EXTERNAL

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Harmonic Distortion Phenomena & Treatments

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Harmonic Distortion phenomena

Harmonic Distortion phenomena

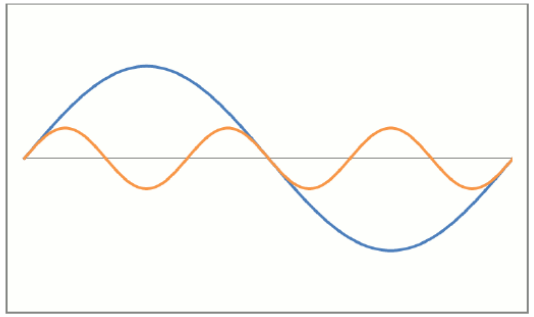
What is harmony

Harmonies Definition

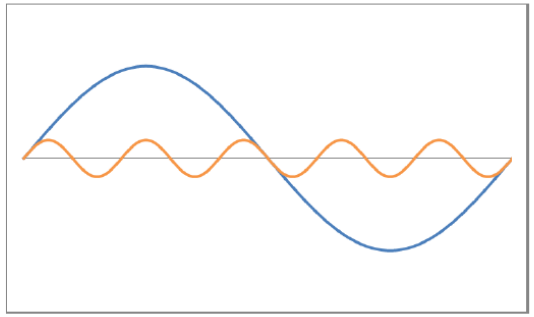
A harmony is a wave with a frequency that is a positive integer multiple of the fundamental frequency, the frequency of the original periodic signal, such as a sinusoidal wave.

The original signal is also called the 1st harmonic, the other harmonics are known as higher harmonics. As all harmonics are periodic at the fundamental frequency, the sum of harmonics is also periodic at that frequency.

The set of harmonics forms a harmonic series.



3rd harmonic (n=3)



5th harmonic (n=5)

Harmonic Distortion phenomena

What is Harmonic Distortion

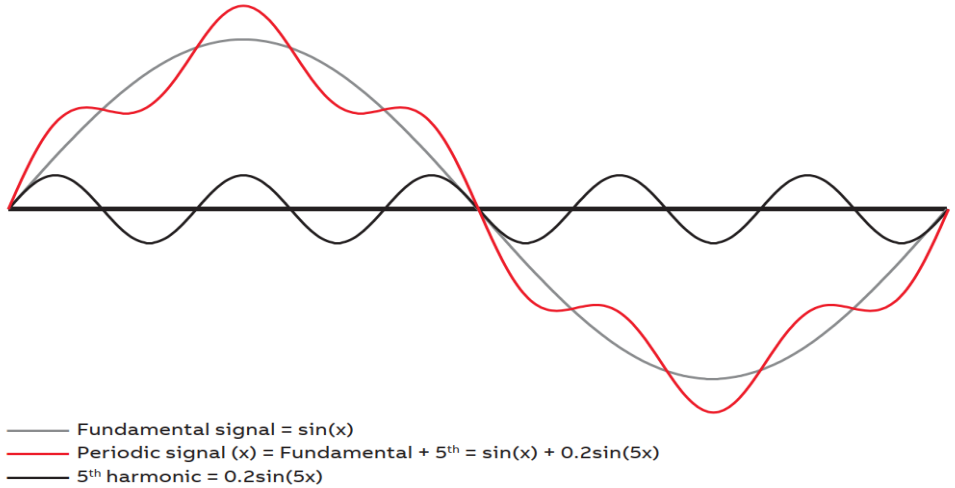
Harmonic Distortion

Harmonic distortion is the deviation from the typical sinusoidal shape of an AC voltage or current signal due to the presence of higher or lower frequency components.

These components are called harmonics, and they can be produced by non-Linear loads or amplifiers.

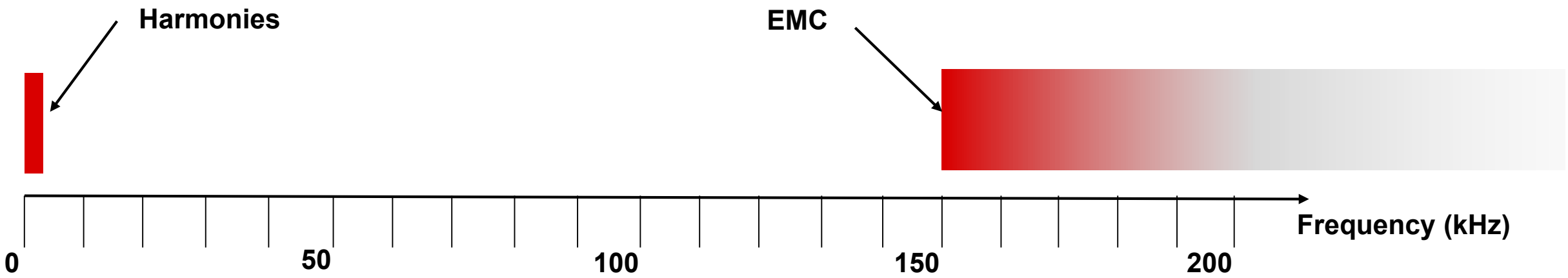
Harmonic distortion can interfere with the power quality and efficiency of the electrical system.

Total **H**armonic **D**istortion (THD) is a measure of the amount of harmonic distortion in the system



Harmonic Distortion phenomena

Harmonies & EMC disturbance



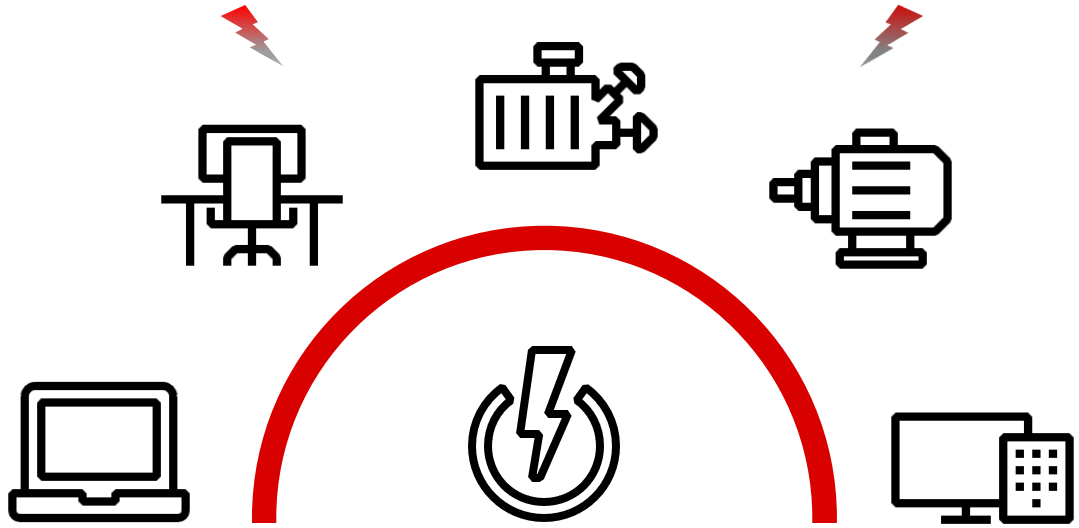
- Harmonic distortion is not EMC disturbances
- Harmonic voltages/currents are a low frequency phenomena
- Typical range is 100 Hz – 3 kHz

Harmonic Distortion phenomena

Loads classification causing to Harmonic Distortion

Linear & non-linear loads

- Linear loads such as light bulbs or 3-phase motors do not create harmonics
- Non-linear loads produce harmonics
  - Power supplies of PCs, PLCs, TVs etc.
  - Photocopiers, domestic appliances
  - Diode and thyristor bridges
  - Uninterruptible power supplies
  - Motor starters
  - Switched-mode power supplies (SMPS)
  - Variable Speed Drives (VSD) also produce harmonics, which makes the issue particularly important for applications with high power consumption, such as pumping.



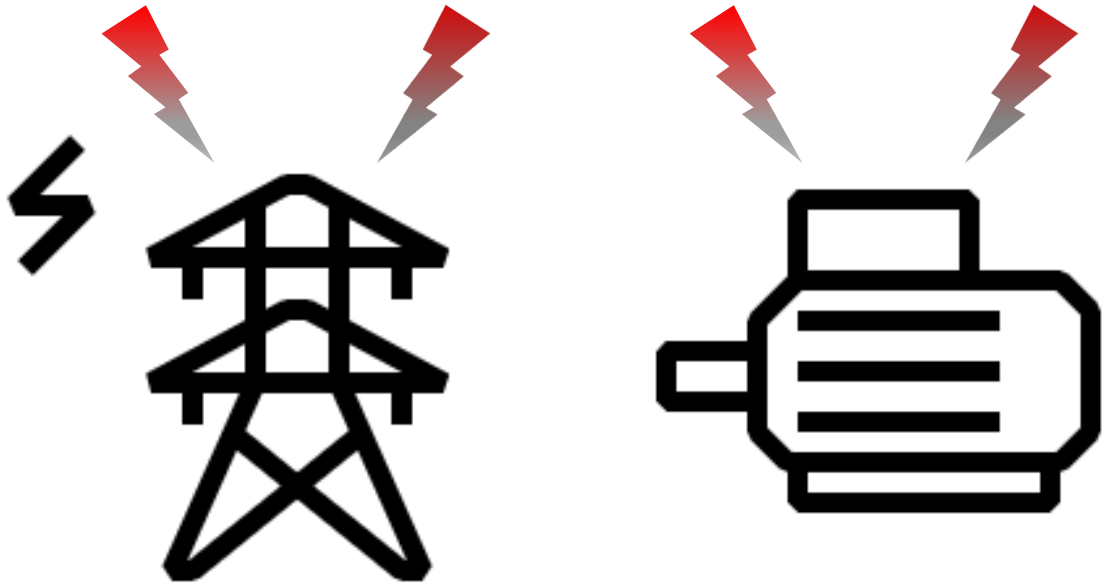
Industrial plants operate many loads that are both susceptible to harmonics and which generate harmonics.

Harmonic Distortion phenomena

Disturbances caused by harmonics

Harmonics pollute the electrical supply and can cause negative disturbances to equipment connected to the grid

- Motors, transformers, cables and other equipment can overheat
- communications equipment can experience interference
- sensitive electronic equipment can be damaged
- measurement devices can give false readings
- capacitor can fail due to resonances
- displays and lighting can flicker
- circuit breakers can trip
- fuses can blow



The phenomena can cause major problems like equipment failure and disrupt the process operation

Harmonic Distortion phenomena

Costs caused by harmonics

- Over dimensioning of primary equipment (Cables, transformers etc.)
- increased losses as equipment wastes more energy due to overheating
- shorter lifetime of the equipment
- unwanted process interruptions, the equipment must be designed to meet the overtones

Challenges caused by harmonics cost money and time

Harmonics Reduction Technologies

Harmonics Reduction Technologies

Solutions to reduce harmonics in drive applications

Choke	Correctly sized choke in a drive with a 6-pulse diode supply unit
Passive or active filters	Active filter with a drive - cancelation of harmonics by equal and opposite harmonic generation Passive filter with a drive - low impedance path for harmonics
Multipulse drives	Increasing pulse number of the drives: 6-pulse -> 12-pulse -> 18-pulse -> 24-pulse
Ultra-low harmonic drives	ABB ultra-low harmonic drives

Harmonics can be suppressed with the correct measures

Harmonics Reduction Technologies

Comparison between different harmonic mitigation techniques

Technique	THDi% current
Ultra-low harmonic drive (IGBT supply Unit)	3%
Active harmonic filter	4%
18-pulse rectifier with 5% impedance transformer	5%
Hybrid filter (a type of a Passive filter)	7%
12-pulse rectifier with 5% impedance transformer	10%
6-p with 5%-line choke + 5^{th} harmonic trap filter	12%
6-p with 5%-line choke, or equivalent DC choke	32%
6-p with 3%-line choke, or equivalent DC choke *	39%
6-pulse rectifier, no mitigation, reference level	72%

Ultra-low harmonic drive has the lowest harmonic distortion

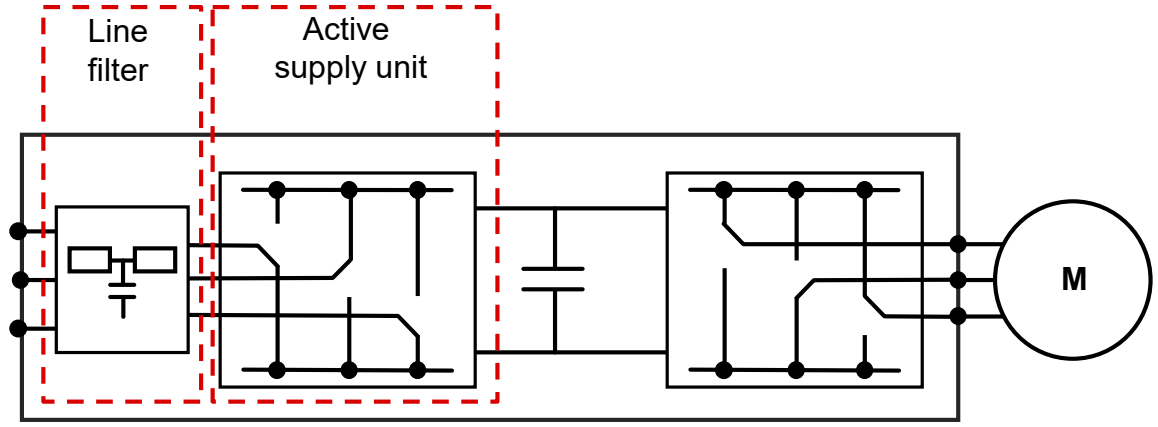
* 3% reactor is typical for ABB's 6-pulse diode bridge drives

Harmonic Reduction technologies

Ultra-low harmonic drives - Harmonic mitigation built-in

Operation principle

- ABB's ultra-low harmonic drives have harmonics mitigation built into the drive
  - Drive has an active supply unit (= IGBT supply unit) and in-built line filter
- Active supply unit is controlled to eliminate low order harmonics in the current.
- Line filter suppresses components above the switching frequency of the active supply unit IGBTs.



Total harmonic distortion, THDI, is typically 3%.
Exceeds requirements set by low harmonic standards

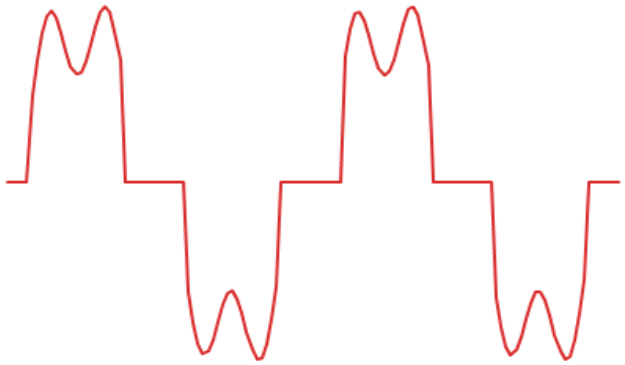
Harmonic Reduction technologies

Ultra-low harmonic drives - Harmonic mitigation built-in

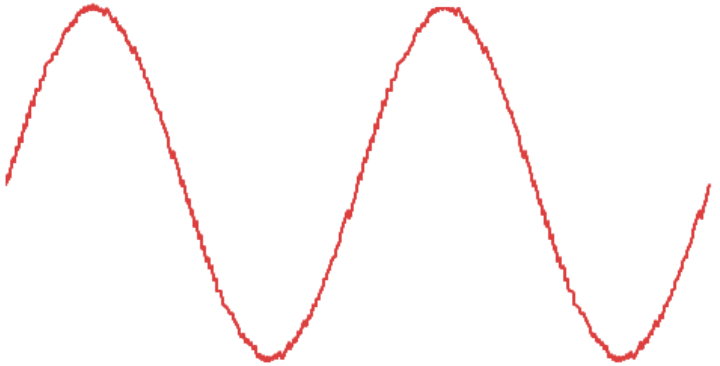
Ultra Low harmonic content, 3% THDI

- ABB ultra-low harmonic drives can help you to overcome the challenges created by harmonics
- With harmonics mitigation built into the drive, the ultra-low harmonic drive produces exceptionally low harmonic content

Standard 6-pulse drive



Ultra-low harmonic drive

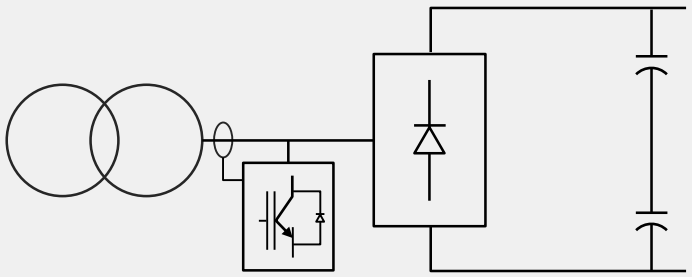


THDI is typically 3%. Exceeds requirements set by low harmonic standards

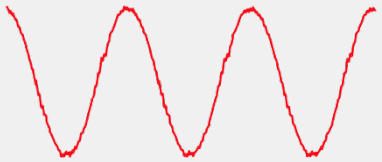
Harmonic Reduction technologies

Active filters for individual or group compensation

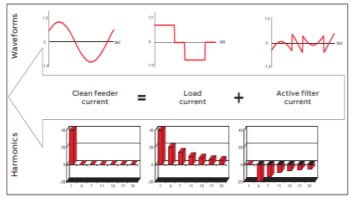
Active filters



Transformer, active filter, drive rectifier and DC link capacitors



Current is quite smooth THD, 4-7%



Advantages:

- Can reduce harmonic current distortion down to 5% of rated current
- Performance improves on partial loads due to the connection topology
- Maintains a high input power factor of the system
- Can be used to correct multiple non-linear loads

Disadvantages:

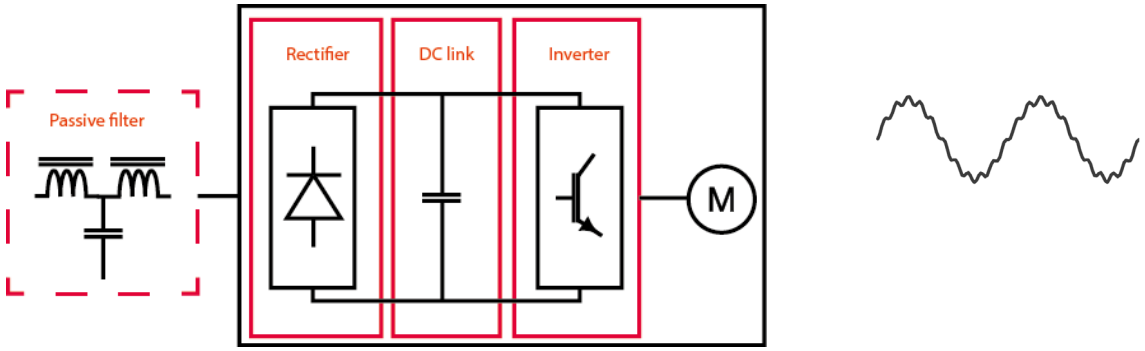
- Large size, high cost, complex installation and commissioning
- A power quality study is needed for filter dimensioning and determining its location
- External sensors must be wired and installed
- If only one active filter is used in the system, a failure may cause high distortion
- THDi is not reduced on the load side

Harmonics Reduction Technologies

Passive filter use vs Ultra-low harmonic drive

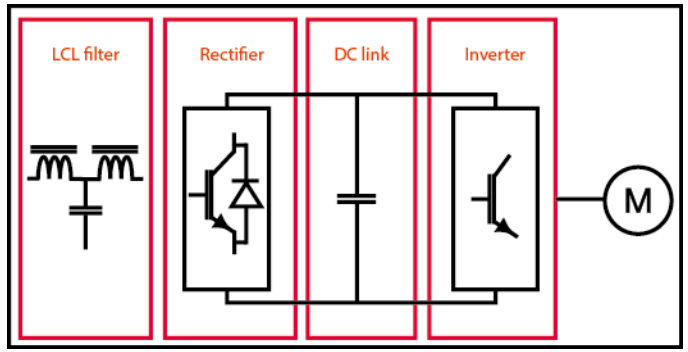
Passive filter & Drive

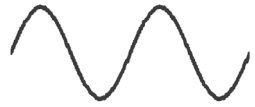
- THDI typically 5 to 10% (depends on filter type)
- Requires additional filter and cabling
- Leading power factor at no load
- Risk of resonance
- Load dependent voltage drop over the filter
- On partial loads DC voltage can rise even by 10%, creating the possibility of an overvoltage fault



Ultra-low harmonic Drive

- THDI typically 3%, i.e. current harmonics are below limits set by harmonic standards like IEEE519 and G5/4
- Does not require any external parts or cabinets
- Power factor unity at any load point
- Full motor voltage
- No risk for resonance



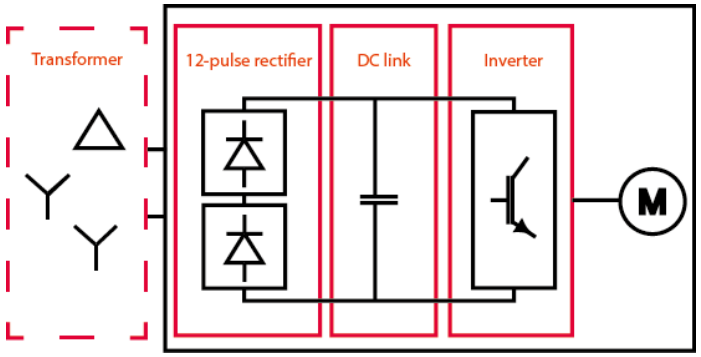


Harmonics Reduction Technologies

Multi-pulse drive versus ultra-low harmonic drive

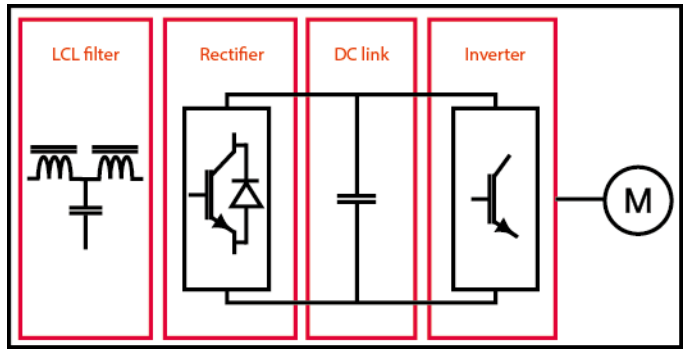
12-pulse drive

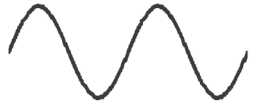
- THDI typically 12%
- Requires a special transformer
- Lower power losses in the drive and lower power factor
- Effectiveness depends online imbalance and transformer windings balance
- Higher cabling and installation cost
- Space and weight demand



Ultra-low harmonic drive

- THDI typically 3%, complies with IEEE519, G5/4
- No need for special transformer and filters
- Lower transformer losses compensates overall efficiency
- Power factor 1.0
- Harmonic performance is robust against supply and transformer variations
- Compact design

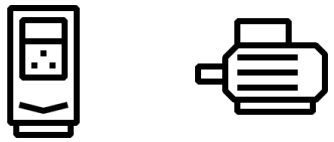




Let's Summarize

Harmonic Reduction technologies

Reasons that bring capital cost savings

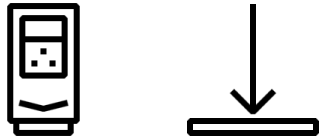


Up to 50% smaller generator

when using ABB’s active front end drives

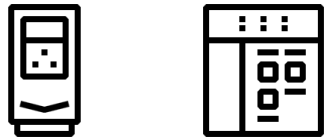
Up to 20% smaller transformers

if using ABB’s active front end drives



Up to 30% cable size down

if using ABB’s active front end drives



10-30% reduction in switchgear, circuit breaker and fuse sizing

if using ABB’s active front end drives

Up to 30% optimized motor size

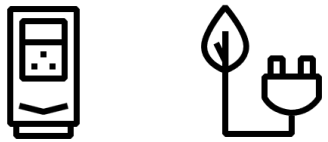
if using ABB’s active front end drives

No need for step-up transformers or oversized motors

if using ABB’s active front end drives

Harmonic Reduction technologies

Reasons that bring operational cost savings

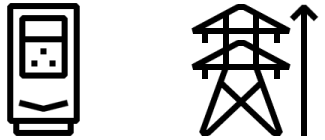


40% THDi means 16% higher current losses

Avoided if using ABB's active front end drives with THDi < 3%

Increased generator operation reliability

if using ABB's active front end drives with THDi < 3%



Increased operation reliability in weak networks

if using ABB's active front end drives with voltage boost feature

Reduction of random disturbances

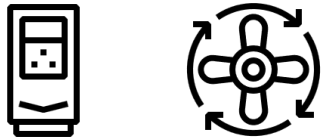
when using ABB's active front end drives

Reliable system without fuse and circuit breaker tripping

by using ABB's active front end drives

Reduce wasted power from distorted waveforms

using ABB's active front end drives



Reduce wasted power from additional cooling

by using ABB's active front end drives

Avoid power factor penalties

by using ABB's active front end drives


ABB