–COMSYS–

Sinexcel Active Harmonic Filter

Test report

REV.1 2021-03-24

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Contents

Overview

Aniro provided Comsys with a Sinexcel Active Harmonic Filter 3p-4w 60 A for testing. The filter has been installed in a test rig with a Comsys ADF P300 150 A, in harmonic generator mode, as a load. Filter has been produced and been tested at Sinexcel's factory 2020-September-21.

The Sinexcel filter has been tested both in Open-Loop as well as Closed-Loop. However, most tests have been done in Open-Loop.
All measurements, if not otherwise stated, have been done with L1 = Grid; L2 = ADF; L3 = Sinexcel

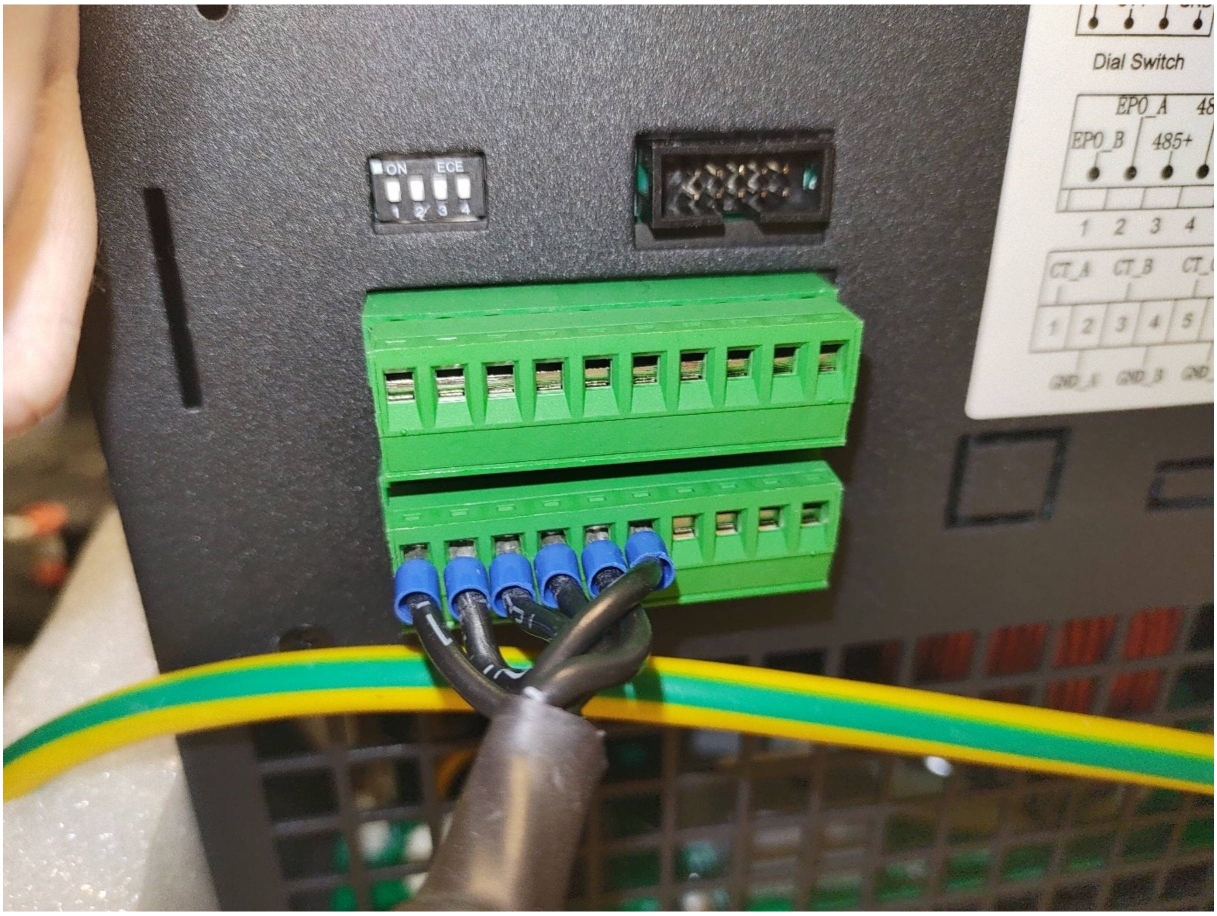
Mechanical

Mains connection

There are some nice protections that cover the mains terminals (not pictureed). But equal to the ADF P25/100/200 there is no cover that keeps the cable until a point where two insulations are around the cable.
Connection can only be done in a screw terminal and the neutral only has a single connection. This can potentially get overloaded on full 180 A.

CT connection

CT connection uses a regular Phoenix connection terminal. There is no possibility for short circuit close to the filter due to barrier in between the cables. The connector does not have any fixation and the cable could get loose.



Documentation

Comsys got a manual in PDF format in advance. This electronic manual is clearly different to the one in the shipment.
The manual, attached, seems to be dated around 2014 whilst the digital manual seems to be from 2017 or later. There is a clear design change in the 7” display. Pictures in the hardcopy have screenshots of this HMI with the date 2014-Oct-20 (4” display has a date of 2014-Oct-09). In the digital version, the pictures for the 7” screen changed with a nicer, cleaner design. The date has changeed to 2017-June-16 with some screens showing 2015-July-03.
Above proves that the attached hardcopy manual has been created sometime between 2014-Oct-09 and 2015-July-03.
There is some indication that the PDF manual is in fact a bit newer than 2017. The creation date of the PDF file is 2019-Feb-27.

Filter connection

CT setup

All documentation solely handle open loop operation. Closed loop is nowhere indicated. The manual even states that for a closed loop operation, two sets of CTs must be used and summed up with a summation CT or wired directly together (Comsys are not convinced that is a good idea). One of these sets is on the filter and with this removes the filter current from the CT signal making it an open loop connection.(Omformulera sista meningen)

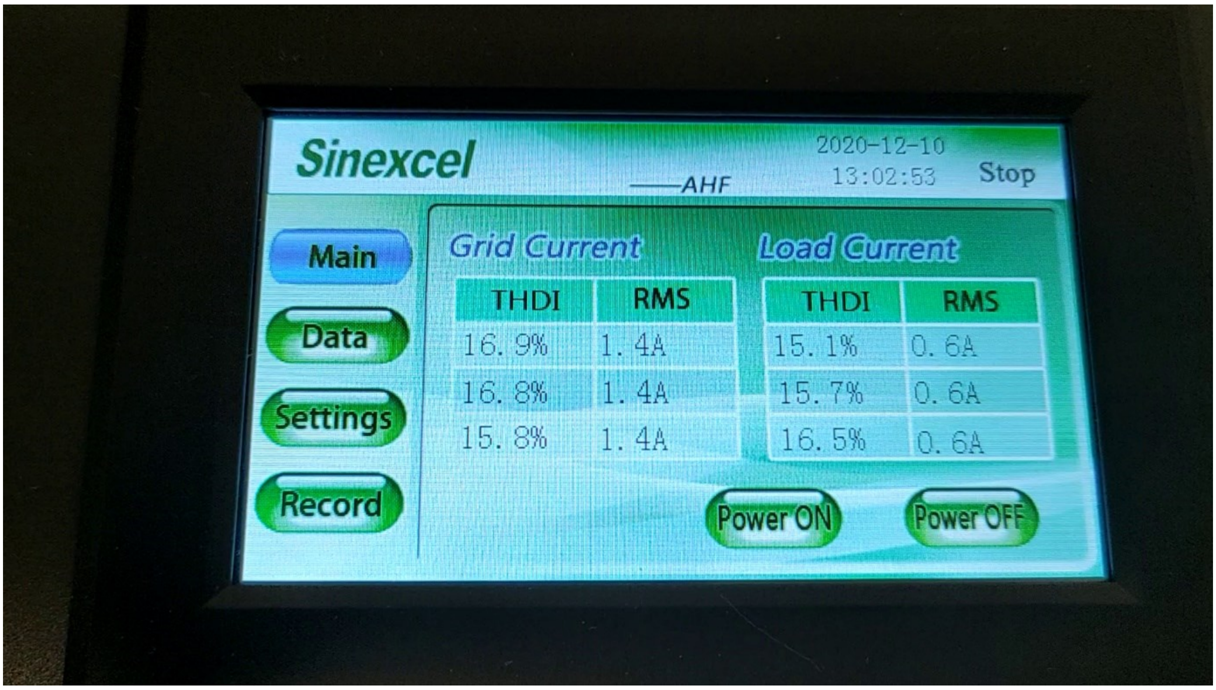
The interface on the other hand has both open loop and closed loop available as an option. After discussion with Aniro it turned out that closed loop is implemented and somewhat works according to Sinexcel.
Quote from Anna Hondo at Aniro 2020-Dec-04: “In manual they inform that it can not be work, but I know two examples where we connect the AHF in closed loop/with the CT on grid side and it work ok. We talked to them and they do some corrections and now, it can work.”
Even the oldest manual has the “source side” setting available. This, together with notes in the manual like “Reserved function” indicates that Sinexcel might add functions initially to the interface and later as a woring feature.
When testing it is obvious that the filter operate identiacally no matter if set to open look or closed loop operation. Meaning, it calculates and measures its own current. By removing that signal from the CT it work internally as an open loop. This can be seenby analyzing the phase shift on the harmonics the filter had.
Operation with two CTs on two of the phases is allowed in a 3p-3w system.

Operation of Sinexcel filter

Sinexcel filter can only be operated by the touch screen HMI. Response time of the HMI is reasonable but the the menu structure is complicated and names are often not clear. Menu structures seem to be stored in the HMI directly. Connection between the HMI and the main controller is via RS485. When more data like FFT or waveform is transferred, there is a bit of a lag due to the low transfer rate.
To adjust settings, a numerical password is required. None of the documents in the shipment had a note of this password. Only by looking in a different manual Comsys obtained revealed the password as “080808”.

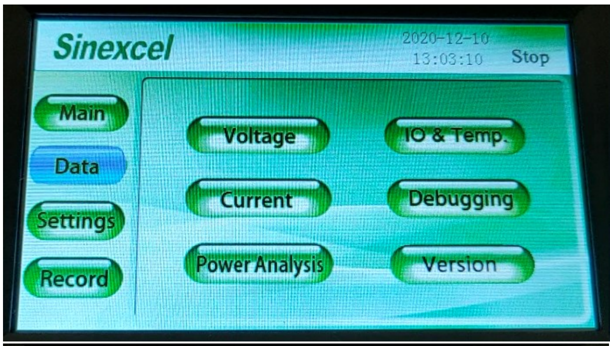
HMI main screen

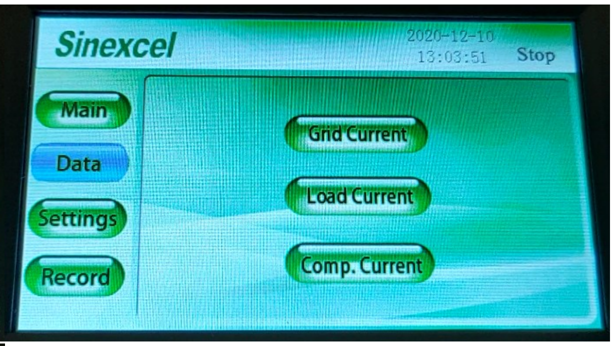
Main screen shows the status “Stop” or “Normal” (running). It shows the grid current and the load current both in RMS as well the THDI. Start and Stop of the filter can be done from here and only from here.

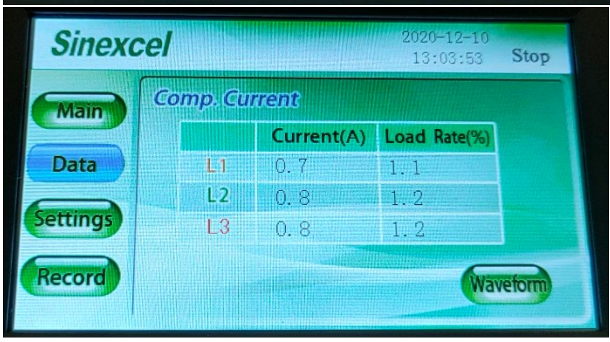


Utilization

Utilization of the filter can only be seen by going into “Data” -> “Current” -> “Comp. Current”

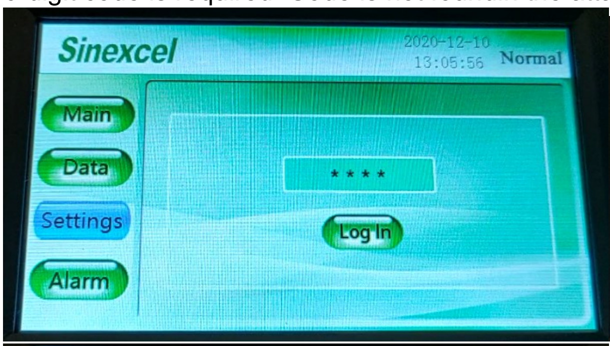


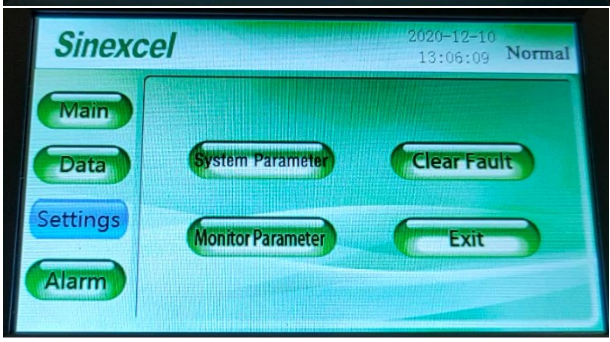




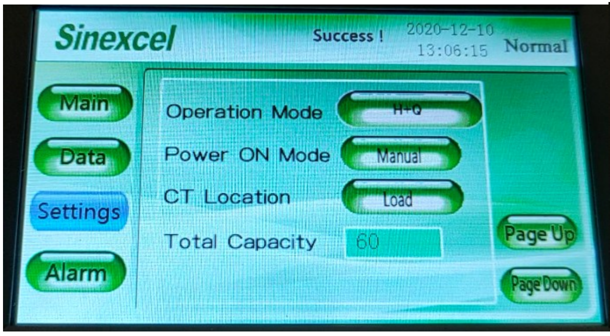
Settings

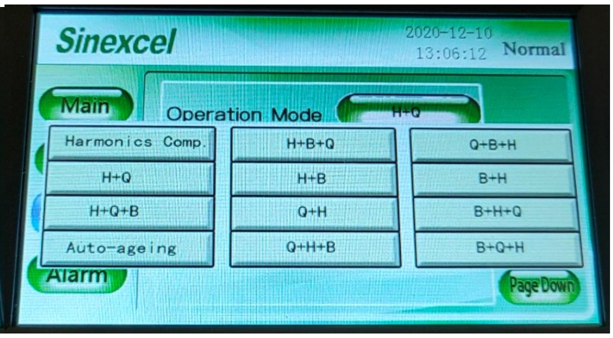
Settings are locked with a numeric password. When opening the screen, it looks like there is already a 4-digit code set. But the login button does not do anything. First you must click into the password field and type the password.
6-digit code is required. Code is not foundin the attached manual. “080808”



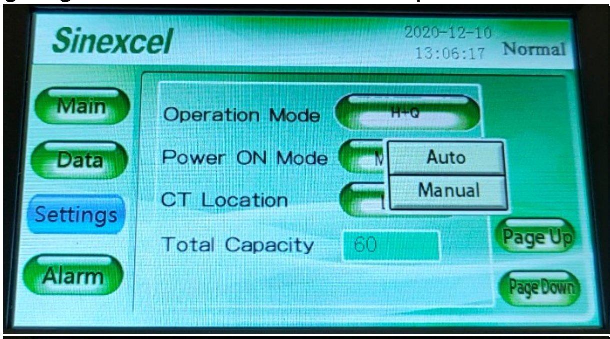


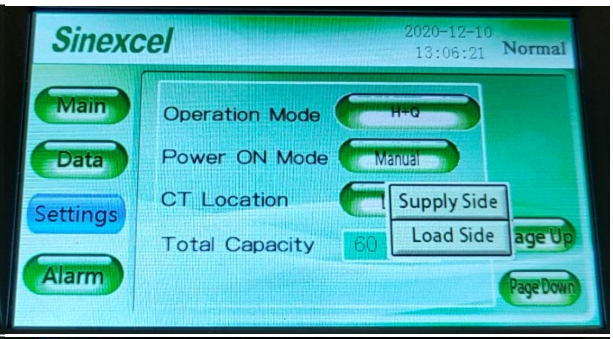
Settings are not detailed described in the manuals.
Following options are available in the menu:

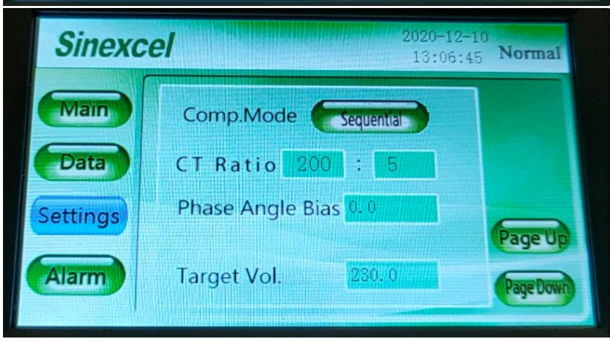


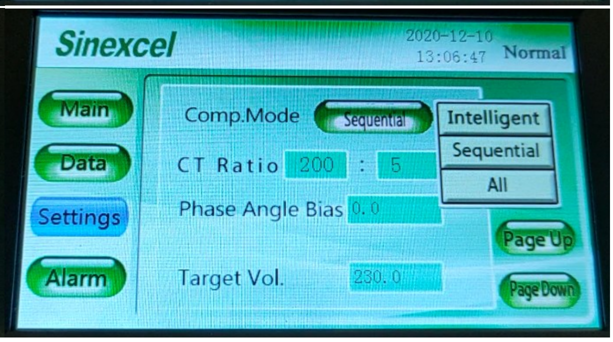


H = Harmonics compensation
Q = Reactive compensation
B = Load balancing
Different functions can be combined as well as priorities can be given.
"Auto-ageing" should never be used. It is in fact a function for the factory testing where the filter is giving out fixed amount of reactive power.

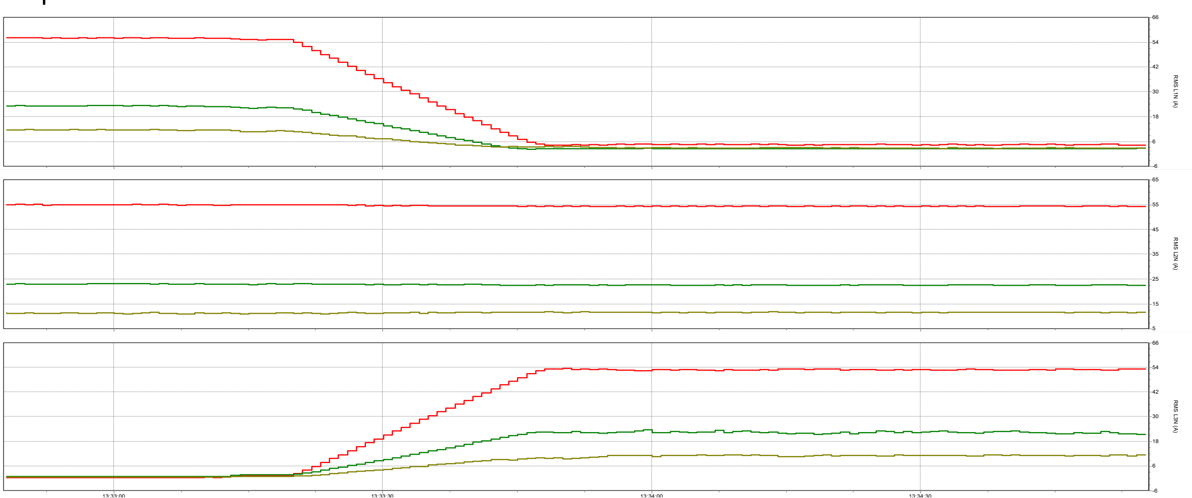




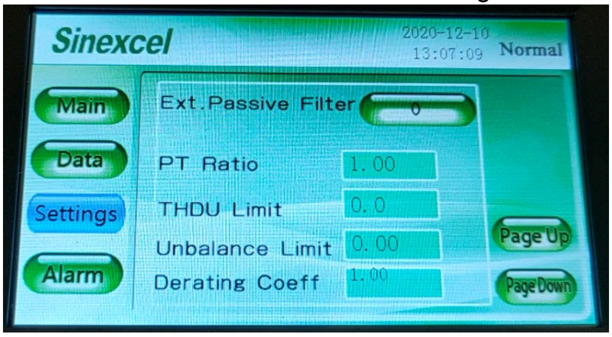




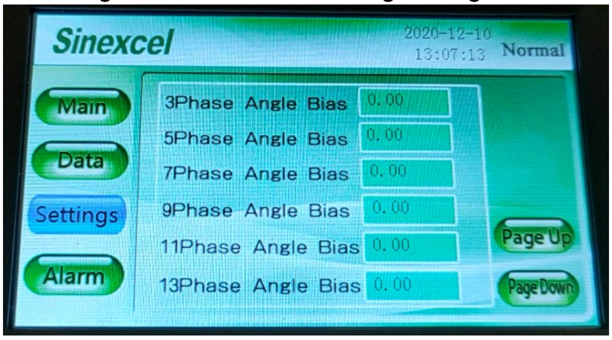
The compensation modes "Sequential" allows the user to select what harmonics to compensate. "All" is compensating all harmonics. "Intelligent" is not clear what it does, more information further below. In the measurements however, you can see that it slowly step by step increases the harmonics compensation.



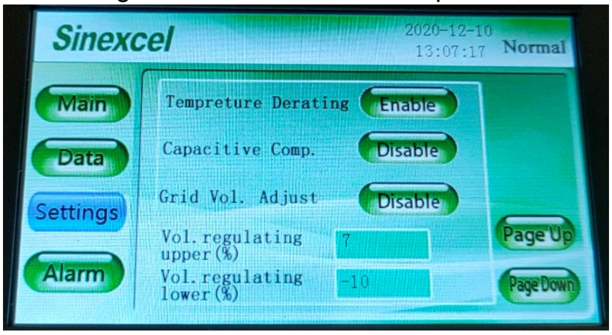
“Phase Angle Bias” seems to be an overall phase shift of the CT current. But not clearly explained in manual.
“Target Vol.” is not clear at all what this is doing. Potentially connected to the “Grid Vol. Adjust” further down the menu. This could allow a voltage stabilization with reactive power.



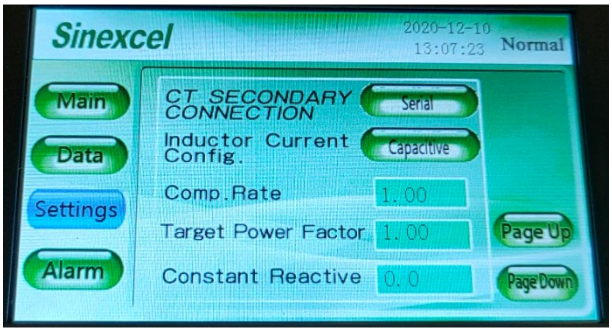
None of these settings are clear.
“Ext. Passive Filter”: no effect could be seen. Manual states “Reserve function”
“PT Ratio”: No external input for voltage exists. Manual states “Set the ratio of external transformer”
“THDU Limit”: Resonance detection??
“Unbalance Limit”: ???
“Derating Coeff”: Overall derating setting?



Phase angle calibration can be set-up for a few selected harmonics. Values are probably in radiant.

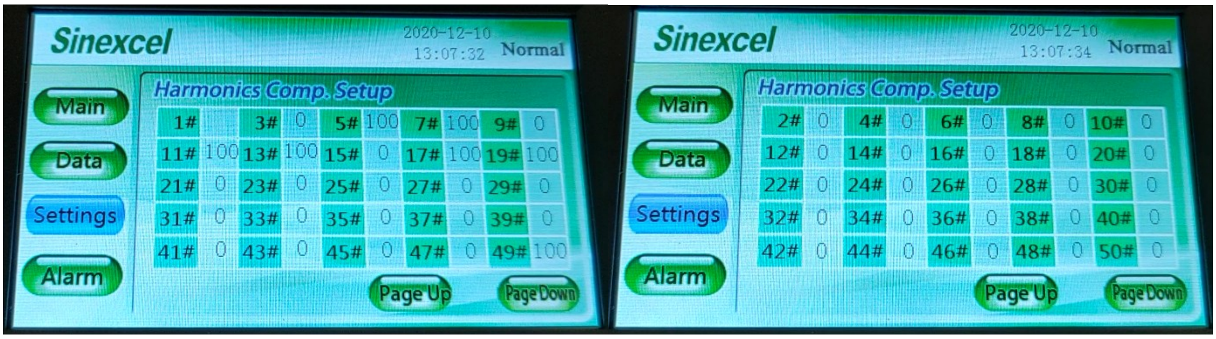


None of the settings are described in the manual.
“Temperature Deratings”: Not clear why it should be allowed to deactivate that.
“Capacitive Comp.”: Not clear what that is. Maybe allow or not allow the grid to become capacitive.
“Grid Vol. Adjust”: This could allow a voltage stabilization with reactive power and would then be connected to the setting a few pages before.
“Vol. regulating upper (%)”: Connected to “Grid Vol. Adjust??
“Vol. regulating lower (%)”: Connected to “Grid Vol. Adjust??

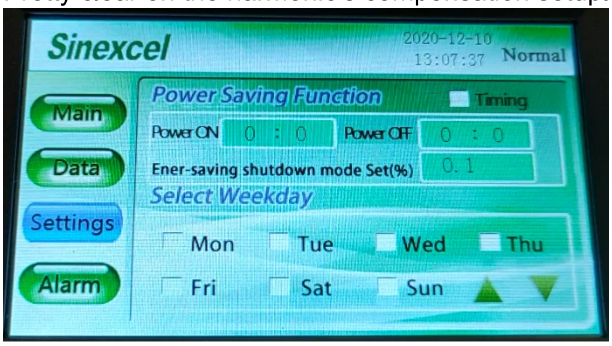


"CT SECONDARY CONNECTION": Not quite clear. Potentially if the CTs are connected in series or summed up with a summation CT
"Inductor Current Config": Not clear at all. Manual states "Used to select compensation of inductive or capacitive reactive power, user not allowed to change it"
"Comp. Rate": Most likely overall degree of compensation.
"Target Power Factor": This one is clear. Never tested.
"Constant Reactive": Should be clear as well, but never tested.

Not at all clear what the difference is between these settings and the "Phase Angle Bias" on the second screen.



Pretty clear on the harmonic's compensation setup.



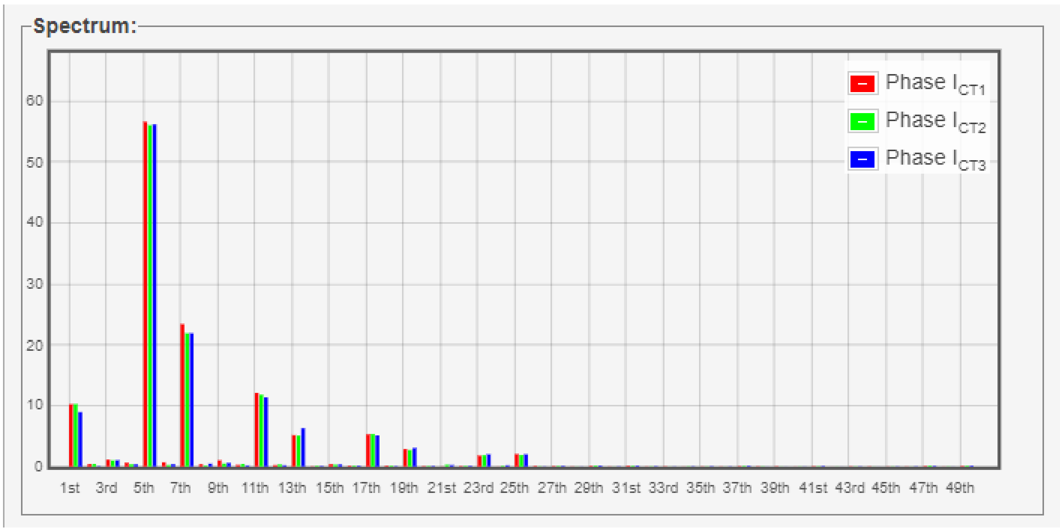
Stand-by has not been tested!

Compensation

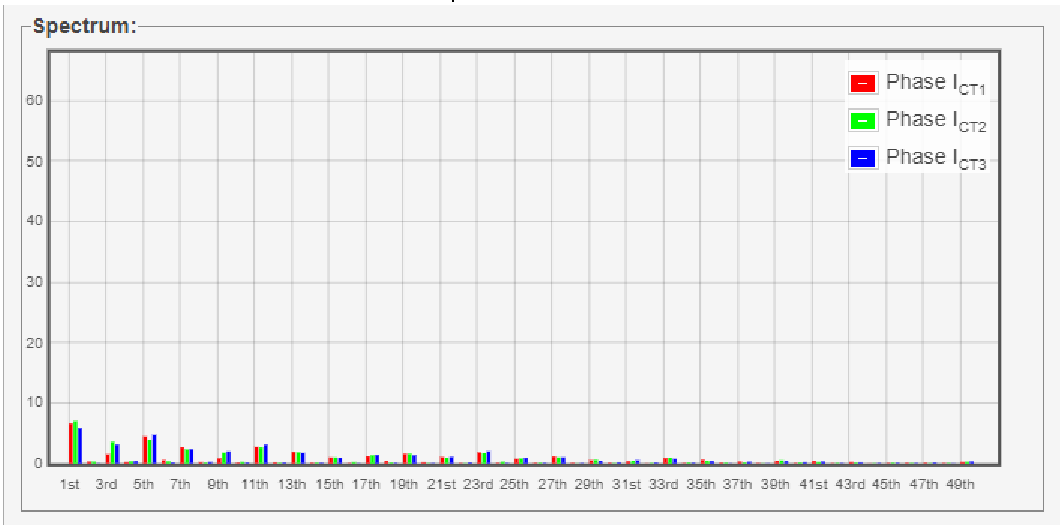
Operation modes

The filter has three operation modes “Sequential”, “Intelligent” and “All”. Sequential is using an FFT to analyze and then allows single order harmonics to be activated and compensated to a degree. All function modes are identifying a fundamental current and consider everything else as current to compensate. Intelligent appears to take a learning approach, at least according to the manual:
“Sinexcel AHF possesses three different algorithms: instantaneous reactive power algorithm (displayed as “ALL”), FFT and intelligent FFT.
Instantaneous reactive power algorithm identifies the Fundamental current 50Hz and then take all the other frequencies as harmonic. Technically it can not only compensate the harmonic limited to the 50 th , but also the 99 th and even above. The logic of this algorithm is simple, the response time is very fast though. Even if the load current frequency changes rapidly, it could still mitigate the harmonic with high accuracy. However, this algorithm has a big disadvantage. That is the detecting current accuracy could be very easily impacted by the voltage change. If the system appears THDu or the voltage of 3 phase are unbalance, the detecting current accuracy will reduce. Consequently, the harmonic mitigation performance becomes poor.
FFT algorithm, totally digital control technology, can mitigate specific harmonic (like 11th mitigate to 70%, 15th to 59%) and the detecting current accuracy is also very high. FFT analyze every frequency of the current within a cycle. Then AHF will send a reverse current into the next cycle to mitigate harmonic. Thus, there will always be one cycle delay for the compensation. The workload of a lot of calculation makes FFT’s responding speed slower than instantaneous reactive power algorithm. But the speed is totally acceptable though as it does not impact the harmonic mitigation performance. Just as it has been explained, one current cycle could be even omitted.
Intelligent FFT is Sinexcel’s original unique technology. Each system has its specific impedance. Some VSD’s harmonic consist of the 5th, the 7th and some consist of the 9th, the 13th. Thus, AHF should be capable to adapt to different system impedance. We come to develop intelligent FFT to avoid the IGBT burning down by the resonance. We have collected a great deal of experience from the installation to make a data base of the algorithm as the first step. Take 100A AHF as an example, for intelligent FFT, it will not use full 100A capacity to compensate harmonic. AHF will automatically learn about the system impendence itself and then start with 10A to compensate all the harmonic in the system. In the meantime, AHF will keep observing the compensation performance and then operate with 20A for the compensation. After the harmonic mitigation is stable, keep on compensation with 30A and 40A and more. Given that when it goes to 80A, AHF found resonance on the 15th harmonic. It will stop compensation for the 15th harmonic and allocate all the capacity to compensate the other all. It means intelligent FFT is aware to avoid the resonance point.
Intelligent FFT makes AHF keep on detecting and self-learning to adapt to the system’s impendence, increase AHF’s capacity to mitigate harmonic step by step and keep the system away from the resonance. It takes about 5 min to operate intelligent FFT to control AHF at a very stable status.”

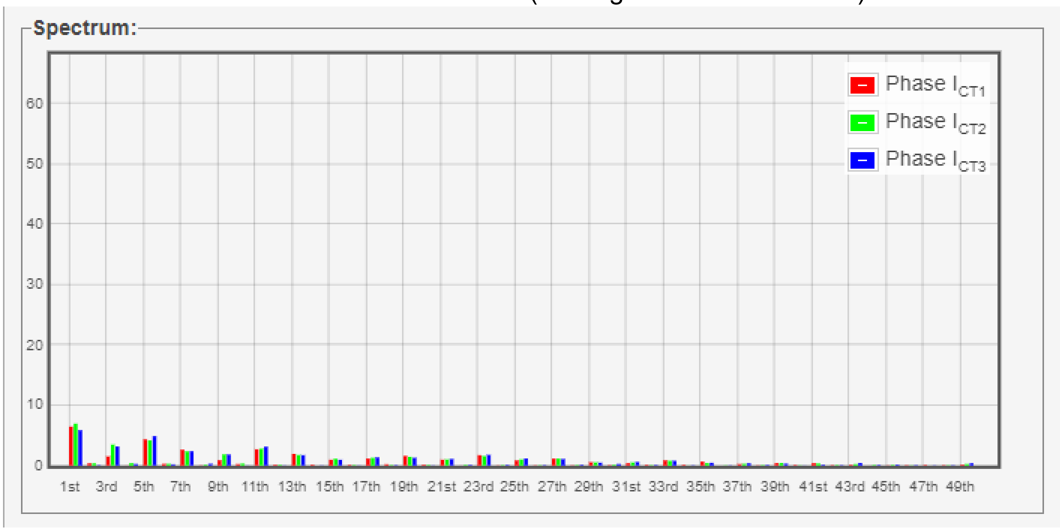
Grid current with Sinexcel filter OFF:



Grid current with Sinexcel filter in “Sequential” mode:



Grid current with Sinexcel filter in “All” mode (“Intelligent” looks the same):

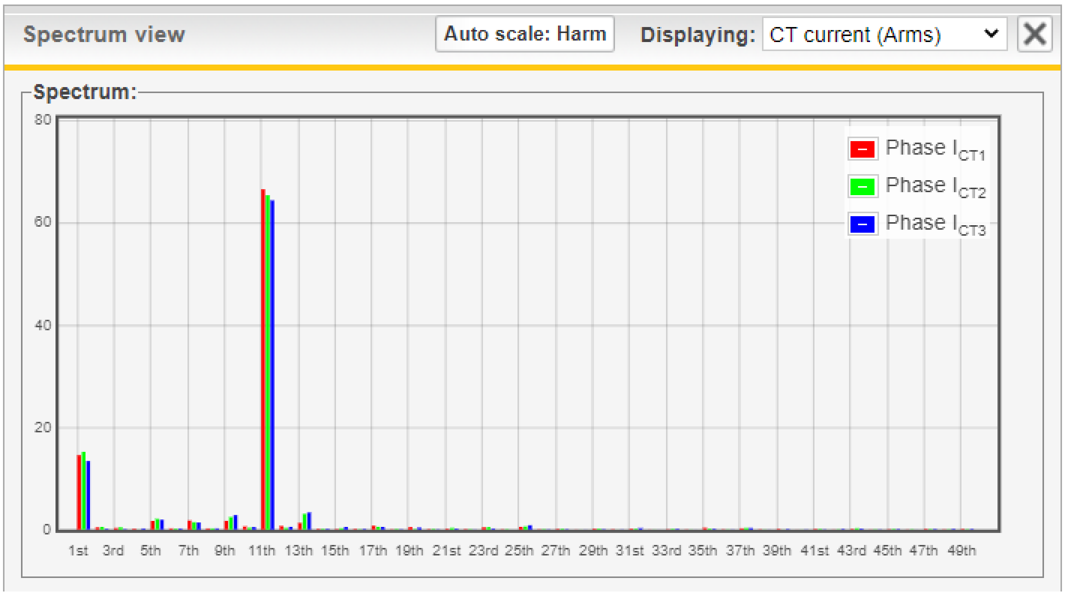


In all cases it is clearly visible that other harmonics are increasing after compensation.

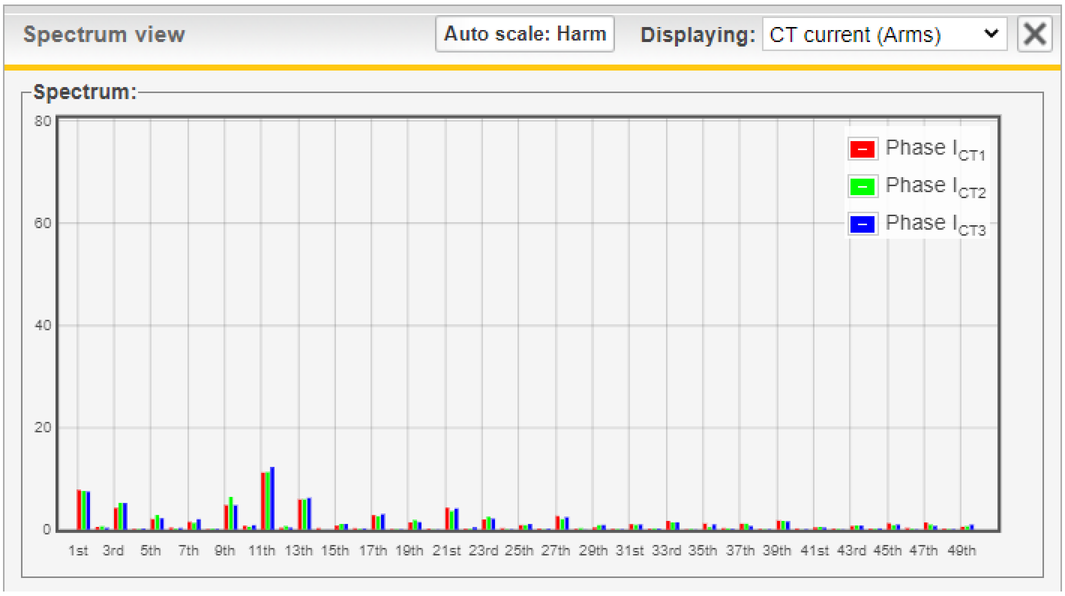
Increase of other harmonics with only 11th compensation

One more example has been measured with a PQ device to show the increase of the harmonics. In this case the load only creates 11th harmonic and the Sinexcel filter is setup in “All” mode.

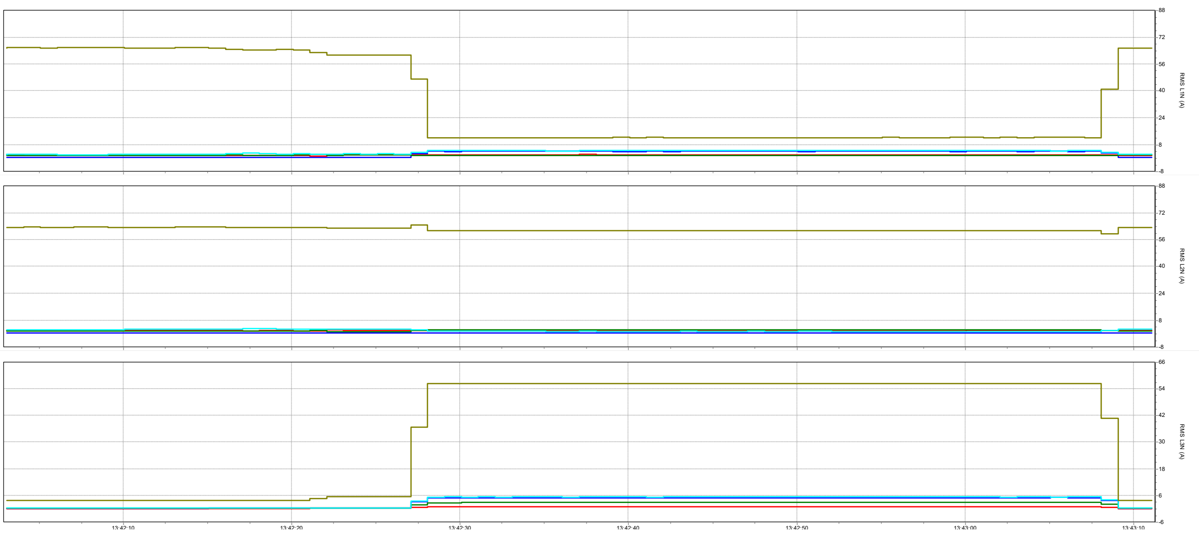
Grid current with Sinexcel OFF:



Grid current with Sinexcel filter in “All” mode:



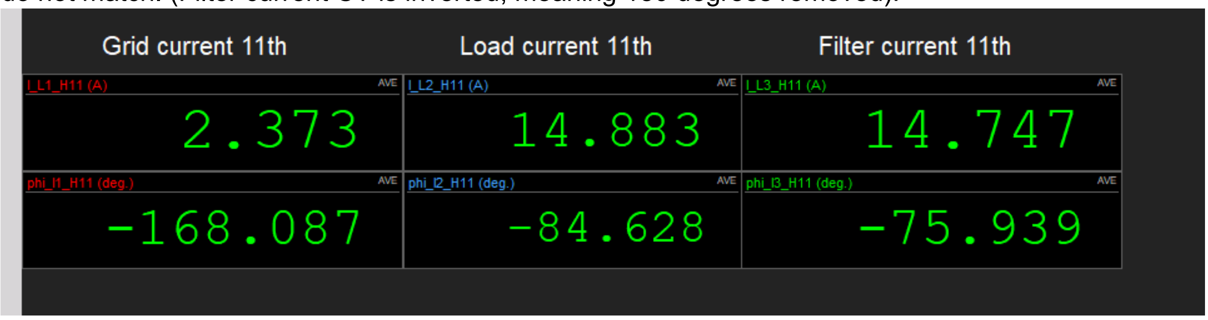
Trend of Grid current, Load current and Filter current:



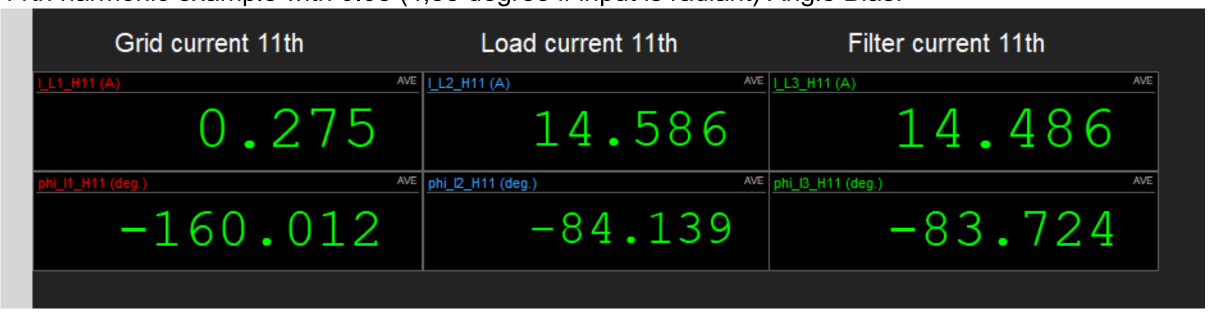
Issue with phase angle calibration

Compensating the 5th and 7th harmonic did give a reasonable result without any finetuning required. However, from the 11th harmonic, it could be seen that the output current is not exactly 180 degrees shifted to the load current.
This has been tested both an Open-Loop as well as in Closed-Loop. Results have been the same. This means that internally they calculate the Closed-Loop current back into an Open-Loop current by removing the filter current.
The settings do allow for a “Angle Bias” or phase angle calibration of the harmonics. However, this setup is only available for 3rd, 5th, 7th, 9th, 11th and 13th harmonic. No other harmonics could have been adjusted.
Testing the filter was therefore more demanding because a large amount of higher order harmonics could have been left over in the grid.

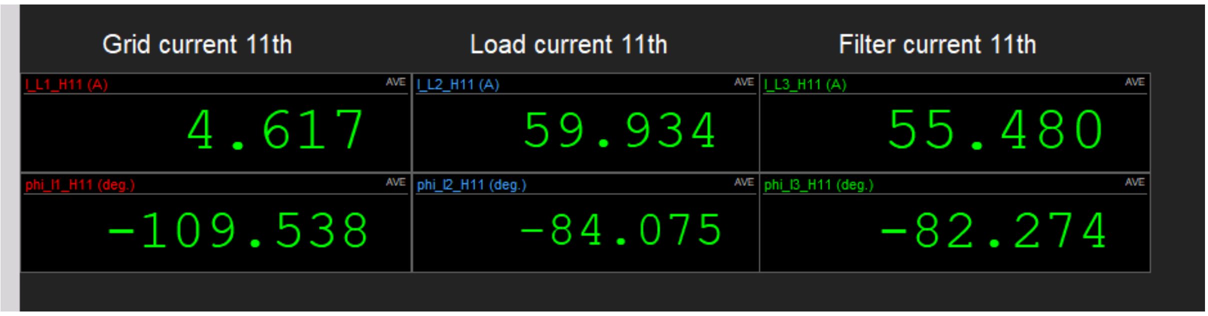
11th harmonic example with 0.00 Angle Bias. It can be seen that the load current and the filter current do not match. (Filter current CT is inverted, meaning 180 degrees removed):



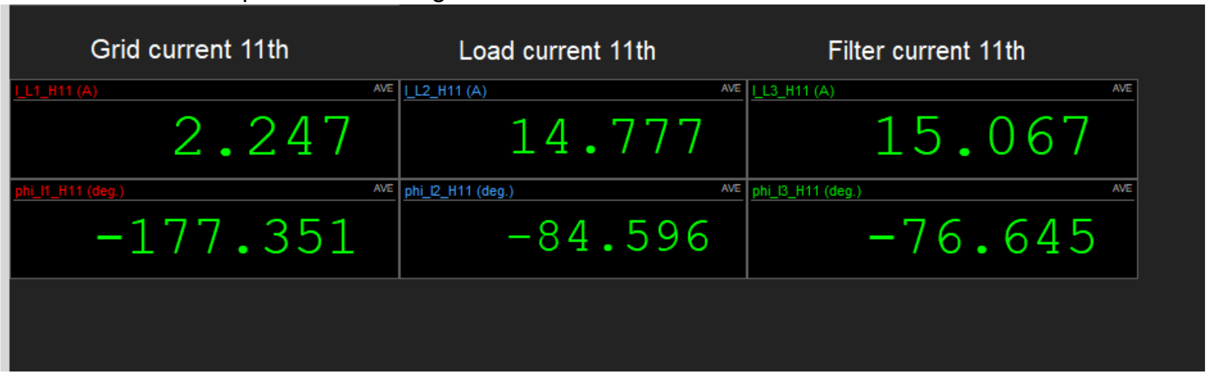
11th harmonic example with 0.08 (4,58 degree if input is radiant) Angle Bias:



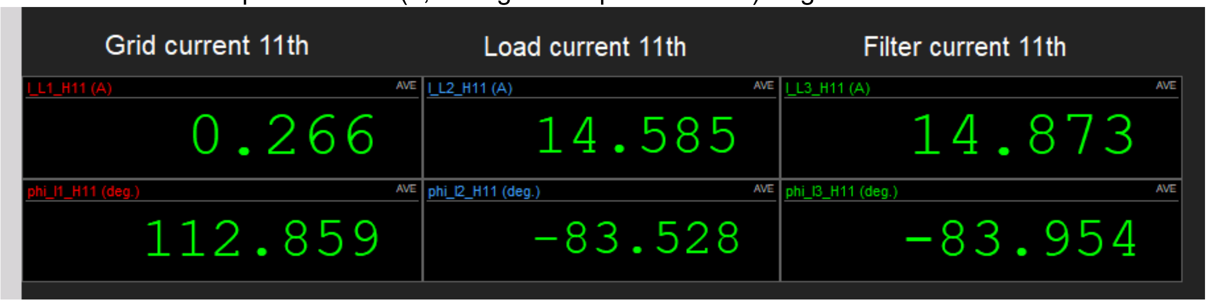
Same but full load current:



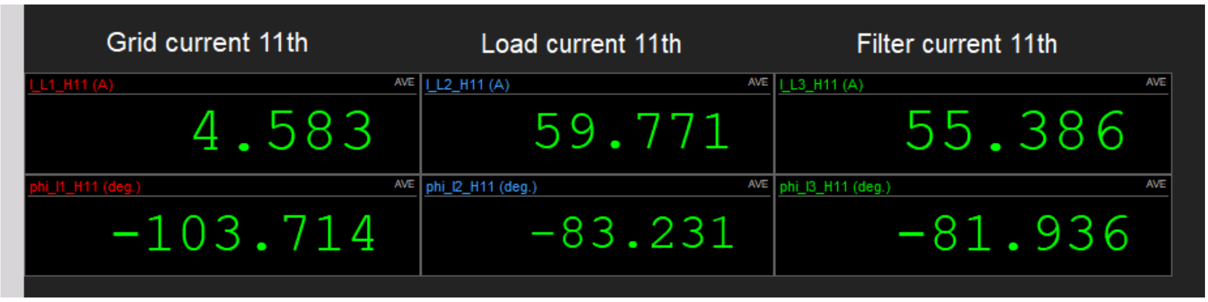
Same setup but with CTs connected in closed-loop.
11th harmonic example with 0.00 Angle Bias:



11th harmonic example with 0.08 (4,58 degree if input is radiant) Angle Bias:



Same but full load current:



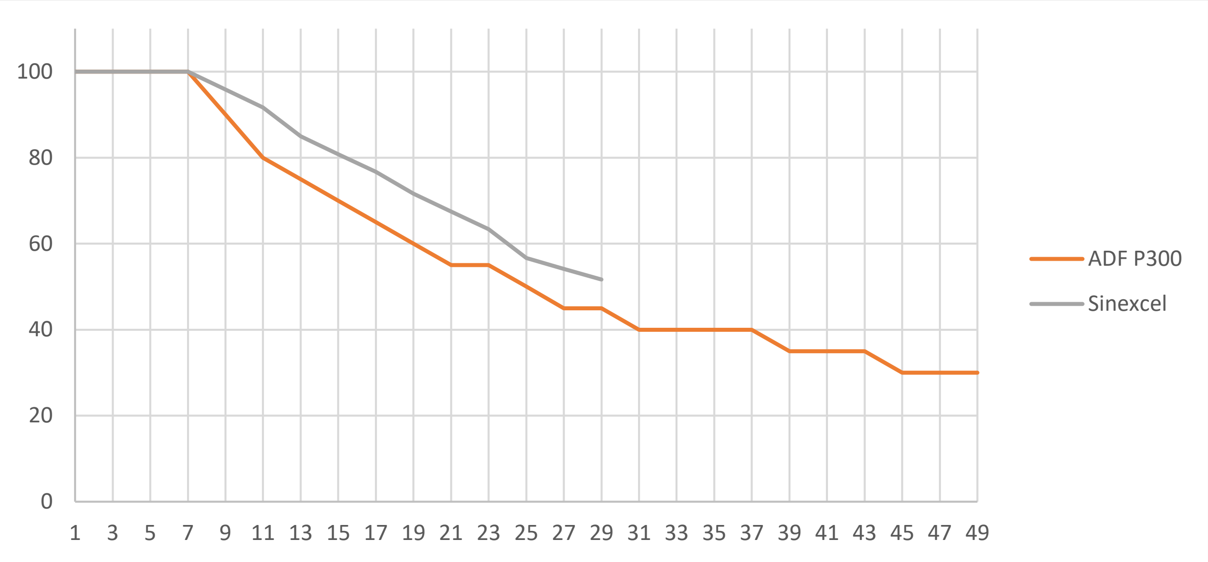
Filter TRIP during testing

During the tests, the filter was tripping several times. When the filter is running and the load slowly increases the 11th harmonic, everything works fine. However, when the load increases the 11th harmonic in a step, then the Sinexcel filter seem compensate for a few seconds and then just stops with an error “Output current abnormal”. The included manual has some alarms listed; however, this alarm is not part of the list. The filter seems to be working fine for steady state loads, but for dynamic loads there seem to be difficulties to properly mitigate given harmonics.

Harmonic derating

Harmonic derating could only be tested up to the 29th harmonic on the filter as it does not seem to work for higher harmonics!? But this needs to be further tested as we did not get this to work this time.

Every harmonic above that compensated by itself did lead to an error “Output current abnormal”. Even the tested harmonics could only be run when the load slowly increases. Derating curve looks in fact good but it difficult to verify further due to mentioned.

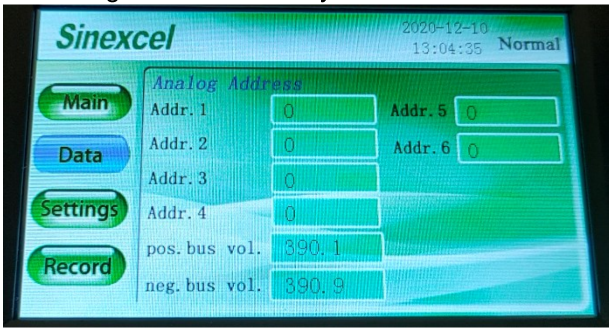


Order	Current	Order	Current	Order	Current
5th	60 A	17th	46 A	29th	31 A
7th	60 A	19th	43 A		
11th	55 A	23rd	38 A		
13th	51 A	25th	34 A		

Technical details

DC-link voltage

DC voltage seem to be very stable at 780 V.

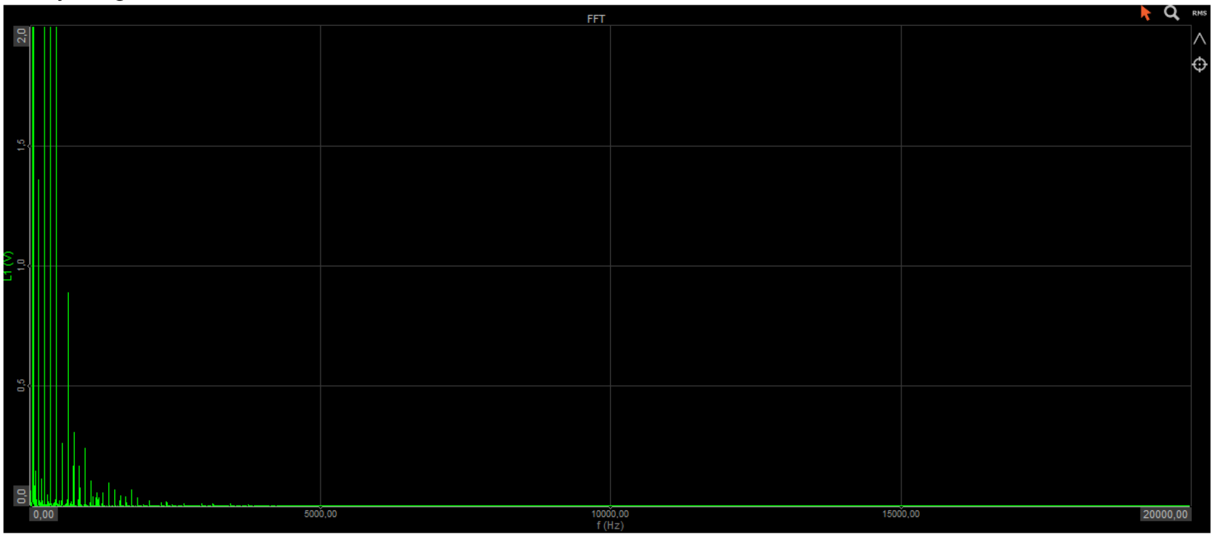


In stopped mode, the DC-link voltage is charging up to 2x 330 V = 660 V. That indicates that the two levels of the pre-charge are feed by two independent pre-charge circuits. Each connected phase-neutral.

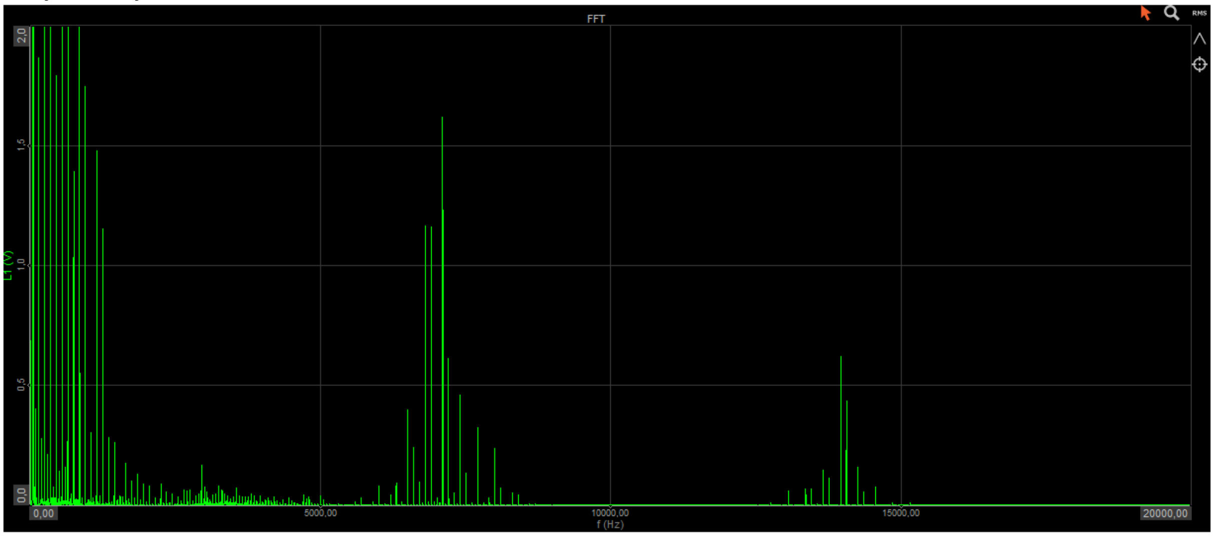
Switch ripple and switching frequency

All documentation of the Sinexcel filter states that the switching frequency is 20 kHz. That could not be measured. It looks more like the filter is running with something like a “bang-bang” control. This is like the ADF P200. The frequency peaks more around 8 kHz.
However, it is also clear that the Sinexcel filter has a lower switch ripple in comparison to the ADFs. The ADF in this case is a 150 A module so we do have a switching frequency at 7.3 kHz.

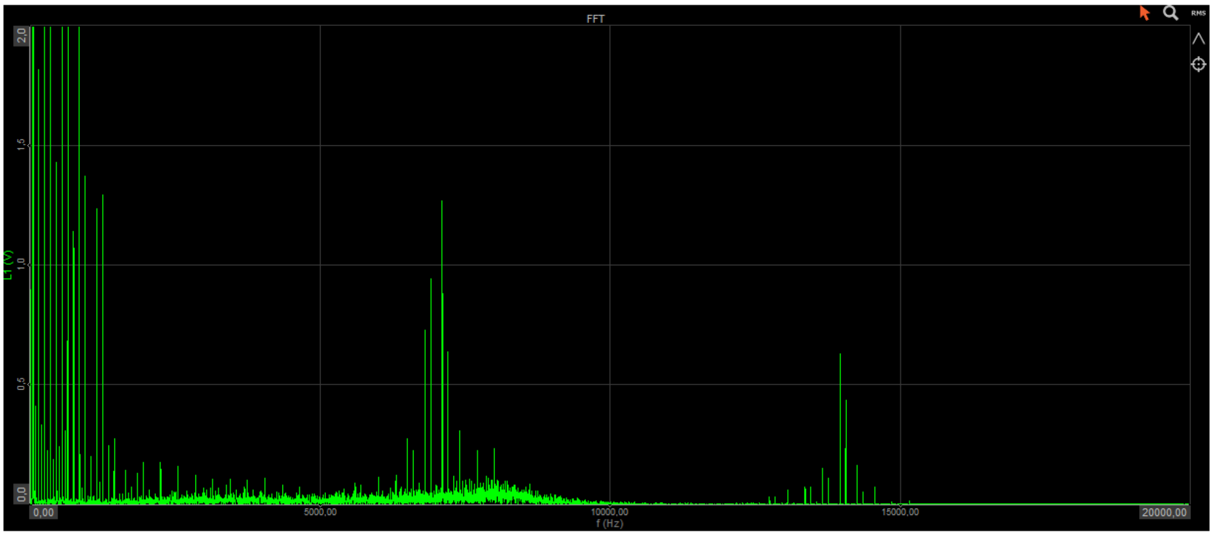
Everything off:



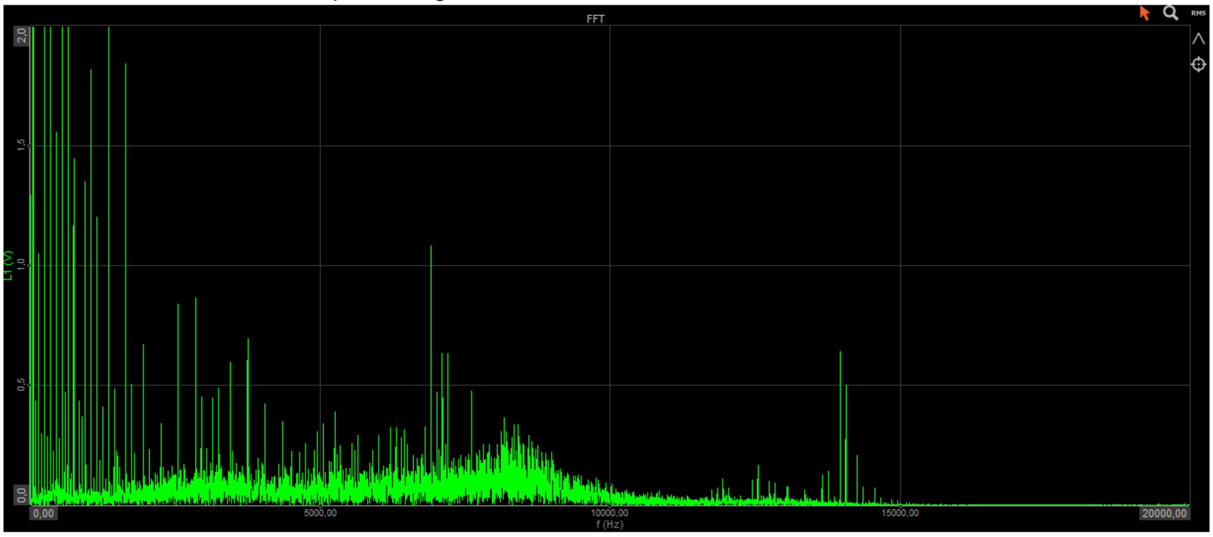
Only Comsys ADF:



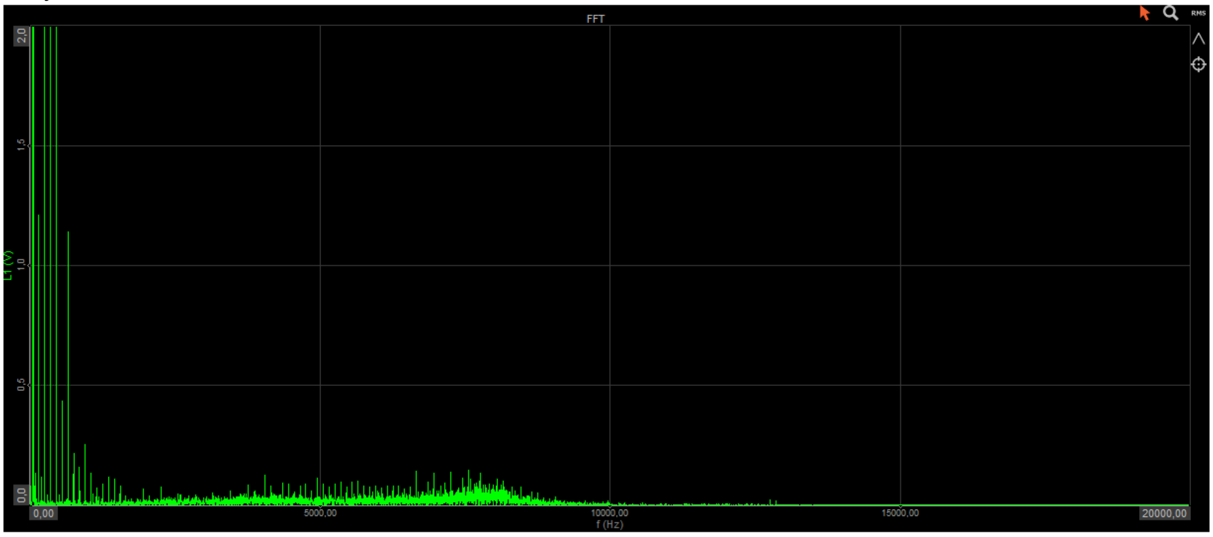
Both filter but Sinexcel only idle:



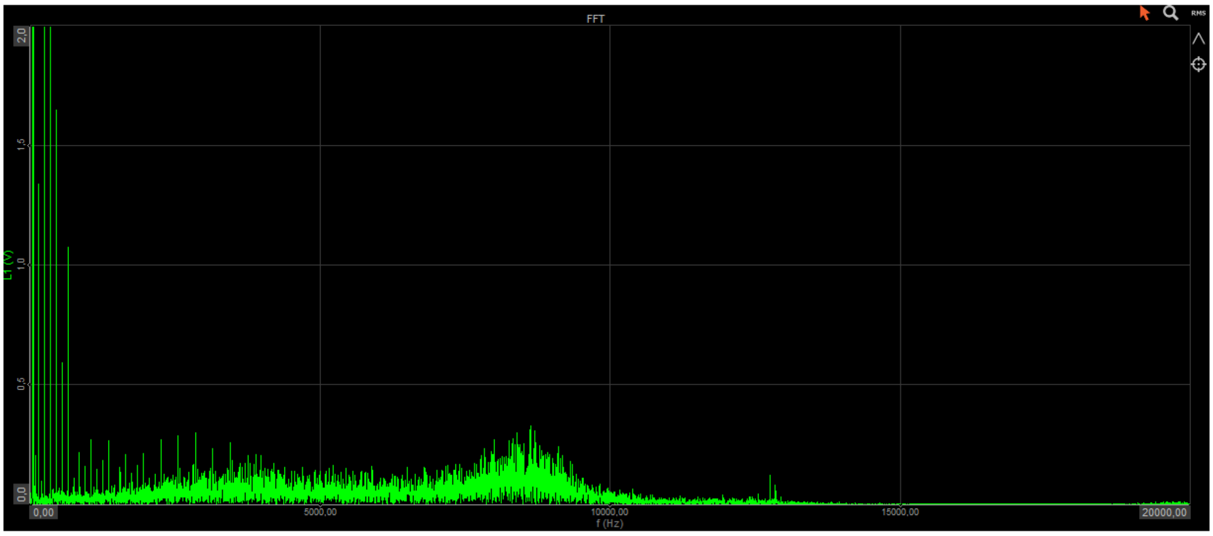
Both filter and Sinexcel compensating:



Only Sinexcel in idle:



Only Sinexcel in full load on reactive power:



Losses

Following losses have been measured:
Off, fan low: 5 W
Off, fan med: 15 W
Off, fan high: 35 W
Idle: 110 W
20 A: 440 W
40 A: 960 W
60 A: 1430 W

Based on the losses and the capability, the filter has about 2.6 – 3.5 % of losses

Summary