ENGINEERING
TOMORROW

Harmonics – a costly problem easily solved

<40%

Transformer loading with Danfoss VLT Drives prevents harmonic issues. Hereafter filtration is needed.

www.danfoss.com/drives

VLT® THE REAL DRIVE

Q What are harmonics?

A

An electrical AC supply is ideally a pure sine-wave of either 50 or 60 Hz fundamental frequency and all electrical equipment is designed for optimal performance on this supply.

Harmonics are voltages and currents which have frequency components that are integers multiple of the fundamental frequency – polluting the pure sinusoidal waveform.

Power electronics such as those used in rectifiers, variable speed drives, UPS, lighting dimmer switches, televisions and hosts of other equipment, draw current in a non-sinusoidal fashion.

This non-sine current interacts with the mains supply and distorts the voltage to a greater or lesser degree depending upon the strength or weakness (fault level) of the supply.

Generally, the greater the amount of installed electronic power switching equipment on-site, the greater the degree of harmonic distortion.

Q Why are harmonics a problem?

A

Excessive harmonic distortion of the mains supply implies that the source not only carries 50 or 60 Hz frequencies but also components of higher frequencies.

These components can not be utilized by electrical equipment and adverse effects can be severe and include:

- Limitations on supply and network utilisation
- Increased losses
  - Increased transformer, motor and cable heating
  - Reduced equipment life-time
  - Costly unintended production stops
- Control system malfunctions
- Pulsating and reduced motor torque
- Audible noise

Put simply, harmonics reduce reliability, affect product quality and increase operating costs.

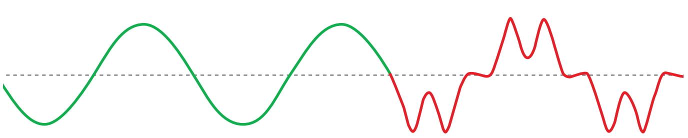


Illustration of a pure sinusoidal waveform being polluted.

Q Does that mean that every drive leads to harmonic problems?

A

Not at all.
All Danfoss VLT Drives come with built-in DC-coils* to reduce the harmonics interference and in most cases this is sufficient to avoid voltage pollution.

In some cases additional harmonic suppression might be required due to grid conditions or when multiple drives are installed.

For that purpose Danfoss offers a wide range of individual mitigation solutions such as: VLT® 12-pulse Drives and standard drives with either built-in or external, active or passive harmonic filters.

In addition to this, Danfoss also offers both passive and active solutions for central harmonic suppression where several loads can be compensated simultaneously.

Determining the degree of voltage pollution on your network is easily done with the free Danfoss VLT® MCT 31 Harmonic Calculation software.

It helps you determine whether or not additional harmonic suppression is needed.

VLT® MCT 31 estimates the harmonic current and voltage distortion of your application and determines if harmonic filtering is needed.
In addition the software can calculate the effect of adding mitigation equipment and if your system complies with various standards.

**With exception of VLT® Micro Drive FC 51 – an external mitigation solution is available.*

Danfoss offers on-site harmonic survey and recommendation of the most suitable mitigation solution.

Q How is the optimal harmonic solution chosen?

A

Different equipment exists to reduce harmonic pollution and they all have their advantages and disadvantages.

No single solution offers a perfect match for all applications and grid conditions.

To achieve the optimum mitigation solution, several parameters have to be considered.

The key parameters can be divided into four groups:

- Grid conditions including other loads
- Application
- Compliance with standards
- Cost

Danfoss will, upon request, carry out a full harmonic survey and recommend the most appropriate and most cost-effective solution for your site.

The survey will take the installed loads, the regulatory standards and the diversity of your operation and application into consideration.

The essential considerations

Two VLT® Active Filters compensate t
on vessel with limited wall space in a

>300 VLT® Advanced Harmonic Filters installed at decentral oil pumping stations. Ensures 24hour/day pumping.

Two VLT® Advanced Active Filters for HVAC installed at a hospital to ensure a stable supply for vital equipment.

Danfoss solutions are easily installed, commissioned and individually tuned for your application.

How do grid conditions affect harmonics pollution?

The most important factor in determining the harmonic pollution of a supply grid is the system impedance.

The system impedance is mostly dependent on the transformer size in relation to the total power consumption of installed loads. The bigger the transformer is in relation to non-sinusoidal power consumption, the smaller the pollution.

The power grid is an interconnected system of power supplies and power consumers all connected via transformers. All loads drawing a non-sinusoidal current contribute to the pollution of the power grid – not just at the low voltage supply but also at higher voltage levels.

When measuring at a power socket, some degree of pollution will thus always be present. This is referred to as harmonic pre-distortion. As not all consumers draw three-phase current, the load on each phase is dissimilar. This leads to unequal voltage values on each phase, causing phase imbalance.

Different harmonic solutions have different immunity against pre-distortion and imbalance and so this has to be evaluated when determining the most suitable harmonic mitigation solution.

hruster drive application
tough environment.

Three VLT® Low Harmonic Drives installed at waste water station ensure compliance with IEEE519.

Six cost optimized VLT® 12-pulse drives incl. transformer installed at facility for material handling.

What application aspects must be considered?

Harmonic distortion increases with the amount of power consumed by the non-linear load and so both the number of drives installed, and their individual power sizes and load profiles, must be considered.

The distortion of a drive is defined by the total harmonic current distortion (THDi) which is the relationship between the sum of harmonic components and the fundamental frequency.

The loading of each drive is important because the THDi increases at partial load, thus over-sizing drives increases the harmonic pollution on the grid.

Additionally, environmental and physical constraints must be taken into account because the different solutions all have characteristics making them more or less suited to specific conditions.

What needs to be considered is, for example, wall space, cooling air (polluted/contaminated), vibration, ambient temperature, altitude, humidity, etc.

Are compliance with standards consistent globally?

To ensure a certain grid quality, most power distribution companies demand that consumers comply with standards and recommendations.

Different standards apply in different geographical areas and industries but all of them have one basic goal, – to limit the grid voltage distortion.

Standards depend on grid conditions and so it is impossible to guarantee standards compliance without knowing the grid specifications.

Standards themselves do not compel a specific mitigation solution and so an understanding of standards and recommendations is important to avoid unnecessary cost for mitigation equipment.

What areas of cost must be considered when applying harmonic mitigation?

Finally, the initial costs and running expenses have to be evaluated to ensure that the most cost-effective solution is found.

The initial cost of the different harmonic mitigation solutions in comparison to the drive varies with the power range. The mitigation solution that is most cost efficient for one power range is not necessary best cost fit over the full power range.

The running costs are determined by the efficiency of the solutions across the load profile and their lifetime maintenance/service costs.

Compared to active solutions, passive solutions often do not require regular maintenance.
On the other hand, active solutions tend to keep the true power-factor close to unity over the entire load range, resulting in better energy utilization at partial load.

Also, future development plans for the plant or system need to be taken into account because although one solution will be optimal for a static system, another will be more flexible if the system needs to be extended.

The route to ...

Grid conditions

Grid conditions
Before considering mitigation equipment, the system impedance has to be known.

No grid is ideal because pre-distortion and imbalance is always present and so needs to be considered when choosing equipment.

Application

Application
A common pitfall is over-sizing of components between load and grid. The consequence is a poor harmonic performance, low system efficiency and a higher initial cost.

Compliance with standards

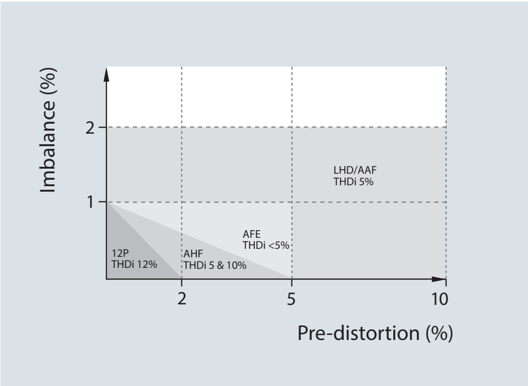
Compliance with standards
A total voltage distortion (THDv) of 5-8% good engineering practice and will, in most cases, make the installation comply with local standards and recommendations. It ensures that unintended tripping or component breakdown is not caused by harmonic pollution.

Cost

Cost
The initial cost of different mitigation equipment depends on power size.

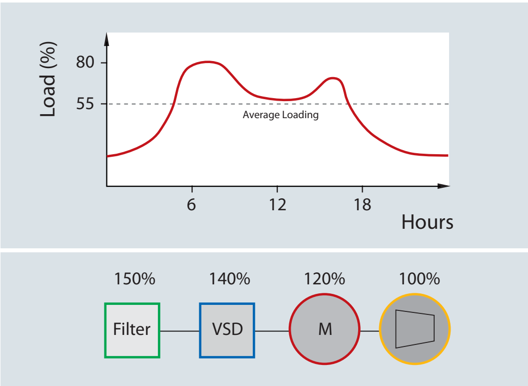
The system efficiency determines the running expenses, but service costs also need consideration.

Cost effective mitigation



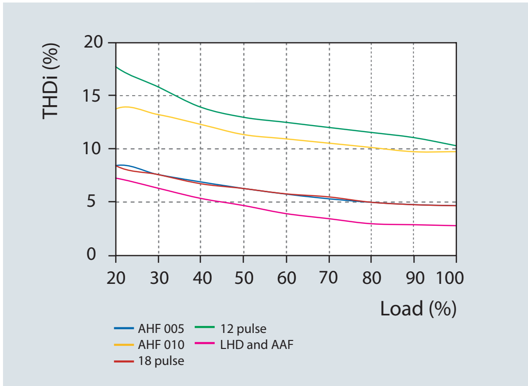
Imbalance and pre-distortion

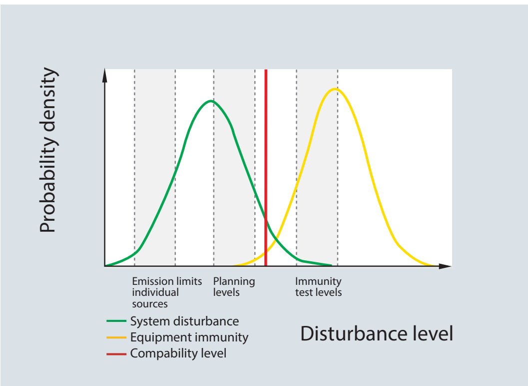
The harmonic mitigation performance of the different solutions depends on the grid quality. The higher the imbalance and pre-distortion, the more harmonic the equipment has to suppress. The graph shows at what pre-distortion and imbalance level each technolegy can keep its guaranteed THDi performance.



Over-sizing

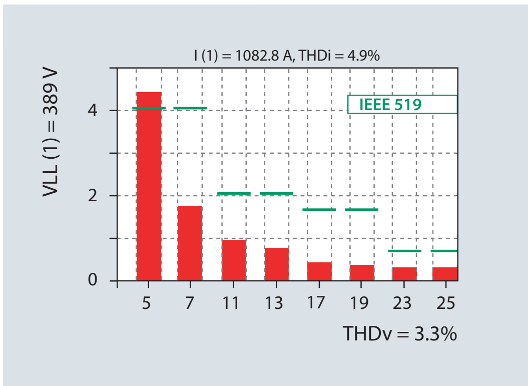
Published filter data are all given at 100% loading but filters are seldom run at full load due to over-sizing and load profile.
Serial mitigation equipment must always be sized for the maximum current, but be aware of the duration of part load operation and evaluate the different filter types accordingly.
Over-sizing gives poor mitigation performance and high running costs. It is also a waste of money.

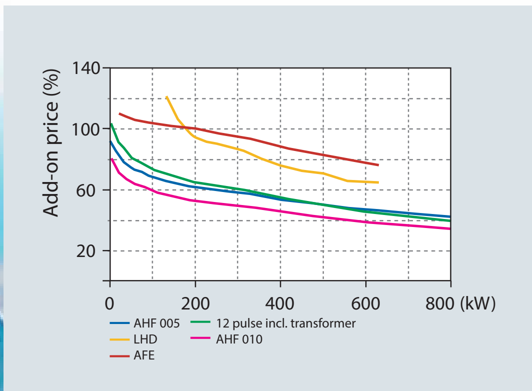




Standards compliance

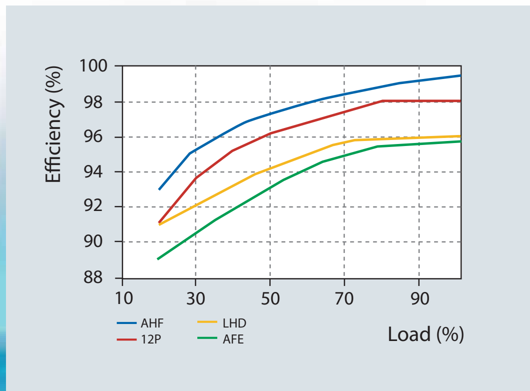
Keeping equipment immunity higher than system distortion ensures trouble free operation.
Most standards set restrictions on total voltage distortion according to a planned level, often between 5% and 8%.
Equipment immunity is, in most cases, far higher: for drives, between 15-20%. However, this influences product life adversely.



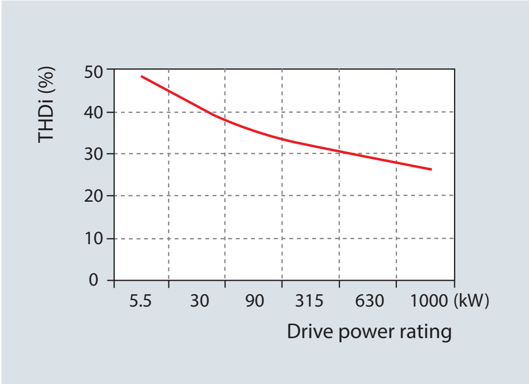


Power size vs. initial costs

Compared to the frequency converter, the different solutions have different add-on prices depending on power size.
The passive solutions in general offer the lowest initial cost and as the complexity of the solutions increase, so does the price.

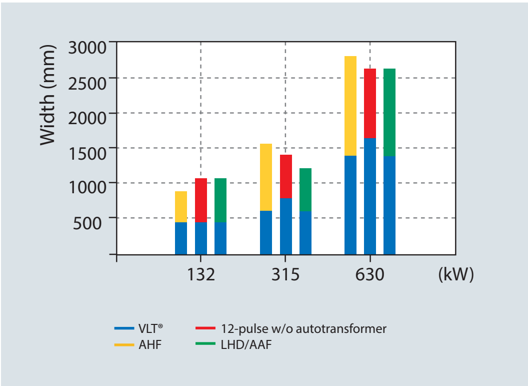


System impedance
As an example, a 400 kW FC 102 drive on a 1000 kVA transformer with 5% impedance results in ~5% THDv (total harmonic voltage distortion) at ideal grid conditions, whereas the same drive on a 1000 kVA, 8% imp. transformer leads to 50% higher THDv, namely 7.5%.



Total Harmonic distortion
Each drive generates its own total harmonic current distortion (THDi) which depends on the grid conditions. The bigger the drive is in relation to the transformer the smaller the THDi.

Harmonic performance
Each harmonic mitigation technology has its own THDi characteristic which is load dependent.
These characteristics are set at ideal grid conditions without pre-distortion and with balanced phases.
Variations hereof will result in higher THDi values.



Wall space
In many applications the amount of available wall space is limited and must be utilized to the greatest extent possible.
Based on different technologies, the various harmonic solutions each have their optimum size and power relationship.

Fulfilling the standards
To determine whether or not the harmonic pollution of a given application/grid exceeds a specific standard, many complex calculations must be done. With the help from free Danfoss MCT 31 harmonic calculation software, this is made easy and less time consuming.

System efficiency
The running cost is mainly determined by the overall system efficiency.
This depends on the individual products, true power-factors and efficiencies.
Active solutions tend to keep the true power-factor independent of load and grid variations. On the other hand, active solutions are less efficient than passive solutions.

... best match

The application
To guarantee the many outdoor activities during the winter season, multiple snow guns are ensuring snow availability around the stadium at Östersund in Sweden.

The snow guns can be quickly connected to a piping network where water is fed from a single large water pump located in a movable hut nearby.

As part of a renovation project, the customer requested that a new 200 kW water pump be installed.

The pump was to maintain constant water flow and pressure through the entire piping system independently of how many snow canons were connected.

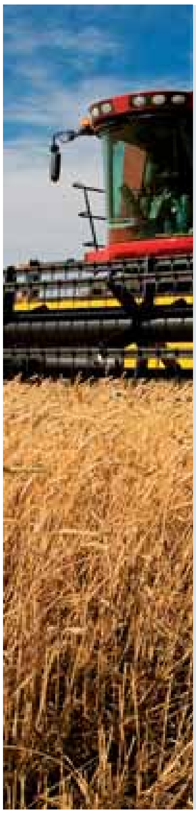
Due to the long distance from the power supply, the local authority imposed a maximum total current distortion of 5%.

The solution
A VLT® Low Harmonic AQUA Drive was installed to provide the required water flow and pressure.

Load variations of 20-100% and existing grid distortion of 2.4% were important factors when the application was evaluated.

The drive was supplied with coated PCBs and installed in IP 54 enclosures to withstand the high humidity in the uninsulated galvanised pump shed.

Although the mains supply was weak, the drive easily met the < 5% THDi requirement.



The application
In a world where the focus on the reduction of CO_2 emissions is increasing, alternatives to fossil fuels are increasingly being sought. The bio-refining of cereals means that grain (such as wheat) is broken down into sugars and proteins and the sugars fermented into bio-fuel. The protein solids and remaining parts of the grain are converted into high protein animal food – leaving no waste.

To build one of Europe's largest bio-refineries, the customer requested VLT®s totalling more than 7 MW, ranging from 2.2 – 350 kW.

With its own 3300/400 V transformer, the bio-refinery had to set and comply with site harmonic standards to ensure high reliability and the longest possible service intervals as demanded by the customer.
To achieve this, harmonics were to be maintained at less than 8% Total Demanded Distortion (TDD) at the supply transformer.

The solution
In total 48 VLT®s were installed to control pumps and ventilation fans throughout the bio-refinery.

Based on the VLT® power sizes and the demands for robustness/reliability, the majority of the VLT®s were designed and installed with Advanced Harmonic Filters mounted side-by-side in IP 54 panels and the specified 8% TDD was easily achieved.

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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.

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