HVAC GUIDE

Harmonics in HVAC applications - what it is and how to solve it

When looking to mitigate harmonic disturbances in a cost-effective way, the ACH580 Ultra-Low Harmonic drive is the solution

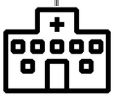
Introduction
HVAC system design technology

Depending on your specific operating sector – buildings, hospitals, data centers, or commercial refrigeration – your HVAC system can control and safeguard much more than just temperature.

Operations Manager

"A major challenge I'm facing as a data center operator is how to cool the facility in an environmentally sustainable way."

In the buildings industry, usage of Variable Speed Drives (VSDs) is now a given for almost all applications like Air Handling Units (AHU), chiller compressors, ventilation fans, stairwell pressurisation fans, chilled water and condenser water pumps, and more. Generally, 6-pulse diode rectifier-based VSDs are used for these applications, and implementing these VSDs contribute immensely to energy efficiency and energy cost savings.



Engineering Consultant

"Healthcare facilities need to perform reliably, consistently, and accurately."

The majority of HVAC applications in Australia feature VSDs equipped with DC chokes to maintain harmonic current control.

However, even with the DC chokes, the harmonics of a 6-pulse VSD is reduced to only 35 -45% THDi (Total Harmonic Current Distortion) from the levels of 80 -120% for those VSDs without any form of harmonic control at all.

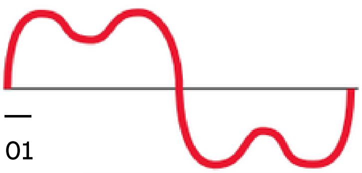
What exactly are harmonics?
and why can they be so damaging?

Harmonics can cause damage to sensitive electronic equipment, interference to communication equipment, tripping of circuit breakers, blowing of fuses, and capacitor failures. The effects can also include overheating of cables and motors, overloading of transformers, generator failure and power factor capacitor damage.

Harmonics is the content of current which causes the distortion of the sine wave. When harmonics are present in the current waveform, the usable part of the current is reduced, as harmonics do not contribute to active power. The closer the current waveform resembles a sine wave, the more active power you have for running the load.

01 Standard 6-pulse VSD current waveform

02 Active front end supply current waveform



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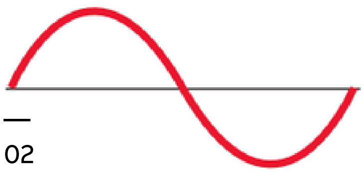

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Designing to limit harmonic interference

When you increase the total number of VSDs in a building – especially for sensitive applications like hospitals and data centers, the effect of the overall harmonics even with DC chokes can go beyond the limits accepted by the Electricity Distributor or as required by the sensitive building type. Often, this is addressed by installing Active Harmonic Filters (AHF) at the Mechanical Service Switch Boards (MSSB) or Main Switch Boards (MSB).

This type of design allows the generation of harmonics at the point of energy consumption (VSDs), and allow the additional harmonics to flow through components such as the cables, switch gear, and busbars. The extra harmonics are then are cancelled out by generating a reverse waveform of the harmonic currents.

A modern, improved way
there's now an easier, more effective way to mitigate harmonics

ABB's ACH580 Ultra-Low Harmonic (ULH) drive is an IGBT front end VSD whose harmonic content (THDi) is approximately 3% at full load.

The United States IEEE Power and Energy Society has developed recommended practices and requirements for harmonic control of power systems. These standards are a relatively authoritative standard worldwide.

ABB's ACH580 ULH drive 3% level of harmonics complies with the limit permissible by the IEEE 519-2022 standard. This means that additional Active Harmonic Filters are not required to be installed in facilities to mitigate harmonics in order to comply with the limits specified by Electricity Distributors, or as required for sensitive applications.

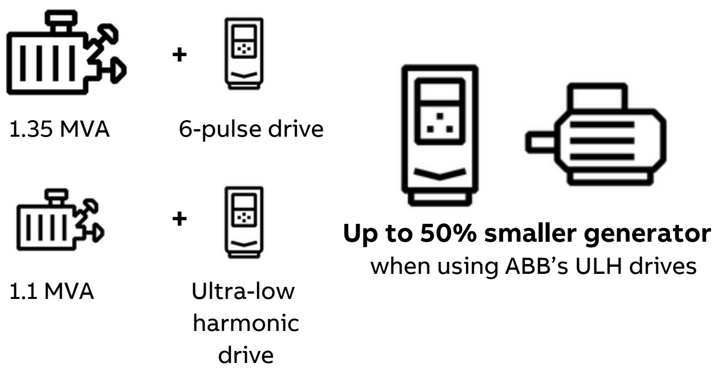
ABB's family of ACH580-31/34 drives with active front end helps your system to comply with IEEE 519 and G5/4 requirements.

Effect on transformer and generator sizing

To manage harmonic current generated by standard 6-pulse VSDs with AC or DC chokes, you will need to oversize cables by about 10%, transformers by 35%, and power generators by 2-2.5 times. Note that these are the most expensive elements of a power network. This massive over sizing can be avoided by using a ULH drive, because these drives necessitate a relatively small need for oversized transformers and generators in comparison.

Typical over sizing for transformers and generators

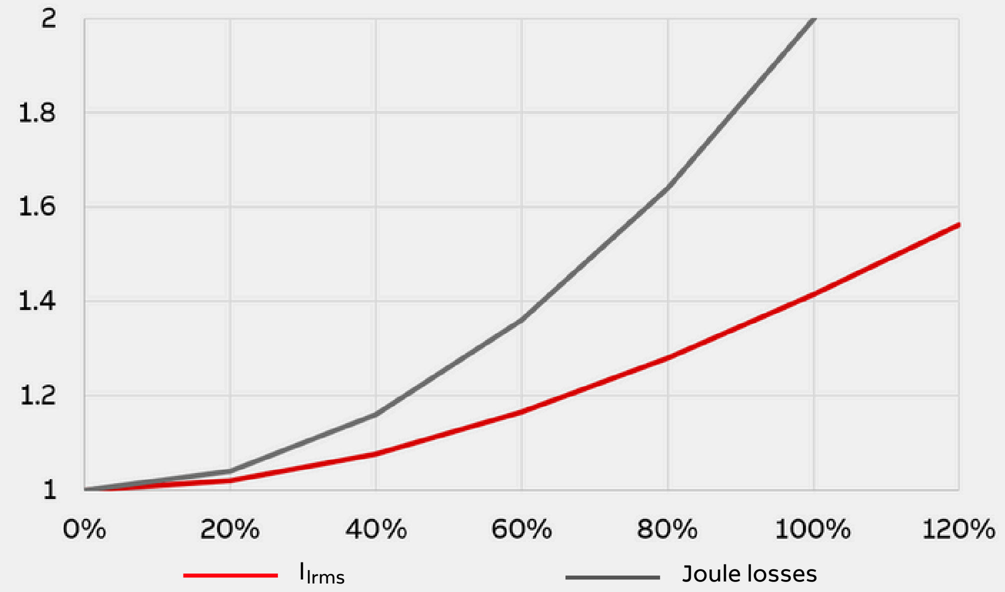
System	Transformer	Generator
6-pulse standard VSD	1.35 times	2-2.5 times
ABB ULH drive	1.1 times	1.2-1.5 times



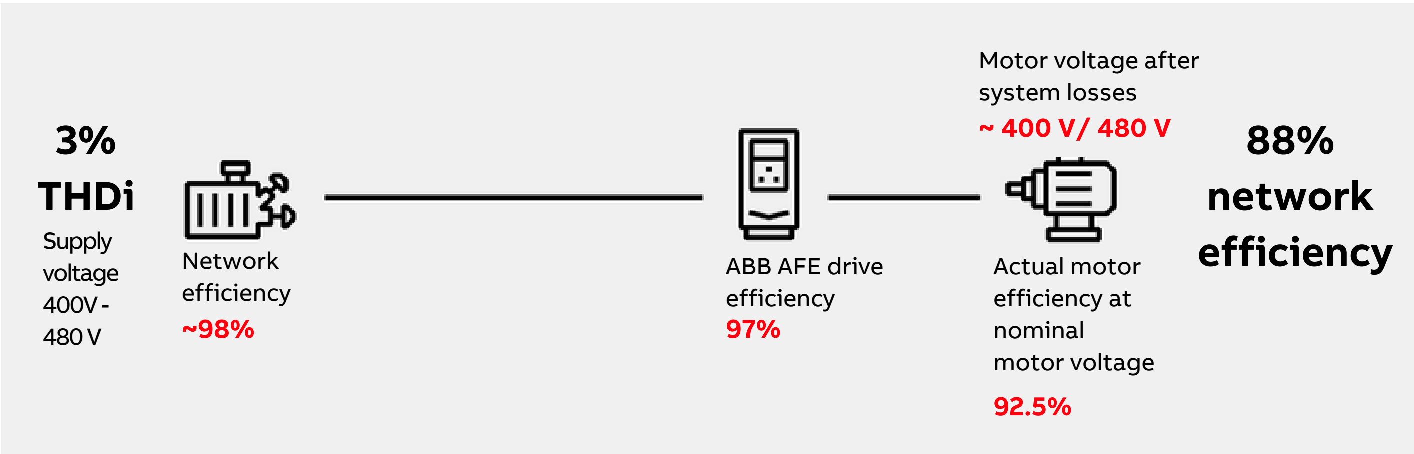
The energy efficiency effect
electrical harmonics and their impact

When current contains harmonics, its total value I_{lrms} is greater than the fundamental frequency current I_1. The harmonic currents cause increased Joule losses in all conductors they flow through. Standard 6-pulse drives with chokes have a THDi of ~40% meaning 16% higher losses in the power system. ABB's ULH drives ensure THDi below 3% and nominal voltage, resulting in zero increased line current, and consequently no add-on losses.

I_{lrms} and Joule losses as a function of THDi



40% THDi results in 16% higher energy losses!



Using Ultra-low harmonic means removing the need for many additional system components

When ULH VSDs are utilised, many other system components and activities required to ensure harmonic mitigation becomes obsolete. The table below shows a comparison of harmonic mitigation using 6-pulse drives with Active Harmonic Filters versus using ULH drives to begin with.

System component/activity	6P VSD+AHF	ULH	ULH savings
Active Harmonic Filter (AHF)	Yes	No	Cost, space
Feeders on MSSB or MSB to connect AHF	Yes	No	Cost, space
Current transformers on MSSB/MSB busbars	Yes	No	Cost
Installation of AHFs	Yes	No	Cost
Commissioning and tuning of AHFs	Yes	No	Labour cost
Verification of harmonics to limits	Yes	No	Labour cost
Periodical verification of AHFs in operation	Yes	No	Labour cost

Just because it's better
doesn't always mean a ULH drive solution will cost more

A comparative model

An analysis of a hospital project in Australia was undertaken to compare the costs incurred for harmonic mitigation using 6-pulse VSDs with Active Harmonic Filter versus using ABB ULH drives. Staggeringly, the costs of the system using ABB's ULH drives are relatively comparable, if not slightly more economical.

6-pulse VSD with AHF	Cost	ABB ULH Drive	Cost
6-pulse VSDs 4kW to 37 kW – 140 nos.	X	ABB ULH ACH580-31 4 kW to 37 kW 140 nos	2.8X
Active Harmonic Filters connected to MSSB, 50A to 400A – 12 nos	1.6X		
Providing feeders for AHFs, current transformers, cables for AHFs and their installation	0.3X		
Commissioning of AHFs and verification of harmonic limits, plus labor costs	0.1X		
Total system capital and installation costs	**3X**	**Total ABB ULH drive costs**	**2.8X***

The final result delivers cost savings and strong system advantages

- Harmonics are avoided plus better harmonic mitigation just ~3% THDi
- No need to periodically check whether the active filters are operating
- No need to prove harmonic levels
- No need to over size cables, fuses, breakers, and switchgear, to account for higher harmonics levels up to the point of connecting active filters
- Significant space savings in MSB/MSSB and switchrooms
- No risk of resonance with VSDs
- Meets IEEE 519:2022 standard
- Emergency backup generator friendly
- Easy 1:1 sizing – no need to do harmonic simulation to select Active Filters
- Lower harmonic content related to I2R losses, which increases efficiency
- Reactive power compensation (improving p.f.) by drawing from the unused capacity of the ULH drives

*Based on a real life project assessment for a hospital infrastructure project in Australia.
Specifications will vary depending on exact project requirements.

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Additional resources

ACH580 drives for HVAC and refrigeration

ABB variable speed drives for HVACR system design projects

Read the story: The success of any HVAC project in healthcare is all about making the right choices

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