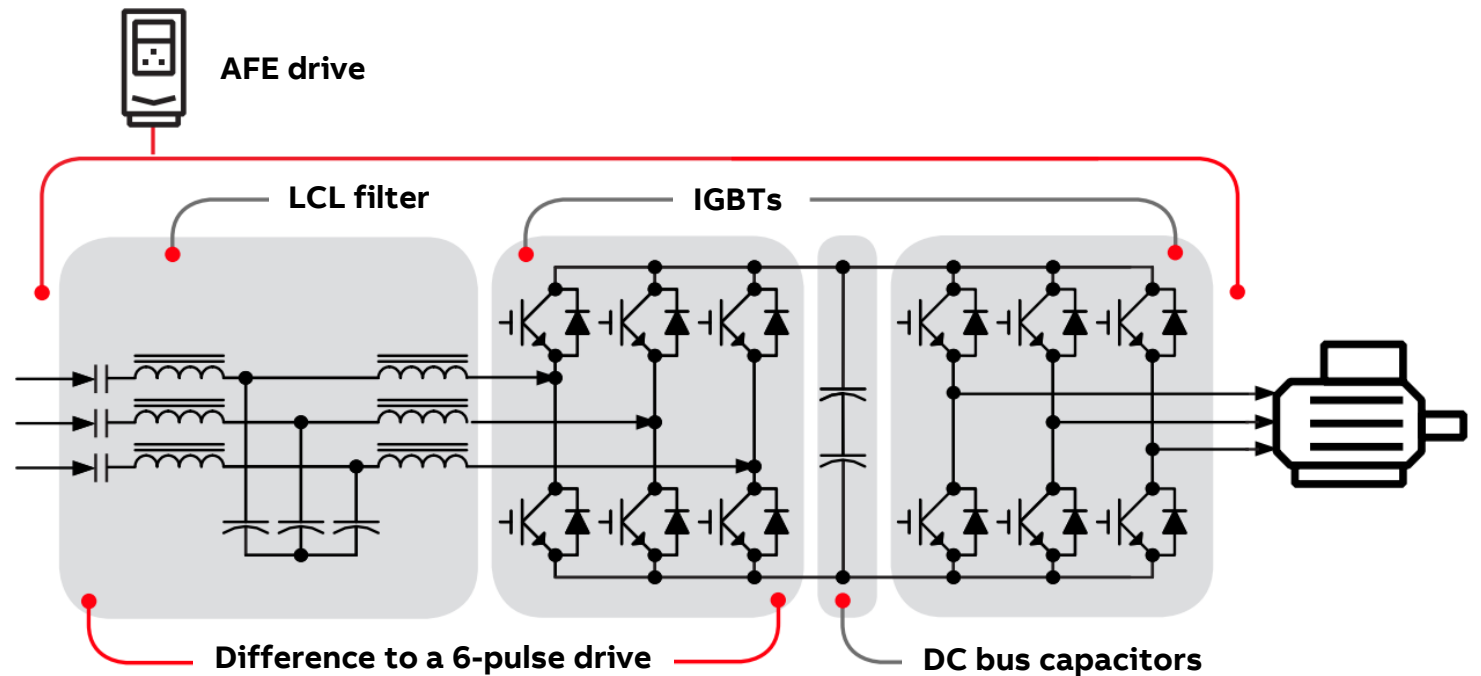
Variable speed solutions for data center cooling

System efficiency over component efficiency

Supply voltage **400 V**	Network efficiency **~ 98%**	Passive filter efficiency **98.5%**	6-pulse drive efficiency **98%**	Actual motor efficiency due to drive waveform and lower motor voltage **92%***	Motor voltage after system losses **~ 370 V**	Network eff x PF eff x Drive eff x Motor eff = 0.98 x 0.985 x 0.98 x 0.92 = **87%**

Supply voltage **400 V**	Network efficiency **~ 98%**	ABB AFE drive efficiency **96.5%**	Actual motor efficiency at nominal motor voltage **92.5%***	Motor voltage after system losses **400 V**	Network eff x Drive eff x Motor eff = 0.98 x 0.965 x 0.925 = **87.5%**

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.

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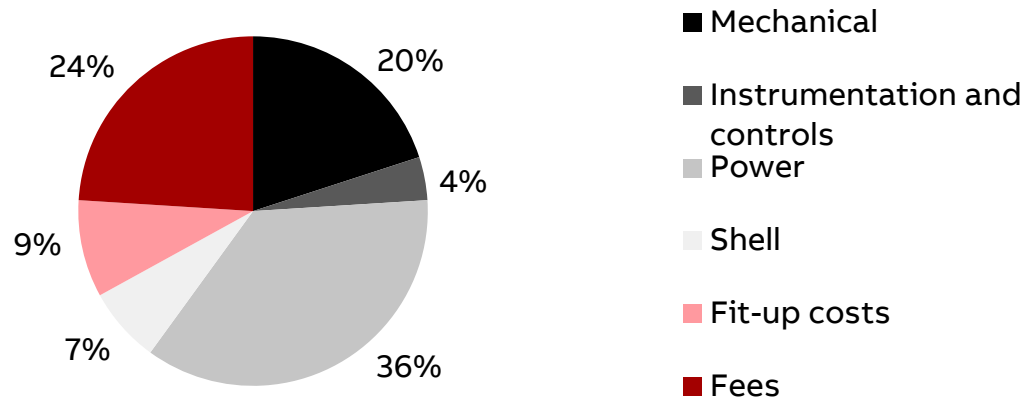
Centralized vs decentralized harmonics mitigation
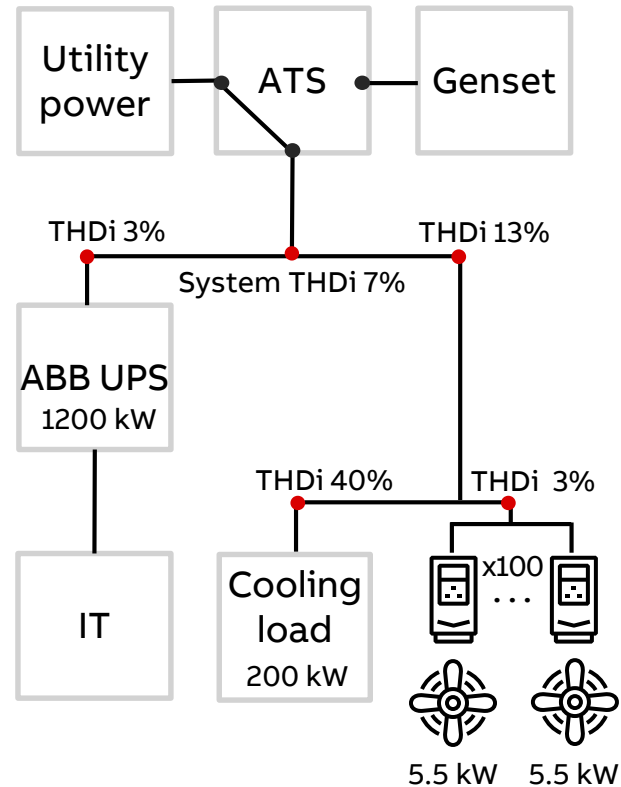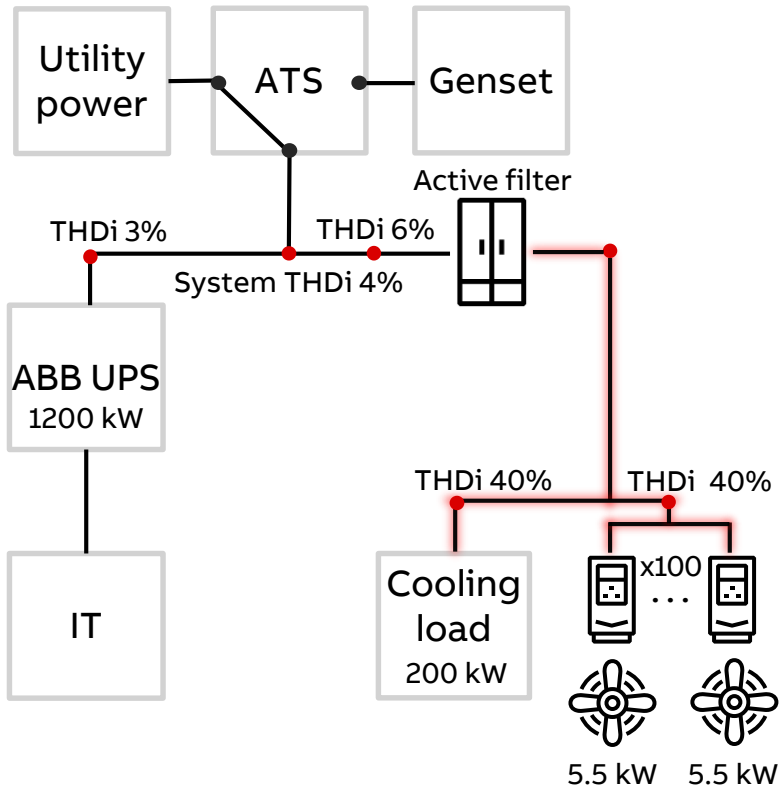
- AFE drives is a decentralized harmonics mitigation solution solving the root cause issue
- Benefits of the decentralized harmonics management:
  - no overdimensioned cables and network components
  - no disruption in power network operation due to harmonics
  - no energy losses over the power network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

Overdimensioned cables and power network components

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Variable speed solutions for data center cooling

Data center capital costs

Data center capital costs breakdown

- Mechanical — 20%
- Instrumentation and controls — 4%
- Power — 36%
- Shell — 7%
- Fit-up costs — 9%
- Fees — 24%

- 20% of data center capital costs come from mechanical and 36% are from electrical systems!

- Power quality significantly affects sizing of electrical system components!

Variable speed solutions for data center cooling

Power quality affect on capital costs

Cabling
Oversizing depends on the harmonics content in the grid.

TDD	Oversize
10%	1.00
50%	1.12
70%	1.22

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

50% cost
down with AFE

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

10% cost
down with AFE

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Variable speed solutions for data center cooling
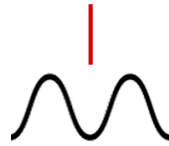
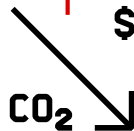Benefiting from ABB ultra-low harmonic drives
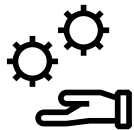
ACS880 ULH   **ACH580 ULH**

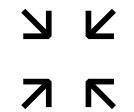**No need to oversize power network components to avoid overheating and downtime**

Continuously clean and disturbance-free network for critical applications

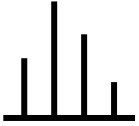**Effective use of energy, no extra cost on the energy bill or utility penalties**

CO_2 $

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

The most compact solution on the market

Compliance with IEC 61000-3-12: 2011
Harmonics are below the limits set by IEEE519-2014 and G5/4

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Summary

Efficiency at part loads

Data centers do not operate at peak loads most of the time, so it's critical to make them efficient at part loads.

VSD power quality effect

Variable speed solutions for cooling must be specified carefully to avoid power quality issues, data center operation instability and excessive capex and opex.

AFE solution delivers superior performance

Active front end drives ensure power quality and bring substantial capital and operating cost savings together with data center power network resilience.

Where to find the information

- ABB HVAC drives global page https://new.abb.com/drives/segments/hvac

- Downloads section at ABB HVAC drives global page

- ABB Data center solutions portal https://new.abb.com/data-centers incl. Data center cooling system tab

- Harmonics in HVAC applications paper https://search.abb.com/library/Download.aspx?DocumentID=3AUA0000230021&LanguageCode=en&DocumentPartId=&Action=Launch

- Data center cooling brochure https://search.abb.com/library/Download.aspx?DocumentID=3AXD50000584352&LanguageCode=en&DocumentPartId=&Action=Launch

- Active front end drive technologies paper https://search.abb.com/library/Download.aspx?DocumentID=3AXD50000478842&LanguageCode=en&DocumentPartId=&Action=Launch