# Content

1. Introduction ....................................................................................................................................... 3
2. Selection of circuit ............................................................................................................................. 5
3. Data for Mains ................................................................................................................................... 6
4. Input data for FC1 (frequency converter) ....................................................................................... 8
5. Selection of FC1 from a list ............................................................................................................. 10
6. Overview / Start calculation ............................................................................................................ 11
7. Results ............................................................................................................................................ 12
8. Protocol ........................................................................................................................................... 13
1. Introduction

The harmonic calculation software HCS is capable to compute the line distortion (harmonics up to 2.5kHz) caused by converters and to check the compliance to limits of norms. For this purpose one has to supply datas of mains and converter to the software. Alternatively it is possible to compute the harmonics of the mains of a generator. The distortion of the mains's voltage through circuit feedback is caused by a current demand of no sinusoidal shape due to power electronic.

The programm is based on an extensive scientific simulation software, that was build up in cooperation with the university of applied sciences RheinMain. The software is available for the user through login on the webpage of danfoss's HCS. The handling of the software is alike the well-known windows surface, composed graphically and easy to understand. The previously given values are meant as hint for the expected magnitude and can be overwritten. Started with the initially given values, the programm considers a mains with average workload.

The results are not based on tables of benchmarks, but on real computations of interactions between workload and impedance of the mains. Correctly reproduced is for example the extinction of harmonics due to single phase devices of office and household (PC, TV, ...) by three phase frequency converters. Furthermore capacitors are not simply considered as compensations of reactive current with 50 Hz sine-current, but there are computed the harmonic currents considering resonances with impedance of transformer and power cables. The results are presented as tables, bar charts and as u(t)- and i(t)-diagramms, and on exceedance of the norms limits, there is given a warning hint.

Click on „Start“. Try the HCS on: http://www.danfoss-hcs.com/.
The harmonic calculation software HCS is capable to compute the circuit feedback (harmonics up to 2,5 kHz) of frequency converters and to check compliance to limits of the norm. For this purpose one has to supply datas of mains and converter to the software. Alternatively it is possible to compute the harmonics of feeder supply by a generator.

For the ease of handling was created a basic level next to the expert level. Therewith (in basic level) is given an easy constellation, that needs only rare input of data and allows a quick working, needing no data for capacity of converter, lengths and diameter of wires, initial and further workloads of the mains. Clearly this way the results are less precise than on expert level.

The programm is based on an extensive scientific simulation, that was build up in cooperation with the university of applied sciences RheinMain. The software is available for the user through login on the webpage of Danfoss's HCS. The handling of the software is alike the well-known windows surface, composed graphically and easy to understand. The previously given values can be overwritten and are meant as a hint for the expected magnitude of values. Started with the initially given values the programm considers a mains with average workload.

The results are not based on tables of standard values, but on real computations of interactions between workload of the mains and impedances of cables and mains. Correctly reproduced is for example the extinction of harmonics due to single phase devices of office and household (PC, TV, …) by three phase frequency converters. Furthermore capitators are not simply considered as compensations of reactive current with 50 Hz sine-current, but there are computed the harmonic currents considering resonances with impedance of transformer and power cables. The results are presented as tables, bar charts and as u(t)- and i(t)-diagramms, and on exceedance of the norms limits, there is given a warning hint.
2. Selection of circuit

On appearance of this graphic, you can choose between feeder supply by transformer or generator. The active feeder supply is marked in bright colours.

On expert level you additionally can take the following into account:

- ohmic and inductive resistance of cables
- internal resistance of a superior mains at medium-high voltage
- background distortion of the mains
- other types of converters and B12-rectifiers
- active and passive harmonic filters
- linear workloads
- etc.
# 3. Data for Mains

**[Picture 4b: Input of data for the mains]**

**$V_0$**  
Mesh voltage (phase/phase) in [V] on the low voltage side of the mains's transformer at idle run. The input value has to be inbetween 200V and 800V. The mains with 120V star point voltage can be presented as mesh voltage using $120V \times \sqrt{3} = 208V$.

To achieve as realistic results as possible in basic level, the background distortion of the mains's voltage at idle run is assumed to be constant at THDu=2%. In expert level variable values for THDu can be entered.

**$f$**  
Frequency of the mains. It is possible to choose 50Hz or 60Hz.

**$S_N$**  
Nominal power resp. rated power of the mains's transformer, using the unit [kVA].

Its nominal current $I_{NTr}$ can be concluded from the equation

$$I_{NTr} = \frac{S_N \times 1000}{\sqrt{3} \times V_0},$$

where $S_N$ is given in [kVA], the mesh voltage $V_0$ in [V] und $I_{NTr}$ in [A].

The short circuit power of the mains at medium-high voltage is for basic level assumed to be $\infty$ (infinitely high).

**$e_k$**  
Short circuit voltage $u_k$ resp. $e_k$ of the mains's transformer, using the unit [%].

The input value has to be inbetween 2,0 and 25%.

If only the short circuit current $I_{KS}$ of the mains's transformer is given, the short circuit voltage $e_k$ in [%] can be calculated using $e_k = 100 \times I_{NTr}/I_{KS}$ (for $I_{NTr}$ look the notes for $S_N$). The ohmic part $u_k$ resp. $e_r$ of $e_k$ is for basic level assumed to be constant at 1,5%. $e_k = \sqrt{e_r^2 + e_k^2}$ has to hold.
Mesh voltage (phase/phase) in [V] on the low voltage side of the generator at idle run. The input value has to be in between 100V and 1400V. A generator with star point voltage of 120V can be represented with $120V \times \sqrt{3} = 208V$ as mesh voltage.

- **f**: Frequency of the generator. You can choose between 50Hz and 60Hz.

- **$S_N$**: Nominal power resp. rated power of the generator in [kVA]. Its nominal current $I_{NGen}$ is computed using the equation $I_{NGen} = \frac{S_N \times 1000}{\sqrt{3} \times V_0}$ with $S_N$ in [kVA], mesh voltage $V_0$ in [V] and $I_{NGen}$ in [A].

- **$x_0$**: Relative zero reactance of the generator in [%]

- **$x_{a''}$**: Relative subtransient reactance of the generator in [%]
4. Input data for FC1 (frequency converter)

**PN1**
Achieved shaft power of the engine in [kW] on nominal operating is entered, instead of the apparent power of the converter on input or output.

*PN1* is the sum of all nominal engine shaft powers of converter-fed motors:

\[ P_{N1} = \sum P_{N,Mot} \]

Here are meant the nominal shaft powers indicated on the type label.

Not every motor and every frequency converter is computed singularly, but one big frequency converter, whose power is the sum of the single ones. The motors, too, are combined together to a summed shaft power *P*\(_{N1}\). The entered value has to be inbetween 0,1kW and 250% of the transformers nominal power (*P*\(_{N1}\)≤0,8SN makes sense).

For Danfoss-converters the input of data on the FC1-mask can alternatively be given by type name and amount/quantity of used converters like on picture 7. *PN1* is then given a value adjusted to the converters.
<table>
<thead>
<tr>
<th><strong>ED₁</strong></th>
<th>Percental occupancy rate ED₁ of the converter in [%].</th>
</tr>
</thead>
<tbody>
<tr>
<td>ED₁ considers a partial load operation of converters and motors. For nominal workload is entered ED₁=100, cause then ED₁=100%. For several drives there has to be generated the average.</td>
<td></td>
</tr>
<tr>
<td>On partial load operation the product of torque M and number of revolutions n (rotations per minute) is decisive. ( ED₁ = \frac{M}{M_N} \times \frac{n}{n_N} \times 100% ). If on M=100%*M₁ appear only n=70%n₀ or appear 70%M₁ on 100%n₀, then ED₁=70% in both cases.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Lₘ₁</strong></th>
<th>Relative short circuit voltage of the line commutation inductivity in [%].</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lₘ₁ determines the value of the line commutation inductivity in [H], that is located between mains and frequency converter. On Danfoss-converters it can even afterwards be provided as front end inductivity.</td>
<td></td>
</tr>
<tr>
<td>If the value of the inductivity is given as relative short circuit voltage, then this value can be input into the Lₘ₁-field, in expression Lₘ₁=2,5 for the relative short circuit voltage ( u_k=2,5% ).</td>
<td></td>
</tr>
<tr>
<td>If only the inductivity L in [H] of the mains commutation inductivity is known, then it is possible to work out Lₘ₁ in [%] using ( Lₘ₁ = \frac{2 \times \pi \times f \times L \times I_N}{V₀} \times 100 ).</td>
<td></td>
</tr>
<tr>
<td>Thereby is to use the nominal current ( I_N ) of the inductivity. The nominal current should coincide with the input current of the frequency converter.</td>
<td></td>
</tr>
<tr>
<td>The input value has to be between 0 and 12.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>L₉₁</strong></th>
<th>Relative short circuit voltage in [%] of the smoothing inductivity on the side of direct current. This inductivity is located in the direct current circuit of the frequency converter.</th>
</tr>
</thead>
<tbody>
<tr>
<td>The input of L₉₁ is obsolete for the user if he chooses the converters using Danfoss's listing, where the L₉-values are preprogrammed.</td>
<td></td>
</tr>
<tr>
<td>For further cases the relative value L₉₁ in [%] has to be provided according to the equation ( L₉₁ = \frac{2 \times \pi \times f \times L \times I_N}{V₀} \times 100 ), instead of the real value of the inductivity L₉ in [H].</td>
<td></td>
</tr>
<tr>
<td>Thereby ( I_N ) is the nominal current on the input of the frequency converter.</td>
<td></td>
</tr>
<tr>
<td>The input value has to be between 0 and 25.</td>
<td></td>
</tr>
</tbody>
</table>
5. Selection of FC1 from a list

Specify the values for FC1.

On the very left is chosen the series of frequency converters, while afterwards in the table on left hand side is entered the amount of used converters into the table of converters. The converters are later presented in the protocol after calculation of the simulation. For motors is presumed a size fitting to the converters. $P_{N1}$ is then the sum of all shaft powers of the motors. Not every motor and every frequency converter is computed singularly, but one big frequency converter whose power is concluded from the whole of the single ones.
6. Overview / Start calculation

To start the calculation you click onto the button „Overview“ below „Calculation“ and you get the above picture with an overview over the entered data. Afterwards the calculation of the simulation is started clicking on „Start calculation“, which takes about 10 seconds.
7. Results

After termination of the simulation-calculation, the above picture appears. By clicking on the shown measuring instruments, you get a bar chart and the time development of voltage or current.

Choosing the functionality „Protocol“, the informations according to picture 11 to 16 are at your disposal.
8. Protocol

![Diagram of Danfoss HCS V2.0 with selection options for norms](image)

After the selection of the button „Protocol“, has to be chosen the norm, that shall be decisive for the comparison of the computed values with norm limits.

[Picture 10b: Selection of a norm for the harmonics]
$V_0 = 400$ V

$\nu = 50$ Hz

$S_N = 1250$ kVA

$\nu_c = 6$ %

$\nu_{LN} = 200$ kW

$\nu_{D1} = 100$ %

$\lambda_{LS1} = 0$ %

$\lambda_{IL1} = 4$ %
At the beginning is at disposal the spectrum of amplitudes for different frequencies of the transformers current. A comparison to values of the norm only takes place if an IEEE-norm was choosen. Using the table, harmonic currents can be computed:

In this example the 5th component has a relative size of 38,65%, an reference value of $I_{1eff}=330,01\text{A}$ and an absolute value of $I_5=330,01\text{A}\times 38,65\% =127,55\text{A}$. $I_{1eff}$ is given below the above table.

The time function of the transformers current is presented in [A] over a time period of completely 30ms.
Using the table, one can compute the harmonics of the voltage:
In this example the 5th component has the relative magnitude of \( u_5 = 0.81\% \), an reference value of \( U_{1_{	ext{eff}}} = 229.88 \text{V} \) and the absolute value of \( U_5 = 0.81\% \times 229.88 \text{V} = 1.862 \text{V} \). \( U_{1_{	ext{eff}}} \) is given below the above table.
The table lists the calculated values and the ones allowed by the chosen norm. Values exceeding the limits are marked in red colour.

The time function of the transformers voltage is presented in [V] over a time period of completely 30ms.