Off-grid variable frequency prosumer control

Description of Cellular Smart Grid Platform (CSGriP) tests and results

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Introduction

The Cellular Smart Grid Platform (CSGriP) project aims to make the electricity grid more reliable by using the grid frequency as communication signal. By using the grid frequency for control of prosumers (producers and consumers), no other communication is required for safe and reliable operation (e.g. during grid failures or intended island operation). Renewable Energy (RE) producers and flex consumers are programmed to react to the grid frequency which is determined by local battery inverters.

The grid frequency represents the grid health status, where:

1. low frequency means an energy shortage; no RE production, high load and/or empty batteries.
2. high frequency means an energy surplus; lots of RE production, low load and/or full batteries.

A very high or very low frequency means the grid health is poor and an energy imbalance is imminent. Small frequency deviations represent a change in available energy and are used to start and stop flexible loads. One or more grid forming batteries are used to change the frequency based on available power and energy.

In the island tests performed in the CSGriP project the local grid is disconnected from the main grid, to make the required frequency changes possible. One central battery was used as uninterruptible power supply (UPS), to make sure no blackout occurs in the cell in case of grid failure. The battery changes the grid frequency based on the state of charge (SOC) and power consumption/production of the local grid. Local distributed production and flexible loads change their behavior based on the locally measured grid frequency, respectively increasing production and reducing load. In this way, energy imbalance is always safely controlled without the use of IT infrastructure between the equipment.

Aerial view of the test site on a low energy day, all flex loads are switched off.

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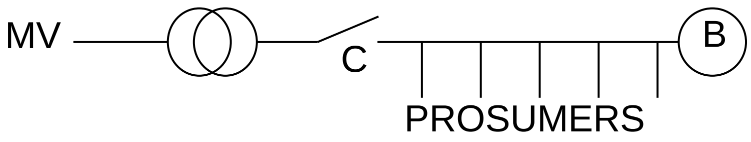
CSGriP principle and test site description

This chapter describes the CSGriP principle, the (semi-off-grid) test site configuration and the programmed behaviour of connected prosumers in more detail. The described tests were performed at the Application Center for Renewable Resources (ACRRES) of WUR in Lelystad. At first, the CSGriP cell grid layout is explained. Secondly, the overall ACRRES test site behaviour followed by the individual prosumers and flex loads is presented.

CSGriP cell grid configuration

A CSGriP cell grid is very similar to normal low voltage (LV) distribution grid. The main differences are the addition of a grid forming battery (UPS) and a central grid failure disconnection switch installed at the grid connection point (distribution station). The layout can be viewed below, where B is the battery and C the switch. This is a simplified schematics, a more detailed single line diagram is shown in the paragraph switch container. Each prosumer in the grid has its own frequency measurement and programmed behaviour based on the measured frequency.

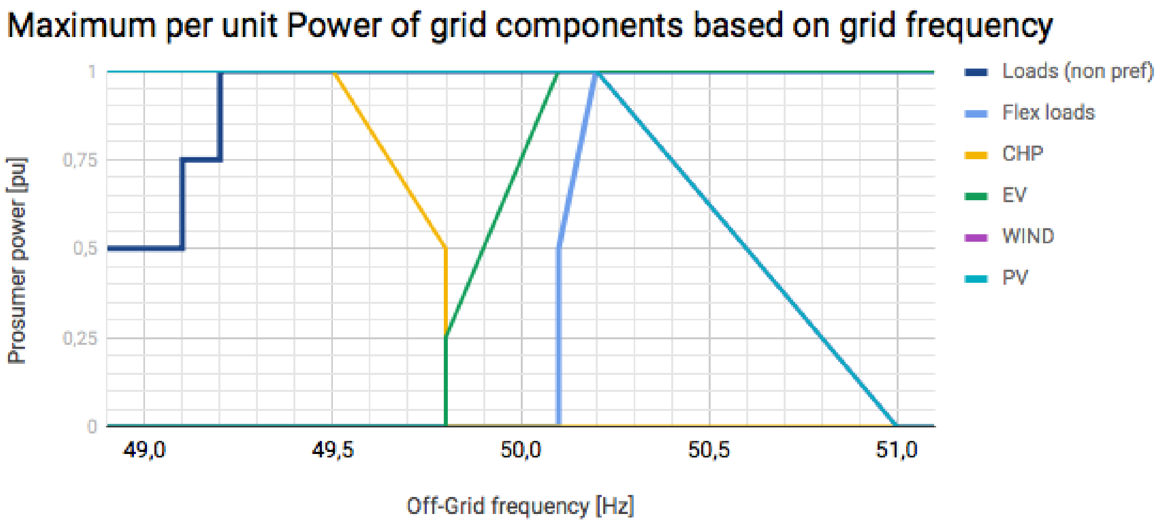


The ACRRES test site is equipped with a measurement on each connection shown above, such that the individual group and thus the prosumer behaviour could be measured.

It is worth noting here that the total summed peak power of prosumers can be larger than the grid connection or the battery power. Overloading of the grid connection is prevented by (dis-)charging the battery or by a grid disconnect and control adaptation of the prosumers. Overloading the battery in off-grid mode can be prevented by a change in (cell) grid frequency, which will reduce the power of the prosumers. This of course requires a continuous load protection measurement on the grid connection.

ACRRES test site components and their programmed behaviour

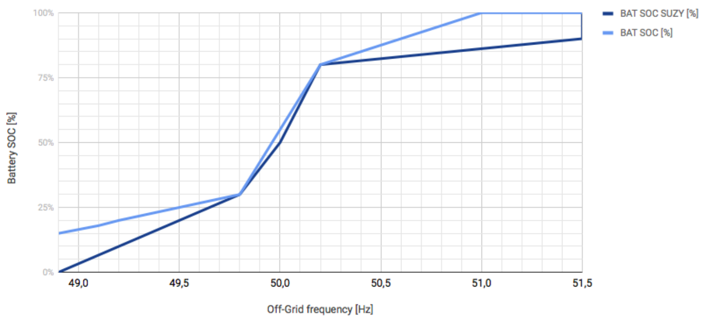
The prosumers in a CSGriP cell all react to the local grid frequency. The figure below shows the individual behaviour of various components. Producers reduce their output above a frequency of 50.2 Hz down to 0 per unit (pu) power at 51 Hz, and increase their output below 49.8 Hz to 1 pu power at 49.5 Hz. Flexible consumers reduce their consumption below a certain frequency, which prioritizes these loads. As an example electric vehicle (EV) charger and flex loads are shown in the graph. As a final measure to prevent a blackout, non preferred loads are being disconnected stepwise below 49.2 Hz.



Wind curve is not vissable because it is the same at the PV curve.

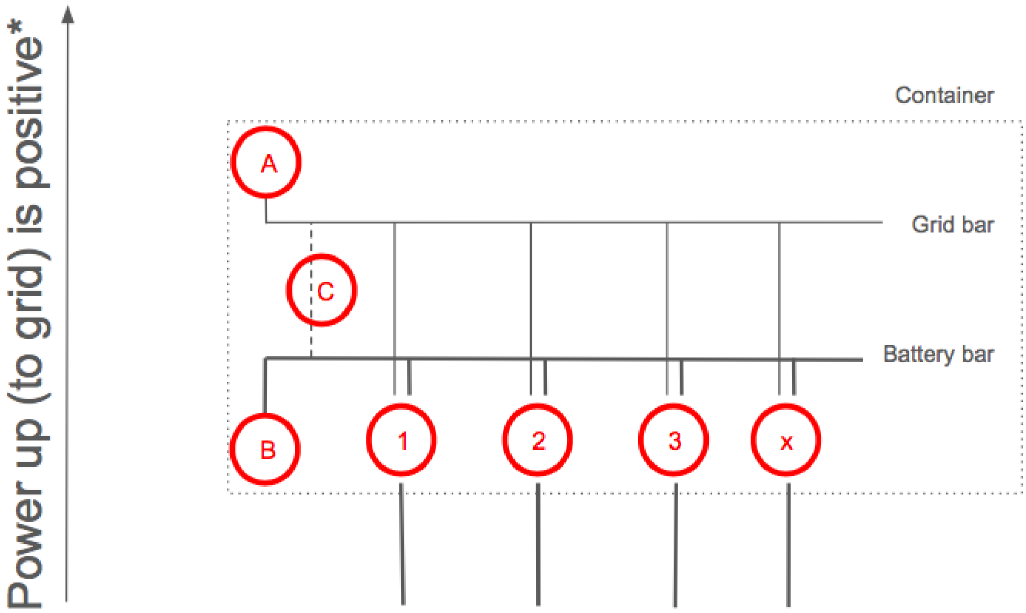
TheBattery – Li-ion battery with variable frequency inverters

The grid forming battery is programmed in such a way that it changes its frequency in island operation based on the SOC and the present power output and on a droop curve. With this behaviour, TheBattery can stabilize the grid, by indirectly controlling the power output/consumption of connected pro-/consumers. The base frequency of TheBattery changes from 49.0 Hz to 51.0 Hz in three linear windows. At 0% SOC the frequency is 49 Hz from which it increases to 49,8 Hz at 30% SOC. The normal operation window is from 49.8 Hz to 50,2 Hz at 80% SOC. Above 50.2 Hz the frequency increases to 50.5 Hz at 90% SOC and to 51 Hz at 100% SOC. The droop coefficient of the battery is 0,00333 Hz/kW.



TheBattery is also equipped with fault ride through capabilities, which makes is possible to switch between off-grid and on-grid operation, without causing a large deviation in local grid voltage and frequency. When a grid failure (voltage drop) occurs, TheBattery automatically switches to off-grid operation mode. When the grid returns after a blackout, TheBattery will synchronize to the grid frequency and reconnect automatically.

Local frequency-based load switch distribution container
A distribution container with 2 distribution bus bars is used, with an interconnection switch (C) between the 2 bars. One bar (A) is always connected to the main grid and one bar (B) always to TheBattery. All groups with prosumers are equipped with manually and automatically controlled switches, which could connect the group to one of the 2 distribution bars. This setup made it possible to connect each component in the local grid individually.



* Power supplied from the grid to the local grid is considered to be positive.

In automatic mode the switch behaviour was based on the measured Battery bar frequency. The figure above shows the 2 distribution bars. (A) represents the grid connection, (B) TheBattery and (C) the connection switch. The numbers represent the connected prosumers, see appendix A for an overview which prosumer was connected to which group number. Each group and connection was measured individually, including all control signals.

During testing it was made sure that none of the groups were disconnected for a longer period of time. To achieve this, the groups were switched between the 2 bars. Based on the test scenario, groups where connected to the Battery Bar and the connection switch was opened to operate in off-grid mode. Groups with energy production were switched to the Grid bar at higher frequencies, reducing energy feed to the battery. Groups with energy usages were automatically switched to the Grid bar at lower frequencies, reducing energy usage from the battery. This made it possible to run all groups full time, without wasting too much energy production or disconnecting loads for a long period of time. Through this, all planned test scenarios could be performed on the Battery Bar.

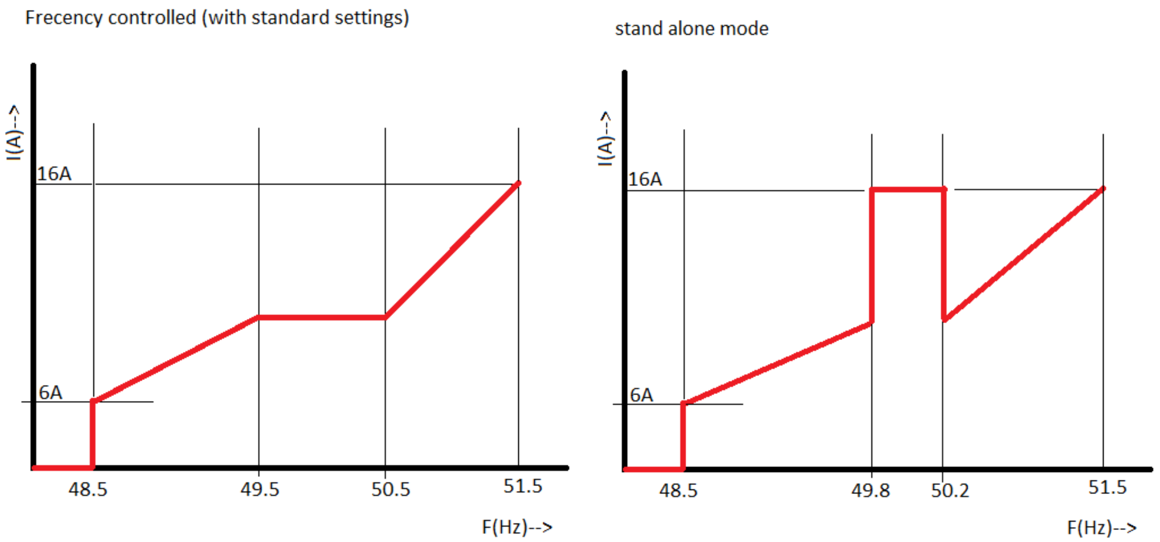
This picture shows the switch container internally.

The switch contained is equipped with an Energy Management System (EMS) that is used to control the switches and change the behaviour as needed.

EV Charger – Electric vehicle charge

A special EV (electric vehicle) charger measured the grid frequency. This EV charger was preprogrammed to limit the EV's charge power. The charge power was limited below 50,1Hz to 25% of its maximum power at 49,8Hz. The charge stopped charging below this frequency.

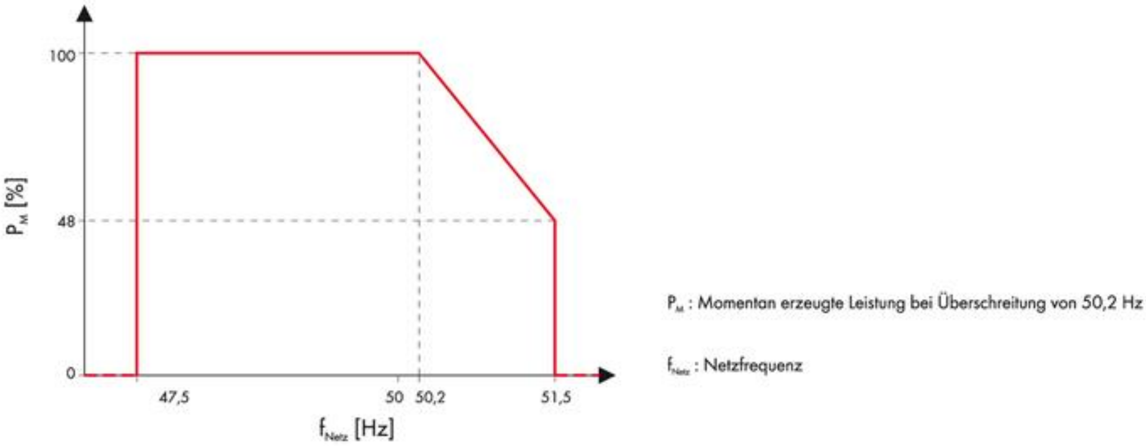
The EV-flex charger in operation.



The exact behaviour of the EV-flex charge.

PV inverter – Photo-voltaic DC-AC inverter

A standard PV DC-AC inverter was configured according to the norm AR-N 4105, which led to the AC power reduction above 50.2 Hz to 48% of the nominal inverter power at 51.5Hz.



Wind – Three wind turbines

3 BESTwind winturbines where specially configured according to the norm [AR-N 4105](), which led to the AC power reduction above 50.2 Hz to 48% of the nominal inverter power at 51.5Hz.

Note : the “bestwind” wind turbines have a high filter capacitor on the output each 10kVAr / turbine. So 30kVA in total , at high power the windturbine consumes the reactive power

Flexible loads – Mixers

2 mixers of 5kW each were programmed to increase their power consumption from 0% at 50.1 Hz to 100% at 50.2 Hz to act as flexible loads.

Other loads – Not programmed or un-controlled loads

The test site also has general consumers, which were considered as preferred and non-preferred consumers. Each group was switched over from the battery bar to the grid bar below a given frequency setpoint, thereby reducing the energy consumption on the battery in island mode. To prevent bang-bang behaviour, switching back to the battery bar was delayed by an offset of +0.1 Hz to the previously mentioned frequency, and a minimum waiting time of 5 minutes between 2 switching actions for each group. See Appendix B for more switching details.

Test Plan and Results

A CSGriP cell is capable of maintaining an energy balance within its local LV grid by controlling prosumers with the use of only the grid frequency as the communication signal. Most tests were therefore performed in island mode, so the battery could control the grid frequency and would thereby regulate the prosumers.

The first test was to verify that the behaviour of TheBattery was according to specification, by cycling the battery over the full SOC-Power envelop. This means TheBattery was tested at power levels up to ± 176 kW (3x250A) at each SOC. During this test the frequency was observed and compared to the programmed behaviour.

Secondly, all components in the test site were verified to operate as they should with the variable frequency: all individual devices (groups) were tested in island mode, where the frequency was cycled over the full CSGriP frequency range, i.e. 48 Hz tot 52 Hz.

Thirdly, the load disconnect/switch control of the EMS was tested for each group. This was specifically done as a CSGriP test, allthough it needed to run properly before testing of all components together during a longer period of time without supervision. This test included a grid failure test, which was activated by the EMS, shown below by the ‘Do not press’ button, this is the bar interconnector disconnect button. In this test the grid switch was suddenly opened and it included a grid reconnect by automatic synchronisation of TheBattery.

Finally, a duration test with all components connected to the battery bar was performed in island mode to check if any bang-bang behaviour would occur. Each component reacts with a different speed, so it could happen that 1 or more systems overcompensate the stabilization behaviour of another device.

Test 1: The Battery SOC-power envelope

(TBD)

Test 2: Full frequency cycle for each prosumer

A full frequency cycle was performed by virtually changing the SOC in the battery. In this way each possible frequency and battery behaviour could be tested with. Each group/component was connected to the battery bar, which was held in island mode.

CHP generator - Combined heat and power generator

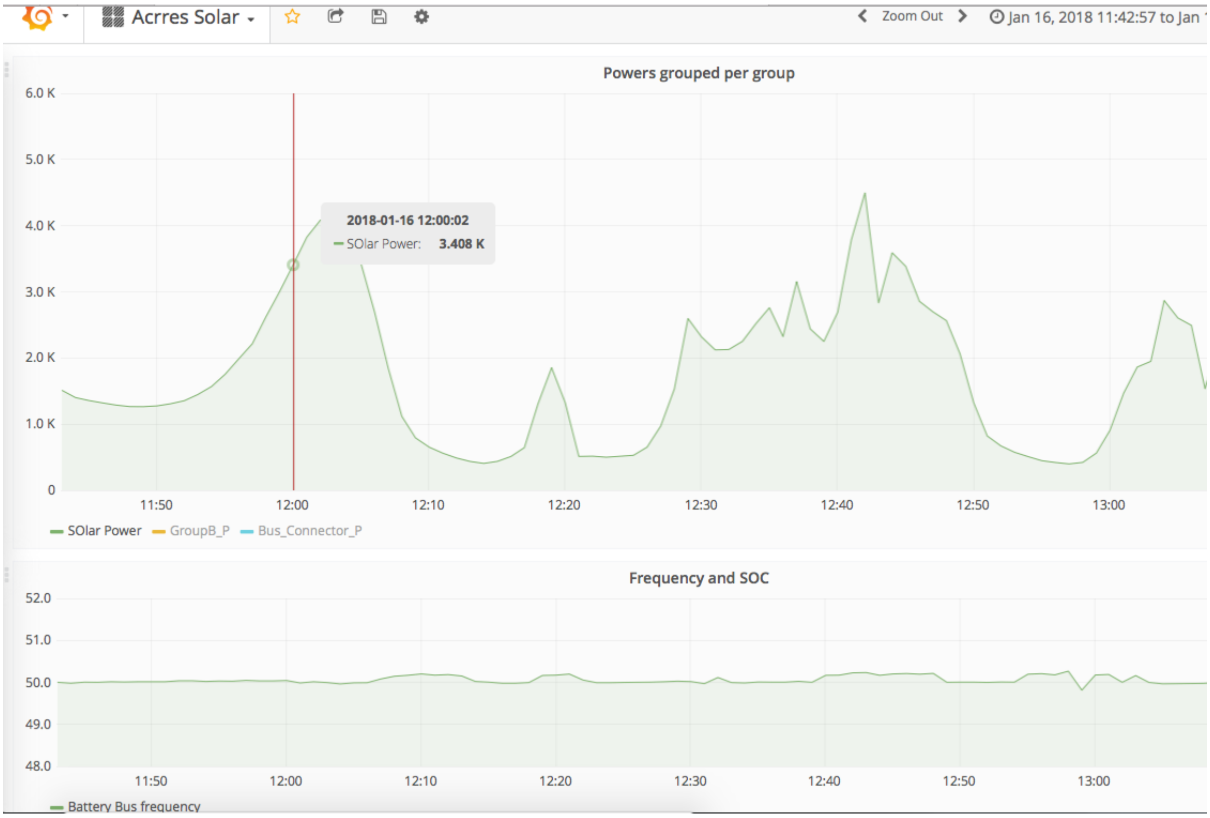
The biogas CHP generator acted as a backup generator in the performed CSGriP tests. The CHP started-up at 49,8 Hz and increased its power linearly from 50% power to 100% at 49,5 Hz. In this way, when an energy shortage occurs, the local grid is fed with extra energy, which stabilizes the SOC of the battery. The CHP runs on locally produced biogas.

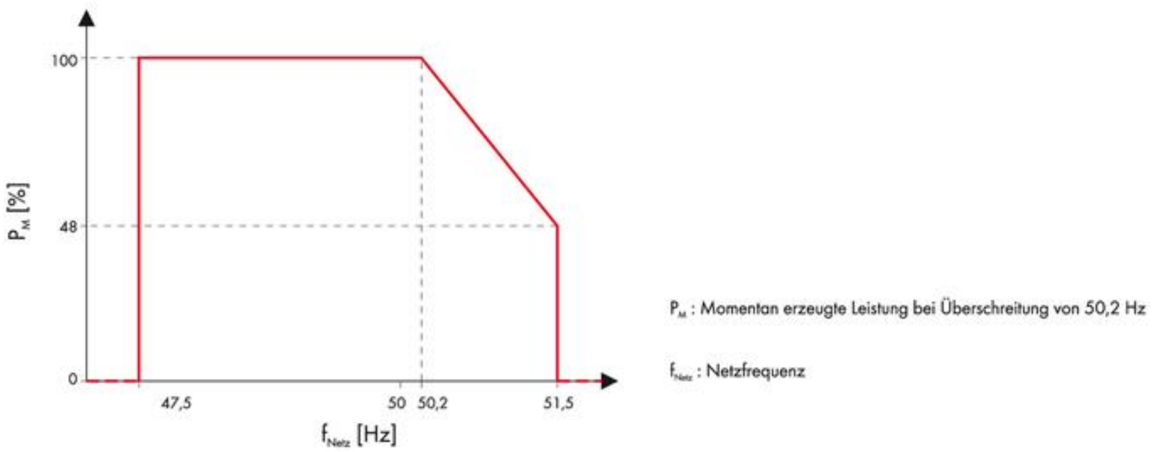
The CHP cycle tests power regulation and disconnect from the battery bar as expected. The image below show a power increase around 12:30 to 75 kW, which correspond to the 49Hz. The CHP only shows this power response when connected to the battery bus as can be seen between 14:00 and 15:30. Is can also be seen that CHP only connects to the battery bus during time windows where the frequency is lower than 49.8Hz.

1 dec https://acrres.grafana.net/dashboard/db/acrres-chp?orgId=1&from=1512458624000&to=1512498224000
5 dec https://acrres.grafana.net/dashboard/db/acrres-chp?orgId=1&from=1512113024000&to=1512152624000

PV

This test was only partially performed due to lack of irradiance in the test period. Increasing the frequency led to power reduction, but not as percentage of the maximum power as the [VDE-AR N-4105](VDE-AR N-4105) standard prescribes.

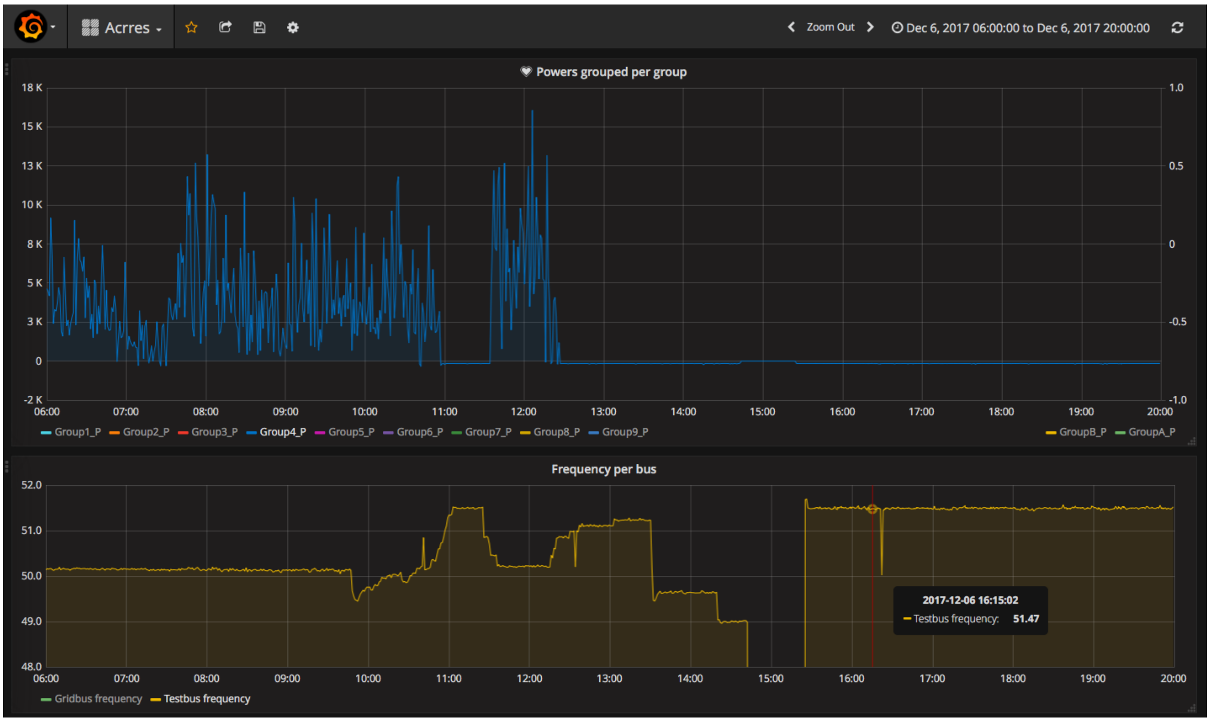




Frequency response of PV according to VDE-AR N-4105.

Wind

Control was not yet working as expected in this period.

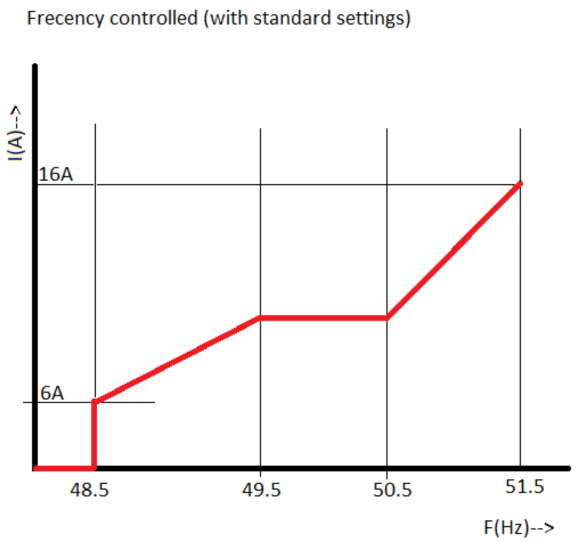


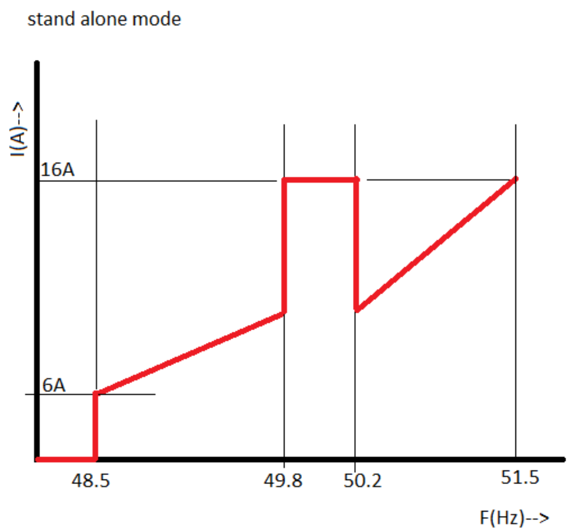
Wind turbines power reduction

Above 51 hz the turbines are disconnected and braked, that is not power limit control.

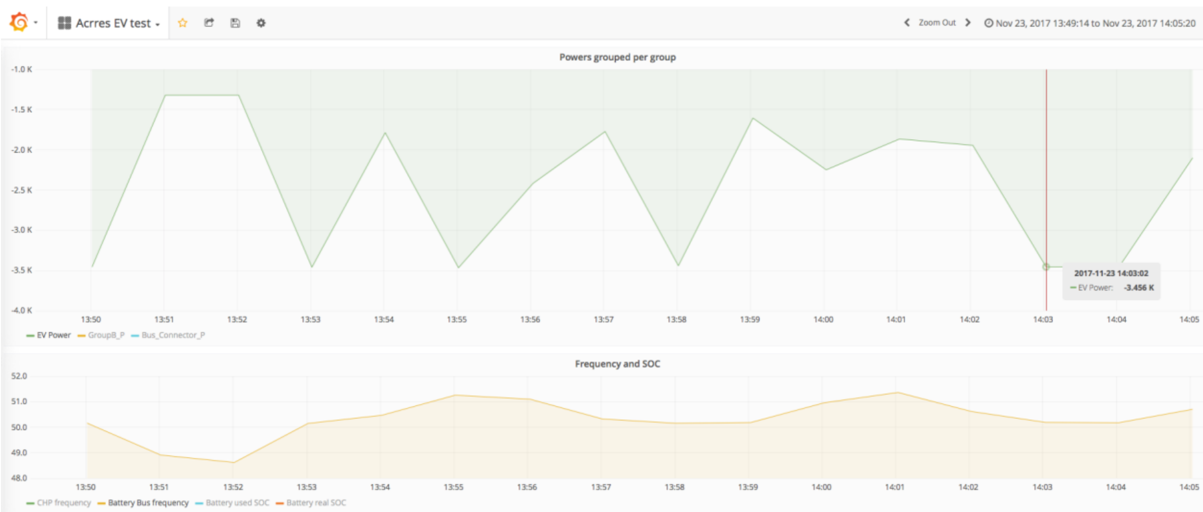
EV

The EV charger was programmed to reduce its power at lower frequency and increase at higher frequency, according to the figures below. During the test the modus on the right figure was used.





Because the charger was programmed to allow full power around 50 Hz (the right figure above), the results of the frequency variation loops shows more power peaks of the EV charger than expected (assuming the left figure above).



https://acrres.grafana.net/dashboard/db/acrres-ev-test?orgId=1&from=1511441354670&to=1511442320276

The charger operated as expected.

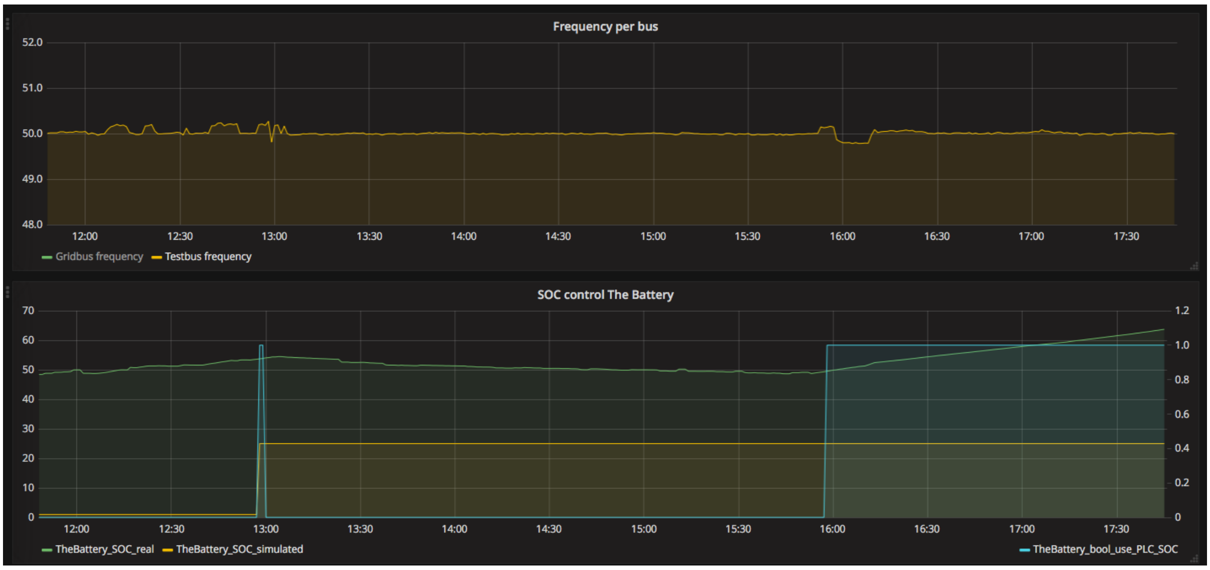
Test 3: EMS auto disconnect and reconnect cycles

The EMS at the ACRRES test site disconnected all power producing groups at their lower frequency limit during the tests. The disconnection of non-preferred loads was not tested during the test, because of the small blackout period these groups would endure.

Most test where done on 1 dec 2017 around 14:00. The images below shows the connect and disconnect cycles for the CHP installation.

Test 4: Complete CSGriP cell operation, with all components

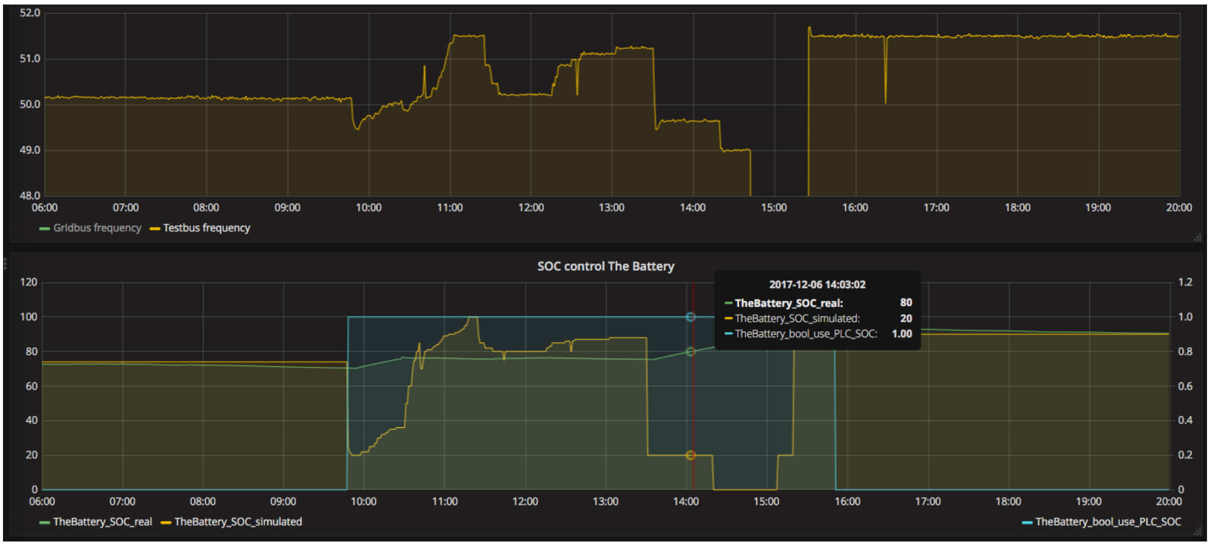
Image taken from acrres.grafana.net, where all the data is hosted.



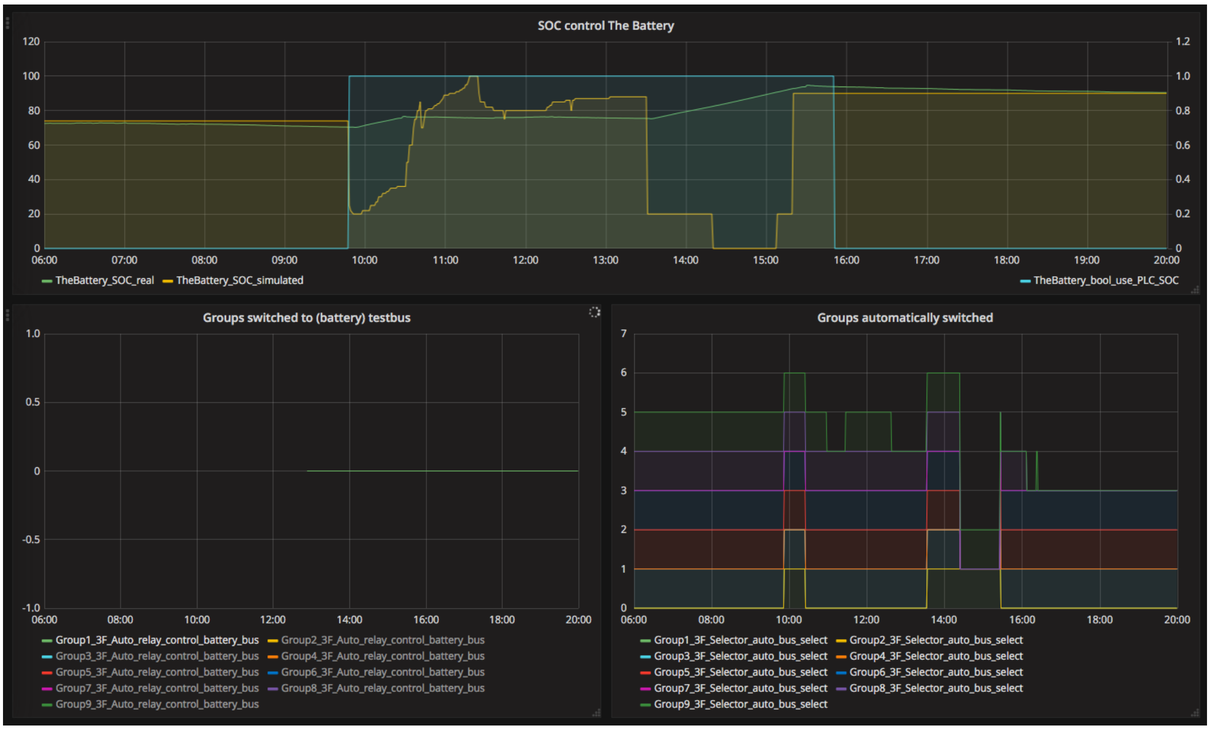
EV charge power limitation

battery load during testing

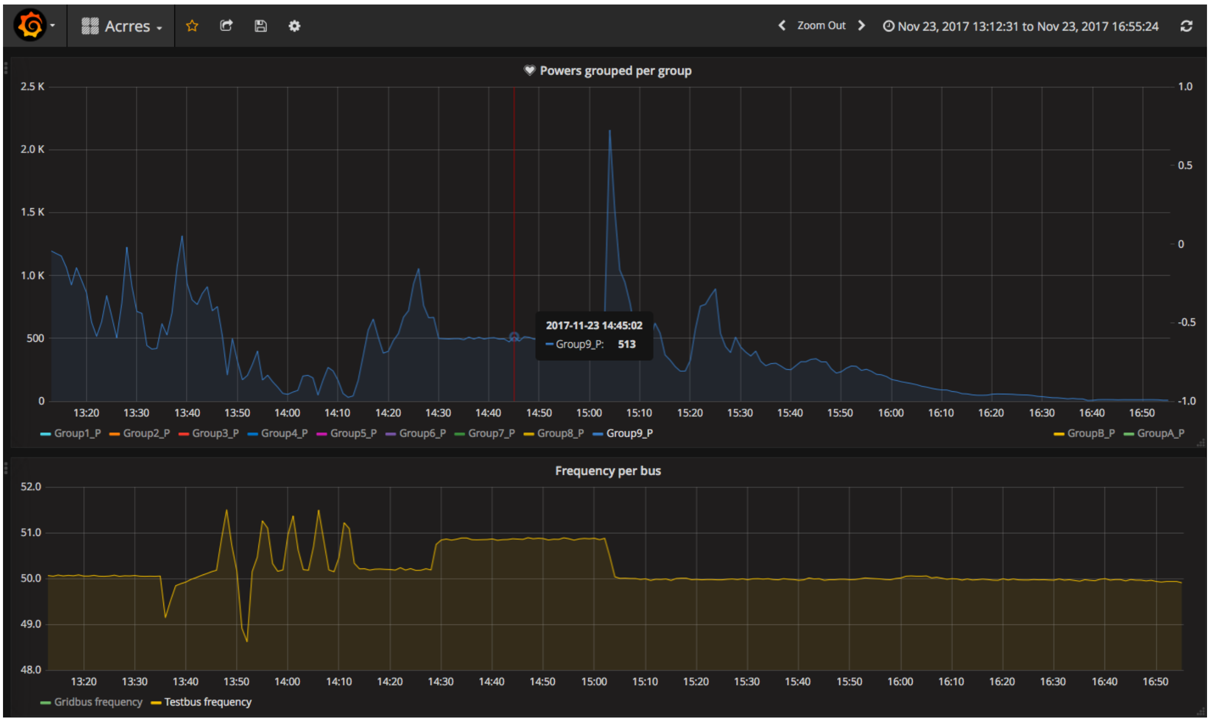
SOC controlled by central PLC



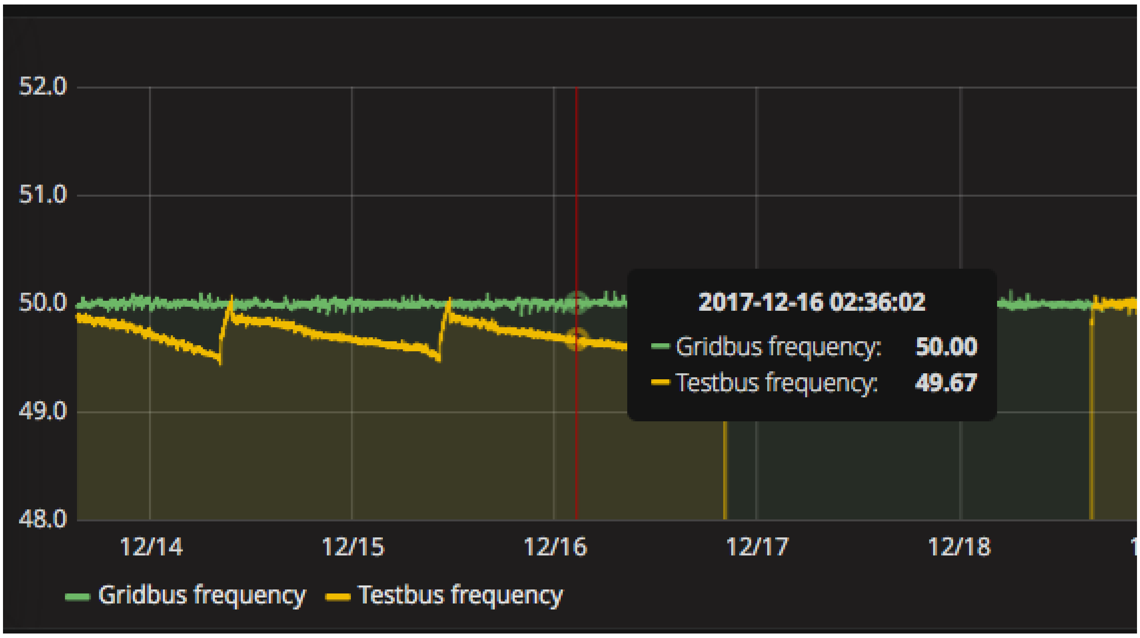
grid failure and load disconnect



PV inverter power limitation

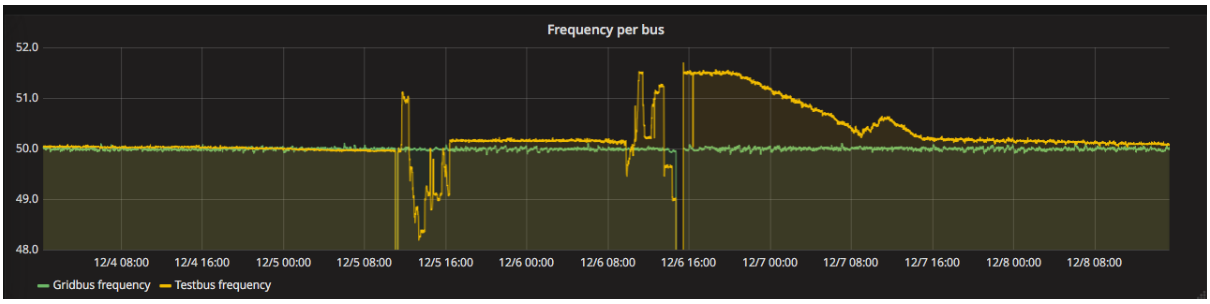


cyclic duration test - frequency loop



https://acrres.grafana.net/dashboard/db/acrres-ev-test?orgId=1&from=1513149824000&to=1513535024000

unknow test



Discussion

Lack of solar generation during test period

Not all test could be performed in the test period, because of lacking solar power production. The test period could have been extended, but because of the project deadline this was not an option. Data of a different location were used. This site also had the capability to change the frequency.

Two cell operation was not performed in the large setup

The CSGriP principle also includes cell to cell support or MV support during grid failure. Because of financial limitations, there was no second battery and therefore no cell to cell support testing done.

Voltage stability of CHP

The CHP had some stability issues. During connecting at lower frequencies the CHP could not always synchronize to the battery bus frequency. After synchronization it showed some oscillations, see appendix D for details.

Conclusion

The CSgriP principle works like it should, al prosumers reacted to the variable grid frequency. There were no major problems in maintaining energy balance, not even during grid failures tests. This means the principle can be applied to more real cases.

Recommendations

Creating a standard for frequency behaviour of prosumers

Not all prosumers currently react to the grid frequency. A standard should be implemented that requires response to grid frequency changes of larger energy users and consumers, such as: washing machine, dryers, fridges, EVs, CHPs, HACS (Heat and Cold storage), etc. A price incentive for support during grid frequnency deviations should be determined by grid operators.

Mobile CSGriP backup battery

A battery on a truck could be purchased by grid operators, for example, which could resolve a grid failure is a very short period of time in a sustainable way. Local production in this area should be available of course. When not available, the battery can be assisted by an emergency generator.

Reliable power supply on the way to a grid failure.

The backup battery could also be used to support weaker grid areas where prosumers overload the grid connections during some periods of the year.

Appendix A: Group names at ACRRES testsite

The loads connected at the testsite during the CSGriP test are shown below.

GROUP 1	CHP (WKK)
GROUP 2	Vergister
GROUP 3	Bio-ethanol (buiten)
GROUP 4	Wind
GROUP 5	Bio-ethanol (hal)
GROUP 6	EV charger
GROUP 7	Algenkas
GROUP 8	Molaris
GROUP 9	PV (Zon)

Appendix B: Automatic-switching frequency setpoints

The main PLC will change the relay positions of the load groups. The different load groups will switch from and to the grid-bus at different local frequencies, measured on the battery-bus. The settings in the table below can be changed in the PLC at any time.

1. groups will switch to grid-bus if frequency is continuously below OFF frequency for OFF time
2. groups will switch to battery-bus if frequency is continuously above ON frequency for ON time
   - this switch-over only happens if the switch-over to the grid bus happened longer than “Min OFF time” ago

Group	ON frequency	ON time	OFF frequency	OFF time	Min OFF time
1 (low prio)	49.9 ± 0.05	60 sec	49.2 ± 0.05	60 sec	300 sec
2 (med prio)	49.8 ± 0.05	60 sec	49.1 ± 0.05	60 sec	300 sec
3 (high prio)	49.0 ± 0.05	60 sec	49.0 ± 0.05	60 sec	300 sec
4 (flex load)	50.1 ± 0.05	60 sec	50.0 ± 0.05	60 sec	300 sec

Randomisation of the frequency setpoints should be implemented in real life (to prevent that everything happens at exactly the same moment), but this is not required in the test site.

Appendix C: Original testplan of Alfen

1. Monitor the parameters (frequency, active power, reactive power, voltage… to be completed) under **On-grid** mode (main switch between grid-bus and battery-bus keep **Closed**)
    a. Check the **Control Regulation1** for remaining in **On-grid** mode.
        i. Set state of charge to 5% and 95% and let the batterycontrol the power to get to 50% SOC.
        ii. Protect maximum power flow from and to grid by with setpoints (calculations at forehand).
    b. View harmonic changes before/after connections.
2. Trigger the transition from **On-grid** mode to **Off-grid** mode (main switch changes from **Closed** to **Open**).
    a. Specifying the conditions trigger the switching (Auto/Manual)
        i. Normal disconnect (bring grid power to zero)
            1. The aflen battery should read grid power (over modbus and reduce power)
            2. Disconnect request can be sent (over modbus)
        ii. Manual disconnect (simulated grid failure)
            1. Negative grid feed disconnect
            2. Positive grid feed disconnect
    b. Check the **Transition Regulation1** to make sure the transition goes successfully and smoothly.
3. Check the **Control Regulation2** for remaining in **Off-grid** mode (main switch keeps **Open**)
    a. Grid disconnected frequency based prosumer control (Reference: Testsite setup plan: SAT Test1)
    b. Start the test at ~10% SOC.
        i. load reduction (disconnect) @ critical SOC; 49,5Hz; SOC's 49.8=30% 48=0%
        ii. production increase (CHP) @ low SOC; 49.8Hz=30%
    c. Start the test at ~100% SOC.
        i. load increase (EV) @ medium SOC; 50.0Hz to 50.2Hz=80% (Ballard)
        ii. production reduction (PV) @ high SOC; SOC's 50.2Hz=80% to 51.5%=100%
4. Trigger the transit from **Off-grid** back to **On-grid** (main switch changes from **Open** to **Closed**).
    a. Check the triggering conditions (Auto/ Manual) from Grid point of view.
    b. Check the triggering conditions (Auto/Manual) from the battery point of view.
5. Check the **Transition Regulation2** from **Off-grid** to **On-grid**.
    a. View Power quality and harmonics.
6. Repeat step1.

Standard conditions
Measure the power quality during all tests.

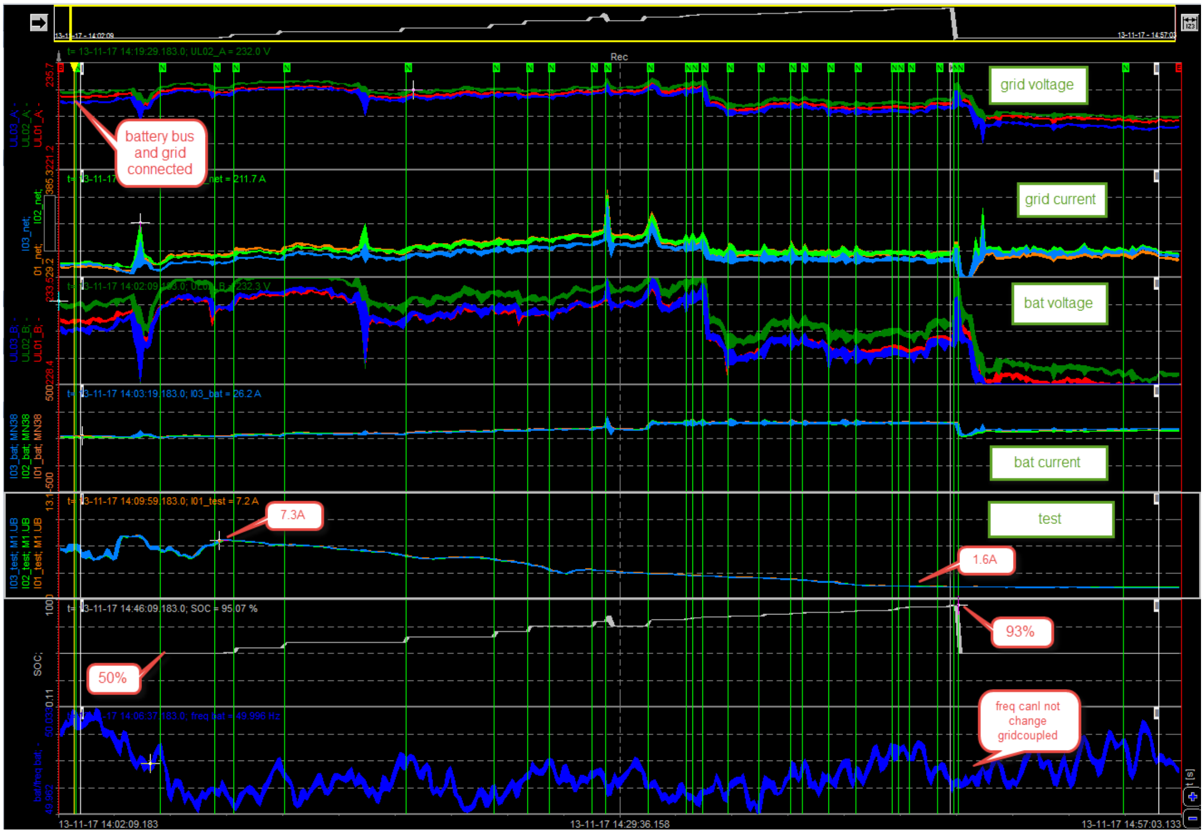
Reference for control and transition regulations: CSGrip Documentation final (System Modeling & Control).

Appendix D: General test results

General test results of the battery system

Simulated state of charge was introduced to speed up measurements.

(Below: wur_test01_2017_11_13_140208.d7d)



General measurement screen layout (can be 10k samples/sec or 0.1 sec average , depending on recording settings)

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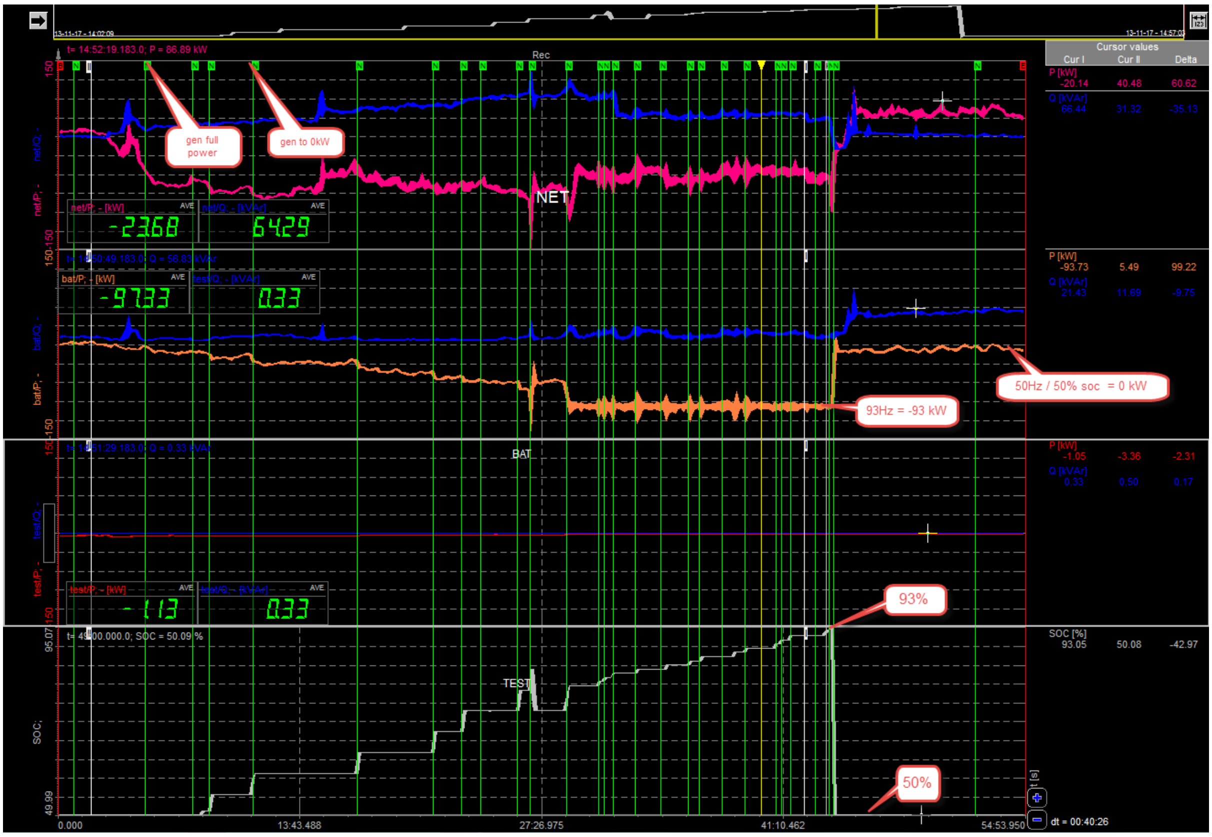
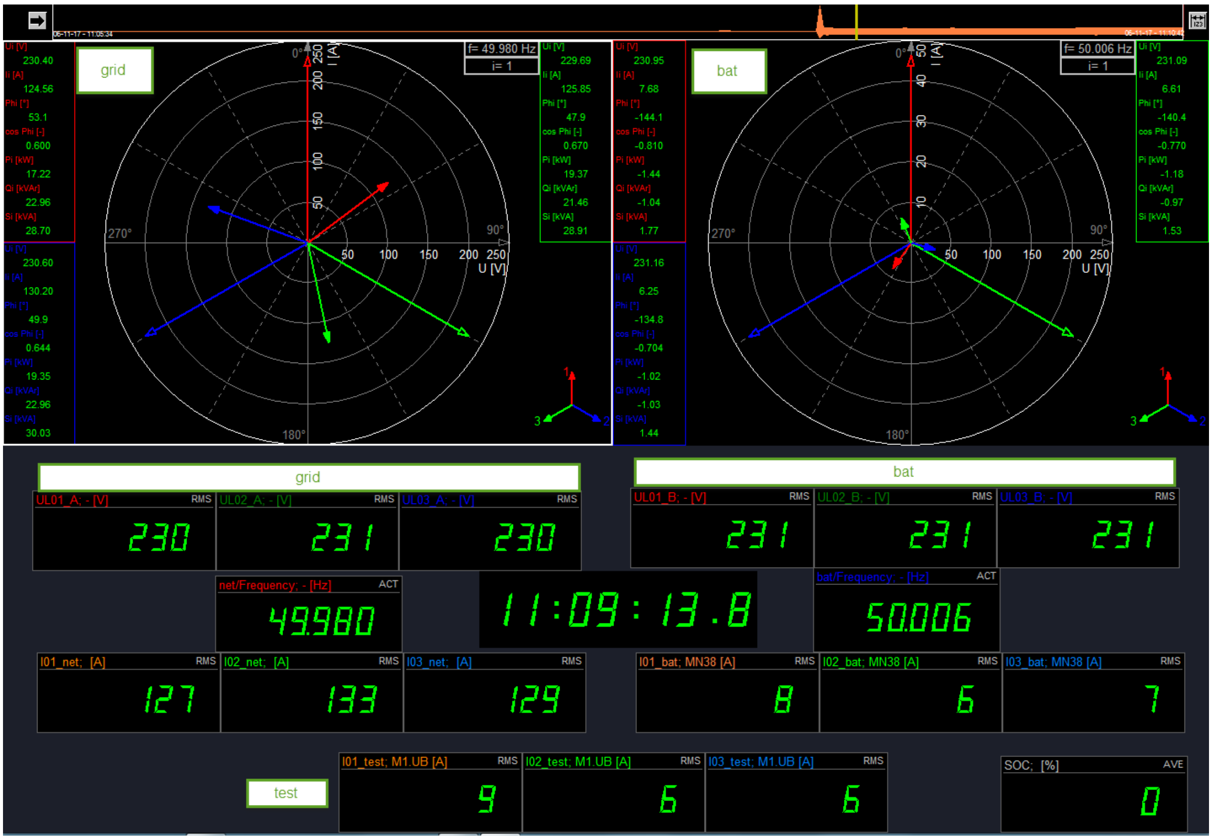
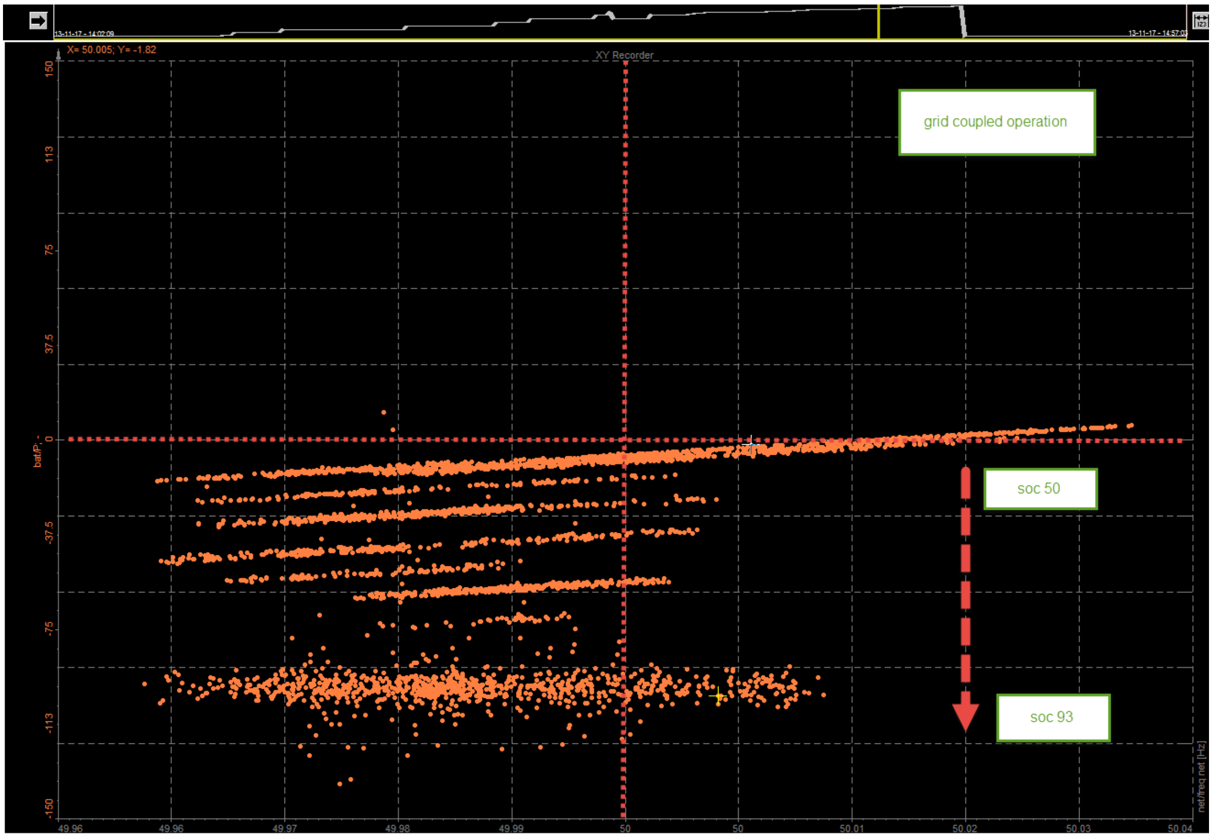




Dashbord during testing (only if recording is 10kS/sec; not recorded on 10Hz average recording)

Here simulated SOC steps



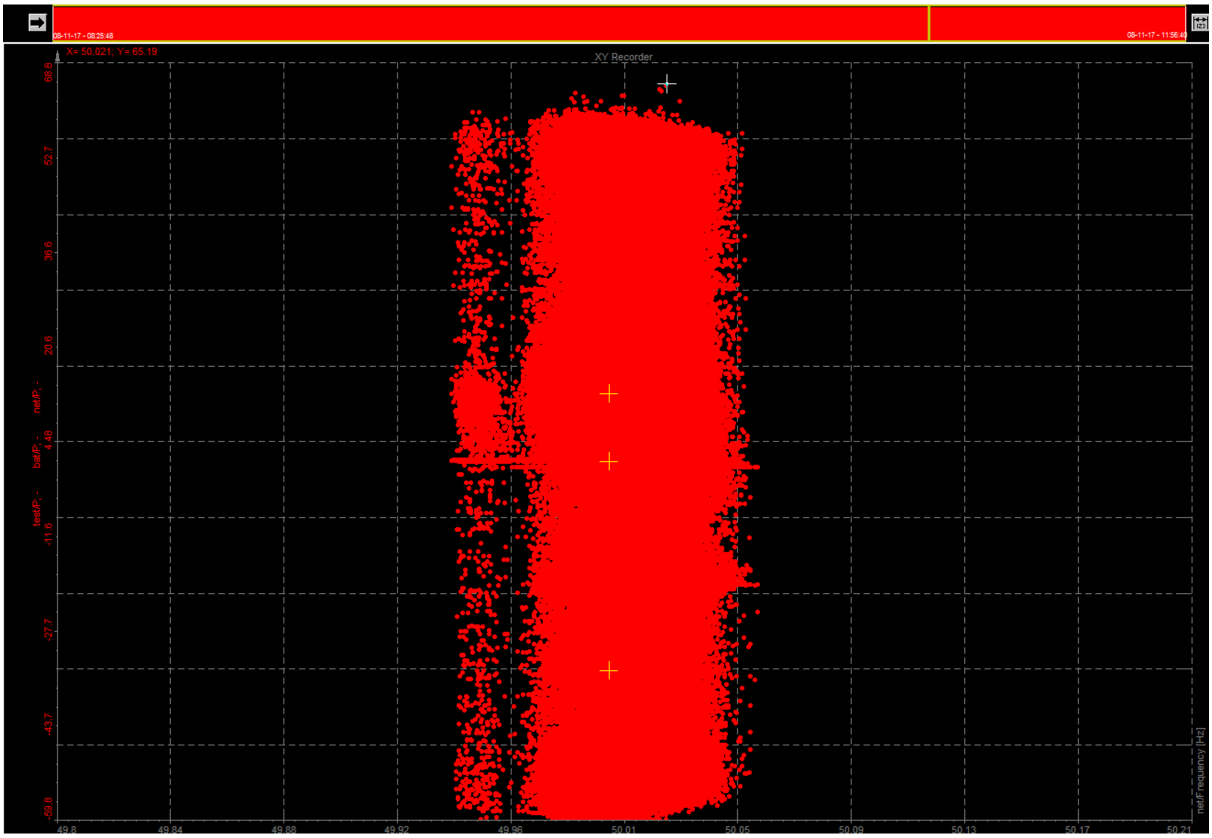
Vertical SOC change → SOC > 50% → discharge

Startup problems

wur_test01_2017_11_08_082549.d7d

SOC instable output (solved)

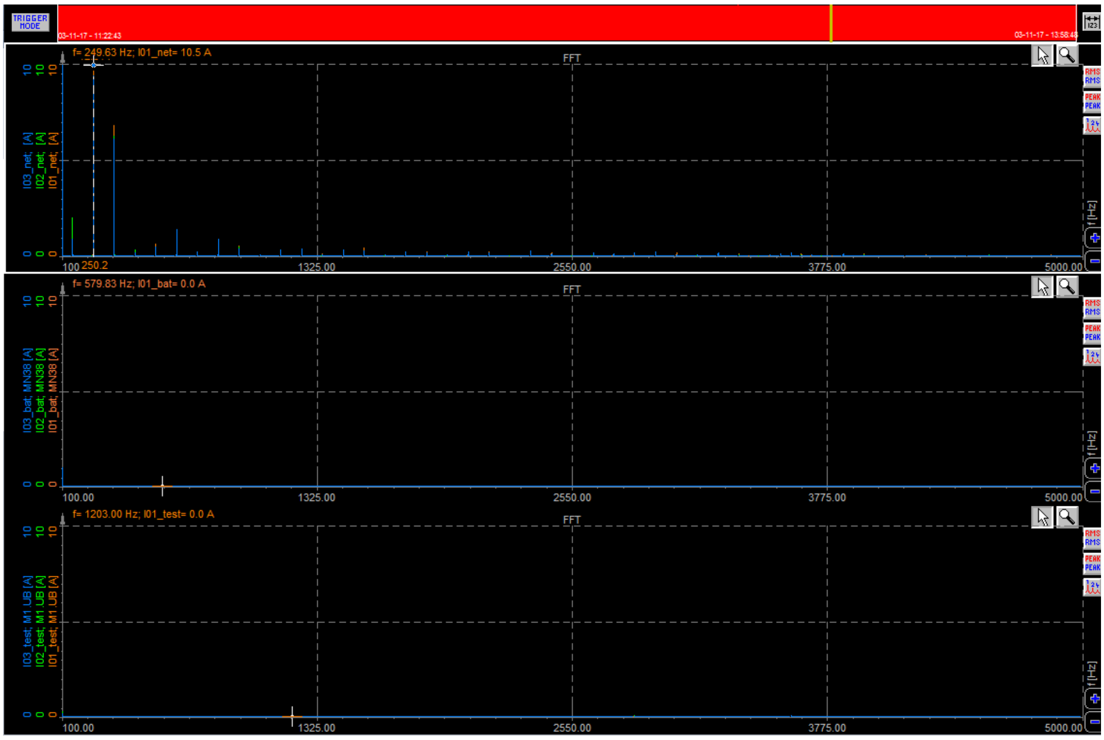
wur_test01_2017_11_08_082549.d7d



Frequency deviation on grid independent of local power (is depending on global power)

Harmonics on grid compared to island operation

wur_test01_2017_11_03_130654.d7d



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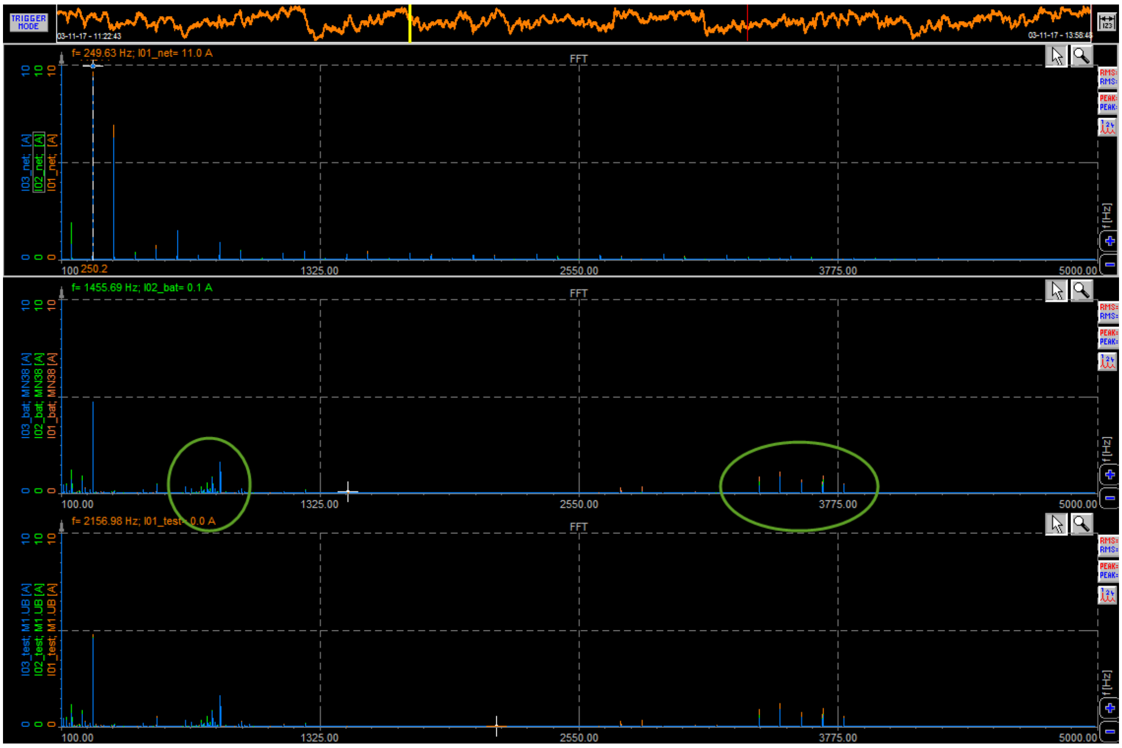

Harmonic cluster on 3.6kHz and 850Hz

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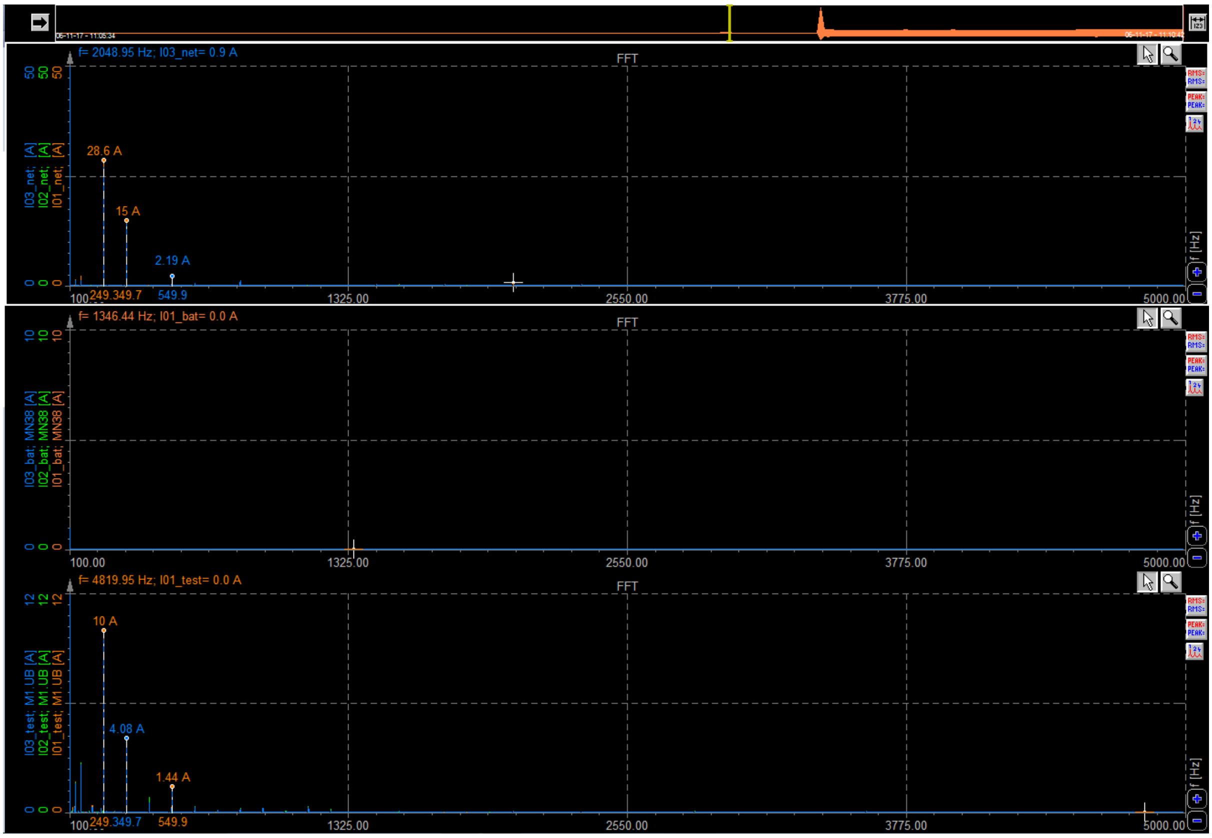
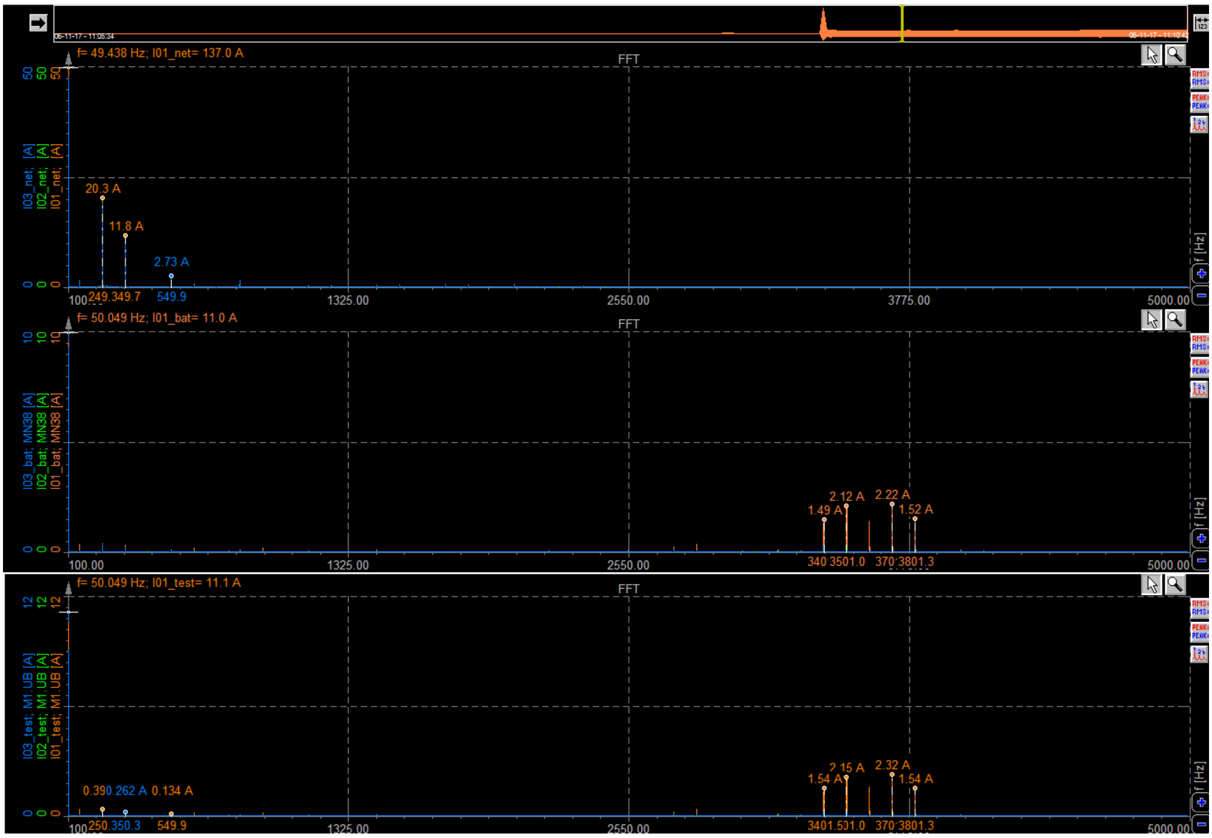


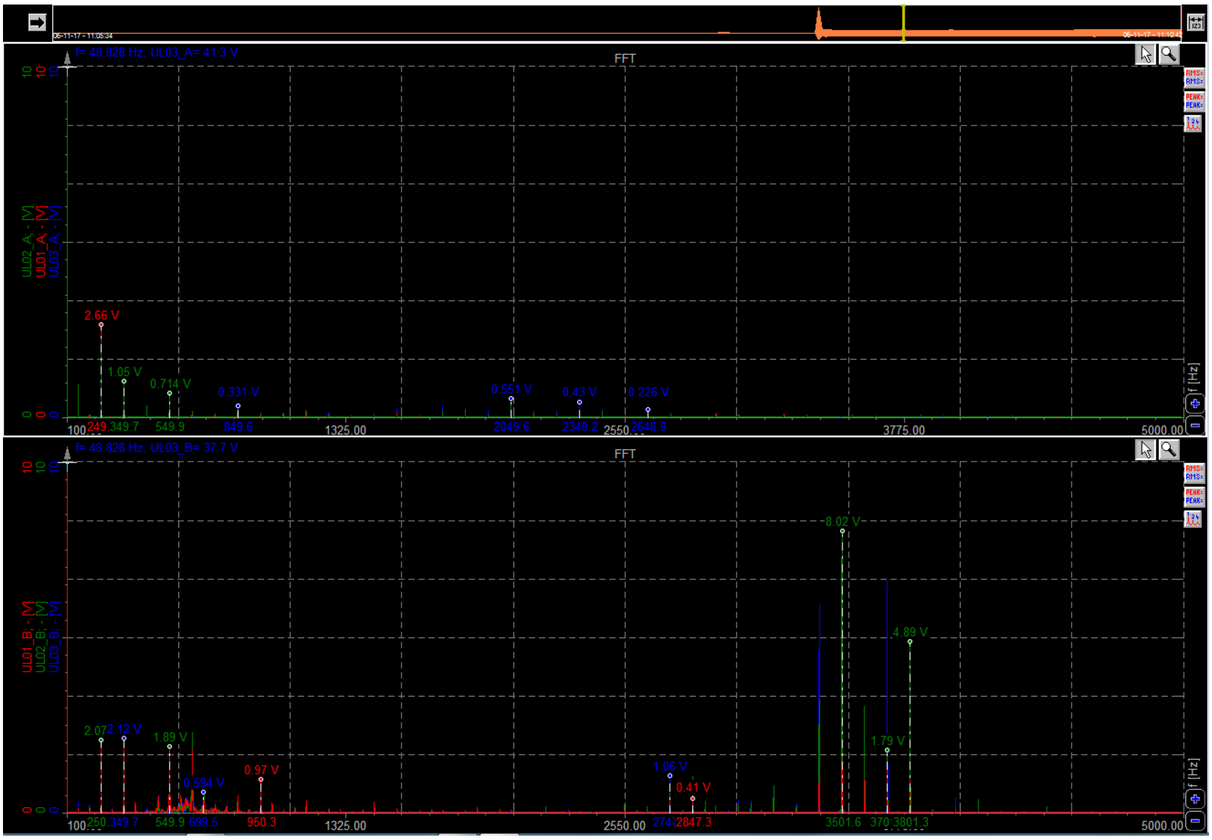
Harmonic current on the grid

wur_test01_2017_11_06_110533.d7d



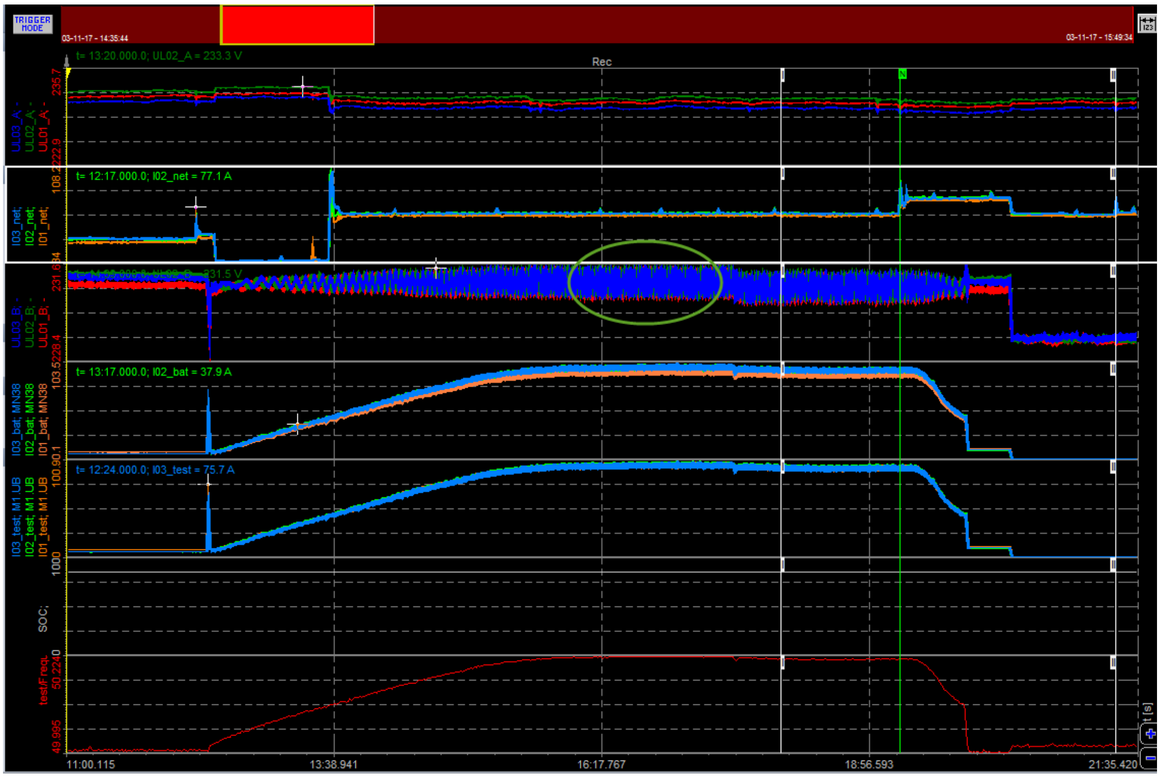
Harmonic currents injection on batter

wur_test01_2017_11_06_110533.d7d



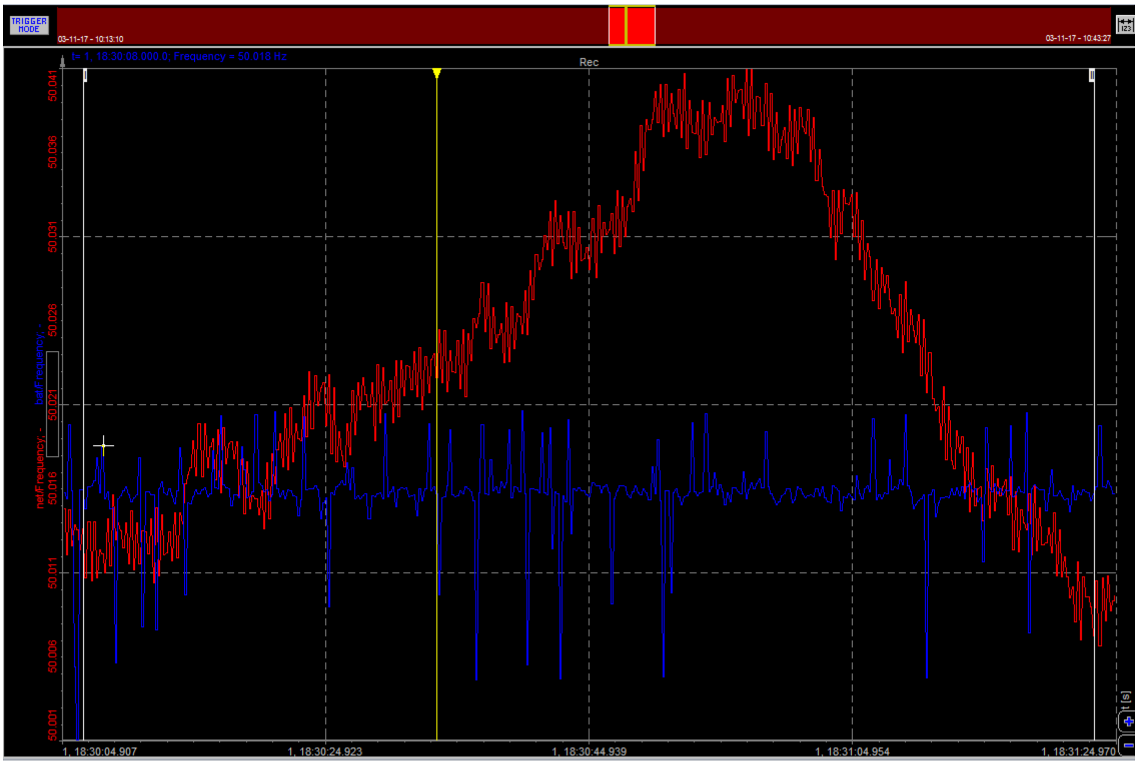
Harmonic voltages

wur_test01_2017_11_03_143543.d7d



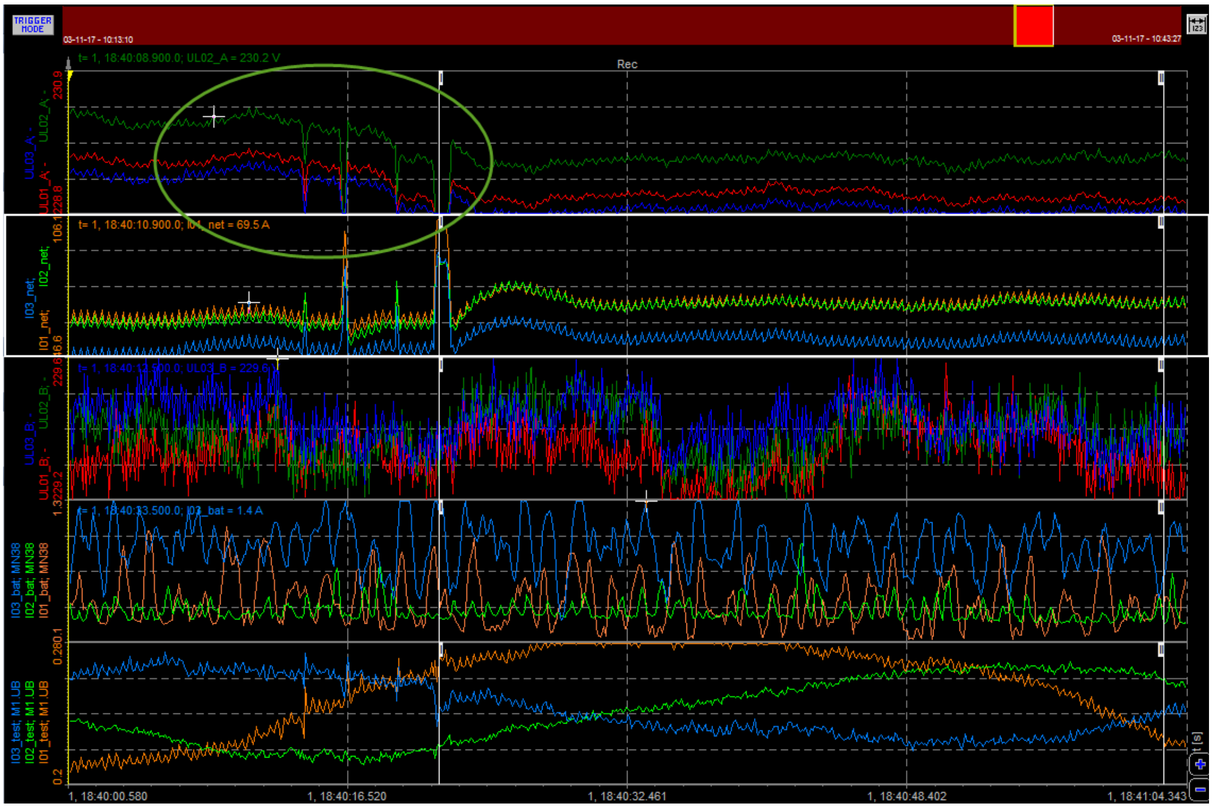
Charging the battery is causing instability on rms voltage: 0.9V at 2.4Hz oscillation
There is a clear reproducible relation with the charge power: if we go to 120kW charge , the problem gets worse.

wur_test01_2017_11_03_101311.d7d



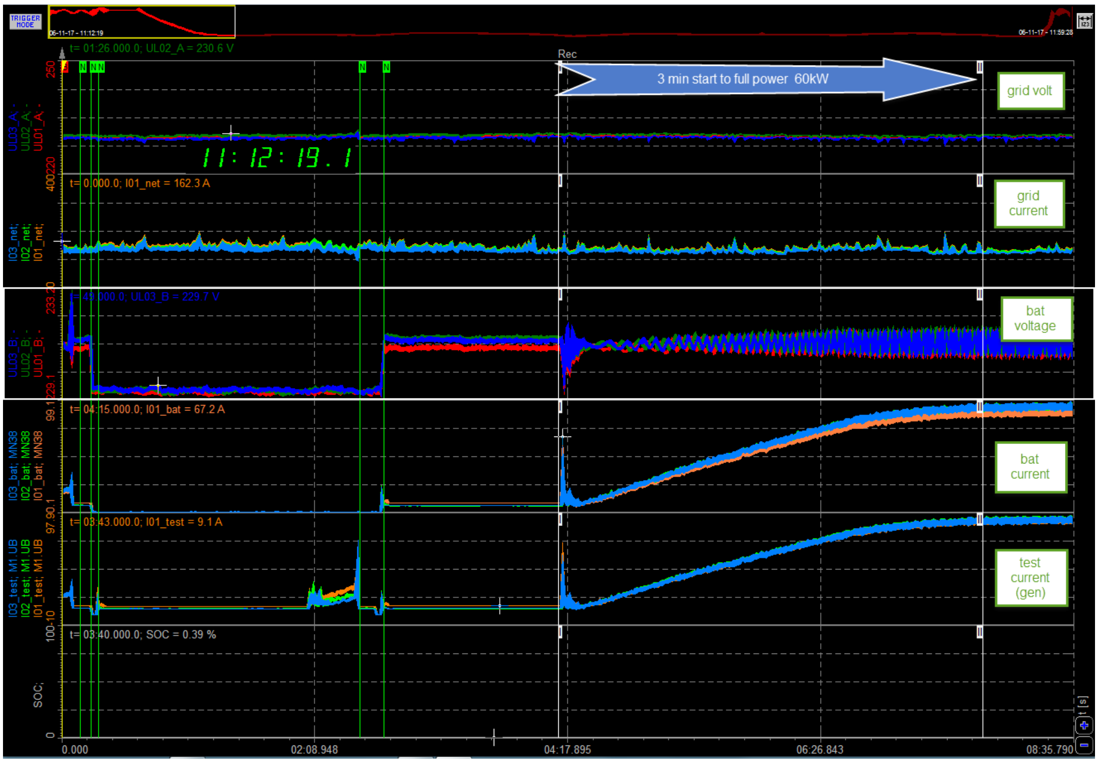
Battery frequency compared to grid frequency
? frequency jups / noice 10mHz in 200msec up

wur_test01_2017_11_03_101311.d7d



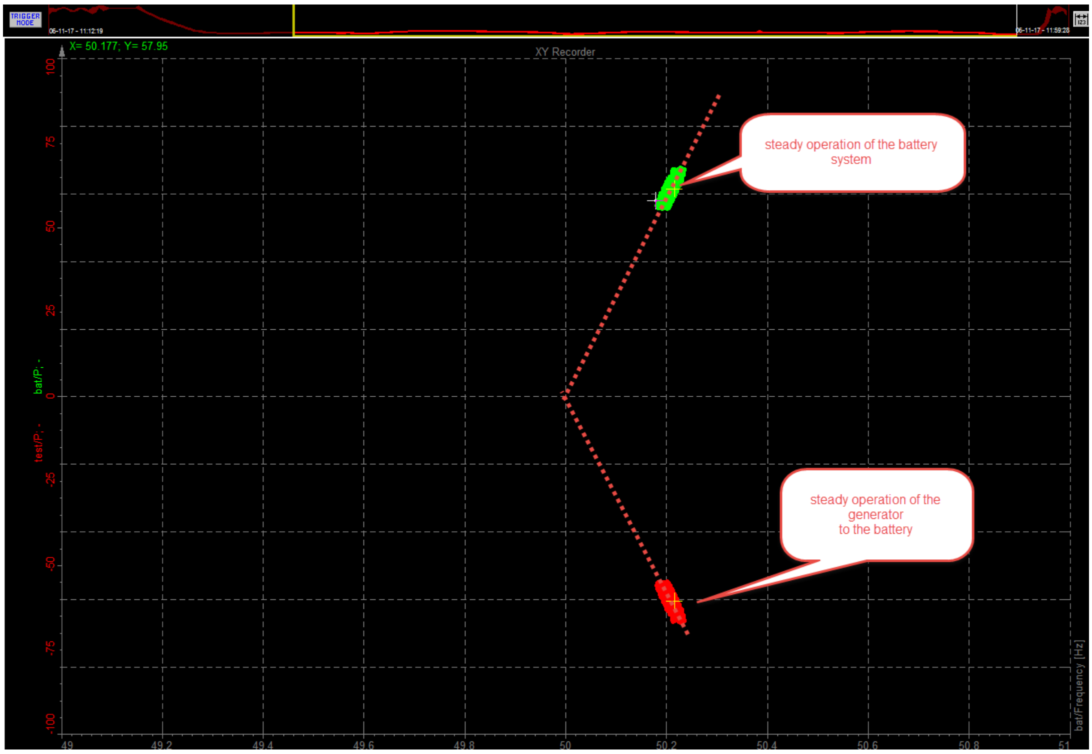
Unsymmetric grid voltage could be solved by ESS → 0.8V / 230 = 0.34%.
Note: this are calibrated voltage channels so the deviation is real and checked.

wur_test01_2017_11_06_111218.d7d



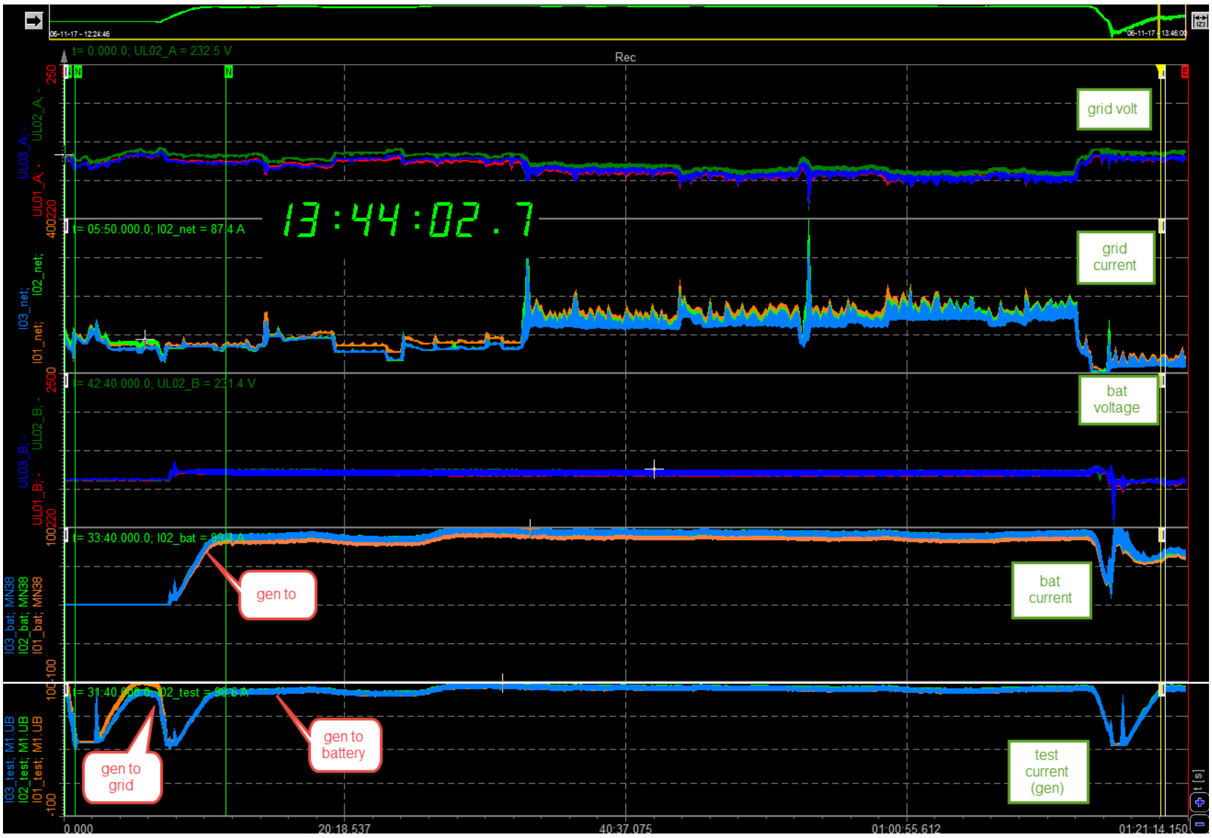
The oscillation of the battery voltage is about 2.5Hz when charging the battery with 60kW.
What if we increase the infeed to the battery to 120kW? It looks like there is a relation.

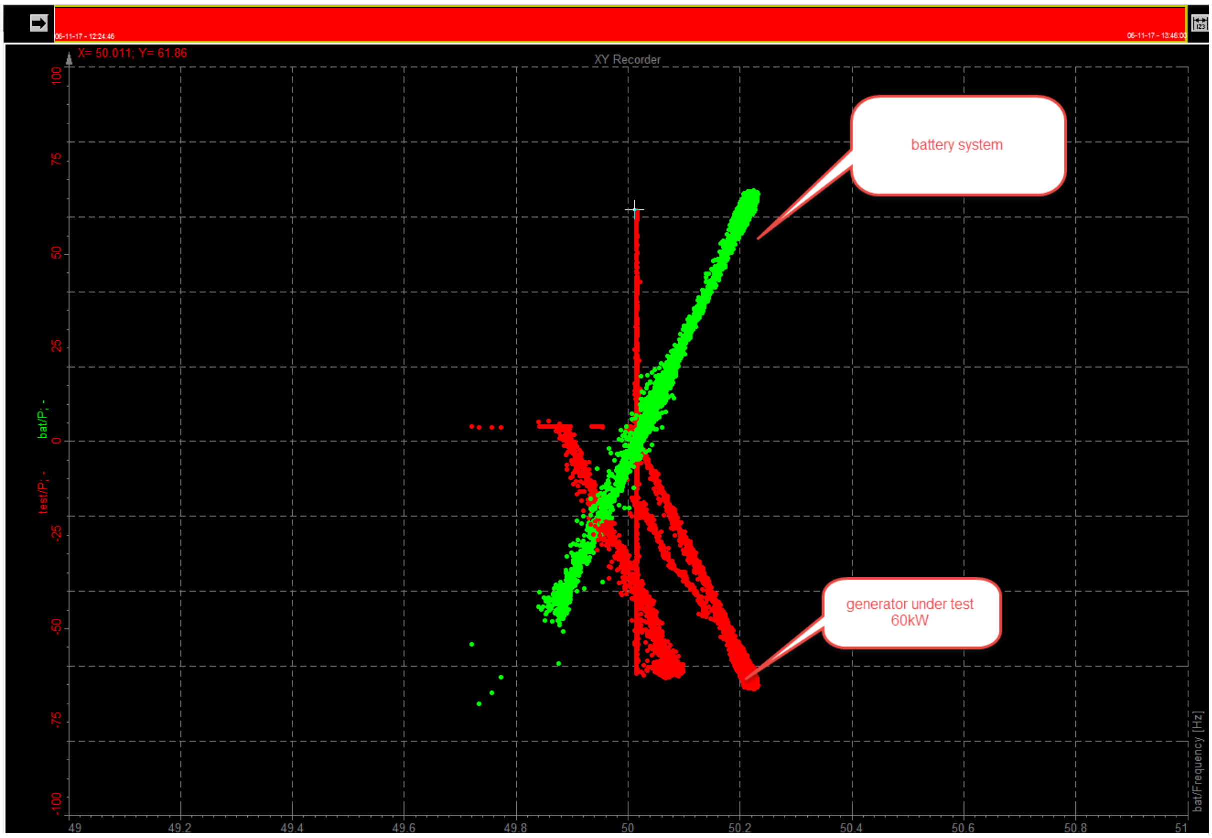
wur_test01_2017_11_06_111218.d7d



The frequency rose 0.2Hz due to the 60kW infeed to the battery.

wur_test01_2017_11_06_122445.d7d

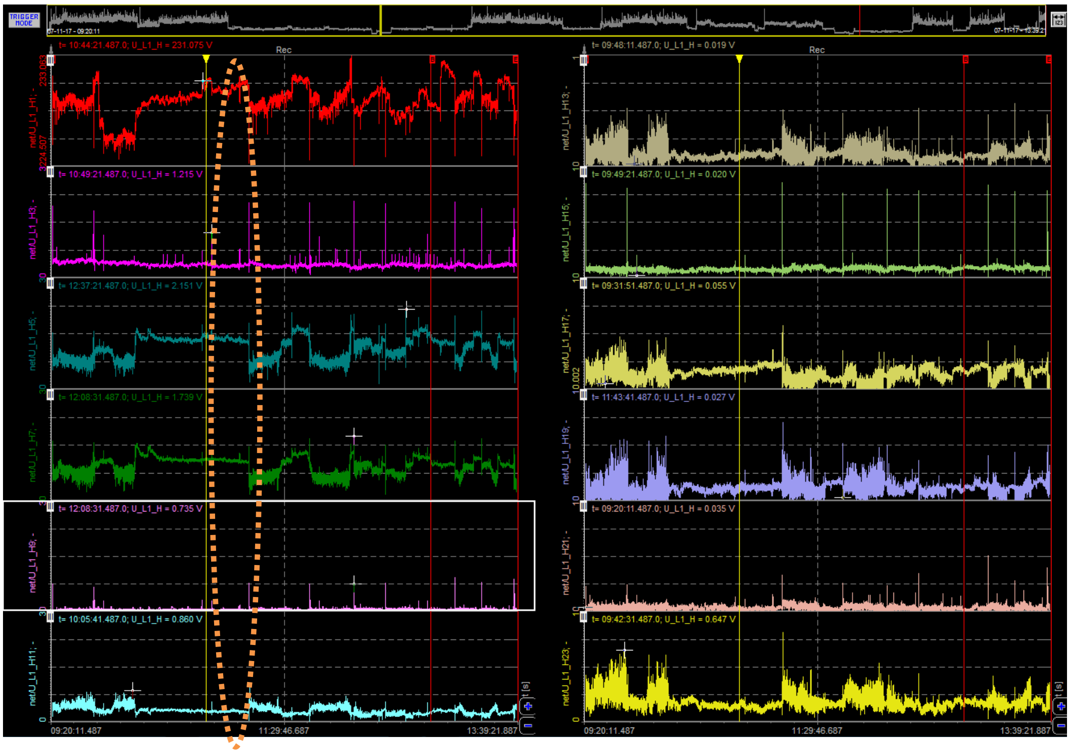




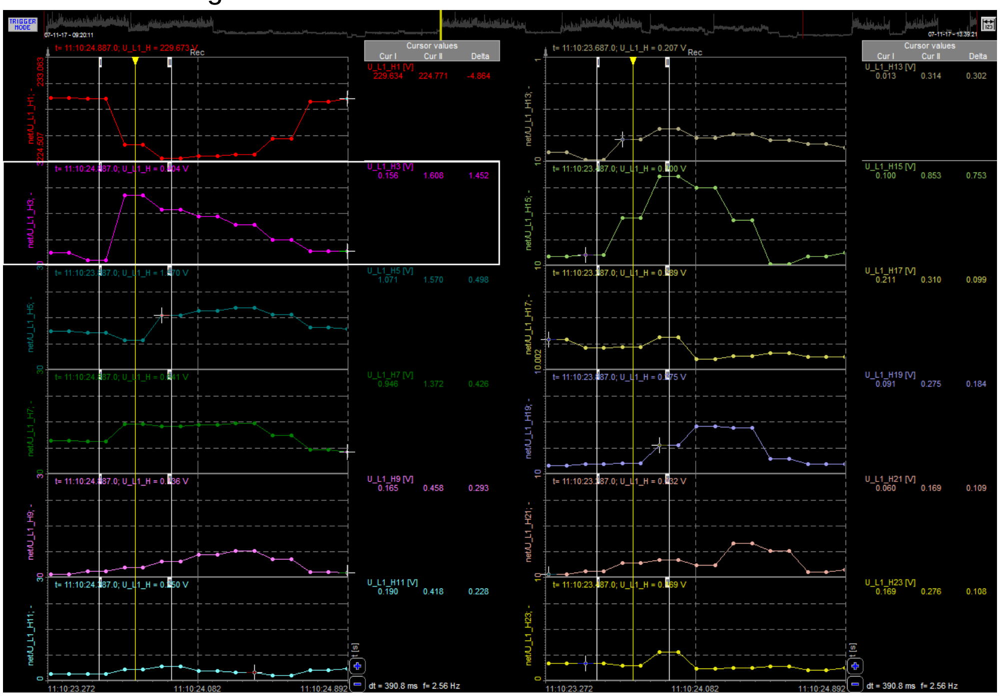
60kW will shift the frequency from 50 to 50.2Hz

CHP generator - Combined heat and power generator

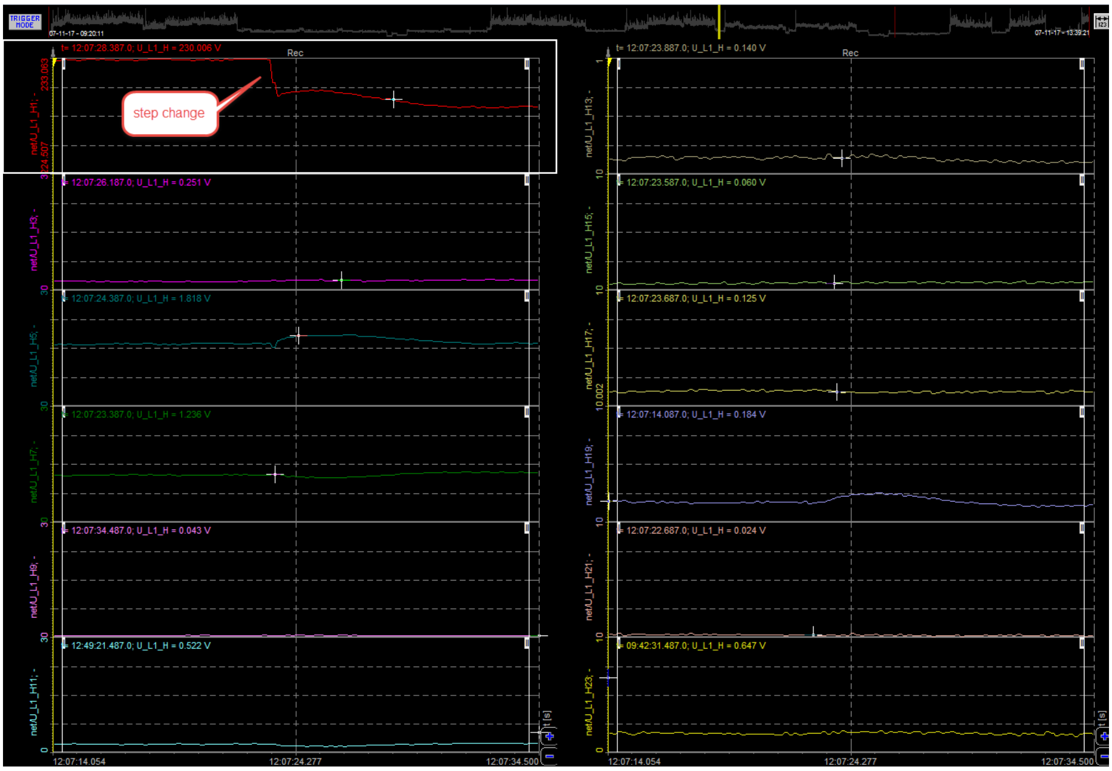
wur_test01_2017_11_07_092010.d7d



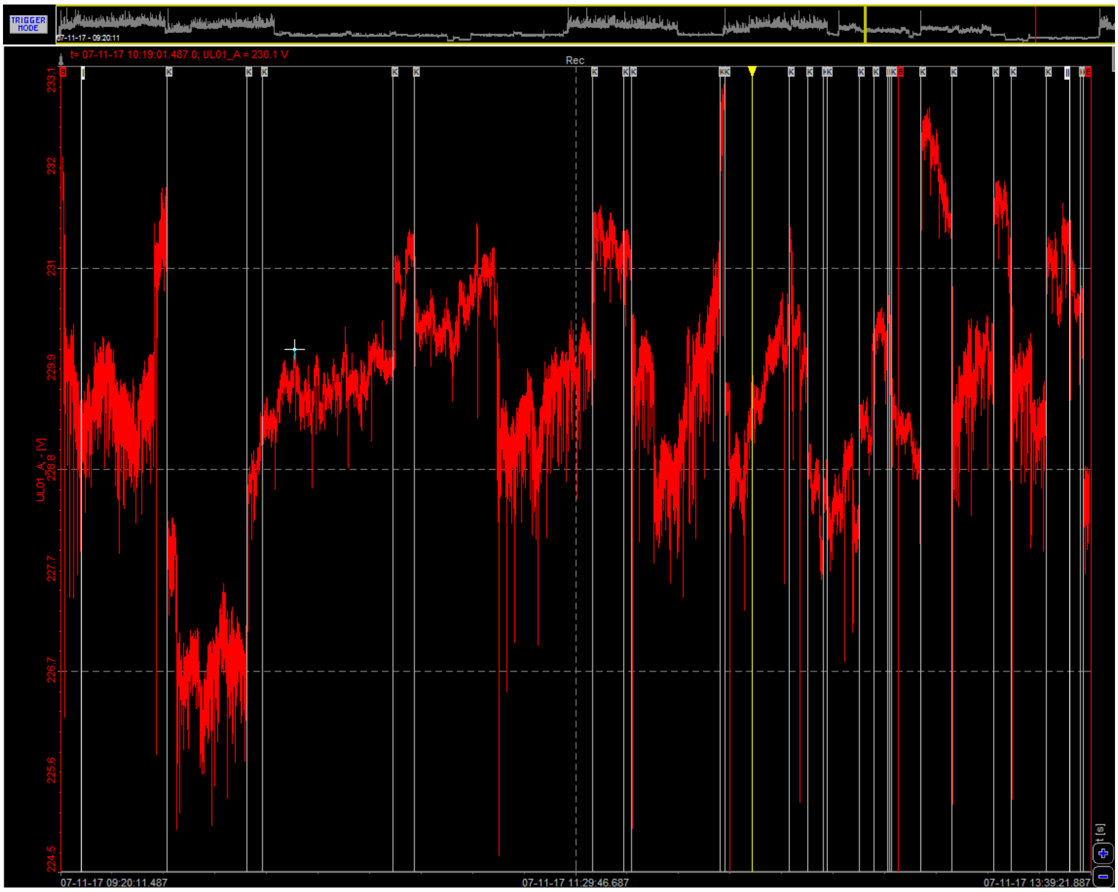
Zoom in on the grid harmonics



wur_test01_2017_11_07_092010.d7d

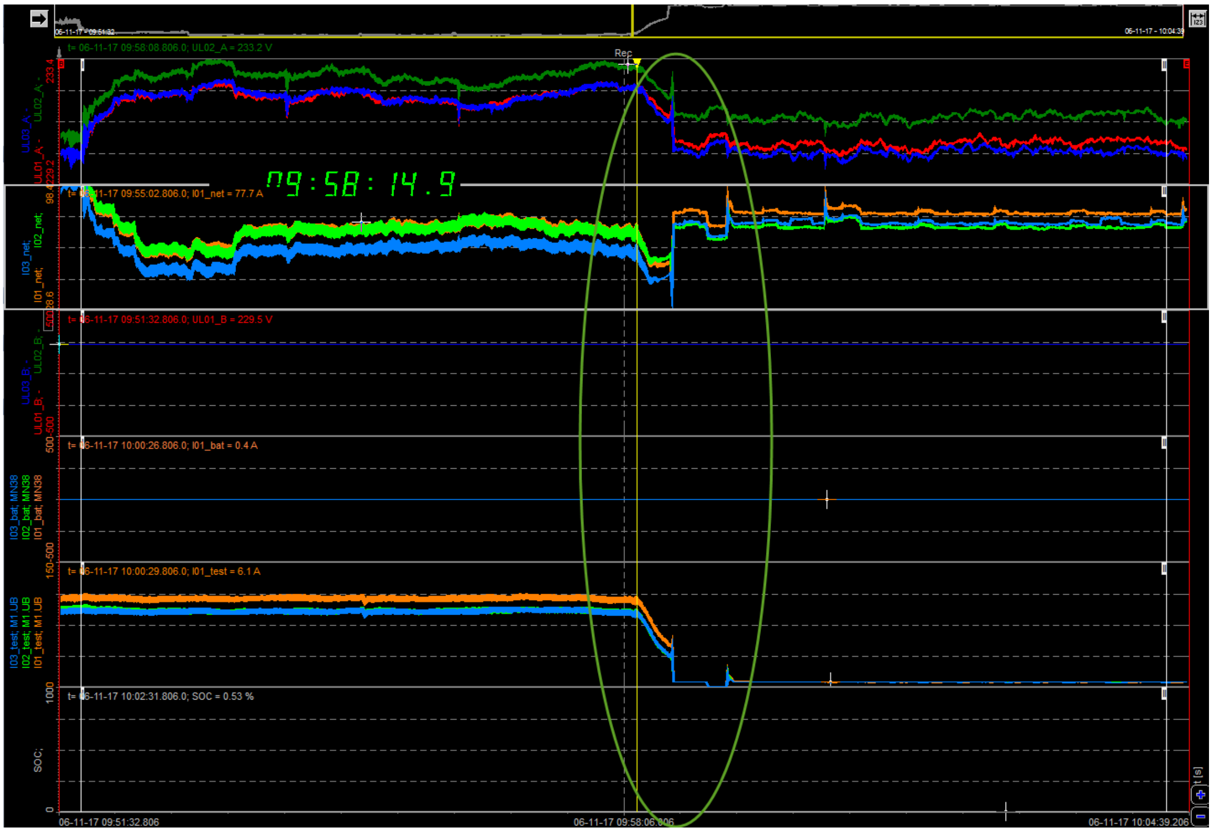


Nice to know: a step change is not causing large harmonics.

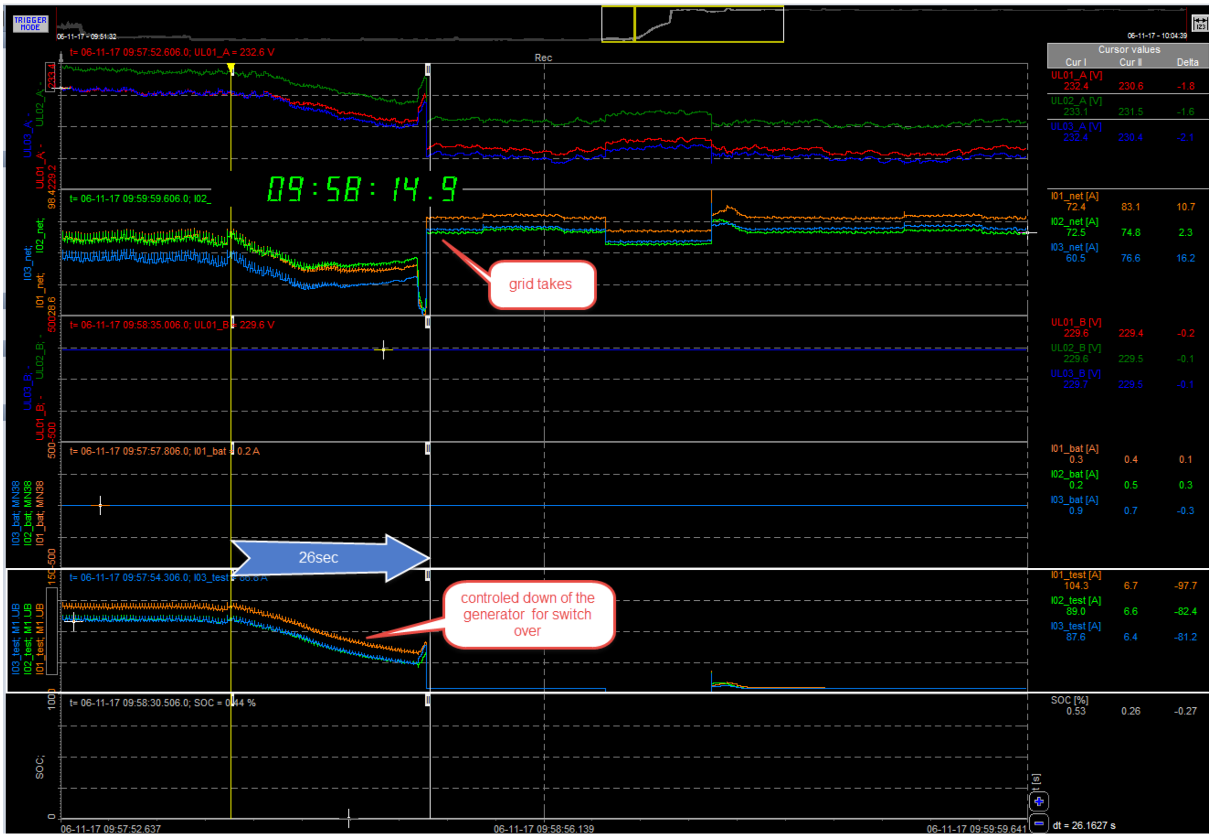


27 step changes in 4.19h → 1 step change per 10 min = 52000 step changes per year.
Because the CSGriP container has no reactive power control, we could not test to compensate for the step change voltage drops by inrush currents.
Reactive power control could help to reduce the number of transformer tapchanges

wur_test01_2017_11_06_095131.d7d

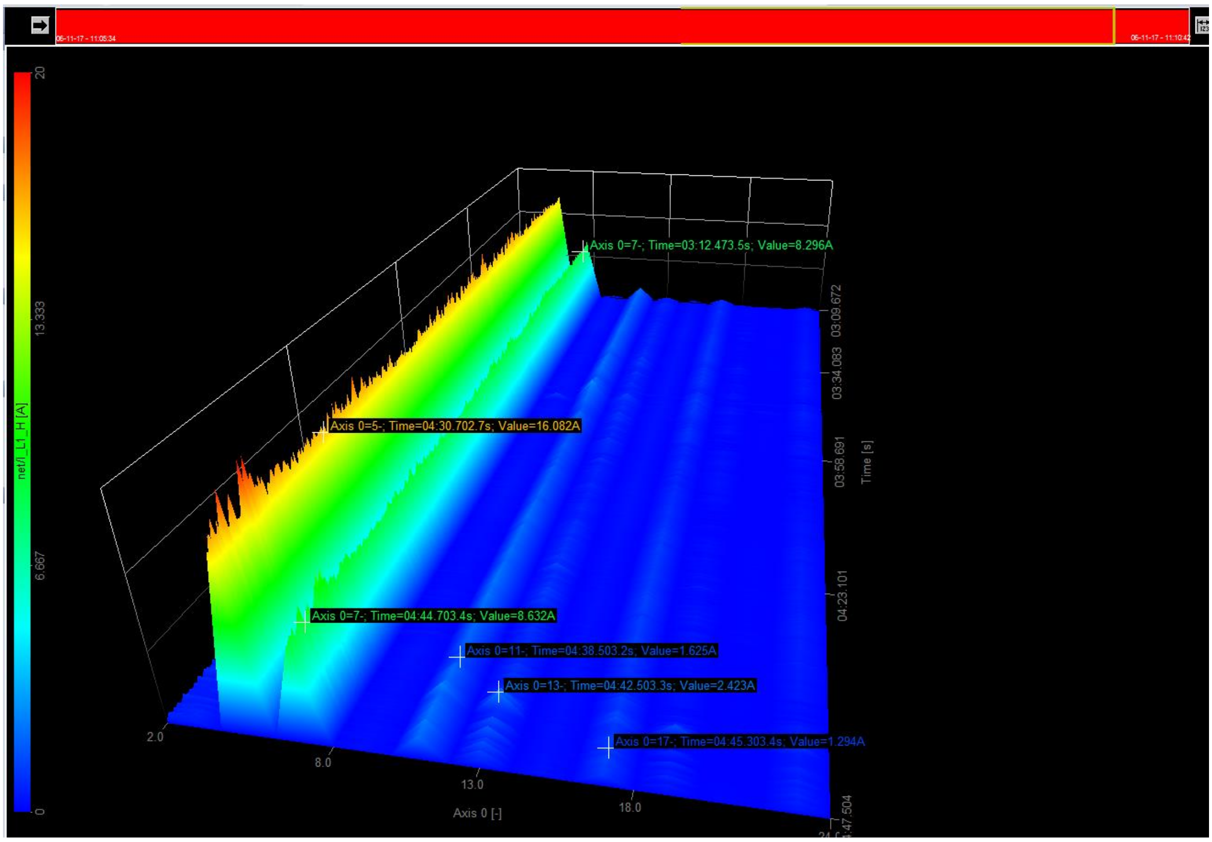


wur_test01_2017_11_06_095131.d7d



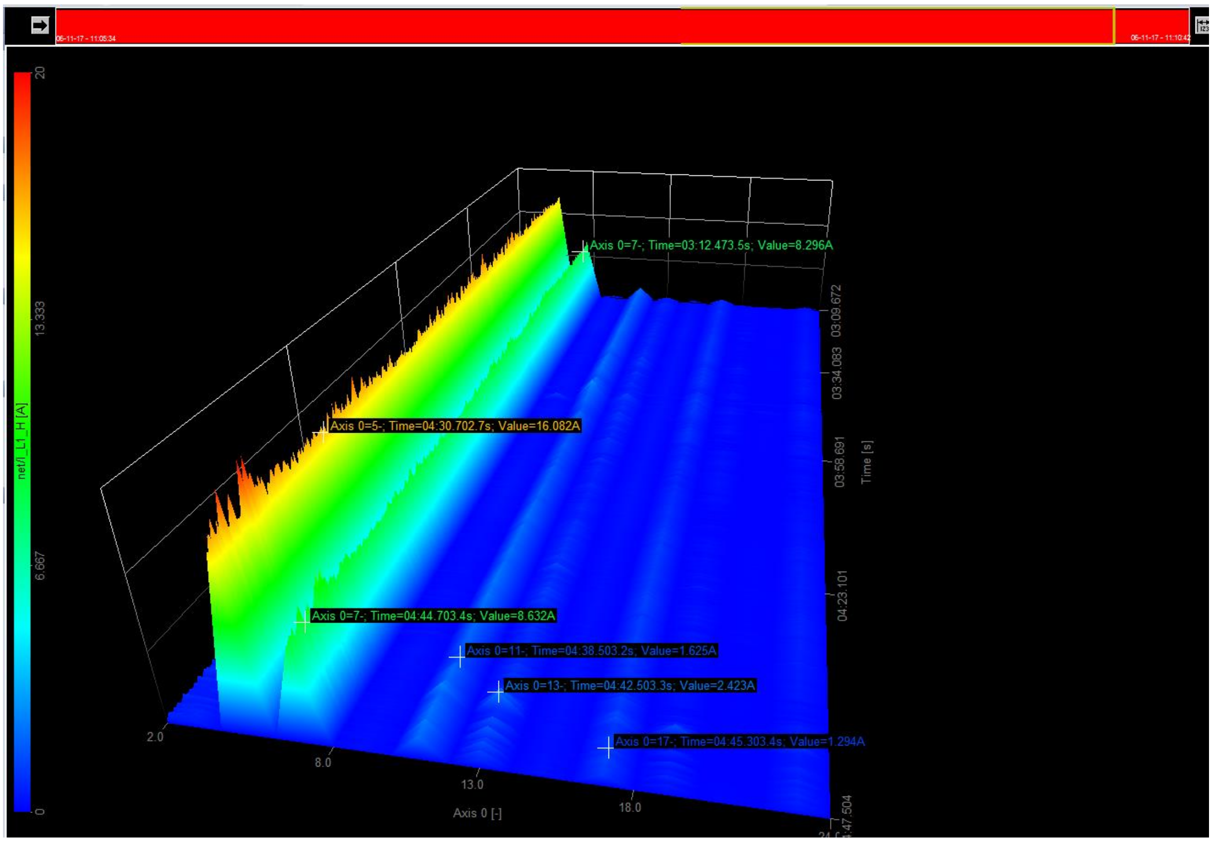
wur_test01_2017_11_06_110533.d7d

wur_test01_2017_11_06_110533.d7d



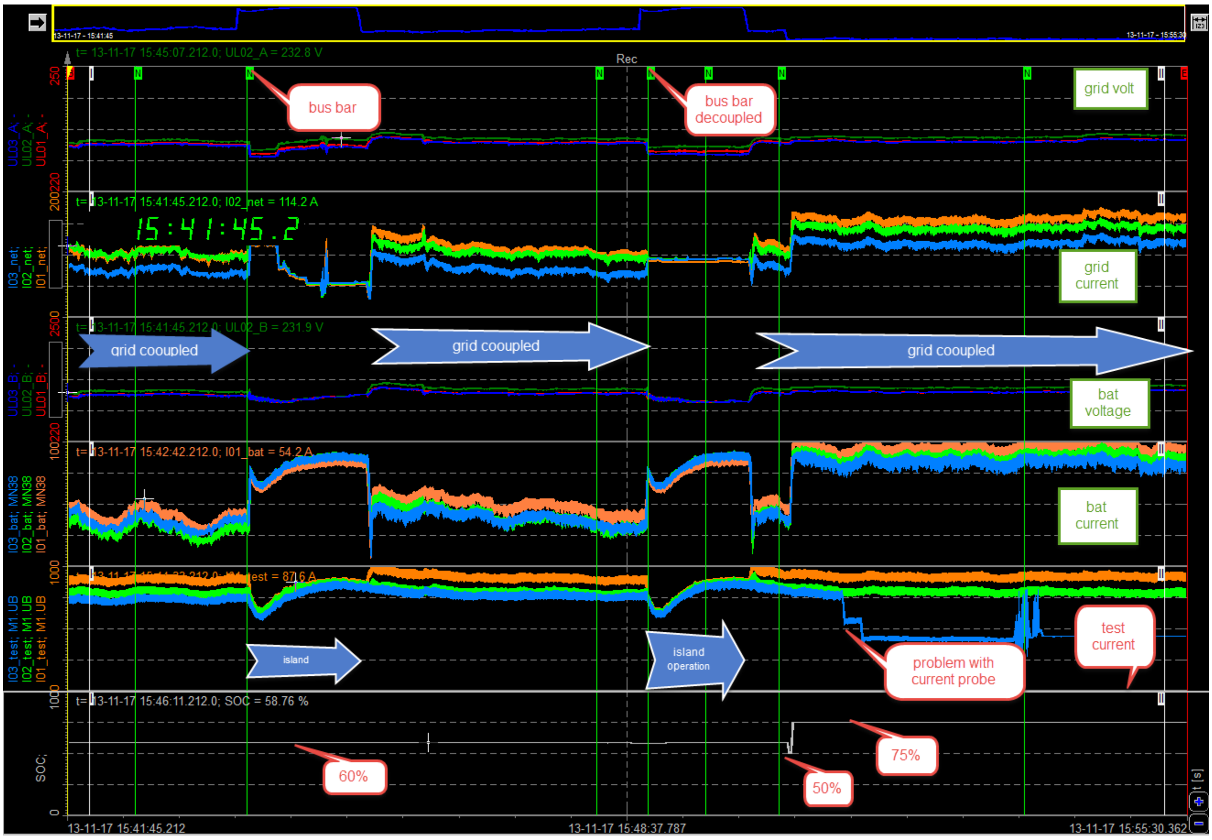
Harmonic currents of phase 1

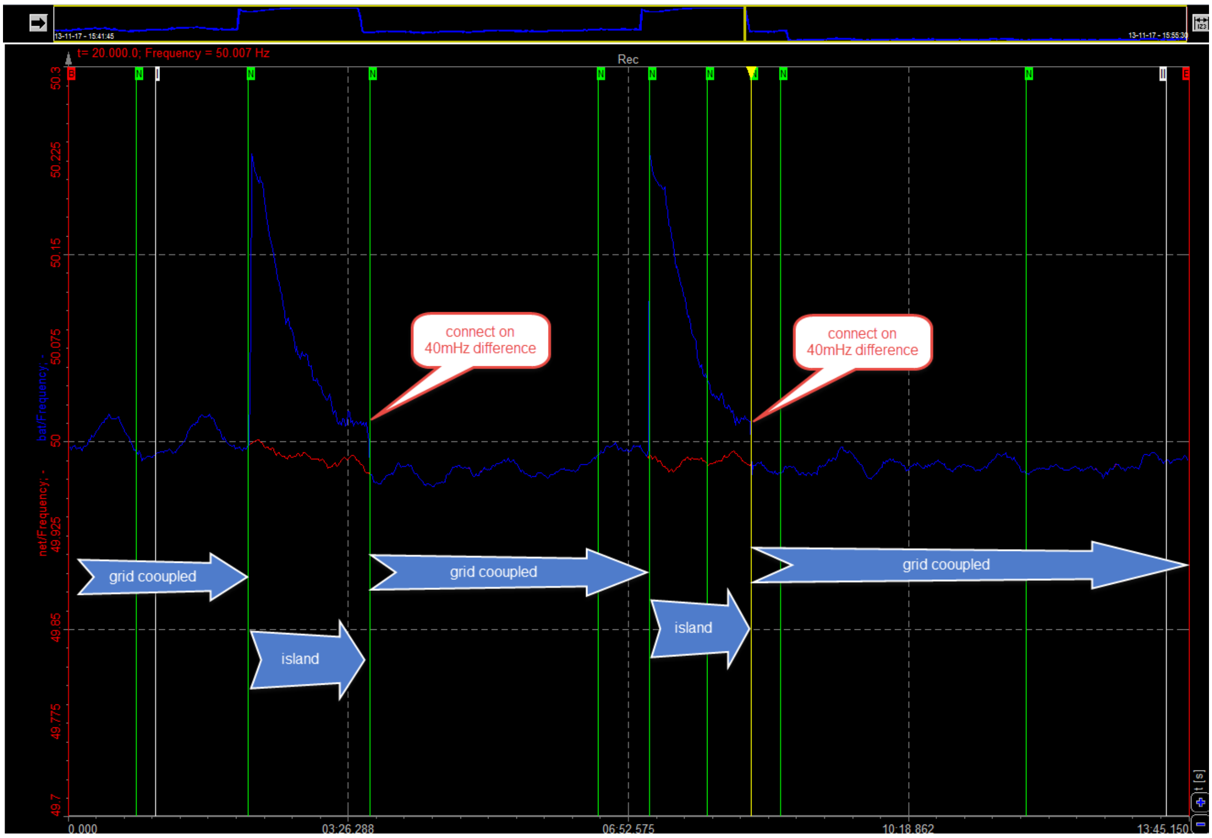
wur_test01_2017_11_06_110533.d7d



Harmonic voltage of phase 1

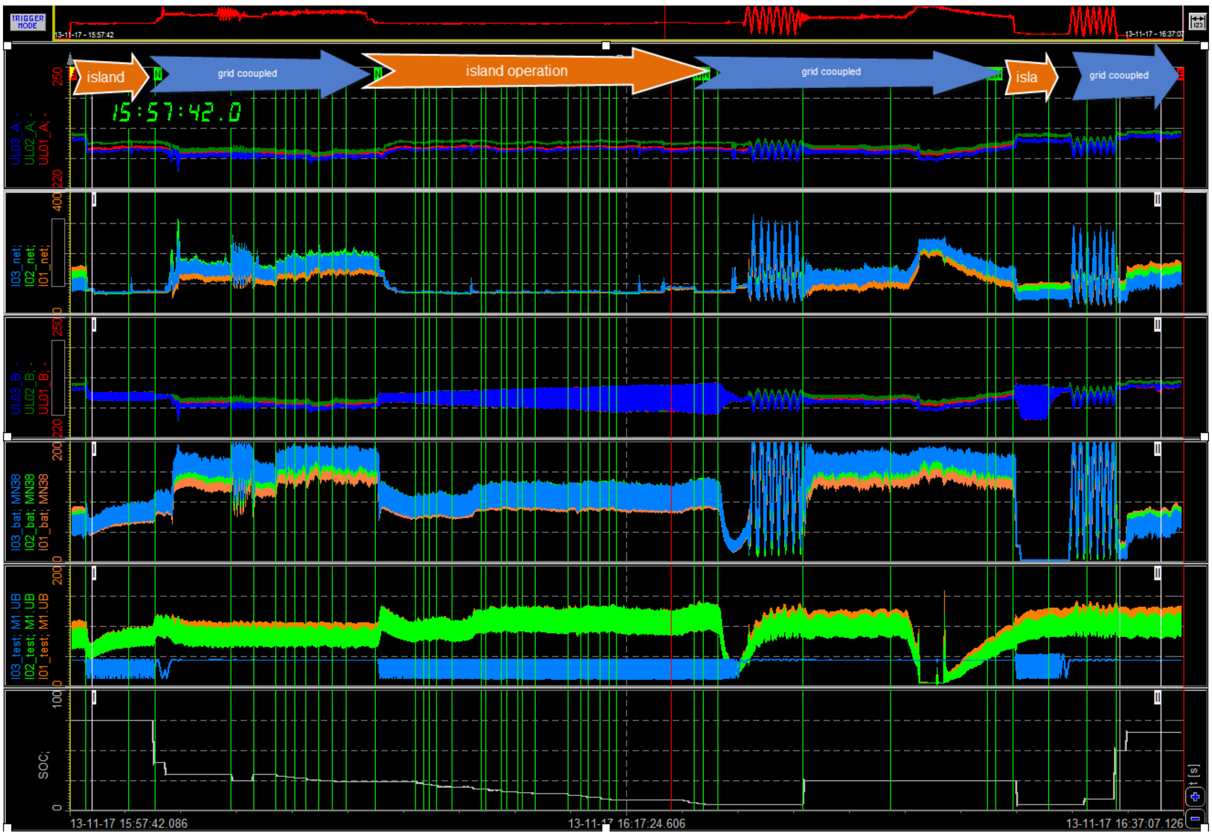
wur_test01_2017_11_13_154144.d7d

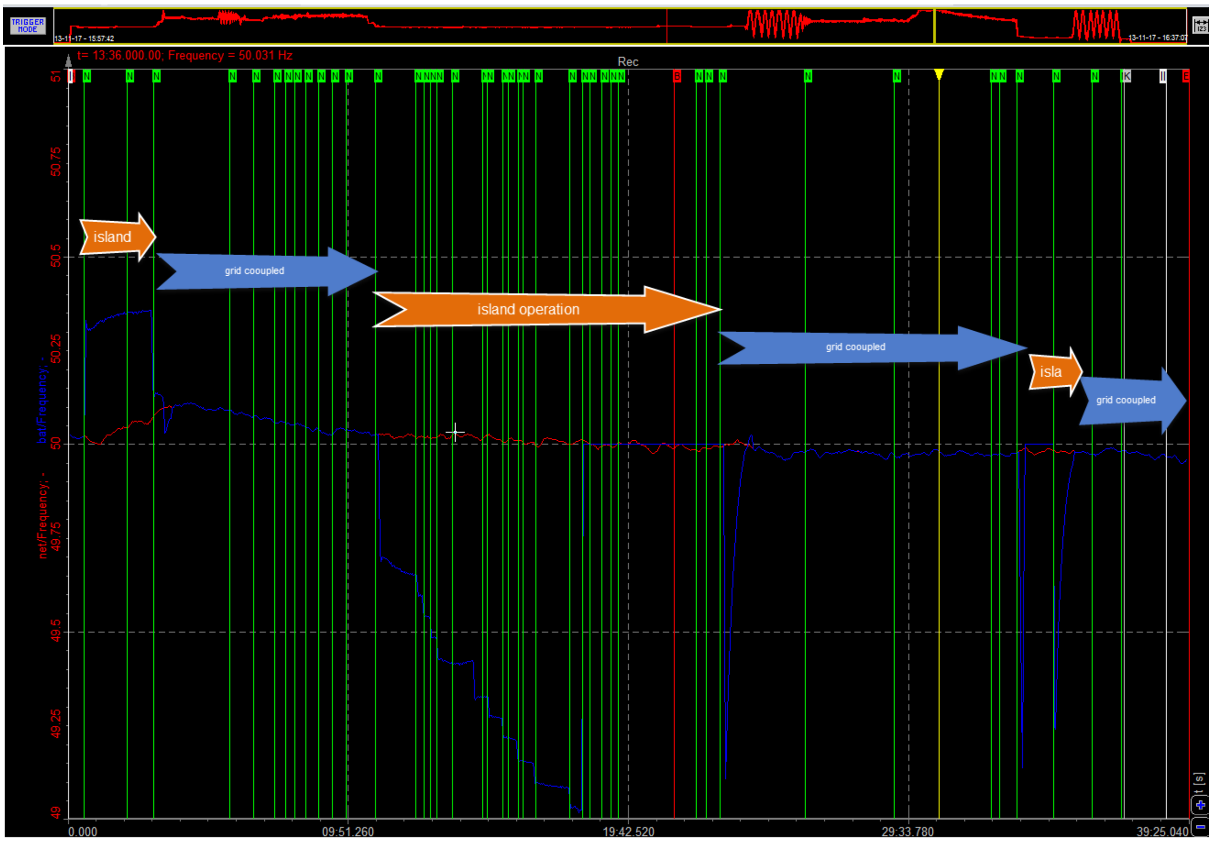




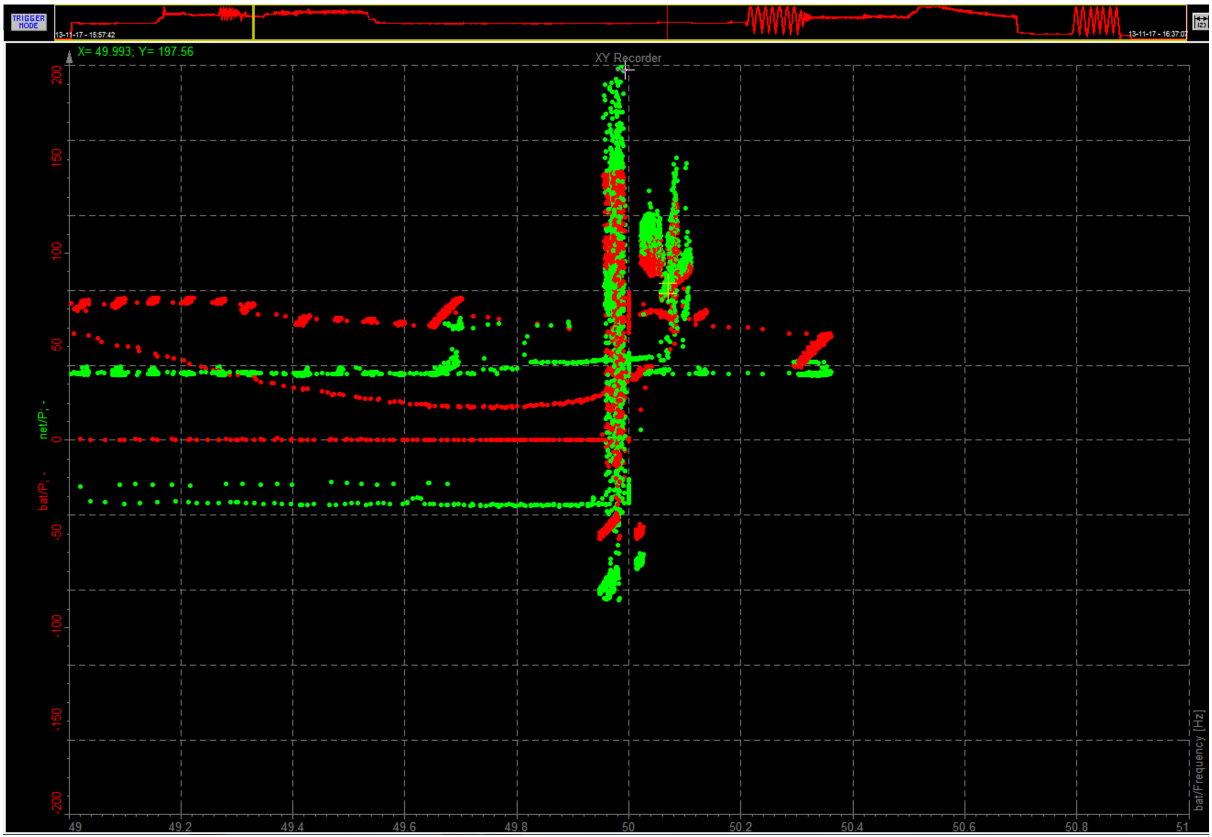
2 mp4 made harmonics an sycronoscoop

wur_test01_2017_11_13_161900.d7d



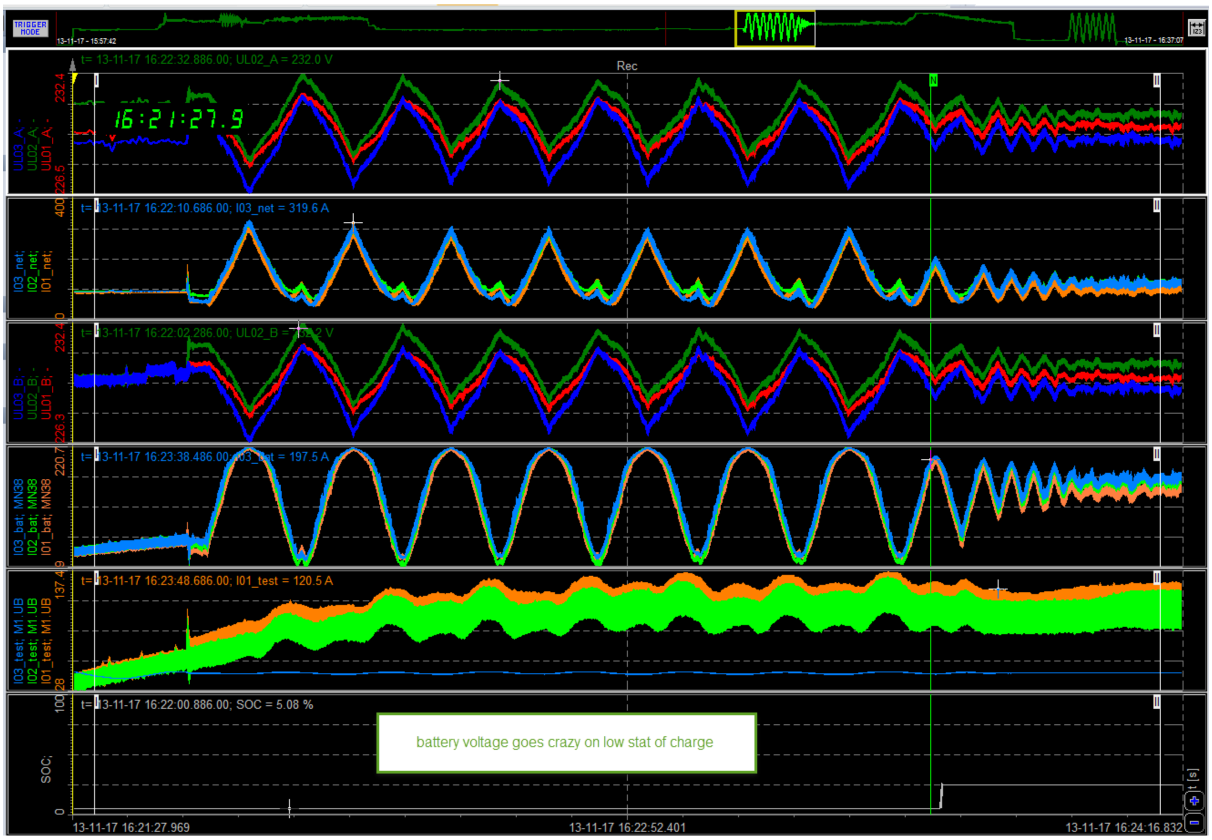


t= 13:36:000.00; Frequency = 50.031 Hz
Rec
island
grid coupled
island operation
grid coupled
isla
grid coupled
0.000
09:51.260
19:42.520
29:33.780
39:25.040
net/Frequency; -
bat/Frequency; -

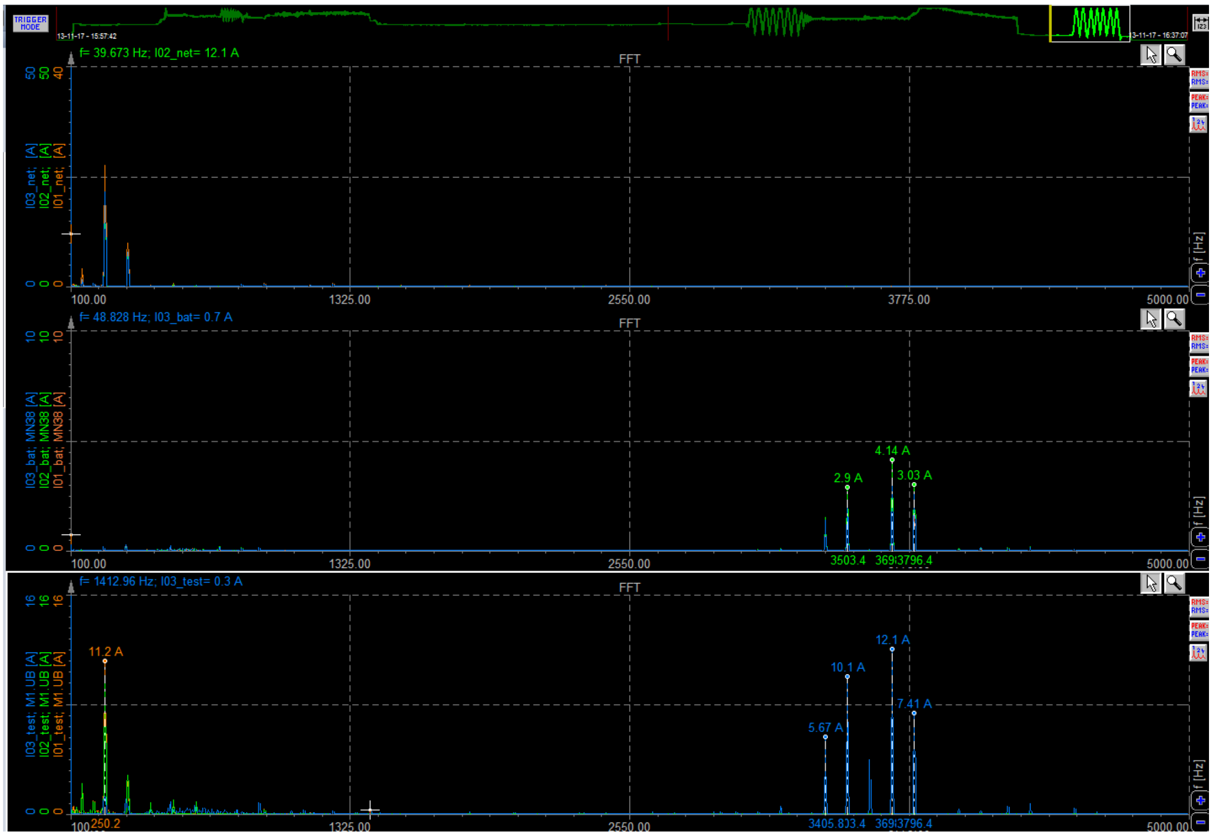


X= 49.993; Y= 197.56
XY Recorder
net/P; -
bat/P; -
bat/Frequency [Hz]

Droop curve



Detail



Large harmonic contribution during this oscillation

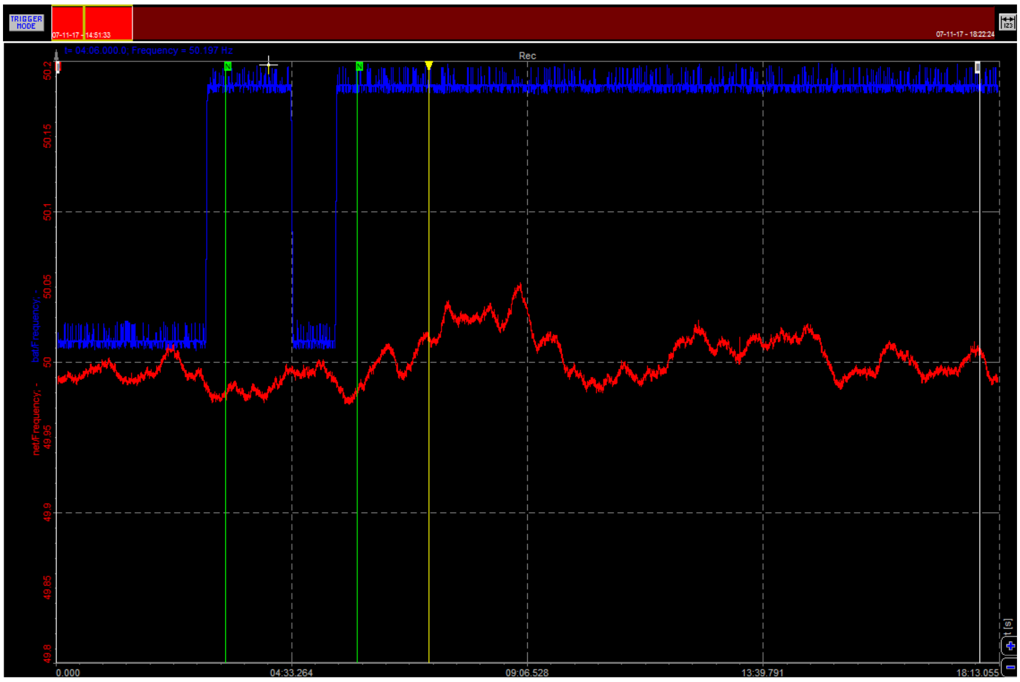
EV Charger - Electric vehicle charge

No specific test results

PV inverter - Photo Voltaic DC-AC inverter

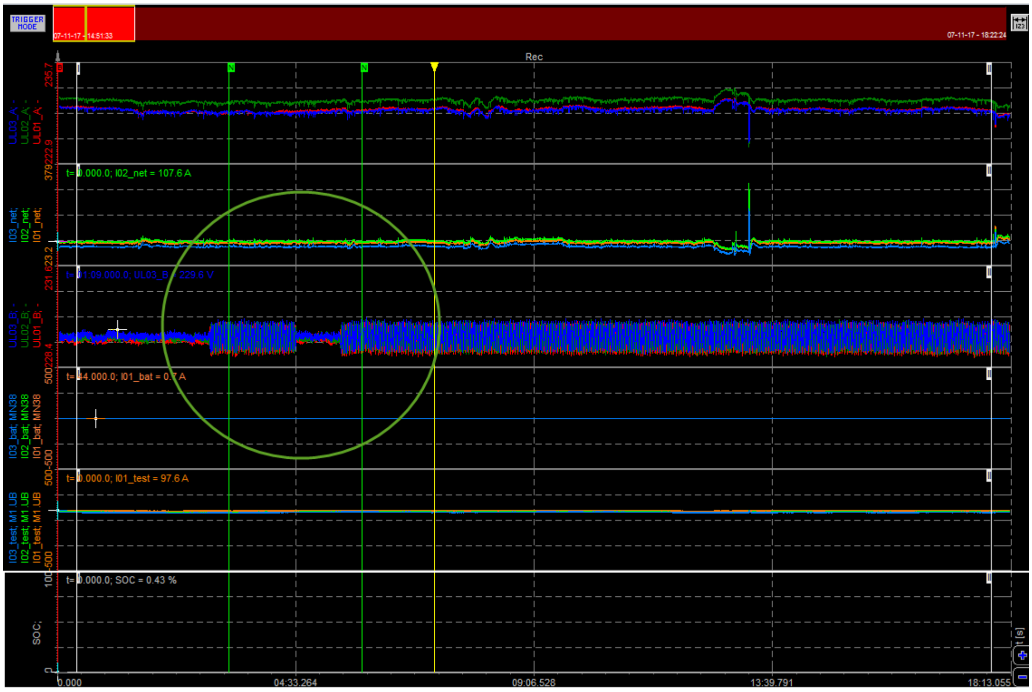
wur_test01_2017_11_01_143026.d7d

wur_test01_2017_11_07_145132.d7d



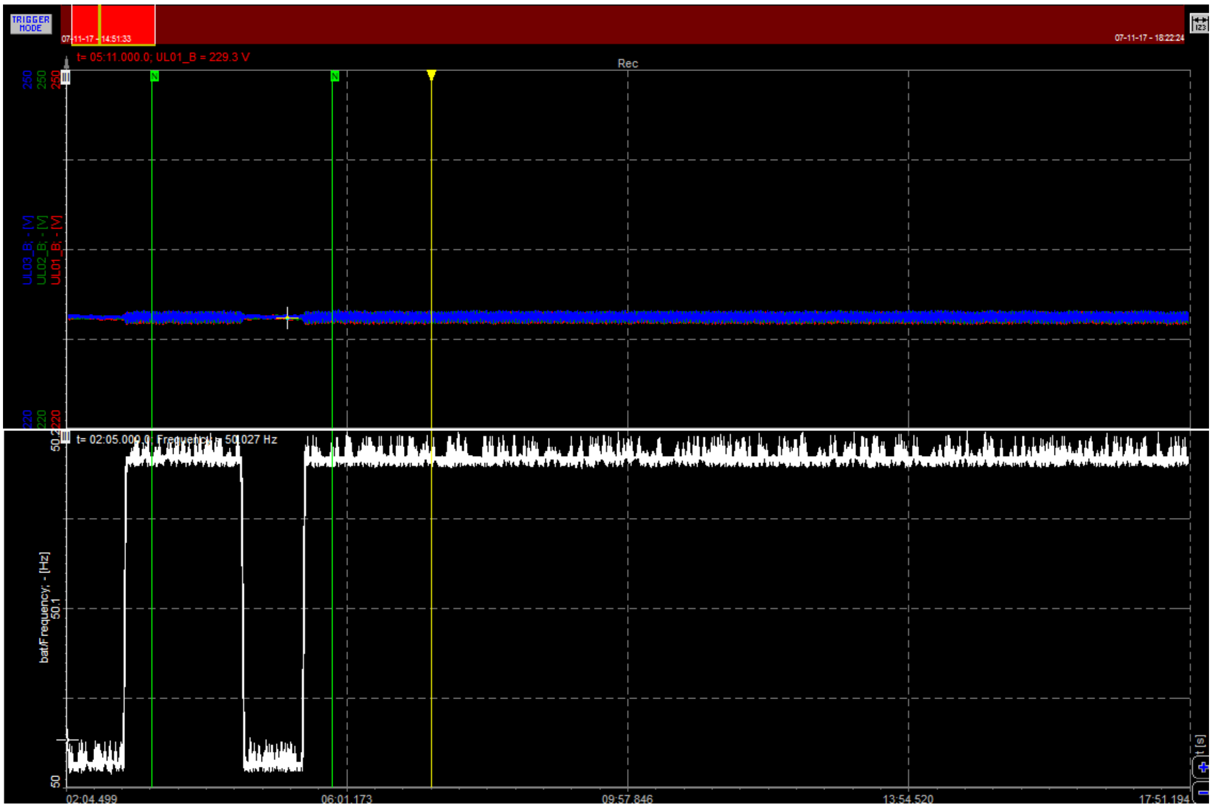
Frequency jump as result of the PV inverter

wur_test01_2017_11_07_145132.d7d



Voltage instability as result of the pv feedback

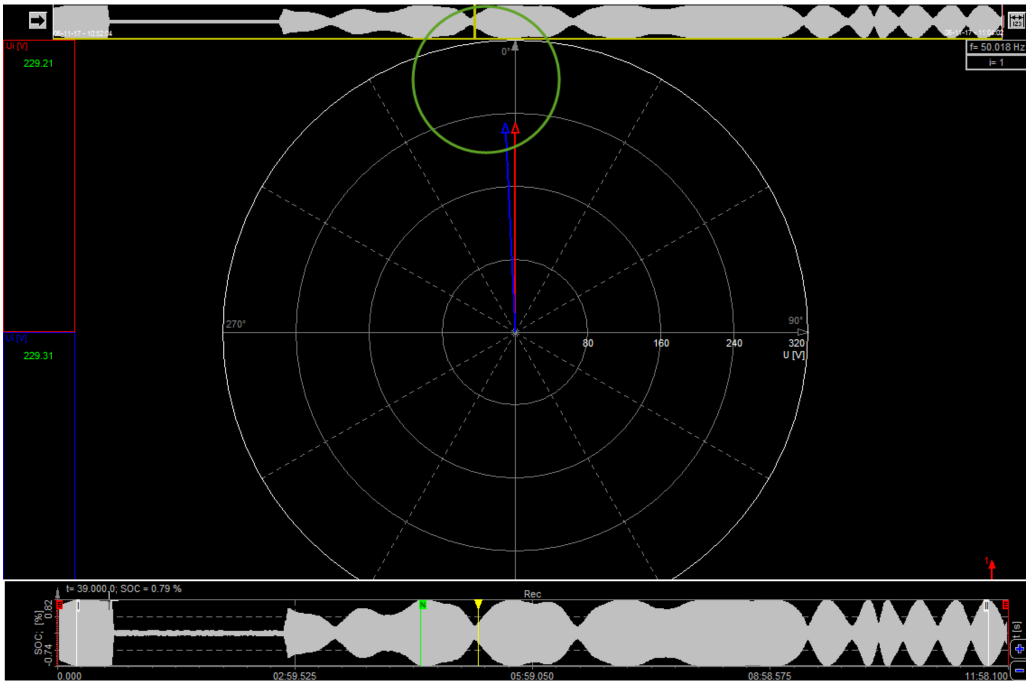
Relation between frequency above 50Hz and voltage instability (at no load situation)



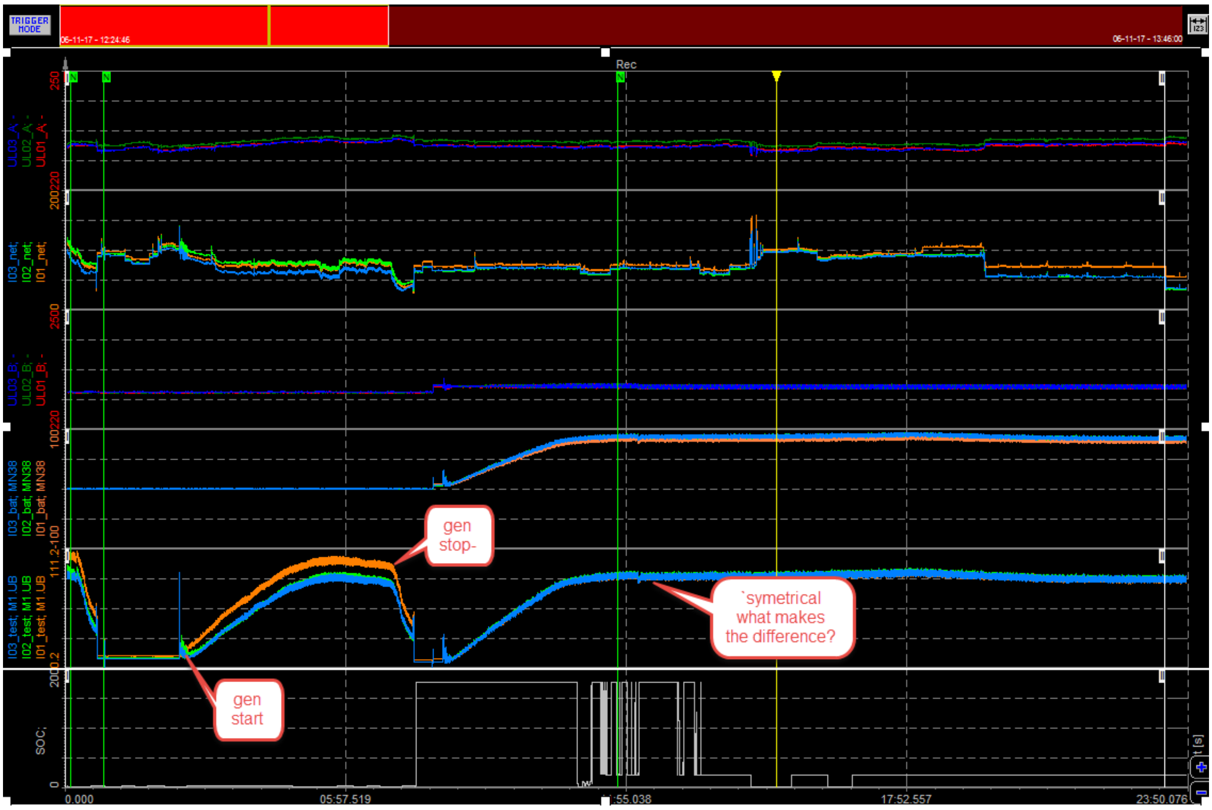
Cos phi is from 0-180°

As result from just PV connected

wur_test01_2017_11_06_105203.d7d



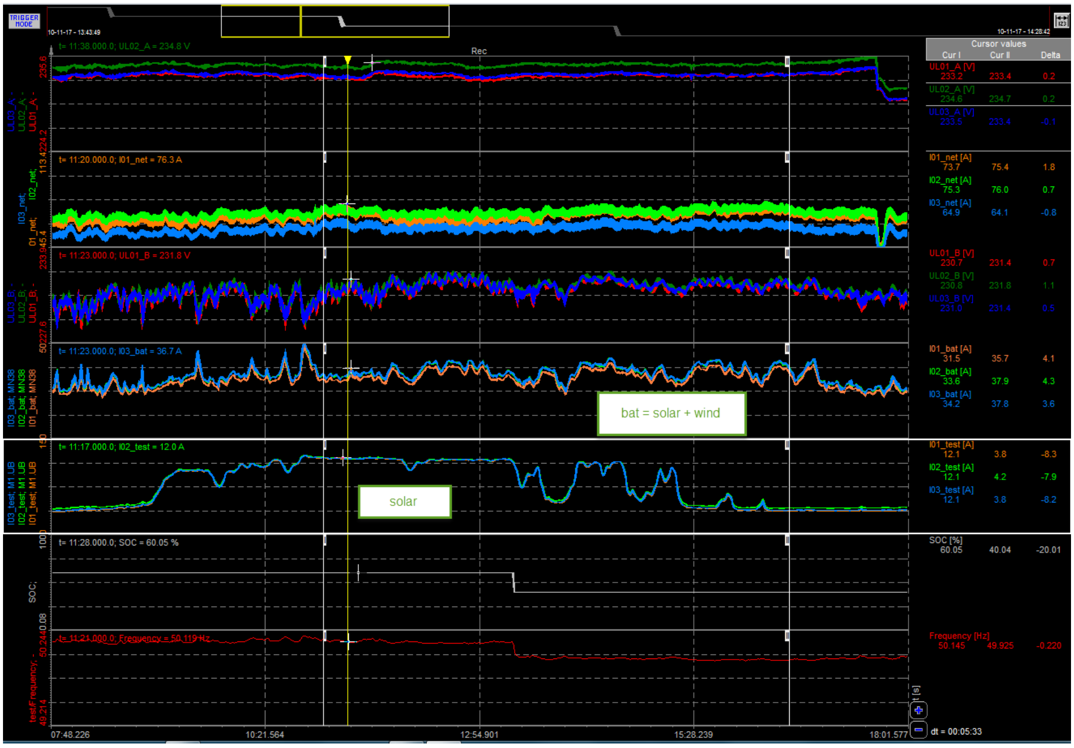
There is a relation between the state of charge oscillation and the difference between grid and battery frequency , each time the orientation is the same we have a knot in the oscillation The oscillation is minimal but present.



We don’t understand what makes the unsymmetrical current on island operation , which disappears when gridconnected.

We had to solve a scaling problem in the wur plc of the soc (solved)

wur_test01_2017_11_10_134349.d7d



It looks that the solar is limited , however it makes no sense at soc of 60%

wur_test01_2017_11_13_111046.d7d

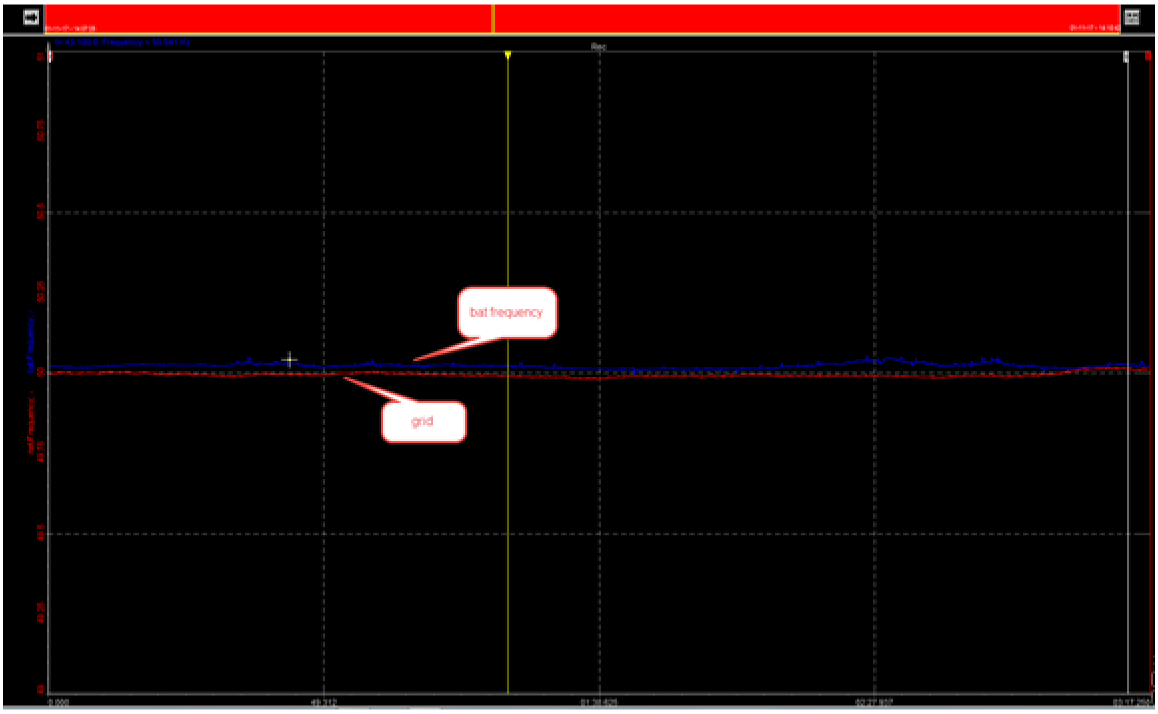
Flexible loads - Mixers

2 mixers of 5kW each were programmed to increase their power consumption from 0% at 50.1 Hz to 100% at 50.2 Hz to act as flexible loads. They are programmable ABB inverters reducing the 15Hz to 5Hz which translates in 60 rpm on a 1500rpm motor.

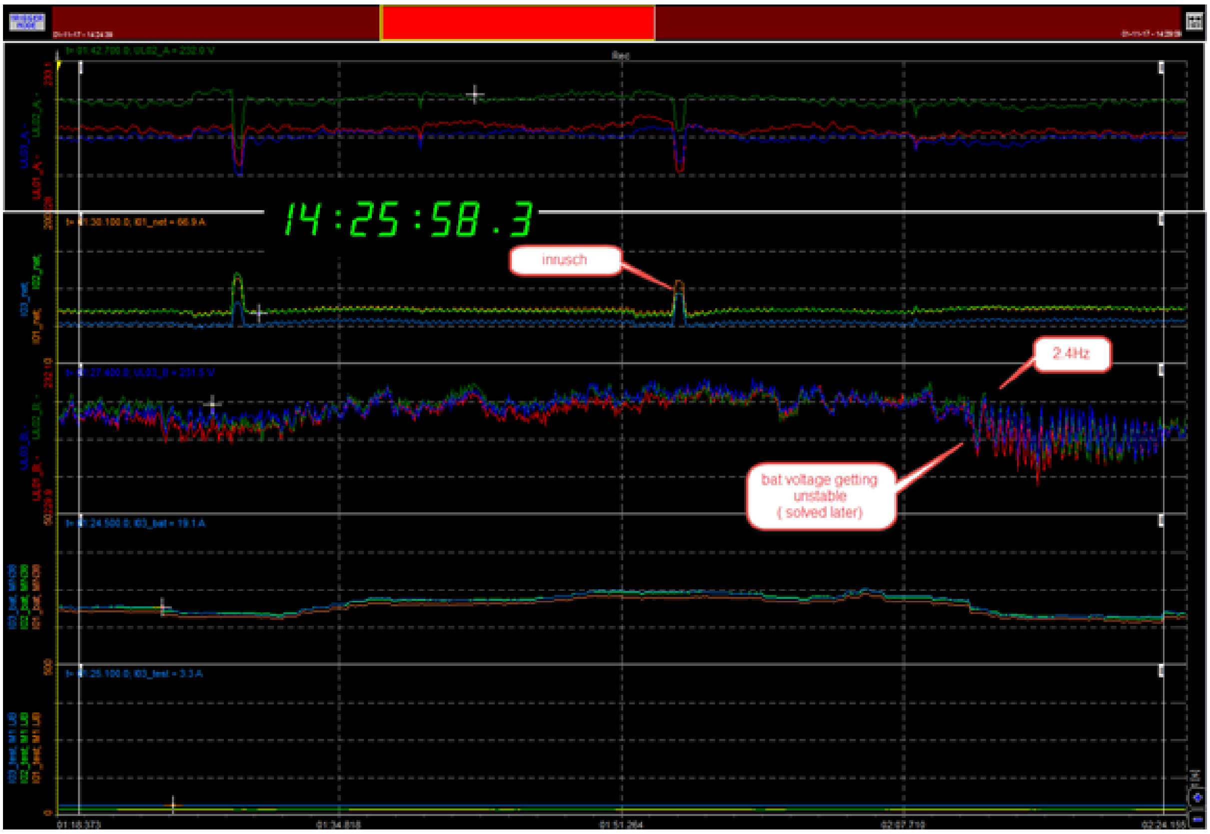
Bioethenol outside

wur_test01_2017_11_01_140724.d7d

wur_test01_2017_11_01_140724.d7d

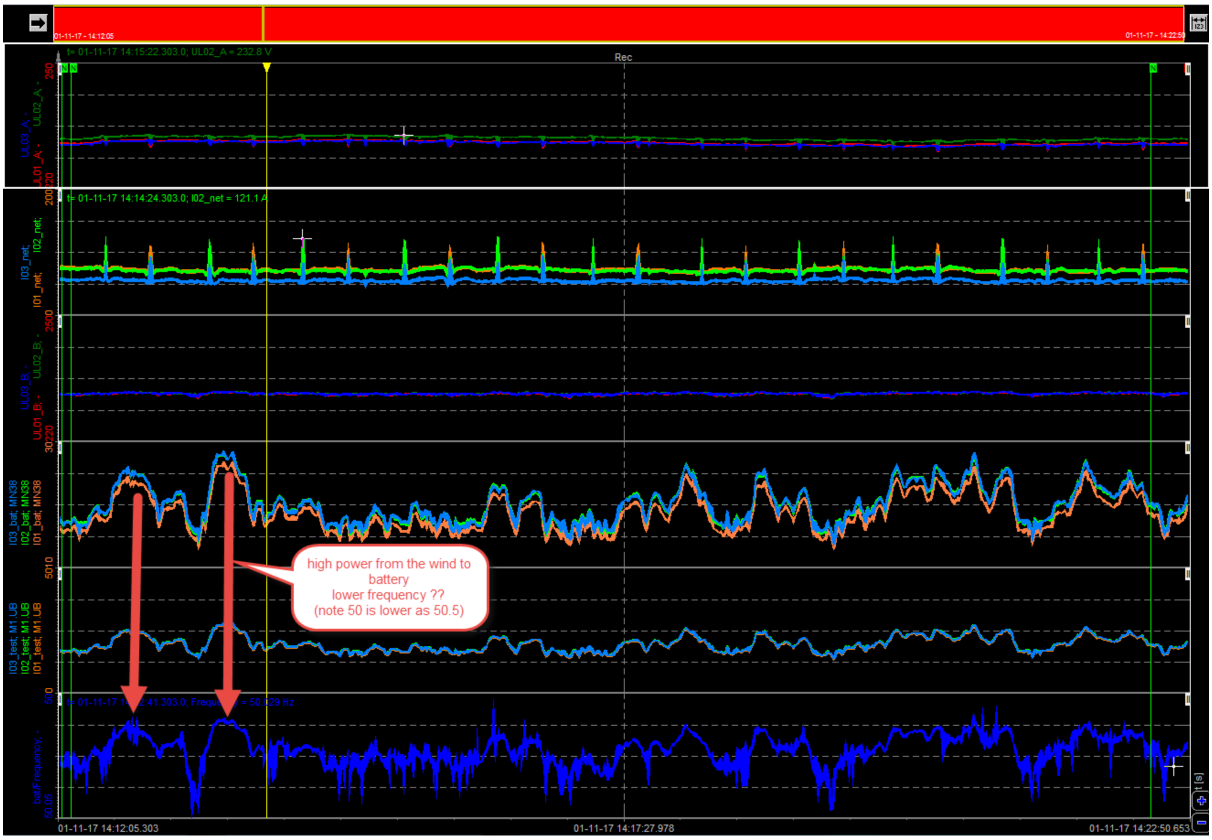


wur_test01_2017_11_01_142439.d7d



Wind – Three wind turbines

wur_test01_2017_11_01_141204.d7d



Note →for pattern recognition, I reversed the frequency order in the diagram

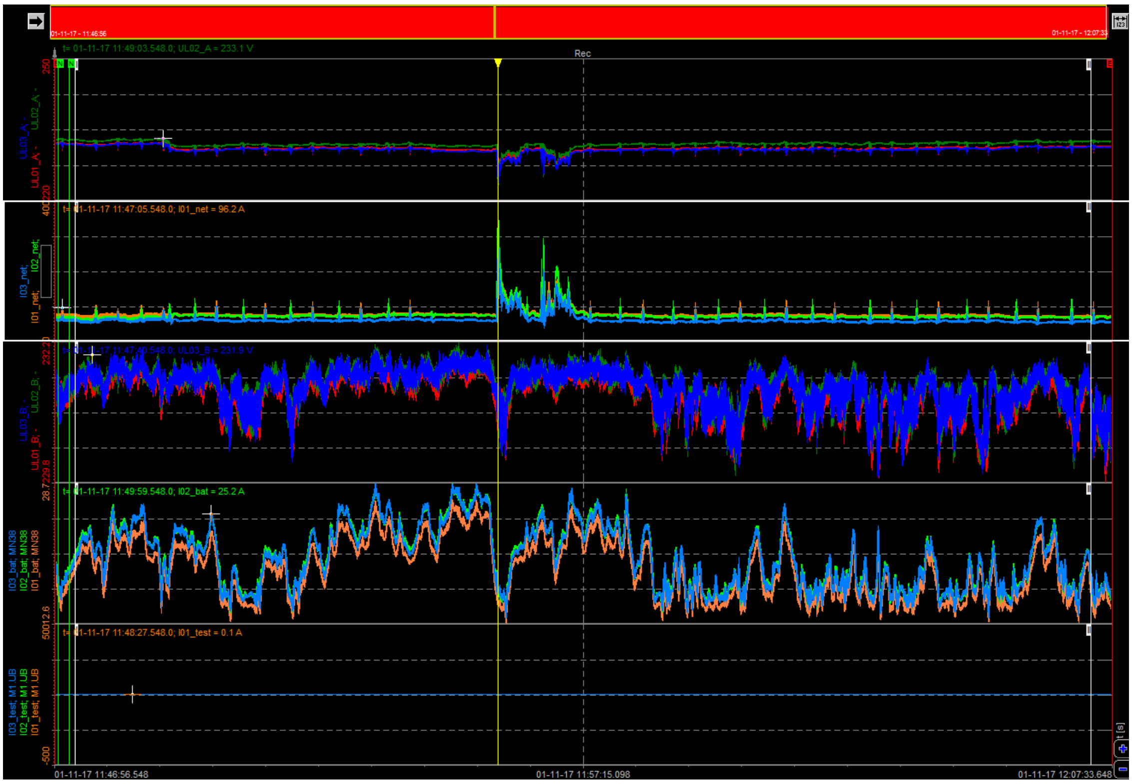
??? expected that SOC determines the frequency , not the power

Here there is a direct relation between frequency and power to the battery from the wind

If there should be a power relation , I would expect power to the battery (charging) will rise the frequency a bit, signaling loads they can use more

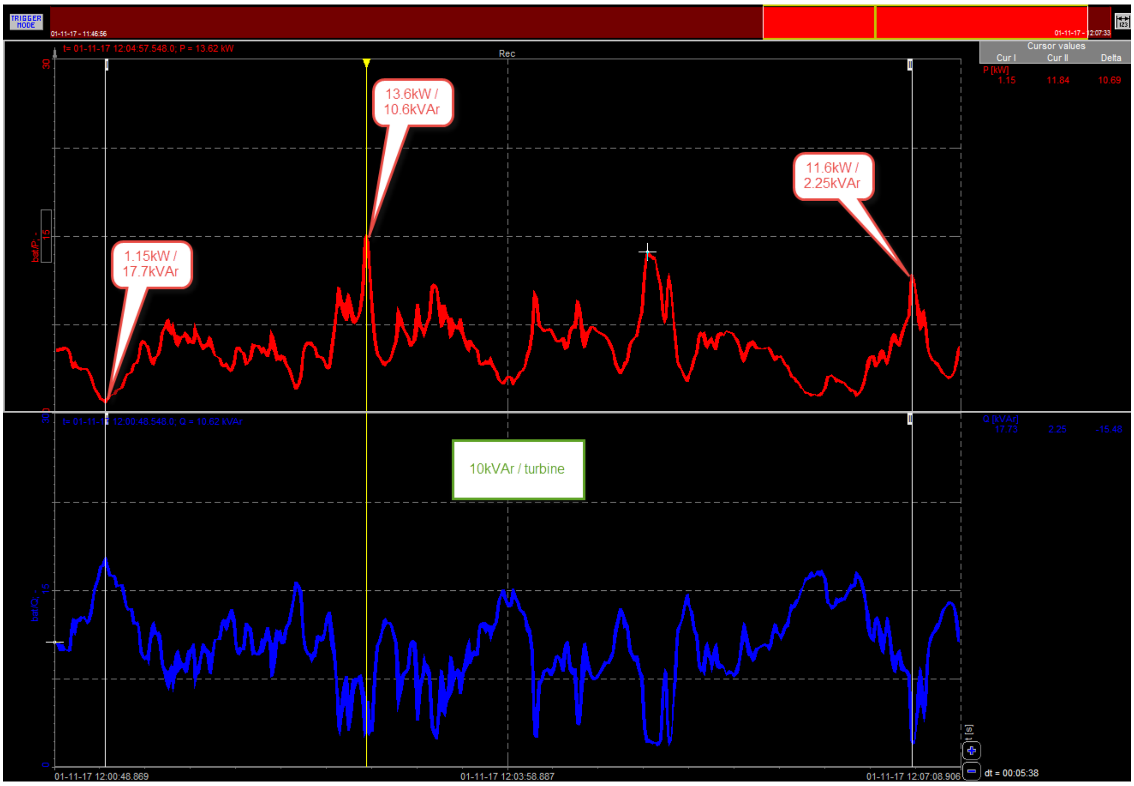
Here it seems invers how more decentral production , how more loads will shut down.

wur_test01_2017_11_01_114655.d7d



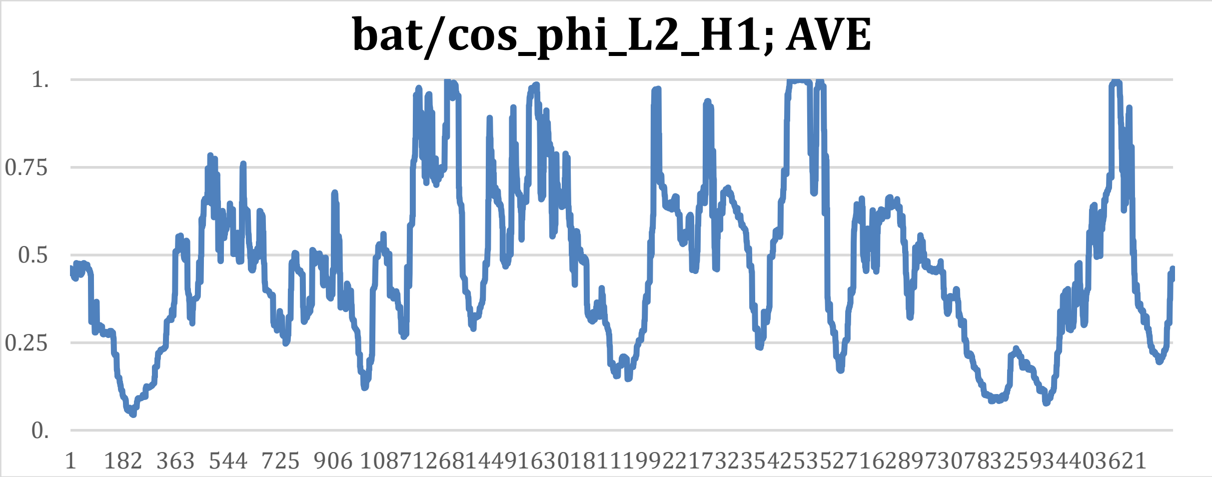
2 wind turbines are running on battery system

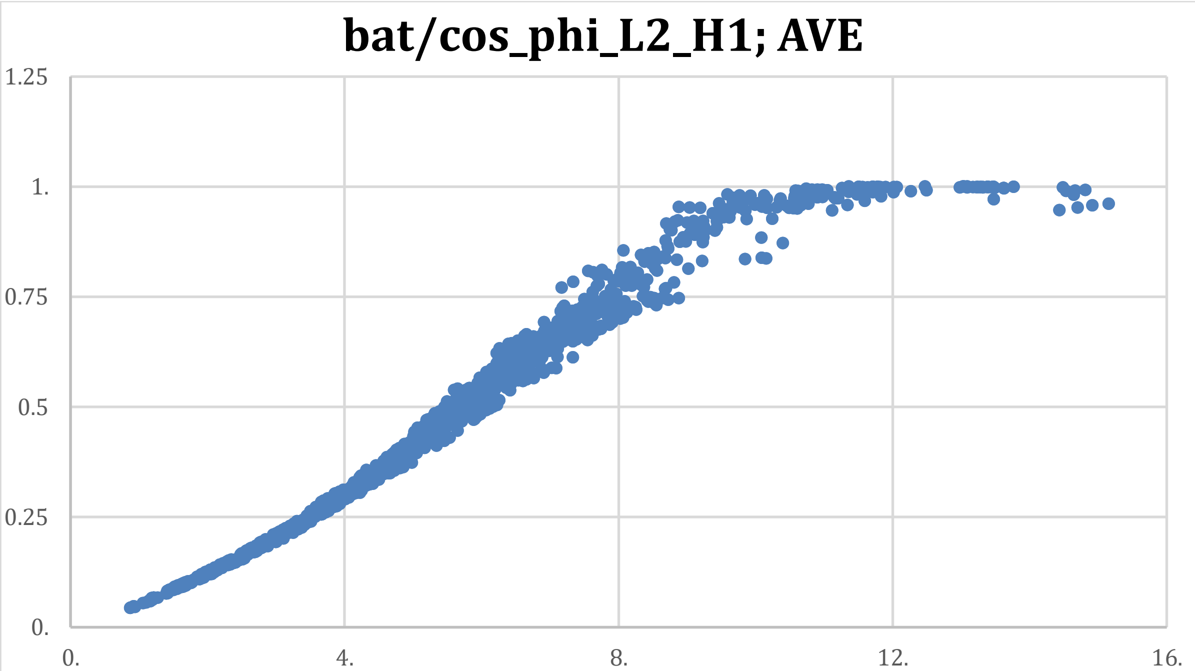
wur_test01_2017_11_01_114655.d7d



10kVAr per turbine seems to be overkill

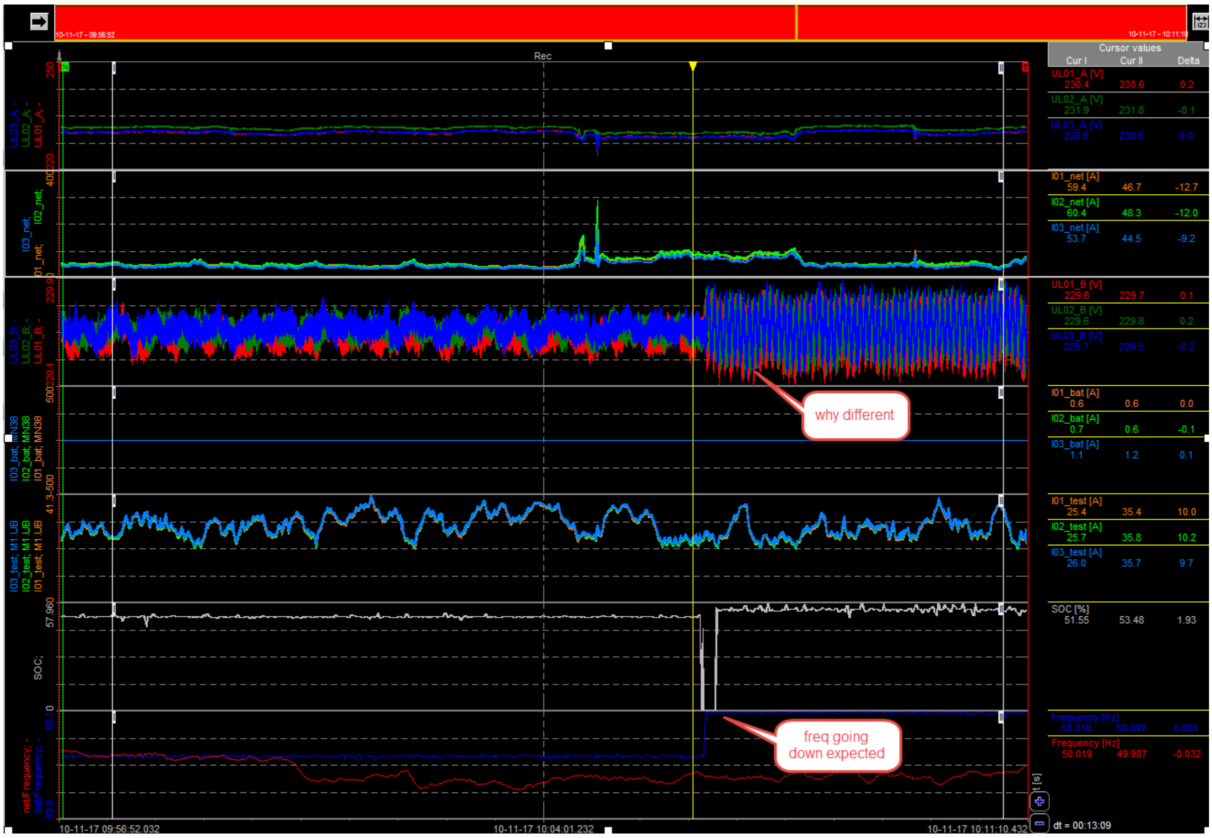
Normal is zero load compensation and 0.97 inductive on full load , consuming reactive power lowers the voltage , keeping it more stable





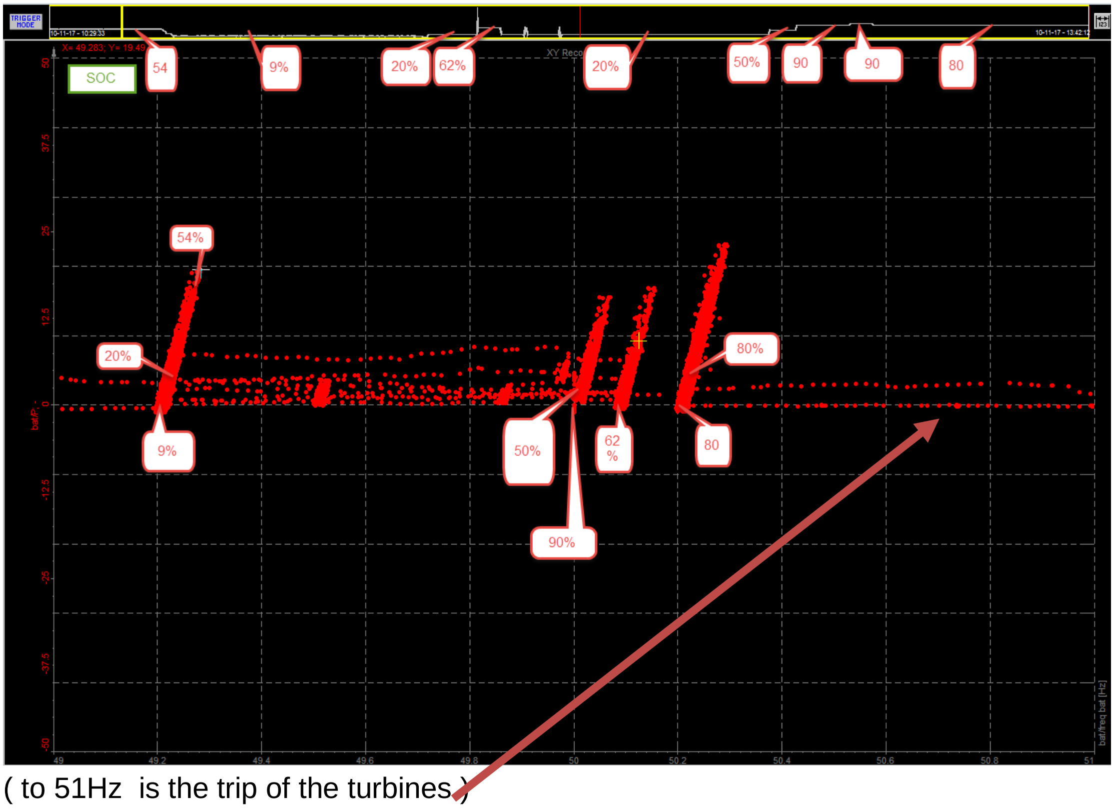
From close of 50% (10 kW) the 2 wind turbines operates close to cos phi = 1
10kW is 5 kW each of 2 turbines running

wur_test01_2017_11_10_095651.d7d



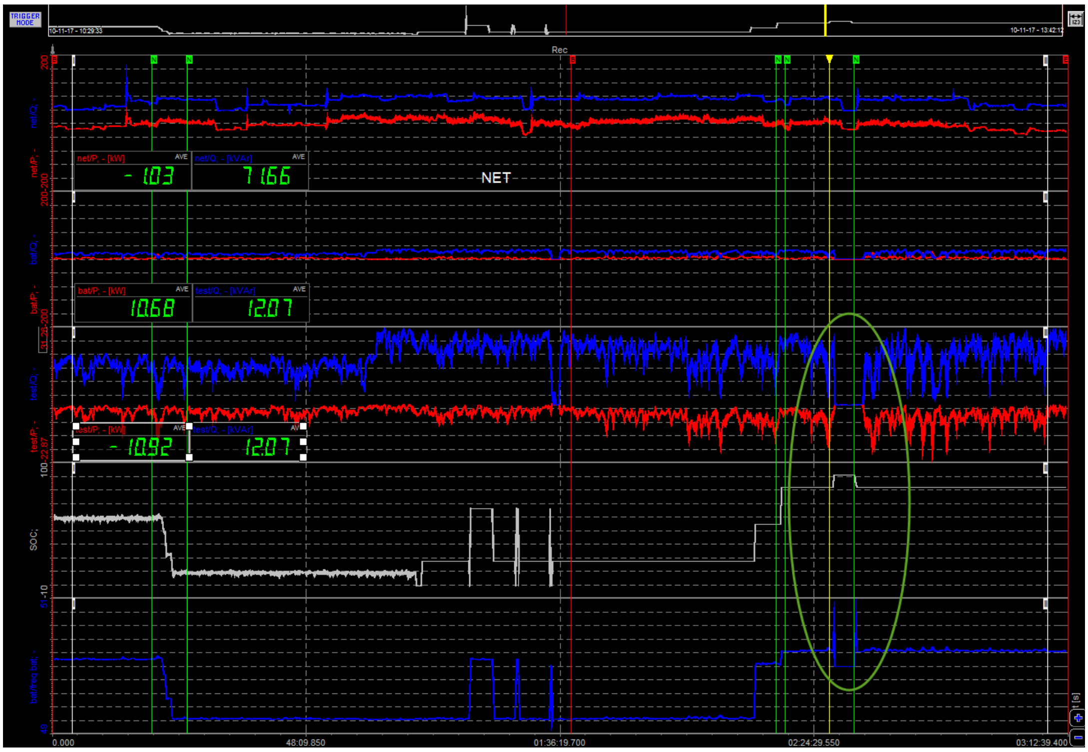
Expected the frequency goes down on soc =0 , instead its going up
expected if soc goes to the original value , frequency comes back
No idea yet what triggered the minor oscillation in the battery voltage

wur_test01_2017_11_10_120754.d7d



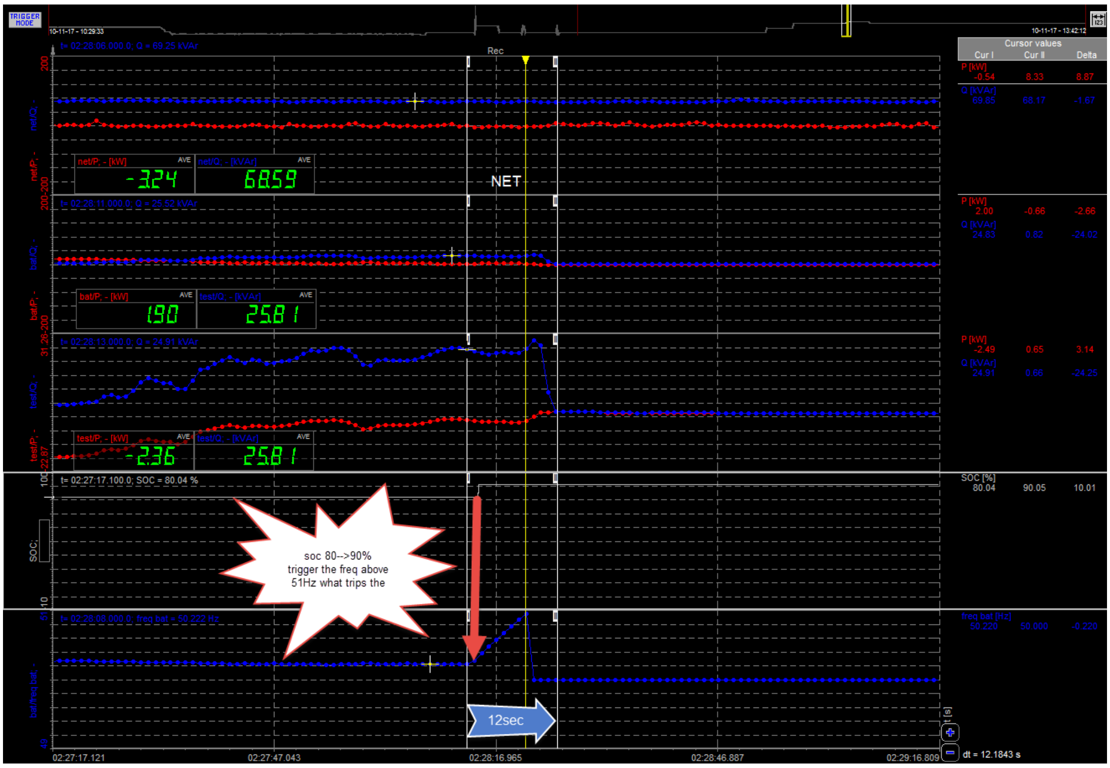
(to 51Hz is the trip of the turbines)

wur_test01_2017_11_10_120754.d7d

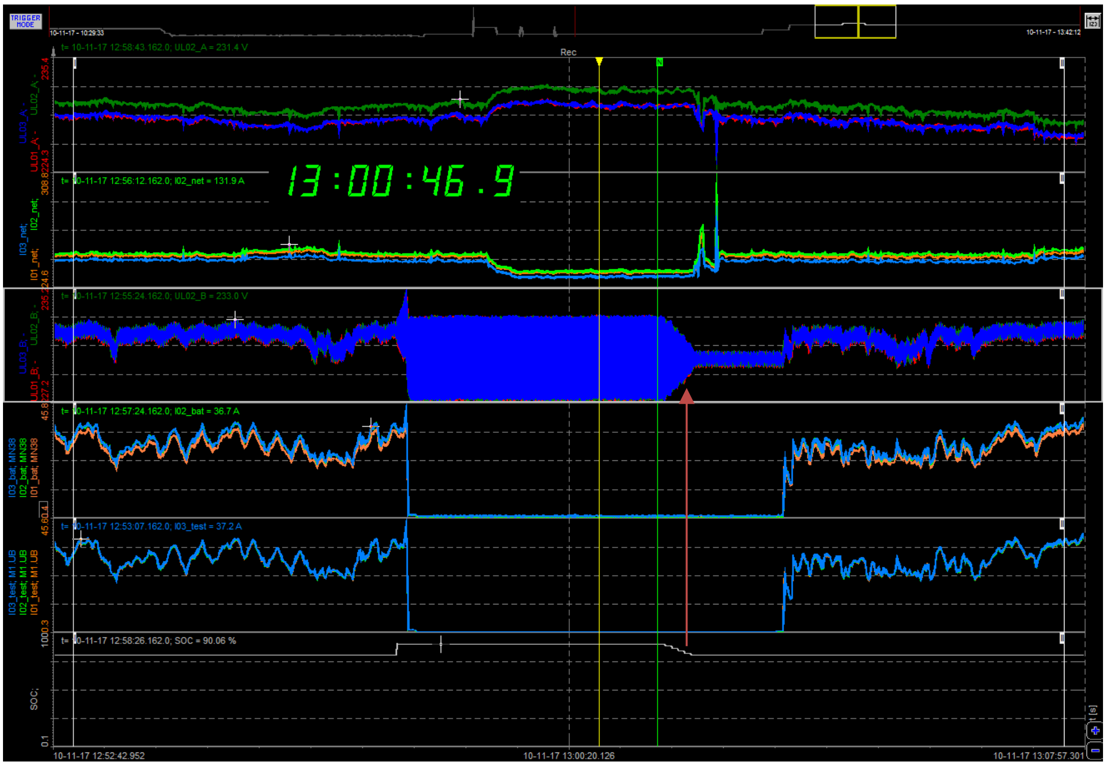


The wind turbine trips on high frequency , as the frequency was normal again it took the wind turbine more as a minute to com back in

wur_test01_2017_11_10_120754.d7d

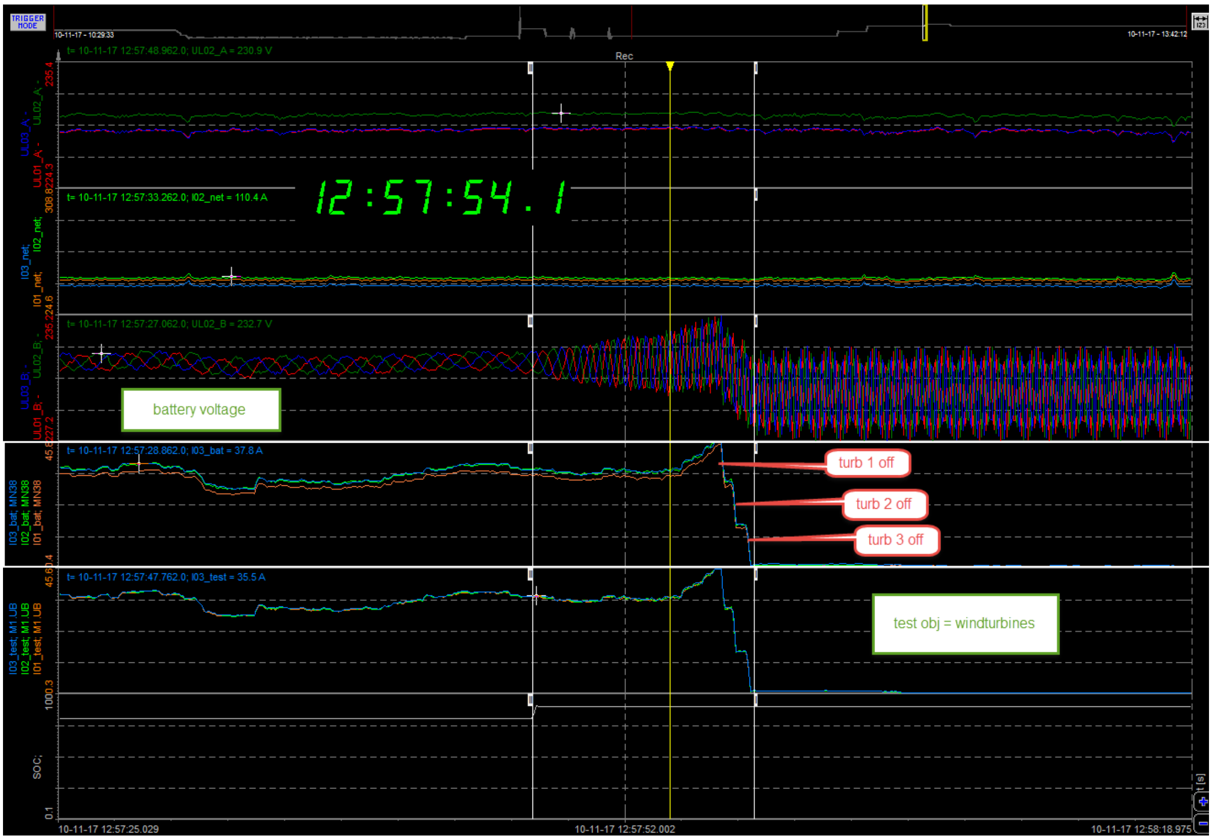


Going from 80% SOC to 90% SOC should be no reason to trip !!



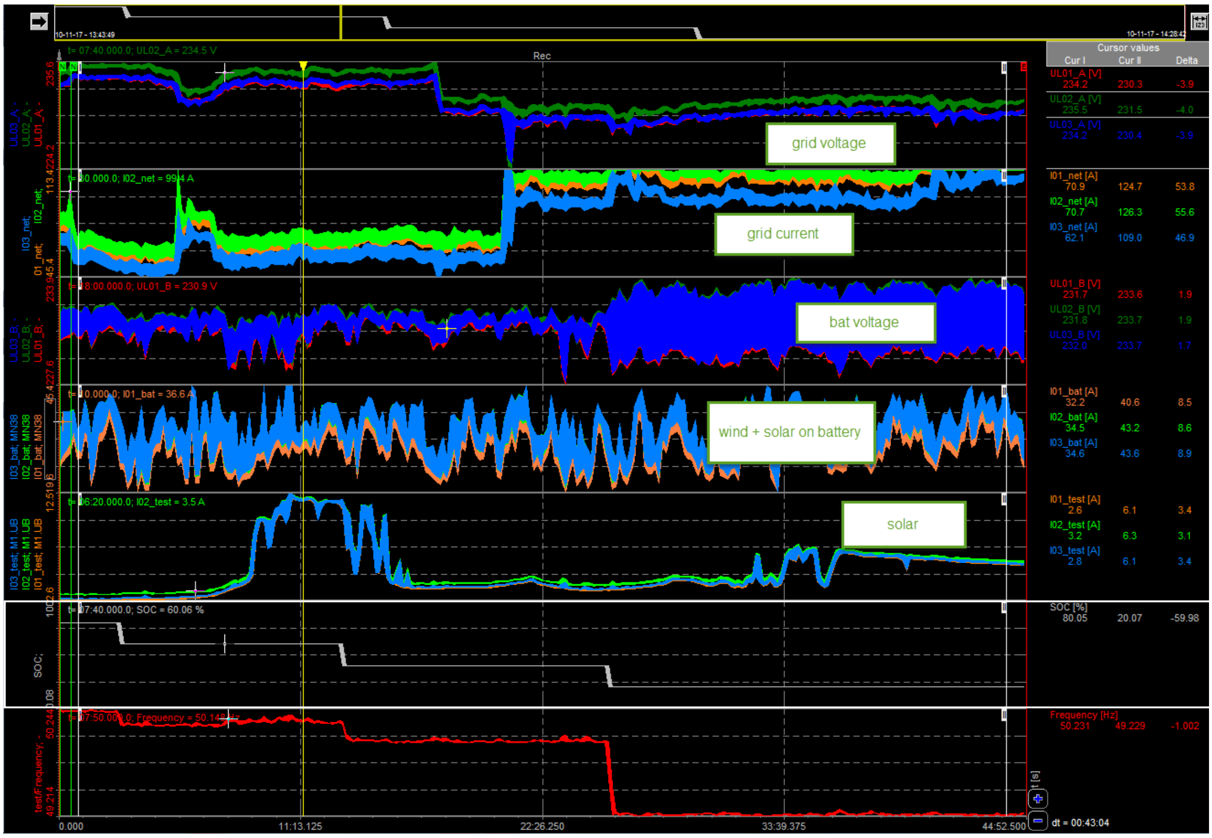
There is a clear relation between the battery voltage oscillation and the SOC > 80% (problem still to solve)

wur_test01_2017_11_10_120754.d7d

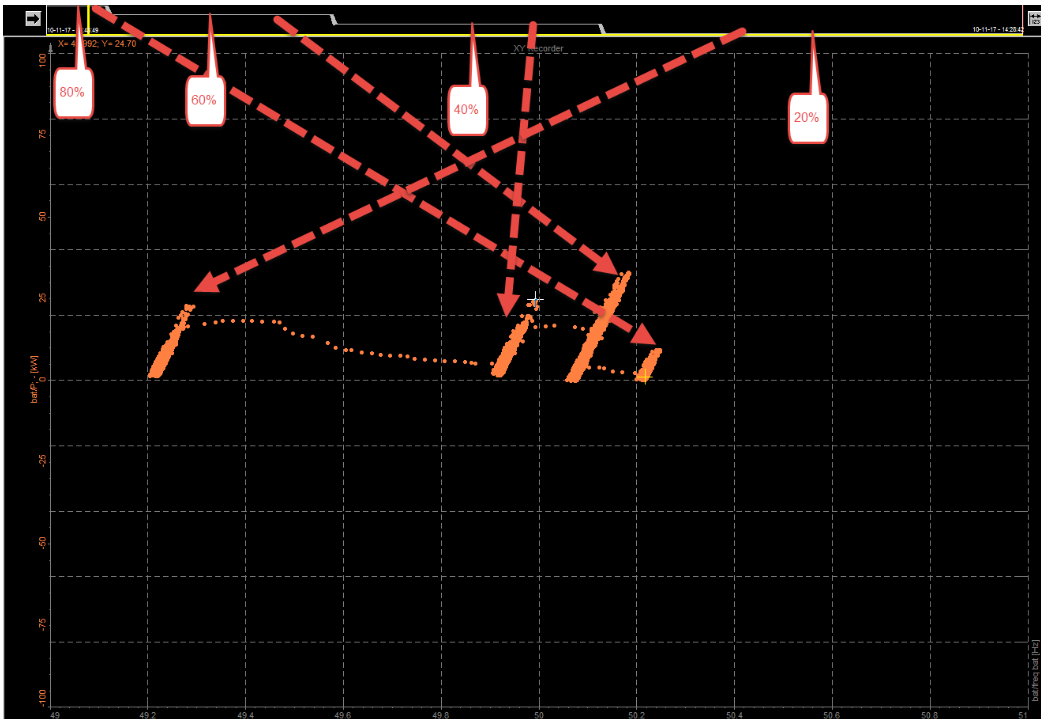


Detail of the trip currents

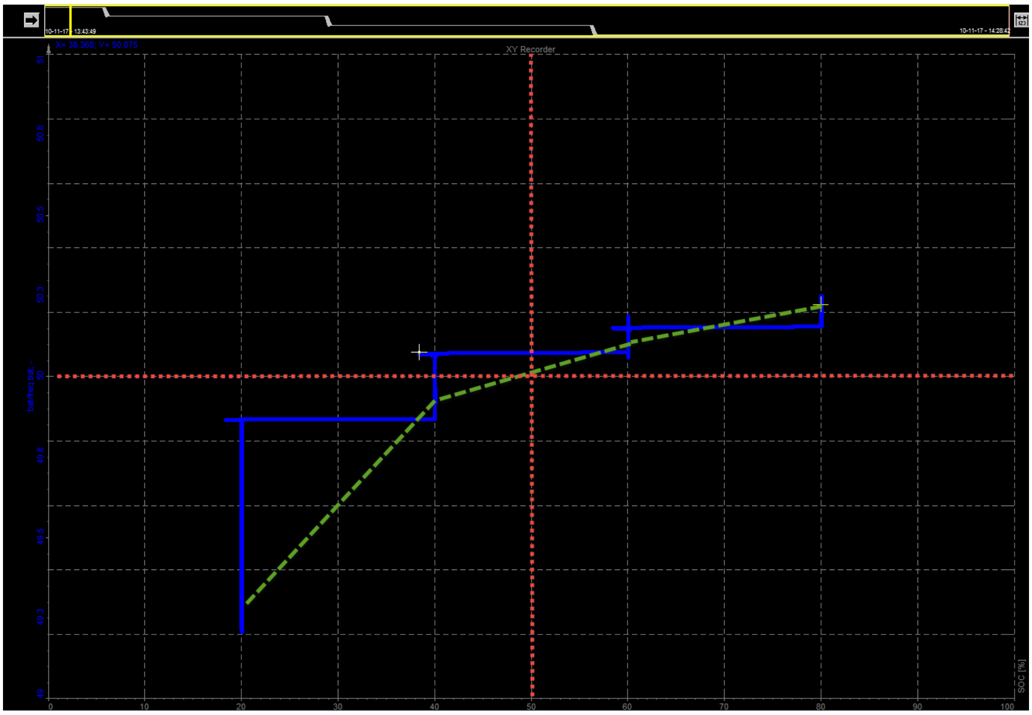
wur_test01_2017_11_10_134349.d7d



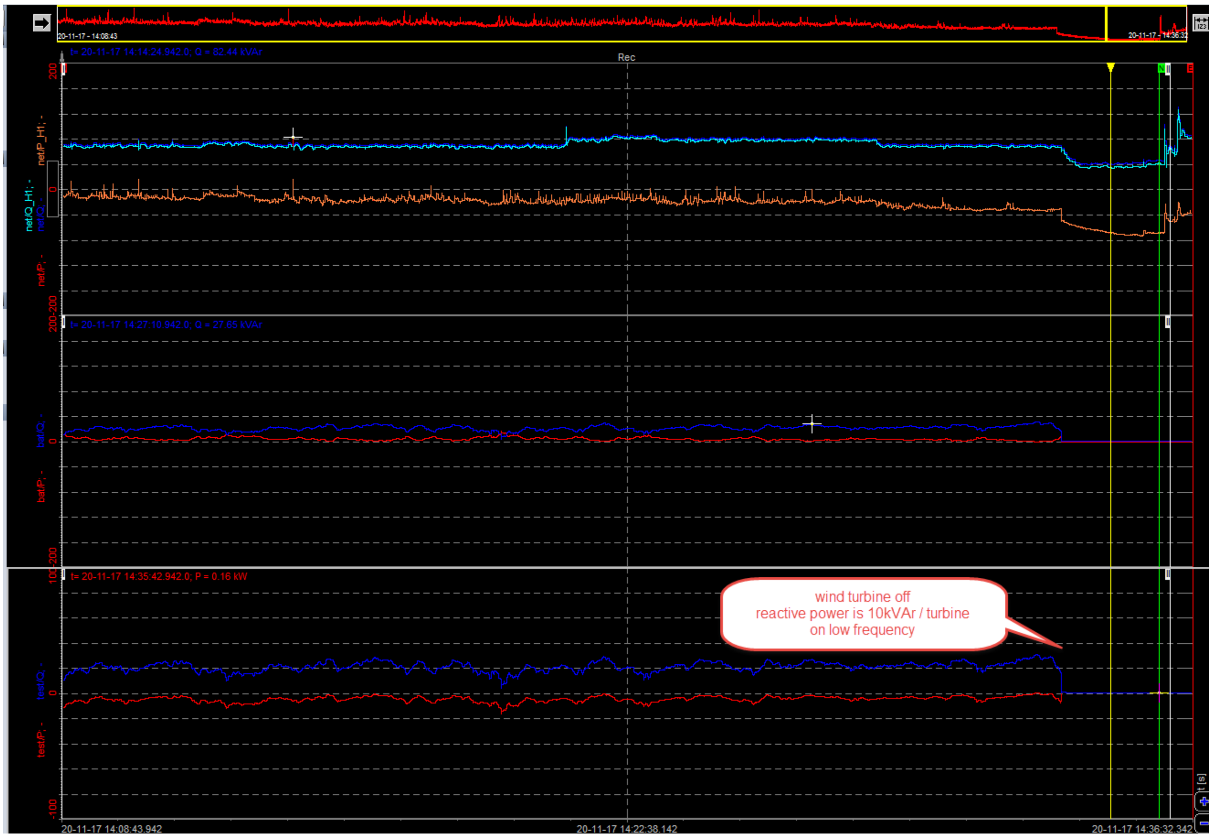
wur_test01_2017_11_10_134349.d7d

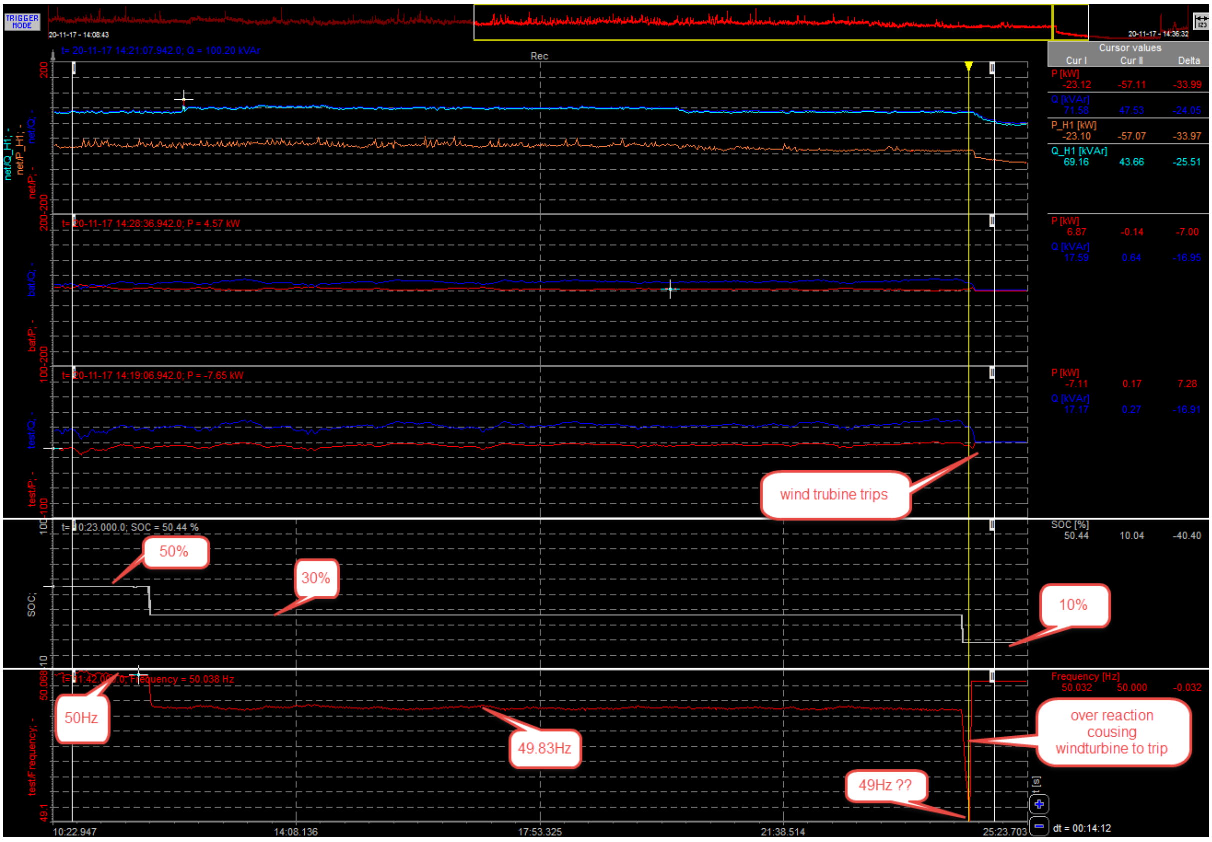


wur_test01_2017_11_10_134349.d7d



wur_test01_2017_11_20_140842.d7d





Conclusion → frequency response is overreacting cousing the windturbine to trip , and probably also the solar contribution

wur_test01_2017_12_01_145055.d7d

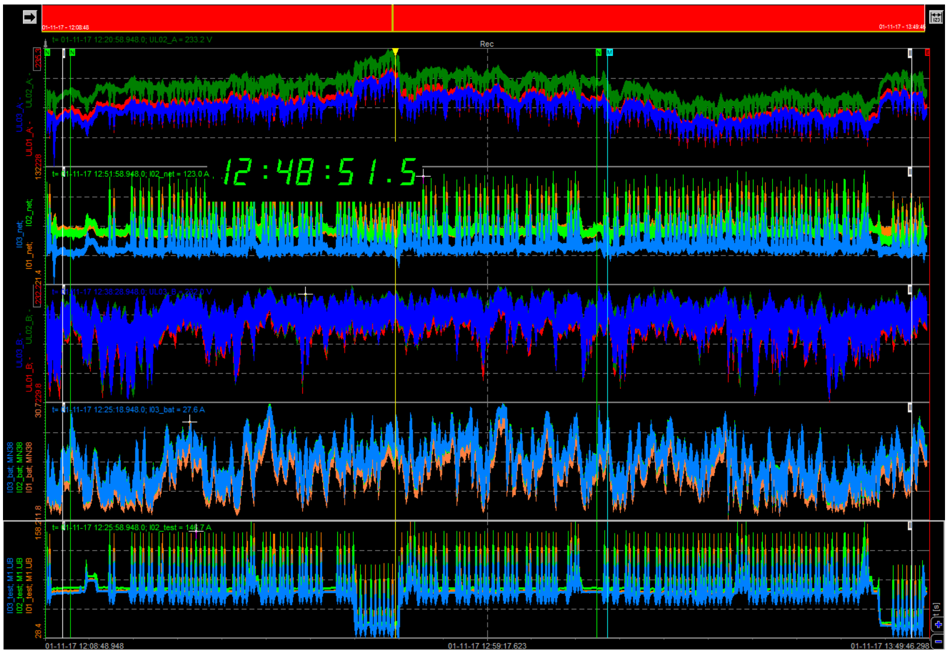
After we solved all child diseases in coordination of generator / battery system switch over grid / battery bus did go perfectly

The generator runs normally at 60kW however peak production is 120kW , methane gas can be stored for a day (1500kwh electrical), to adjust production to the load
1500kwh electrical means with an efficiency of 35% 400Nmtr3 of gas (at 2 bar = 200mtr3)

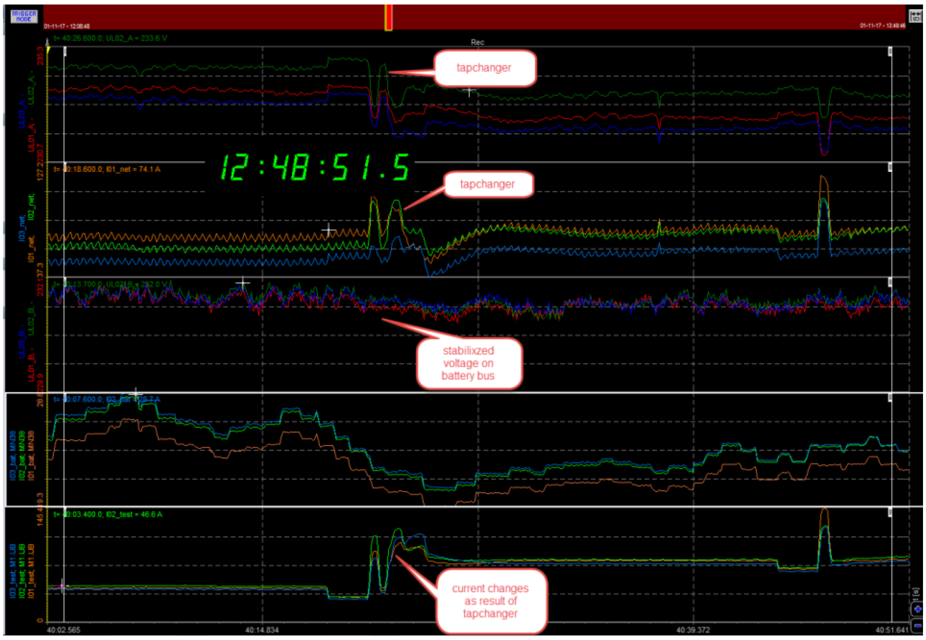
Other loads - not programmed or un-controlled loads

Vergister

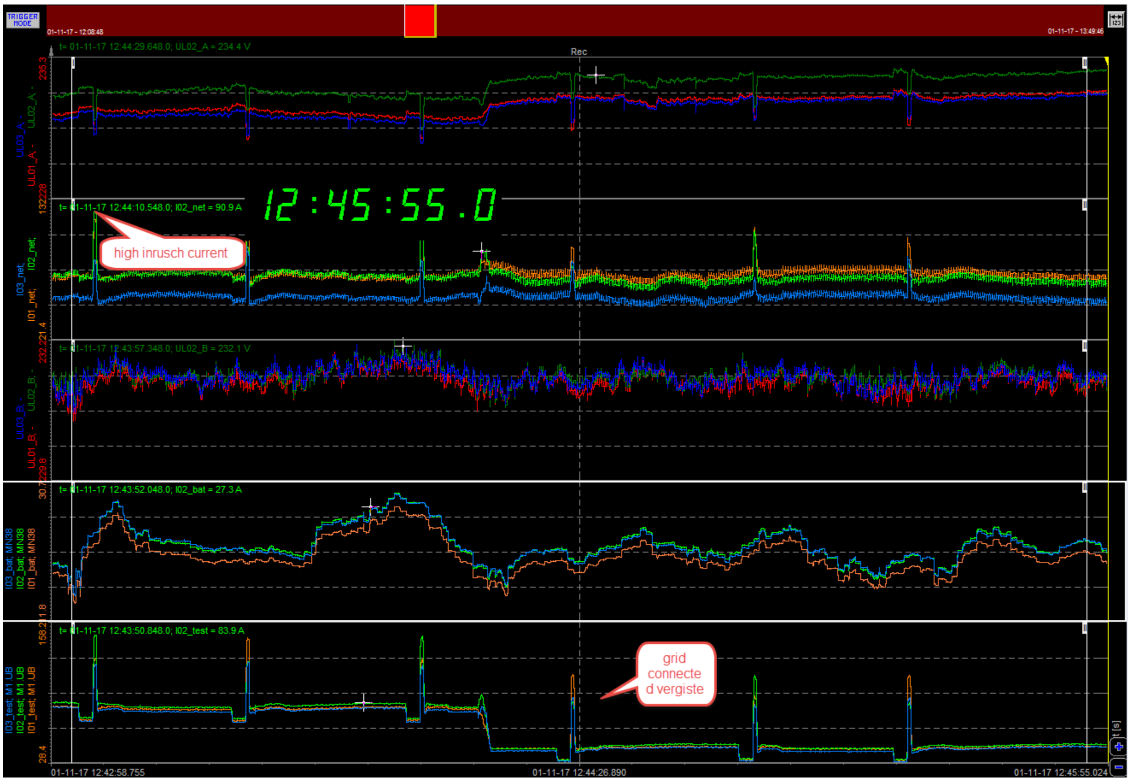
wur_test01_2017_11_01_120848.d7d



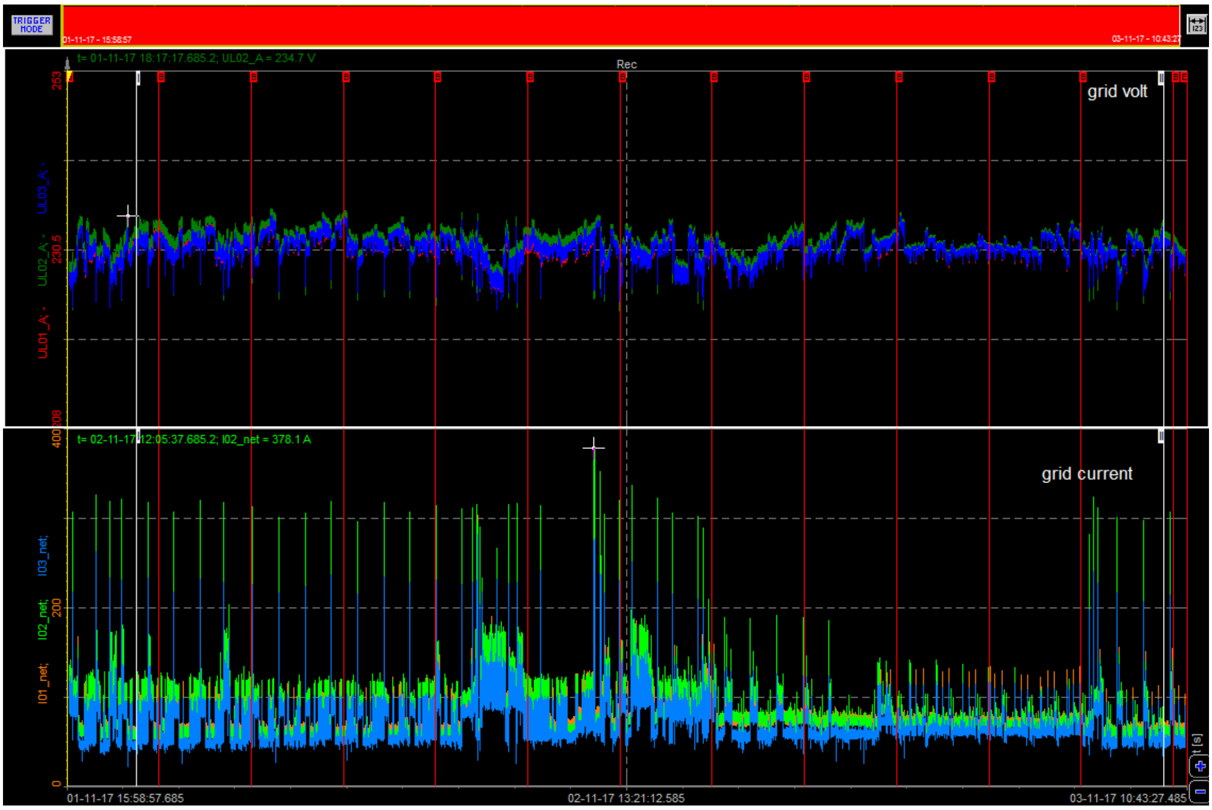
wur_test01_2017_11_01_120848.d7d



wur_test01_2017_11_01_120848.d7d

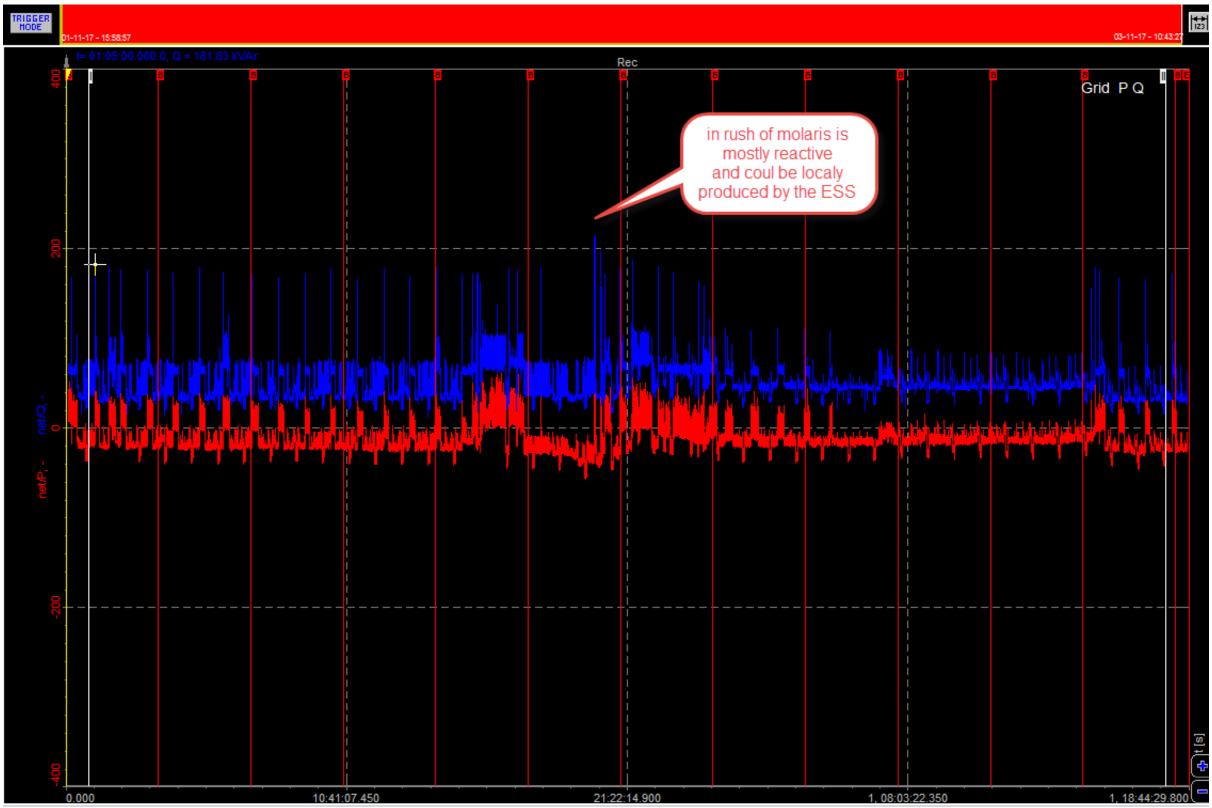


Non flex load Molaris
wur_test01_2017_11_03_101311.d7d



Just grid connected free running on the 10% voltage band; peak current 273A = inrush of the molaris mill.

wur_test01_2017_11_03_101311.d7d



Response time for reactive power must be smaller than 0.3sec.