ENGINEERING
TOMORROW

Danfoss

Why should you care about **mitigating harmonics?**

1.7%

better efficiency via VLT® Advanced Active Filter instead of an active front end drive for harmonic mitigation

www.vlt-drives.danfoss.com

VLT® THE REAL DRIVE

Are you using the best method of harmonic mitigation?

The so-called AFE (active front end) technique has rapidly become popular when the target is low harmonic levels. This article however challenges AFE as the most frequently used solution for harmonic dampening.

Should you care about harmonics?

Harmonics can create problems for you, for instance

- transformer overload and audible noise
- overheating in cables
- premature aging of serially installed equipment like PLCs and protection relays
- torque ripples from direct-on-line motors
- malfunction or even breakdown of electronic equipment

So the short answer is - YES. It is also worth considering requirements from the grid supplier (DNO) for maximum tolerable current distortion on the primary side of the transformer. So in a nutshell, you should care about harmonics - but there is no need to panic.

Why is there no panic?

Most premium drive manufacturers supply their drives with standard harmonic mitigation in the form of integrated DC or AC chokes. With this technique, the generated THDi (total harmonic current distortion) is dampened from as much as 100% (for drives without DC or AC chokes) down to a level below 40% THDi.

This level is sufficient to minimize harmonic problems in most cases, depending on the general load of the transformer and the share of drives on the transformer.

When a major portion of the load is in fact due to drives, then it is a good idea to perform a harmonics calculation.

- For a general calculation, use a harmonics calculation tool such as the Danfoss VLT® Motion Control Tool MCT 31 available for free download here: ***http://www.danfoss.com/BusinessAreas/DrivesSolutions/Softwaredownload/*** or
- For a more accurate result, you could hire Danfoss or a specialised power company to measure your current and voltage harmonics level.

Regardless of enclosure size, the Danfoss VLT® AQUA Drive is equipped with an integrated DC choke. One of the advantages of a DC choke over AC choke is that there is no voltage loss over the coils in the DC link. Drives equipped with an AC choke typically lose 3% of the supplied voltage. This loss leads to lower voltage on the motor terminal, thus generating a higher current.

AFE and power loss

Active Front End (AFE) drives were initially developed to regenerate power back to the grid for applications with heavy braking cycles, for instance in crane and hoist applications. Since an AFE drive uses an active rectifier, usually in the form of an IGBT bridge, harmonic current distortion is very low. However there are some disadvantages with the AFE technique:

- In an AFE drive, the power electronics are placed in serial current flow. Serial connection means that if one power electronic component fails, for example in the filter, the entire drive stops, resulting in a stand-still.
- An AFE drive contains twice the number of power electronics as a standard drive, plus an LCL filter, which does not exist in a standard drive. Twice the number of electrical components means there is twice the risk of a component failure.
- Twice the power electronics also means greater power loss over the drive:
  - A normal drive from a premium drive manufacturer has a heat loss of about 2% over the drive. For precise figures, refer to the VLT® AQUA Drive Design Guide.
  - The heat loss from an AFE drive can easily exceed that of a VLT® AQUA Drive by 137% or more – as shown in Table 1 below.

Frequency converter	Manufacturer	Heat loss
VLT® AQUA Drive FC 202 132 kW with DC choke	Danfoss	2.9 kW
Standard drive, 132 kW with AC choke	Other leading drives manufacturer	3.3 kW
AFE drive, 132 kW with AC choke	Other leading drives manufacturer	7.0 kW

Heat loss comparison

So if the extra harmonic dampening is not needed then don't invest 150-200% of the price of a normal drive in buying a drive with lower efficiency. After all, the most important task of the drive in a pump application is to save energy.

Are there alternatives?

In short, yes! System mitigation using a VLT® Advanced Active Filter (AAF) is a preferable method to dampen harmonics in most cases. An AAF is easy to retrofit, can compensate multiple drives, and cleans up the entire transformer.

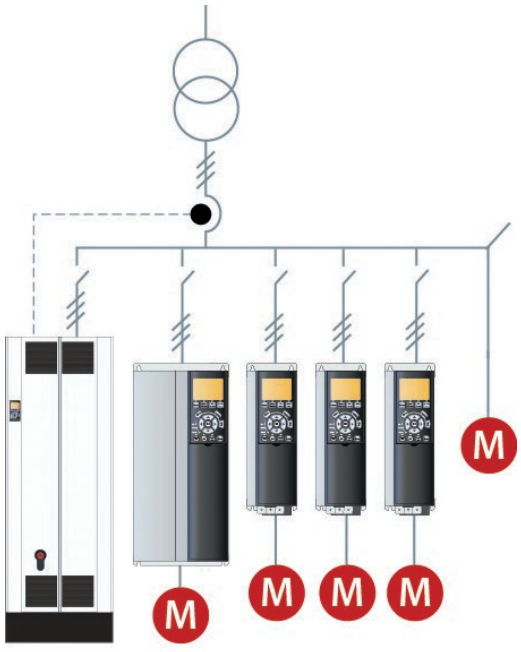
In contrast to the AFE drive, the AAF solution is installed in parallel with the current flow, meaning the current to the drives does not flow through the filter. Should any component in the AAF should fail, the current will continue to flow unhindered to the drives. So if a filter breakdown occurs, the harmonics level will of course rise, but the water treatment plant or pump station can still continue its business.

Another benefit of the AAF is the built in "sleep mode" function. When load level is low and thus the harmonic level becomes low (settable value in the AAF) the AAF enters sleep mode to conserve energy. For a comparable AFE solution, the extra losses due to harmonic dampening are constantly present.

See below for calculation examples based on a fictional water treatment plant with a number of drives.

Harmonics mitigation method	Advantages	Disadvantages
AFE drive	■ Excellent harmonic mitigation	■ Low efficiency at all load levels ■ Only available for ratings 55 kW and above ■ Serial connection means plant downtime in the event of filter component failure
Advanced Active Filter serving conventional drives	■ Excellent harmonic mitigation ■ Sleep mode activates when transformer load is low, and the extra harmonic dampening is not required – saving even more energy ■ Filter mounted in parallel to current flow means breakdown of filter does not result in plant downtime ■ Lower power losses than AFE	■ System level harmonics calculation is often required, for example using VLT® Motion Control Tool MCT 31 from Danfoss.

Comparison of AFE and AAF solutions



Group compensation using Danfoss VLT® Advanced Active Filter

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Operating cost and efficiency comparisons

The cost and efficiency comparisons are calculated based on an example: a small water treatment plant comprising

- Transformer 1000 kVA, 400 V, 50 Hz
- Installed equipment

Frequency converter rating [kW]	Pcs	Losses per frequency converter using standard drive + AFE on 90 & 132kW from competitor [kW]	Losses per frequency converter using standard Danfoss VLT® AQUA Drive + AAF 250 A [kW]
1.1	2	0.1	0.058
5.5	2	0.2	0.187
15	2	0.44	0.392
22	2	0.61	0.525
55	2	1.44	1.083
90	2	6.0	1.474
132	2	7.0	2.949
AAF 250A	1	-	7.0
Total installed power **641.2 kW**		Total heat loss **31.58 kW**	Total heat loss **20.336 kW**

Operating cost comparison

The operating costs are calculated on the basis of 24/7 operation at 60% average load.

1. AFE solution:

Installed equipment:

- 2 pcs 90 kW +2 pcs 132 kW AFE drives.
- The remaining drives are standard drives with AC choke (≈40%THDi)

Total heat loss, calculated on the basis of catalogue data: **31.58 kW**
Performance: THDi ≈ 13%, THDv <5%

Operating cost
24 h x 365 days x 8760 h x average load
31.58 kW x 8760 h x 0.1 EUR/kWh x 0.6 = **16,598 EUR** annually.

2. Danfoss VLT® Advanced Active Filter compensating multiple drives:

For all installed drive ratings, VLT® AQUA Drive with DC choke is installed (≈40%THDi) + 1 pc VLT® Advanced Active Filter 250 A

Total heat loss: **20.336 kW**
Performance: THDi ≈ 14%, THDv <5%
Operating cost
24 h x 365 days x 8760 h x average load
20.336 kW x 8760h x 0.1 EUR/kwh x 0.6 (average load) = **10,689 EUR** annually.

The operating cost difference between the AFE and Danfoss VLT® Advanced Active Filter solutions is 16,598 – 10,689 EUR = **5,909 EUR.**

Over a time span of 10 years the difference is huge: 5,909 EUR x 10 = **59,090 EUR.**

Efficiency comparison

To compare efficiency, we compare the ratio of power loss to total installed power (for AFE and AAF respectively:

1. AFE solution:
Power loss / total installed power
= 31.58/641.2 = **4.9%**

2. AAF solution:
Power loss/ total installed power
= 20.336/641.2 = **3.2%**

Difference in power loss = 4.9 – 3.2 = **1.7%**

The difference in power loss amounts to a 1.7 % efficiency improvement by operating AAF instead of AFE.

The AAF advantage

The calculations clearly show that using an AAF solution, harmonic mitigation is achievable free of plant downtime, at lower operating cost, and also at higher efficiency, compared to an AFE solution.

Author: Peder Wale (Business Developer Water & Energy, Danfoss AB Sweden)
Technical inputs: Vasile Bucelea (Business Developer High Power Drives, Danfoss Power Electronics A/S)

Danfoss VLT Drives, Ulsnaes 1, DK-6300 Graasten, Denmark, Tel. +45 74 88 22 22, Fax +45 74 65 25 80, www.danfoss.com/drives, E-mail: info@danfoss.com