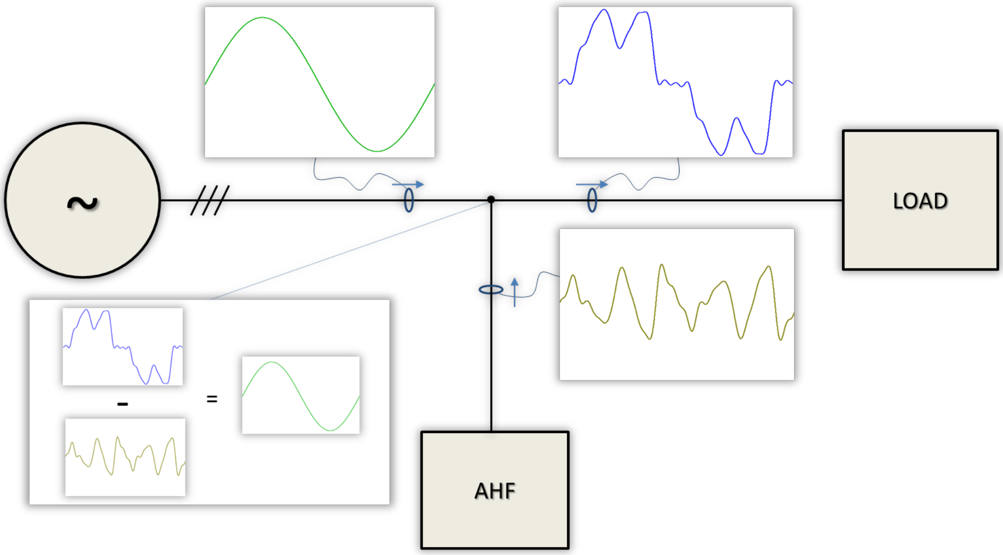
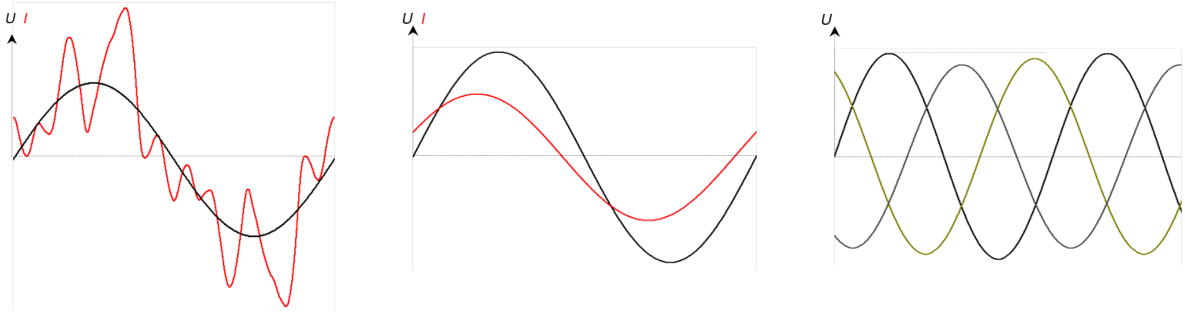
Active Harmonic Filter

The working principle of an active REVCON Harmonic Filter RHF-Active is completely different from any other harmonic solution. Instead of working as a line filter with tuned passive filter circuits, the active solution is connected in parallel and injects harmonics. These injected harmonics are of inversed polarity (180° phase shift) to the load harmonics. As a result these harmonics are eliminated!



The RHF-Active, and most other active harmonic filter may be used for *pf* correction, unbalance compensation, harmonic mitigation or altogether. It reduces the harmonic current distortion of non-linear loads and sources to any required *THDi*. This is necessary to reach various standards and recommendations, such as IEEE 519-2014.

Harmonic Mitigation | *pf* Correction | Unbalance compensation



The RHF-Active is a very efficienct solution to reduce harmonics. Many active filter solutions are unfortunately not sized accurate which leads to dissapointing results in performance.
This guide was written to explain how the Harmonic Filter Current of an aktive filter can be calculated.
This guide assumes that the active filter shall focus on harmonic mitigation and not deal with *pf* correction nor unbalance.

Calculating the harmonic current

In order to size any active Filter correctly, the calculation of the harmonic current I_H is essential.
The THDi is defined as:

$$THDi = \frac{I_H}{I_1} \; whilst \; I_H = \sqrt{\sum_{n=2}^{n=50} I_n^2}$$

Basically the THDi can be defined for any Harmonic spectrum. Most standards refer to THDi defined up to 40th or 50th Harmonic. Therefore this is used in this explanation.

This lead to:

$$THDi = \frac{\sqrt{\sum_{n=2}^{n=50} I_n^2}}{I_1} \bullet 100\% = \frac{\sqrt{I_{h2}^2 + I_{h3}^2 + I_{h4}^2 + I_{h5}^2 + I_{h6}^2 + \cdots + I_{h50}^2}}{I_1} \bullet 100\%$$

I_1 is indicating the fundamental part (50Hz) of the I_{RMS} current.
I_H is indicating the harmonic content of the I_{RMS} current. (In this example up to 50th Harmonic = 2500Hz @ 50Hz).

Looking at the I_{RMS} this value has a fundamental current part (green) and a harmonic content (red).

$$I_{RMS} = \sqrt{I_{h1}^2 + I_{h2}^2 + I_{h3}^2 + I_{h4}^2 + I_{h5}^2 + I_{h6}^2 + \cdots + I_{h50}^2} \rightarrow I_{RMS}^2 = I_1^2 + I_H^2$$

As mentioned above, the Harmonic Current I_H is essential to size any active filter. This value is corresponding to the injected current by the active filter.
Most common harmonic power quality analyzer are able to give this value. Nevertheless, many tasks will only specify value of *THDi* and I_{RMS}. It is essential to understand that a I_{RMS} *of 100A and a* THDi of e.g. 45% is not equal to 45A Harmonic current!

The following calculation show how to calculate the I_H from I_{RMS} and *THDi* value by using the *THDi* equation and the I_{RMS} equation:

① $$THDi = \frac{I_H}{I_1} \rightarrow I_1 = \frac{I_H}{THDi}$$

② $$I_{RMS}^2 = I_H^2 + I_1^2$$

① + ② $$I_{RMS}^2 = I_H^2 + \left(\frac{I_H}{THDi}\right)^2$$

$$I_{RMS}^2 = I_H^2 \bullet \left(1 + \frac{1}{THDi^2}\right)$$

$$I_H^2 = \frac{I_{RMS}^2}{1 + \frac{1}{THDi^2}}$$

$$I_H = \sqrt{\frac{I_{RMS}^2}{1 + \frac{1}{THDi^2}}}$$

This equation can be used to calculate the harmonic content by using I_{RMS} and *THDi* values.

Using this equation, the THDi value should be used as a factor value. E.g.:

I_{RMS} = 227A

THDi = 57%

$$I_H = \sqrt{\frac{(227\ A)^2}{1 + \frac{1}{0.57^2}}} = 112.4\text{A}$$

This current value of 112A is corresponding to the Total Harmonic Current component of I_{RMS}. This is typically different from the required active harmonic filter compensation current. To define the required harmonic filter current we first of all need define the harmonic distortion target.

REVCON strongly recommend to use the IEEE-519-2014 for evaluation of harmonic distortion current. Due to lack of site information, the target is often defined as 5% TDD of the current. This can be considered as equal to 5% *THDi* at full load (simplified).

The required *THDi* compensation ($THDi_{comp}$) needs to be defined. This can simply be calculated as:

$$THDi_{comp} = THDi - THDi_{target}$$

Using the $THDi_{comp}$ and the I_{RMS} we can calculate the required compensation current I_{comp}.

$$I_{comp} = \sqrt{\frac{I_{RMS}^2}{1 + \frac{1}{THDi_{comp}^2{}^2}}}$$

Looking at our previous example, and a *THDi* target of 12%, this result in:

$$THDi_{comp} = THDI - THDi_{target} = 57\% - 12\% = 45\%$$

$$I_{comp} = \sqrt{\frac{227^2}{1 + \frac{1}{0.45^2}}} = 93.2\text{A}$$

This is the theoretically required compensation current for the above example.

Measuring the harmonic current in an existing application under real conditions is the most reliable way to evaluate the harmonic current. In order to calculate the required active harmonic filter compensation current I_{HF} please consider the following calculation:

$$I_{HFC} = \sqrt{\frac{I_{RMS}^2}{1 + \frac{1}{(THDi - THDi_{target})^2}}} * 1.071$$

Basically the I_{HFC} is the I_{Comp} multiplied with a the factor of 1.071. This factor is used to compensate the following two effects when using active harmonic filter.

1. Active harmonic filter inject harmonic currents into the grid. These harmonics are calculated based on the measured load current. Due to individual harmonic amplitude and phase angle measurement accuracy the compensation of each harmonic cannot be 100% accurate.

2. When improving the THDi value of the current, the voltage distortion of the mains supply will decrease. This better voltage quality will cause the load side current harmonic distortion to increase.

This factor is an easy to use, but strongly simplified. The effect of 1 will depend on accuracy of the CT, and system impedance. The effect 2 will depend on the ratio between short circuit current and compensation current. The factor represents typical values.

This factor can be used on active harmonic filter with high performance control, a switching frequency of 20kHz or higher and a high quality 3-Level IGBT based hardware. E.g.:
RHF-Active 100-400-50/60-20-A

Using SiC-MOSFET based technology such as RHF-Active 15-480-50/60-20-A RHF-Active 35-480-50/60-20-A or RHF-Active 55-480-50/60-20-A with high switching technology, will allow for a lower factor, due to the fact that compensation accuracy is higher.

$$I_{HFC} = \sqrt{\frac{I_{RMS}^2}{1 + \frac{1}{(THDi - THDi_{target})^2}}} * 1.062$$

This guide was written to help understanding the sizing calculation of active harmonic filter. These calculations can be used to verify any active harmonic filter, but due to its simplified calculations it should not be considered as a complete harmonic calculation as a basis for sizing an active filter.

In any case, the harmonic filter manufacturer, or their official partner should be involved in the sizing of any active filter solution.