ENGINEERING
TOMORROW

VLT® Advanced Active Filter

Reliable harmonic suppression for your **installation**

84%

THDi reduction achieved at Skejby Hospital installation

www.danfoss.com/drives

VLT® THE REAL DRIVE

Harmonics – a hindrance to increased energy savings

Industrial trend

During the next 20 years it is expected that global energy demand will increase by close to 25%.

This is a consequence of the anticipated increase in living standards of people in the developing countries.

Meeting this growth will undoubtedly require a higher production of energy but as climate change is already a challenge, most of the increased demand has to come from renewable energy initiatives, conservation of energy and energy savings.

How to conserve energy

By controlling the speed of motors in, for example, HVAC or water pump installations, energy savings of up to 50% are not uncommon and thus the proliferation of variable speed drives seems natural.

In addition, the increased use of fluorescent lights is a sensible way to save huge amounts of energy.

Unfortunately, most electrical equipment that saves energy comes with the side effect that it draws current in a non-sinusoidal way – known as harmonic current distortion. Harmonic distortion is consequently of increasing concern.

Harmonics – an obstruction

Harmonics are a by-product of modern power electronic control equipment. If you use variable frequency inverters for example, these all generate harmonics.

Harmonic currents result in:

- Increased consumption of power
- Increased system losses
- Stress of serial equipment
- Increased grid resonance currents

The problem of distorted current is that it affects the voltage waveform, leading to distortion in the voltage supply.

If the power grid is corrupted with harmonic distortion, all equipment supplied from this grid is operating under non-ideal conditions and so will deviate from its ideal behavior.

This leads to:

- Limitations on supply and network utilisation
- Premature product aging
- Higher losses
- Shaft pulsations on motors
- Production stops
- Increased EMI

Put simply, harmonics reduce reliability, increase downtime, affect product quality, increase operating costs and lead to lower productivity.

A typical drive installation with multiple frequency converters all installed on the same power supply often requires supplementary harmonic mitigation to avoid harmonic voltage distortion.

The equivalent

A good analogy is to consider a reservoir system, with the water being the power supply and harmonics the contamination within the water.

The degree of pollution is obviously dependent on the amount of contamination in relation to the reservoir size – in electrical terms – the amount of non-linear load in relation to the power supply capacity.

It is also obvious that the pollution will spread throughout the entire network, unless filters are installed to avoid the spread of pollution.

Clearing up corrupted supplies

You can be pretty sure your main supply is corrupted already but it is the degree of distortion that is important.

Standards and recommendations set restrictions on maximum allowed voltage distortion to values of 3-10% depending on the application.

It will never be possible to eliminate harmonics completely but by reducing the harmonic current stress of individual non-linear loads the voltage distortion can be diminished.

As an alternative for individual harmonic compensation, a Danfoss VLT® Active Filter can be fitted at the point of common coupling to compensate several or all loads simultaneously.

The Danfoss VLT® Active Filter can also be retrofitted to installations that suffer from corrupted supplies or in cases where additional non-linear loads are connected later to improve energy efficiency.

Active Filter working principles

The effect of harmonics

The harmonic currents generated by non-linear loads such as drives, run toward the lowest source impedance. Without effective filtering, this typically is in the direction of the source transformer or generator.

The supply transformer or generator will experience increased eddy-currents, and stray load losses, in turn leading to increased heating and reduced system efficiency within the installation.

The additional losses reduce the loading ability of the supply and result in voltage deformation or distortion of the ideal sinusoidal voltage waveform.

The deformed voltage waveform increases losses in other online connected loads such as direct-on-line motors, switchgear and frequency converters etc.

Typically, a 10°C rise in temperature above the rated temperature can reduce insulation life by up to 50%.

Analyses show that the effect on temperature from harmonics distortion is typically in the range of 2-5°C depending on harmonic order and individual amplitudes.

The most common side effect of harmonic distortion thus is not immediately obvious but a long term derating of product life.

In extreme cases, harmonic distortion will lead to erratic operation of control equipment, trips and cause product breakdown.

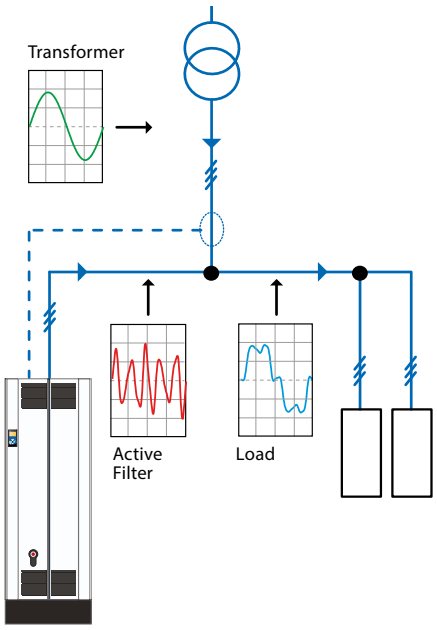
How it works – simply and reliably

An active filter works analogous to the way noise cancelling headphones filter out extraneous sound.
Using external current transformers, the active filter monitors the supply current including any distortion. From this signal, the control system identifies the required compensation and creates a switching pattern for the IGBT switches.

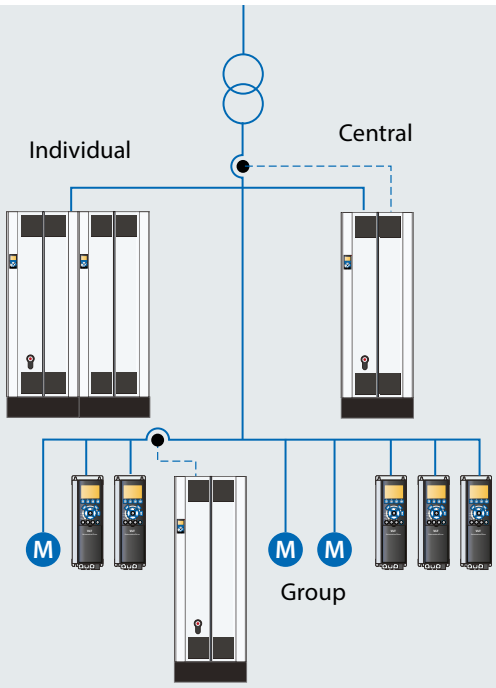
This creates a low impedance path in the filter and harmonics flow into the filter instead of proceeding in the direction of the power supply.

By cancelling out the harmonic current distortion almost completely, voltage distortion of the transformer or generator is no longer a concern.

The filter carries out its current evaluation and cancellation continuously so that plant load variations second-to-second or day-to-day make no difference to the active filter's performance.



Active Filter installation – the choice is yours



Central Compensation
Simply add the filter in parallel at the point of common coupling without disturbing your existing installation and the whole facility can be compensated centrally, even at medium voltage, through an auto-transformer.

Individual Compensation
Uniquely, Danfoss offers a low harmonic series of drives with in-built AAF for compensation of individual VSD driven loads. Current transformers are built-in.

Group Compensation
A selected group of loads can be compensated together. The AAF adjusts automatically to the load and is independent of the supply stability.

That's why Danfoss VLT® Active Filters do more

Besides harmonic reduction the VLT® Danfoss Active Filters also:

- Compensate VAR variations dynamically
- Balance phase loads
- Reduce flicker distortion
- Dampen grid resonances

The VLT® Danfoss Active filter ensures that all three phases are loaded equally, that the power factor is optimized and that lighting flickering is reduced.

The result is optimized energy utilization, higher system efficiency and a better working environment. Due to the fast response time of the VLT® Active Filter, it acts as a resonance damping device and so reduces chances of trips and production stoppages.

The filter runs with the lowest possible switching frequency to reduce IGBT switching losses. This requires a higher filtration from the built-in LCL magnetic circuit, and so heat is moved from the IGBT modules to the more heat tolerant magnetic circuit.

This ensures high energy efficiency, especially at partial load, and improves the thermal strength.

To reduce energy consumption even further, a sleep mode function can be programmed to enable the filter to go to sleep if mitigation is not needed. The compensation is off but control is always on-line, measuring the grid behavior.

Whenever conditions change and compensation is needed, the filter leaves sleep mode and brings in full harmonic compensation almost instantly.

Independent of load type, active filters are directly connectable to any 3-phase network.

The filters are able to operate in conjunction with other harmonic mitigation filters, capacitor banks and other power quality equipment.

When installed in front of non-linear loads, it is important to check that these utilise AC coils to ensure proper operation.

The operation of the filter is dependent on the location of the current transformer (CT) measuring point.

The VLT® Active Filter allows for CT's to be installed both towards the supply and towards the load.

Reliability is key

Over 40 years of drives design leadership and 15 years experience as a manufacturer and developer of IGBT power modules lie behind the ingenious design of the VLT® Active filter.

But design is not everything. Danfoss VLT® Active Filters employ 85% of their proven drive components in the VLT® Active Filter.

Not only does this improve the quality, reliability and durability but it also ensures continued quality monitoring.

All enclosures are mechanically designed with a focus on:

- Robustness
- Ease of access and installation
- Intelligent cooling
- Long service life

As if that were not enough, every VLT® Advanced Active Filter is 100% tested prior to shipment.

This is your guarantee of reliable operation and long-lasting products.

VLT® Active Filter – save energy, space and time

Save energy

The VLT® Active Filter is designed with energy conservation in mind:

- Efficiency better than 96%
- Energy saving 'Sleep' mode
- Displacement power factor correction
- Automatic Energy Optimisation

Save space

The compact design of the VLT® Active Filter makes it easy to fit into even small installation spaces.

- No need for external LCL filtering
- Built-in RFI filter and high-performance RFI filter as built-in option
- Built-in fuses and/or disconnect as option
- Intelligent cooling concept reduces the need for installation space
- Side-by-side mounting

Save time

With the installer and operator in mind, we have minimised installation, commissioning and maintenance time.

- Intuitive user interface with Danfoss' award-winning local control pod (LCP)
- Shares software support interface with VLT® Drives
- Modular VLT® design enables fast installation of options
- Auto tuning of CT sensors
- Supports 18 different languages
- 90% of all installations can be commissioned only be programming two parameters, setting up the CT input

Manufactured to the highest quality standards
VLT® Series are UL listed and made in ISO 9001-2000 certified facilities.

User friendly for quick and easy operation and maintenance

VLT® AAFs share the same user interface, power connections and signal terminals as the rest of the Danfoss VLT® family, so the VLT® concept is the same throughout the plant, all around the world. To know one is to know the whole family.

- LCP can be plugged and unplugged during operation, making the transfer of parameter sets between filters easy
- Info button provides direct access to on-board help, making printed manuals virtually redundant
- Large graphical display and quick setup manual makes commissioning a breeze
- Multiline information display allows for up to 5 different readouts simultaneously giving a full overview of grid and unit performance

Intelligent heat management for longer life

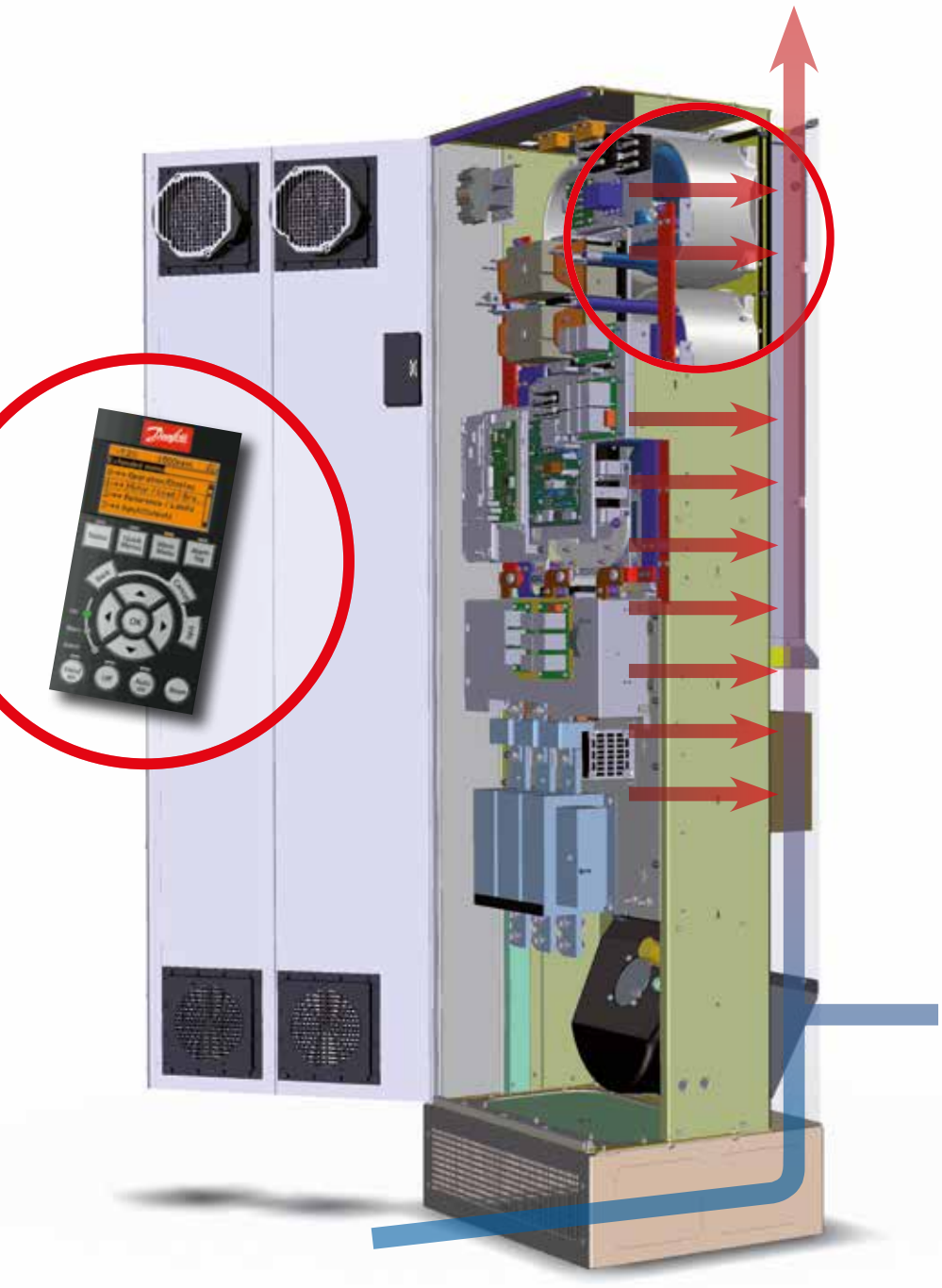
It is vital for reliable operation that excess heat is removed from the filter effectively.

The intelligent heat management of VLT® products removes 85% of the heat losses via finned heat sinks which transfer the heat to the back-channel cooling air.

The heated air is then either exhausted directly into the control room or it can be directly removed from the building via a back-channel cooling duct.

The remaining 15% of heat losses are removed from the control electronics area using low volume door fans.

This reduces potential contamination of the control electronics area resulting in longer life and higher reliability.



Mains Shield options

To meet local demand for extra fall protection during service, all filters can be supplied with a mains shield option. This cover protects all live parts from being touched whenever the door of the filter is opened.

Durable in aggressive environments

In many applications it is often recommended to protect installed electronic devices from moisture and dust. As standard the VLT®Active Filters comply with protection level 3C3 according to IEC 60721-3-3.

Stainless steel back channel

As an option, the back-channel cooling duct can be supplied in stainless steel along with heavier plated heatsinks for an even greater level of protection in harsh conditions, such as those found in salt-air environments near the ocean.

Service you can rely on 24/7 – around the world

Sales and Service

Contacts worldwide. Helping to optimise your productivity, improve your maintenance, and control your finances.

- 24/7 availability
- Local hotlines, local language and local stock

The Danfoss service organisation is present in more than 100 countries – ready to respond whenever and wherever you need, around the clock, 7 days a week.

Find your local expert team on
www.danfoss.com/drives

Pick your dedicated solution from the VLT® service menu:

Keep you running

- Current filter update
- Commissioning and regular adjustments
- Preventive maintenance

Keep you fit

- Training
- Stock maintenance & consignment
- Harmonic Survey
- Environmental Disposal

Fix your costs

- Fixed Price
- Post-warranty agreement
- Transport insurance
- Response time

Harmonic Distortion is widespread




With the widespread adoption of fast semi-conductor power switching, harmonic distortion is no longer a local or regional problem but a global concern within almost all industries.

Some areas are however more exposed to harmonic distortion than others due to conditions of the power supply and sensitivity of other equipment such as airports & hospitals.

As mains power is more corrupted than ever before, recommendations of individual harmonic values to be met are becoming mandatory rather then discretionary before connection to the power grid can be allowed.

Typical applications where harmonic stress needs evaluation

Meeting harmonic standard

Area	Application	Benefits
Contractor specified green field projects:	– Water and waste water – Fans and compressors – Food and beverage	– Meet harmonic standards – Reduce harmonic impact on grid
Process critical production/sensitive environments:	– Building services – Oil and Gas – Clean rooms – Airports – Power plants – Water treatment	– Meet harmonic standards – Reduce lighting flickering – Secure uptime – Resonance damping

Special exposed areas

Area	Application	Benefits
Isolated power grids or generator supplied sites:	– Offshore installations – Marine sector – Hospitals	– Reassure voltage quality on primary and backup supply – Reduce lighting flickering – Prevent trips
Insufficient power grid capacity:	– High Growth areas – Developing countries	– Increase transformer loading capability – Improve power-factor
Soft power grids: (Remote areas)	– Remote areas – Mining – Oil and Gas	– Reduce system loading by improving true power factor – Prevent trips and secure uptime

Find out if harmonics is a problem – free of charge

Save money and reduce running costs

On the basis that it is better to avoid a problem rather than cure one after it happens, it is preferable to calculate the effect of installing non-linear loads before doing so, to estimate the degree of harmonic distortion that may result.

Trying to achieve this on a spreadsheet basis can be time consuming and inaccurate.

To help, Danfoss offers free to download, the VLT® Harmonic Calculation Tool MCT 31, a simple to use and fast software tool for calculating the harmonic disruption from your existing or intended drives installation.

A fast estimate is vital as, in this case, more is not better, simply more costly, so the MCT 31 can help save money when selecting harmonic mitigation solutions.

Simply over-specifying a harmonic mitigation solution will lead to unnecessary initial cost escalation and increased running expenses.

Calculate the harmonic disturbance

The MCT 31 tool can easily be used to evaluate the expected grid quality and includes a range of passive and active counter-measures which can be selected to ease system stress.

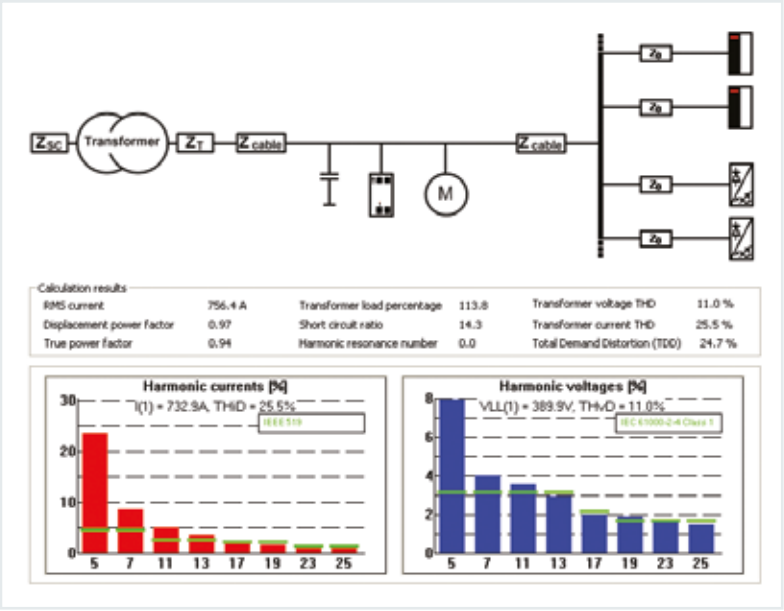
The power quality impact of electronic devices can be estimated in the frequency range up to 2.5 kHz, depending on the system configuration and standard limits.

The analysis includes indication of compliance with various standards and recommendations.

The Windows-like interface of the MCT 31 tool makes possible intuitive operation of the software. It is built with a focus on user-friendliness and the complexity is limited to system parameters that are normally accessible.

The Danfoss VLT® frequency converter and mitigation equipment data is already pre-loaded, allowing fast data entry.

Your local Danfoss consultant will be very happy to provide all the assistance you need to evaluate your power quality and advice in the selection of the correct mitigation for your circumstances.



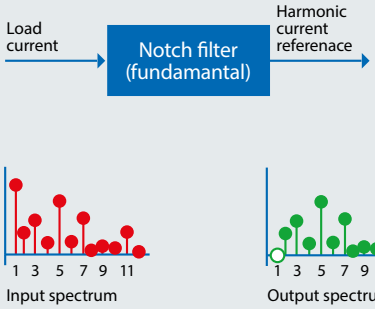
Screen dump of the MCT 31 result summary. Provides fast overview of the installation, such as power factor, harmonic current and voltage and norm compliance.

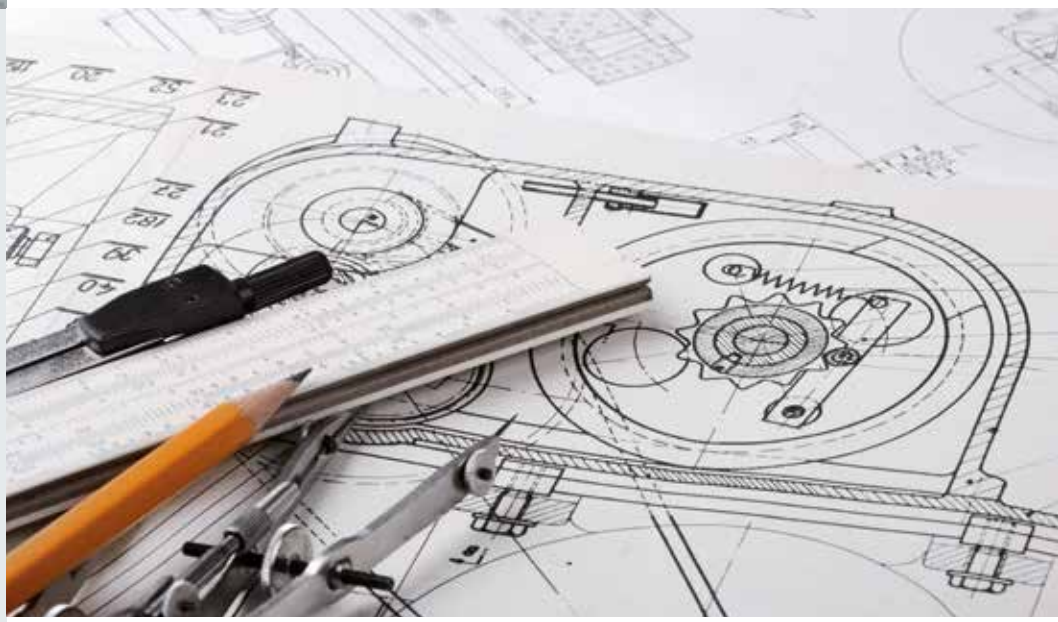
An in-depth look at the technical benefits of AAF

Selective or individual harmonic compensation – an application dependent choice.
Active harmonic filters have previously been designed with either selective or overall compensation mode.

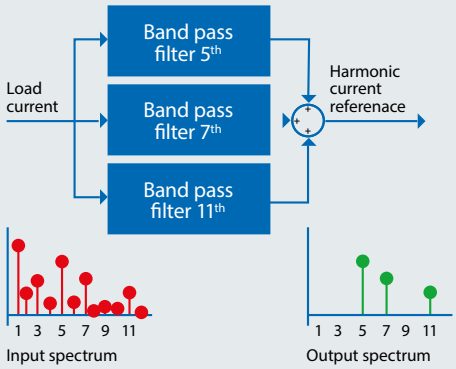
Now, Danfoss VLT® Active Filters allow you to choose the best approach for your application.

Overall compensation control





Selective mode control



Selective mode control

This mode uses Fast Fourier Transforms (FFT) to calculate the amplitudes and phase angle of the individual harmonic orders.

This is a time consuming method but very precise and allows a full overview and compensation of individual harmonic orders to specified target values. It is ideal for grids having a resonance frequency within the working range of the filter.

Furthermore, it allows the user to dedicate individual compensation should the filter be too small to perform full harmonic compensation at any time.

Overall compensation control

This mode removes the fundamental frequency from the current sampling and injects a counter-phase signal to the remaining signal. It compensates for even harmonics, inter-harmonics and triplens, thus gives improved performance on unbalanced and/or pre-distorted grids.

As opposed to selective harmonic compensation, no individual harmonic orders are known nor can they be compensated individually.

Direct harmonic control – for instant compensation

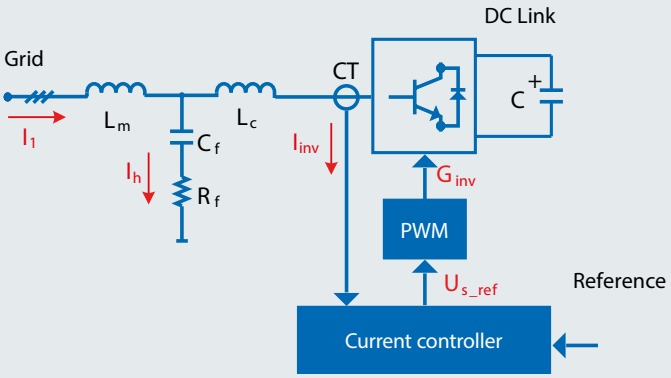
PWM control is widely used and accepted as the preferred control algorithm.

Due to the continuously changing environment of the supply grid resulting from sudden load changes, commutation notches, transients and resonances, the dynamics of a PWM modulator are often too slow to ensure optimal operation and most favourable filtering under these constantly changing conditions.

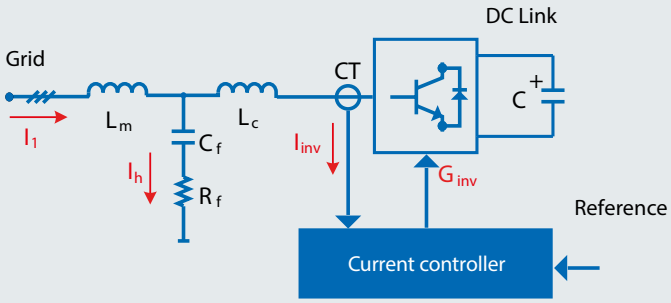
The Danfoss Active Filter cuts off the PWM modulator and provides the gate control pulses directly from the current controller leading to response time of < 30 µS.

The innovative control algorithm not only improves compensation of the high order harmonics but also results in better damping ability. That means that the Danfoss VLT® Active Filter in overall compensation mode is fast enough to reduce flicker and act as grid resonance damping, ensuring greater up-time.

Traditional Active filter control



VLT® Active Filter control



Limited IGBT switching for limited resonance and stress

Where many active filters have a constant switching frequency, the Danfoss VLT® Active Filters has a progressive switching pattern.

This innovative pattern mitigates low order harmonics of high current demand using low switching frequency, and high order harmonics with low amplitude, using higher switching frequency.

The result is reduced IGBT module stress, lower electronic losses and prolonged unit life.

Where fixed switching frequencies have a concentration of switching noise around the switching frequency, the Danfoss VLT® Active Filter has scattered its switching frequency over a broad frequency range.

This lessens the chance of resonances on the grid or toward the load.

Global application examples

Thruster installation

Thrusters systems are generally used on ships for positioning or manoeuvring. Mostly these systems are electrical driven due to the need for precise speed control.

Thruster systems consume a huge amount of power and are often a significant part of the generator load making harmonic mitigation essential.

As active filters are sizable to meet the mandatory levels of marine standards, they are often an economical and attractively sized solution.

This ship, a cable layer for wind turbines, was equipped with seven high power VLT® drives and mitigated via two centrally installed VLT® Active Filters. The mounting flexibility together with the robust and compact enclosure of the VLT® Active Filters allowed installation in the machine room away from the drive installation. As both Danfoss drives and VLT® Active Filters are recognized for most marine standards, Lloyds compliance could easily be fulfilled.

HVAC installation in hospital

Using adjustable speed drives in refrigeration installations enables energy savings and reduces mechanical stress on compressors.

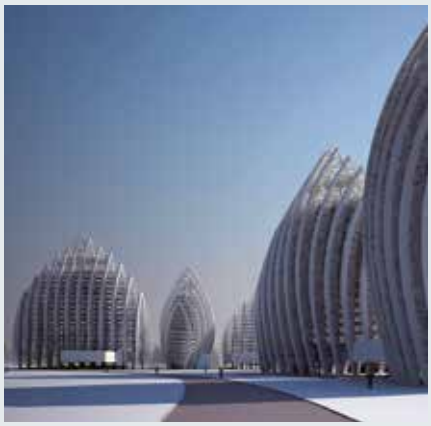
In a hospital, climate control is critical and so most installations are equipped with generator back-up ensuring reliable operation even in the event of a power outage.

With its ability to adapt regardless of mains power source, harmonic correction was achieved via two VLT® Active Filter installed on each distribution line. The active filters were sized to reduce voltage harmonics down to 5% of the entire load in generator supply and filter sleep mode ensures energy conservation in case mitigation is not needed.

Established in 1864, DNV is an independent foundation with the objective of safeguarding life, property and the environment.

The Lloyd's Register Group is an organisation that works to enhance safety and to approve assets and systems at sea, on land and in the air.

ABS Consulting is a leading independent global provider of Risk Management Services that combines industry experts, risk modeling, practical engineering and technology-based solutions.



Waste water installation

This large water treatment plant was mitigated by means of different mitigation equipment. Included in the package were two 190 A VLT® Active Filters.

Snow making

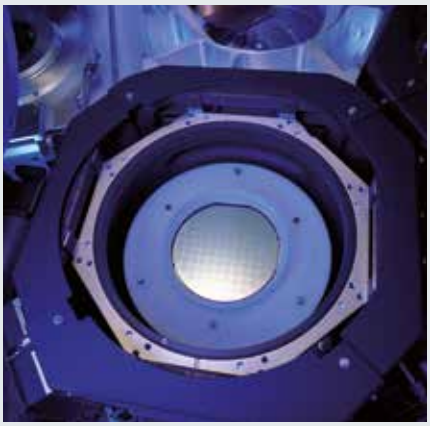
An entire water pump system utilising several small and medium power drives, was compensated via centrally installed VLT® Active Filters. The filter was dimensioned for installation at high altitudes.

Blower for waste collecting system

Four identical transformer systems, each with six large drives, were compensated by one filter each. The bundled solution was enough to meet the system requirement of 5% THDv.

HVAC installation

A complete HVAC drive installation consisting of more then 350 smaller VLT® drives was compensated via two large centrally installed VLT® Active Filters.



Semiconductor industry

Process and energy optimization expanded the use of drives at this semiconductor manufacturer. 5 VLT® Active Filters were installed to ease transformer stress and avoid voltage distortion.

Power plant

At this European power plant where high power drives are driving crude oil pumps, VLT® Active Filters achieved effective harmonic mitigation.

Specifications

E-frame

Norminal Voltage

Frame size		D	E	E	E
Type		**A190**	**A250**	**A310**	**A400**
400 V – Corrected current					
Continuous	[A]	190	250	310	400
Intermittent*	[A]	209	275	341	440
460 V – Corrected current					
Continuous	[A]	190	250	310	400
Intermittent*	[A]	209	275	341	440
480 V – Corrected current					
Continuous	[A]	150	200	250	320
Intermittent*	[A]	165	220	275	352
500 V – Corrected current					
Continuous	[A]	95	125	155	200
Intermittent*	[A]	105	138	171	220
Estimated maximum power loss	[kW]	5	7	9	11.1
Efficiency	[%]	96	96	96	96
Recommended fuse and disconnect**	[A]	350	630	630	900
Copper cable data:					
Maximum cross-section	[mm²]	2 x 150	4 x 240	4 x 240	4 x 240
	[AWG]	2 x 300 mcm	4 x 500 mcm	4 x 500 mcm	4 x 500 mcm
Minimum cross-section	[mm²]	70	120	240	2 x 95
	[AWG]	2/0	4/0	2 x 3/0	2 x 3/0

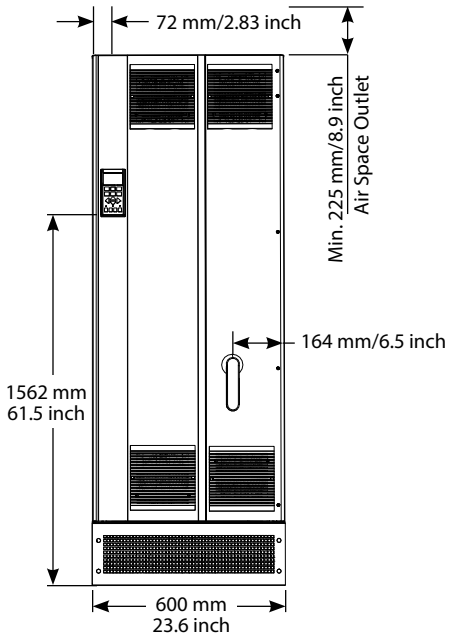
** 1 minute every 10 minutes (automatically regulated)*
*** Built-in options are recommended*

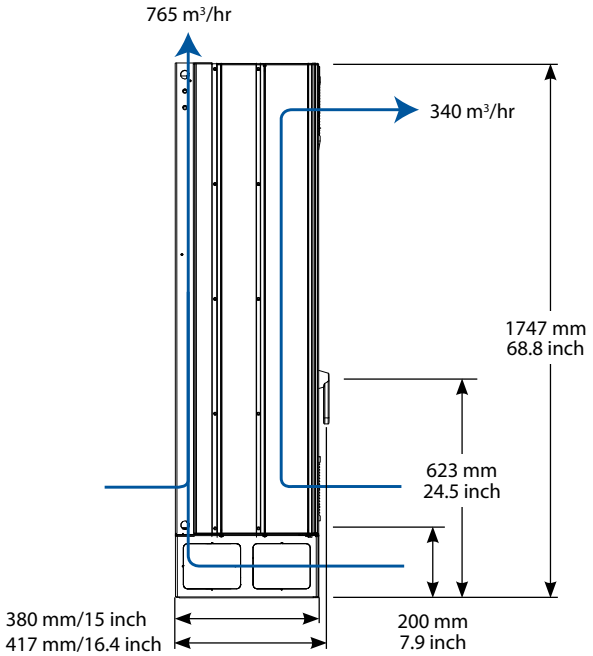
Filter type	3P/3W, Active Shunt Filter
Frequency	50 to 60 Hz, ± 5%
Enclosures	IP 21 – NEMA 1, IP 54 – NEMA 12
Max. grid pre-distortion	10% 20% with reduced performance
Temperature	0-40° C: +5° C with reduced performance -10° C with reduced performance
Altitude	1000 m without derating 3000 m with reduced performance (5%/1000 m)
EMC performance	IEC 61000-6-2 IEC 61000-6-4
Circuitry coating	Conformal coated – per IEC 60721-3-3, class 3C3
Languages	18 different
Harmonic compensation modes	Selective (90% RMS for harmonic reduction) Overall (100% RMS for harmonic reduction)
Harmonic compensation spectrum	2nd to 40th in overall mode, including triplens 5th, 7th, 11th, 13th, 17th, 19th, 23rd, 25th in selective

Individual harmonic current allocation in selective mode	I5: 63%, I7: 45%, I11: 29%, I13: 25%, I17: 18%, I19: 16%, I23: 14%, I25: 13%
Reactive current compensation	Yes, to target value
Flicker reduction	Yes, in overall mode
Compensation priority	Programmable to harmonics or displacement power factor
Paralleling option	Up to 4 units of same power rating in master follower
Current Transformer Support (Customer supply and field mounting)	1 A and 5 A secondary with auto tuning Class 0.5 or better
Digital inputs /outputs	4 (2 programmable) Programmable PNP or NPN logic
Communication interface	RS485, USB1.1
Control type	Direct harmonic control (for faster response)
Response time	< 15 ms (including HW)
Harmonic settling time (5-95%)	< 15 ms
Reactive settling time (5-95%)	< 20 ms
Maximum overshoot	5%
Switching frequency	Progressive control in the range of 1 – 18 kHz
Average switching frequency	3 – 4.5 kHz

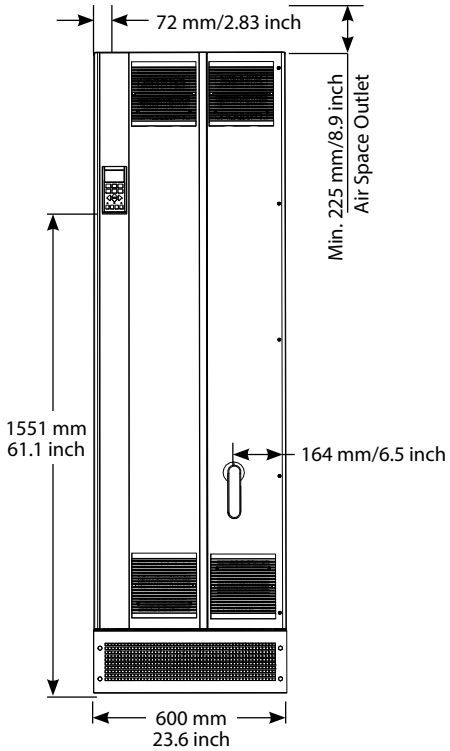
Dimensions

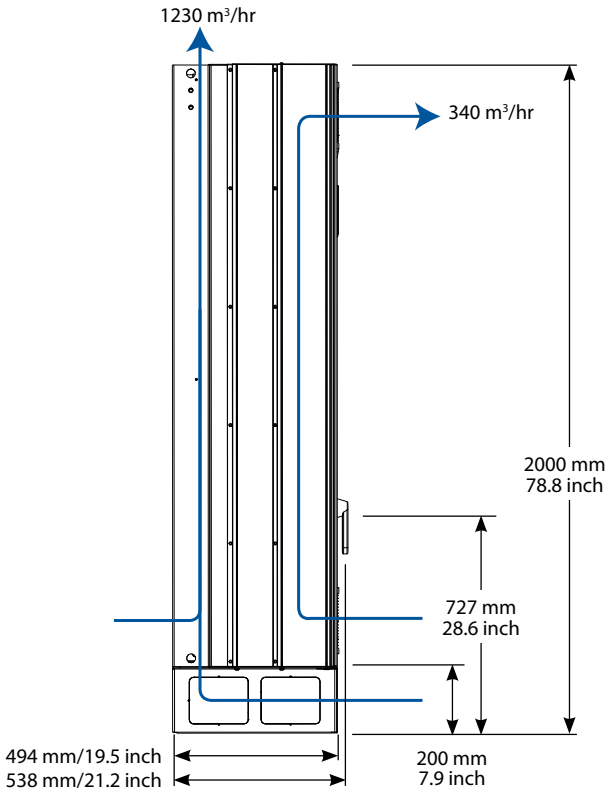
D-frame
IP 21/IP 54





E-frame
IP 21/IP 54





Type code

The different VLT® Active Filters can easily be configured acccording to customer request at www.danfoss.com

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	..	39
A	A	F	0	0	6	A	x	x	x	T	4	E	x	x	H	x	x	G	C	x	x	x	S	.	X

8-10:
190: 190 A correction current
250: 250 A correction current
310: 310 A correction current
400: 400 A correction current

13-15:
E21: IP 21/NEMA 1
E2M: IP 21/NEMA 1 w. mains shield
C2M: IP 21/NEMA 1 w. stainless steel back-channel and mains shield
E54: IP 54/NEMA 12
E5M: IP 54/NEMA 12 w. mains shield
C5M: IP 54/NEMA 12 w. stainless steel back-channel and mains shield

16-17:
HX: No RFI Filter
H4: RFI class A1

21:
X: No mains options
3: Disconnect & Fuse
7: Fuse

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What VLT® is all about

Danfoss VLT Drives is the world leader among dedicated drives providers – and still gaining market share.

Environmentally responsible

VLT® products are manufactured with respect for the safety and well-being of people and the environment.

All activities are planned and performed taking into account the individual employee, the work environment and the external environment. Production takes place with a minimum of noise, smoke or other pollution and environmentally safe disposal of the products is pre-prepared.

UN Global Compact

Danfoss has signed the UN Global Compact on social and environmental responsibility and our companies act responsibly towards local societies.

EU Directives

All factories are certified according to ISO 14001 standard. All products fulfil the EU Directives for General Product Safety and the Machinery directive. Danfoss VLT Drives is, in all product series, implementing the EU Directive concerning Hazardous Substances in Electrical and Electrical Equipment (RoHS) and is designing all new product series according to the EU Directive on Waste Electrical and Electronic Equipment (WEEE).

Impact on energy savings

One year's energy savings from our annual production of VLT® drives will save the energy equivalent to the energy production from a major power plant. Better process control at the same time improves product quality and reduces waste and wear on equipment.

Dedicated to drives

Dedication has been a key word since 1968, when Danfoss introduced the world's first mass produced variable speed drive for AC motors – and named it VLT®.

Twenty five hundred employees develop, manufacture, sell and service drives and soft starters in more than one hundred countries, focused only on drives and soft starters.

Intelligent and innovative

Developers at Danfoss VLT Drives have fully adopted modular principles in development as well as design, production and configuration.

Tomorrow's features are developed in parallel using dedicated technology platforms. This allows the development of all elements to take place in parallel, at the same time reducing time to market and ensuring that customers always enjoy the benefits of the latest features.

Rely on the experts

We take responsibility for every element of our products. The fact that we develop and produce our own features, hardware, software, power modules, printed circuit boards, and accessories is your guarantee of reliable products.

Local backup – globally

VLT® motor controllers are operating in applications all over the world and Danfoss VLT Drives' experts located in more than 100 countries are ready to support our customers with application advice and service wherever they may be.

Danfoss VLT Drives experts don't stop until the customer's drive challenges are solved.