Some Load examples in a cellular electrical grid

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The following article shows some results of a simulation (using Mathworks-Simulink) for load situations in a cellular electrical grid. A cellular grid is an electrical grid which is self-sufficient for a region, has connections to the national grid but with dedicated (and less) power flow. Usual the electrical power is produces where it is used, by renewable energies and gas power stations.

As conclusion: A power bank (battery store) with a proper powerful converter which is also controlled by the power flow to the outer grid is a proper solution for the grid stability without rotating converter..

This article is yet under construction. Look for improved versions time to time.

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1 What is a cellular grid

The idea of a cellular grid come from renewable energies. Not central power stations with coal or atomic energy are responsible to the power dissipation of a wide area. Instead any region have its own power generation plants which is solar energy, wind, also gas power stations possible with hydrogen from renewable energies or from own production to store energy. One of the important is a power bank of electric accumulators.

A cellular grid can supply a range of for example a middle town and the villages around inclusively industry plants, which may be a power consumption in range of ~ 50..100 MW. This is for about 50..100 thousand people and the industry.

This grid cell is connected of course with the national electric grid. But this connection is not used to supply the amount a power. It is used to exchange power in different situation (for example load the accumulator in the night if the sun is not shining from gas power stations in the next neighbor cell if the own cell has not such one, and distribute power if the sun is shining to the neighbors.

1.1 Relevance of the converter to the power bank

Because some power producer depends on the environment situation (solar panels, wind), and some other power producers should only be used in full load situations (gas power stations), the power bank plays a central role. It should store power for full power consumption of the cell for approximately 2 hours, or just typical reduced power consumption for a whole night. It means if the grid cell has a nominal near maximal power consumption of 100 MW, the power bank needs a capacity of 200 MWh, or more, and the converter to the power bank should have a maximal power efficiency of ~ 150 MW (for peak situations).

This documentation essentially highlights the converter to the power bank. This converter should work for the whole time, either load the power bank, or produce power from the bank to the grid, or stabilize the power in the grid cell. The last one is a meaningful task. The power bank converter should immediately compensate fluctuations in energy flow to stabilize the grid cell.

For this presentation a high power converter is not in focus, instead a converter with 60 kW maximal power output for a 230/400 V grid. This is for example for a scattered farm with its own power production, but with a longer line to the next village or town. The given controller simulation uses a double DC link internally. The same results should be valid also for 100 MW and a middle volt converter, adequate scaled. But for that a more complicated converter with multilevel technology is necessary, which is not existing as simulation model yet.

1.2 Should a local grid cell act as disconnected island grid

Normally, a local cell grid is connected to the national electric grid for power exchange and also to hold the frequency and its angle. Because the grid cell should have a concerted power balance between production and consumption, and it has especially a power bank for storing power, it is possible that the grid cell acts in a disconnected state. Such a disconnected island state can occur because of any disruption (short current situation or such) for a few seconds till minutes or hours. For this time range the power bank should be usefully to assure enough power independent of own primary power producers.

For a longer disconnected state, of course there should be enough resources to produce the power to reload the power bank.

Hence, the power bank converter should be able to work both in island situations as well as in connection to the national electric grid.

Basically the idea is to control the amount of power which is exchanged to the national grid. This amount of power depends on contracts and also payment for power.

Hence there are two approaches of control the cell grid:

- If the national grid is connected, its reference values and measured power is responsible to control the power output of the converter. It the power inside the grid cell is volatile, the power bank converter should deliver or consume the difference, so that the power delivered or consumed from the connections to the national grid follows the usual more constant reference values.

- If the national grid is not connected, automatically the voltage and frequency should be stabilized inside the grid cell.

Which behavior is required on overload situation?

- If the national grid is connected, but the own produced power is too less and the power bank runs out, either the reference values to the national grid connections should be changed, or a signal to local consumers should be give to reduce its power consuption. This signal cannot be the frequency because the frequency is determined by the connected national grid. The voltage value can be reduced. This forces reactive current to the national grid which should be admissible in such situations.

- If the national grid is not connected, then the frequency can be dropped to a admissible but signaling value. Normally the frequency should be in range near 50 Hz (or 60 Hz), only with 0.05 Hz difference. A frequency of 49.9 Hz should be a meaningful signal to switch off unnecessary consumers, adequate 50.1 Hz to switch on possible consumers (if the power bank gets filled).

Behavior in disturbance situations?

This is also an important question. There may be a suddenly overload over the power performance of the converter. Also there may be a shorten anywhere in the grid cell.

On a shorten situation normally protection devices monitor the current and switches off the respective parts of the grid (switch gears). This means, the short current should be supplied from the converter. It is important to detect the fail. Then the short is switched off and the remaining grid is already stable. Maybe the shorten is repeated because the shortened grid part is switched on again and the shorten is remaining. It depends on the strategy of protection, which is state of the art in electric grids. The converter should deliver a appropriate current in all these situations. The voltage can be lower of course in the short situation.

If an overload occurs, not a hard short, and the maximum of power for the converter is reached, the only one possibility is also, supply the admissible current. The voltage in the grid may be dropped down. This is especially in disconnected situations of the national grid. But also in connected situations the voltage may be dropped down, if power supply from the national grid is not agreed. Because of the connected grid an additional reactive current will be occur if the voltages are different.

1.3 The goal of this presentation

The main goal is, discuss the problematic of a stable grid without mechanical generators. In the past the national or regional grid was determined by rotating converters. Their rotating energy helps to span power steps on switching loads. Whereas currently semiconductor based converters have not enough current yield and not enough power capacity inside to do the same. So a grid may be unstable if the amount of rotating converters is replaced by semiconductor converters in the course of the use of renewable energy. But the necessary and coming power banks in such environments have the capacity for the power. The discussion is, how many current yield is necessary (especially on disturbance situations in the grid) and how the dynamic of the controlling of these converters should be done.

For that an example model was programmed using Simulink (Mathworks) to explore some situations and develop a proper control. This example works with a 60 kW converter, with this the shown results are done. The converter is a simple built as a 2 * 375 V DC link circuit and a output transformer

230/230V per phase in delta-star configuration. The transformer is necessary to separate the potential of the DC link circuits and the grid. Its leakage inductance acts as inductance on output to manage disturbances in the grid (especially shorten also near the converter). The DC link may be supplied by the power bank. Hence the currents from and to DC link are also the currents from and to the power bank, exclusively fast disturbances which are blocked by the DC link capacitor and a inductance to the power bank itself. But the dynamic of the power bank currents are not detailed explored. The power bank should deliver power and store power depending on the load situation, additional to its main task to store power in defined times and push back it to other times.

This example is used to present the results in some situations which are described in the following main chapters.

2 Example of switching loads with a rotating converter

The situation in the example should be presented as following:

The cellular grid is a scattered farm which was a water mill in the past, but lately equipped with a generator at the mill wheel with 30 kW power. The connection to the national grid is given with a longer line 230/400 V from the next village for power consumption of maximum 25 kW (35 A fuses). The farmer has a business enterprise which needs time to time a power of 30 MW for a heating equipment. If this heating furnace is used, the meal wheel generator is activated to deliver the power. This was the situation in the past.

But with modern equipment additionally a solar panel equipment is added with up to 30 kW power. Additional a power bank accumulator was purchased, which has enough power for two heating furnaces (60 kW). The heating furnaces does not work the whole time, so the solar power and also the given meal wheel generated is enough.

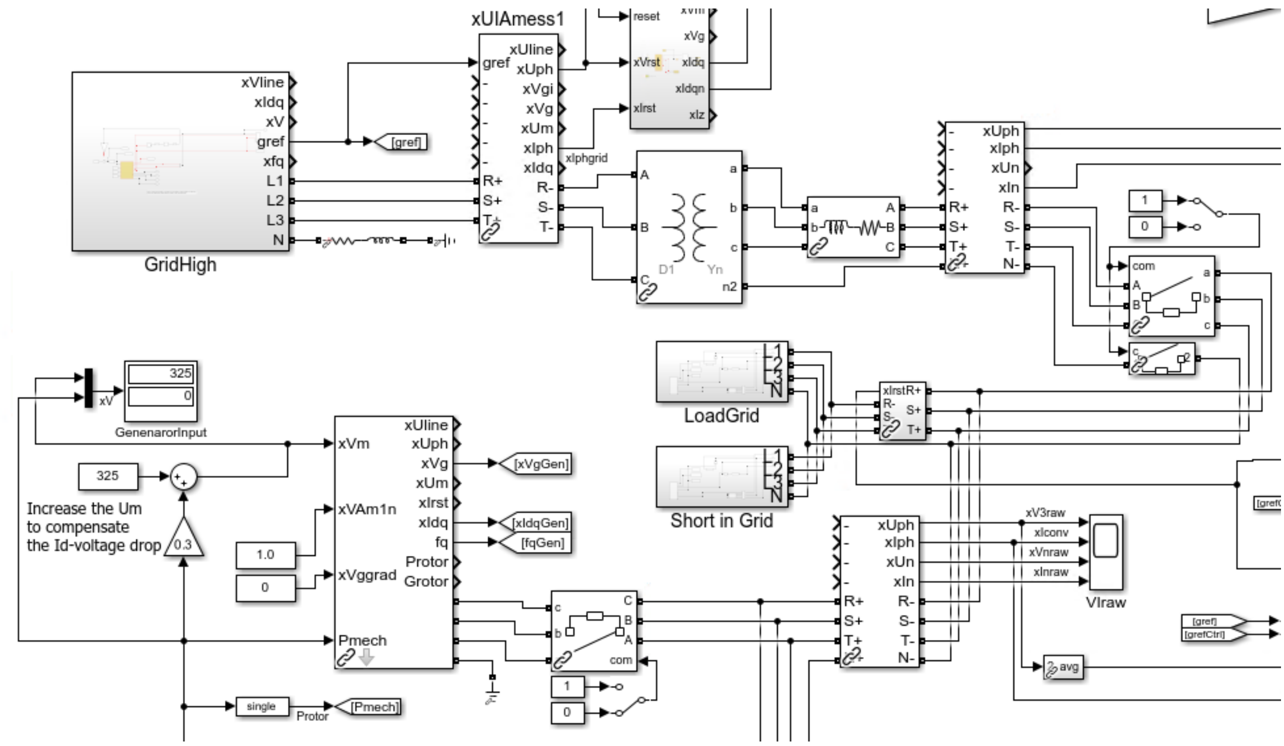

Figure 1: GridHigh_MechGen.png

The figure 1 should be give an overview of this part of the Simulink model. In the mid you see the transformer between the national grid and the grid cell. There are two breaker to switch off the outer (national) grid and the mechanical generator in some simulation situations, and also some measurements. In the mid below the transformer there are two blocks which contains load situation, explained later.

The "GridHigh", the national grid is connected without the neutral conductor as it is usual for middle voltage power supply, but the grid cell has the neutral conductor. This is possible due to the delta-star configuration of the input transformer.

2.1 Short high power steps only on a weak grid

First have a look to the situation without any local power generation. The regional grid is connected with a longer line for a power supply of maximum of 25 kW. The inductance of the transformer and transmission line is ~8 mH per phase with 0.5 Ohm. The load step is 30 kW for nominal voltage.

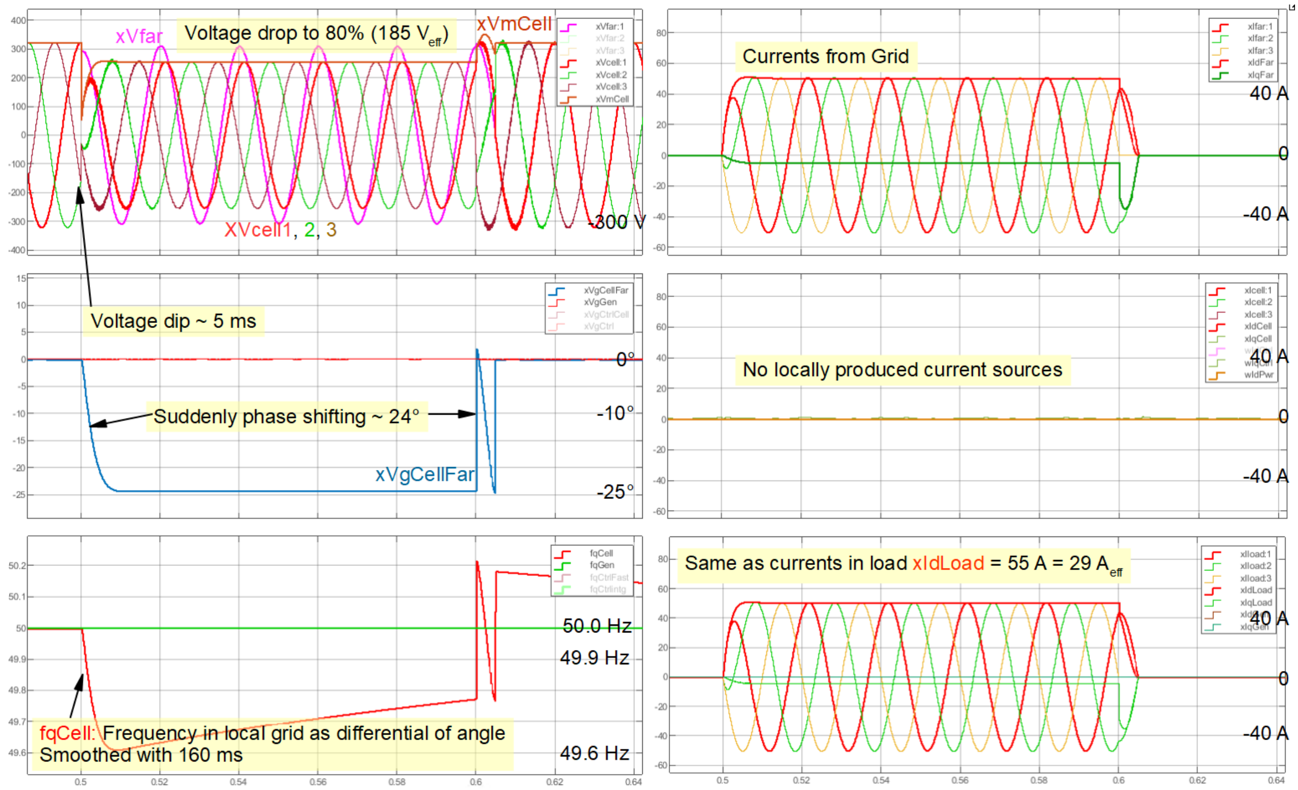

Figure 2: switchOnOnlyLongline.png

Because of the high impedance of the power supply the local voltage drops down to ~185V.

Also on first switching on in the first milliseconds there is a voltage dip to near zero.

But the important impact is, the angle steps suddenly in a few milliseconds to 24°. This is a shock on the shafts of all rotating rotors of motors in the grid. not conducive to their service life.

2.2 Same power step with conducted mechanical generator

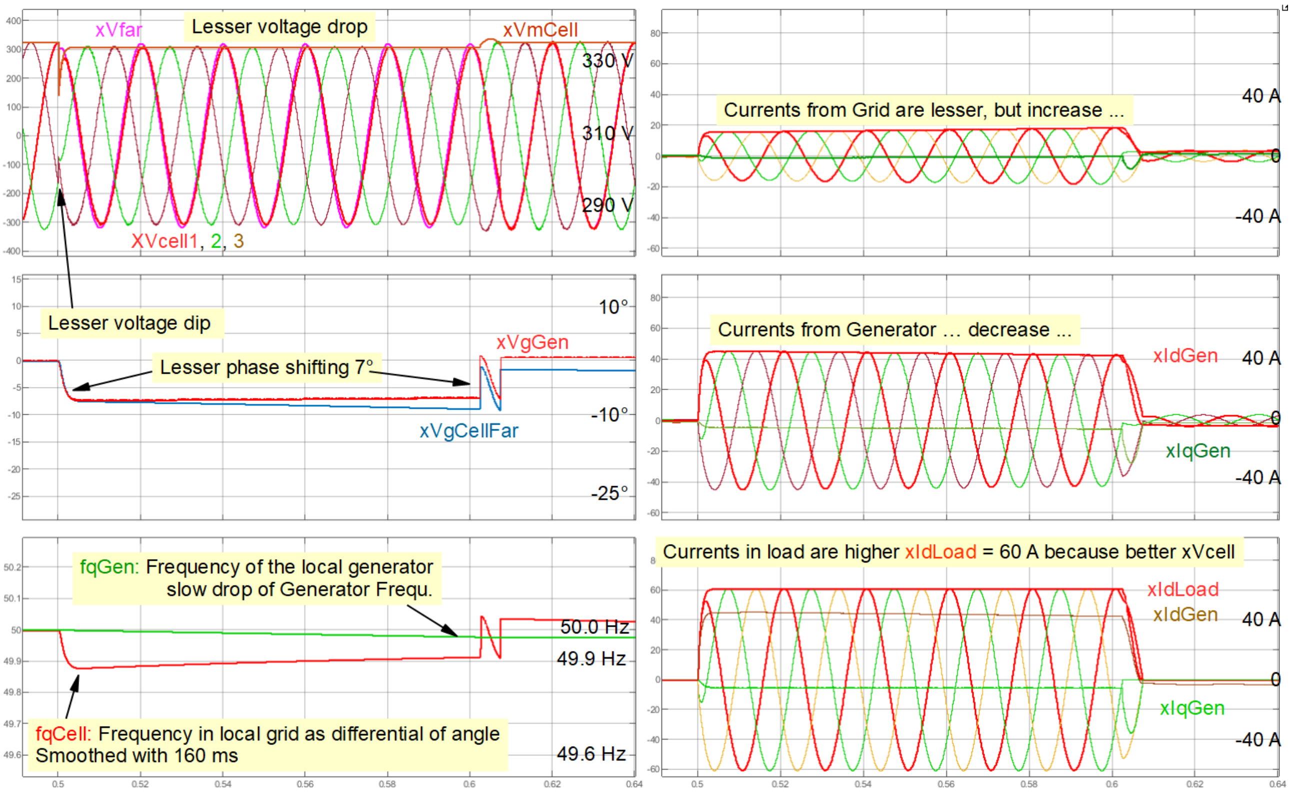

Figure 3: switchOnWithGenFree.png: Switch on/off a high power with coducted rotating machine

If the mechanical generator is conducted without any power step, the following situation occurs:

This is sometimes better. The angle shift is only ~7° which is really reconcilable. Also the voltage drop and the first voltage dip is lesser. This is the stabilization effect of rotating converters. The inner inductance of the mechanical power generator is 3 mH + 0.2 Ohm per phase.

But if you see in this short time, the current from the generator decreases. The same is shown in Figure 4: switchOnWithGenFree-20sec.png right side for a longer time. The small window of figure 3 is demonstrated with the light blue rectangle left side in figure 4. The generator losses its rotation energy. Hence the current from the grid increases. More as that, the generator has a pendulum effect. It means it gets power from the grid to accelerate again reaching a defined difference angle, then feed back again etc. The pendulum effect is always present if high power is switching with such machines. And, of course the generator does not help for power supply in a longer time. It should be fet with mechanical power.

But the important effect with the idling generator is: The suddenly shock to other motors is lesser. This is the advantage of the rotation energy.

2.3 Feeding the generator with water power with the load step

The figure 4 right side shows the situation: Shortly before the load step comes, water is supplied to the meal wheel and the generator gets power. But this needs a few time. The rotation energy and the incoming water power are in balance to reduce the power from the grid.

On switching off the load the water power is reduced before. So the current from the grid increases before switch off, and then on time = 10 sec you have the amount of current change in the mechanical generator, and again a suddenly angle change of only 7 ° (less impact for motors). But the pendulum current is also present.

Figure 4: switchOnWithGenFree-20sec.png

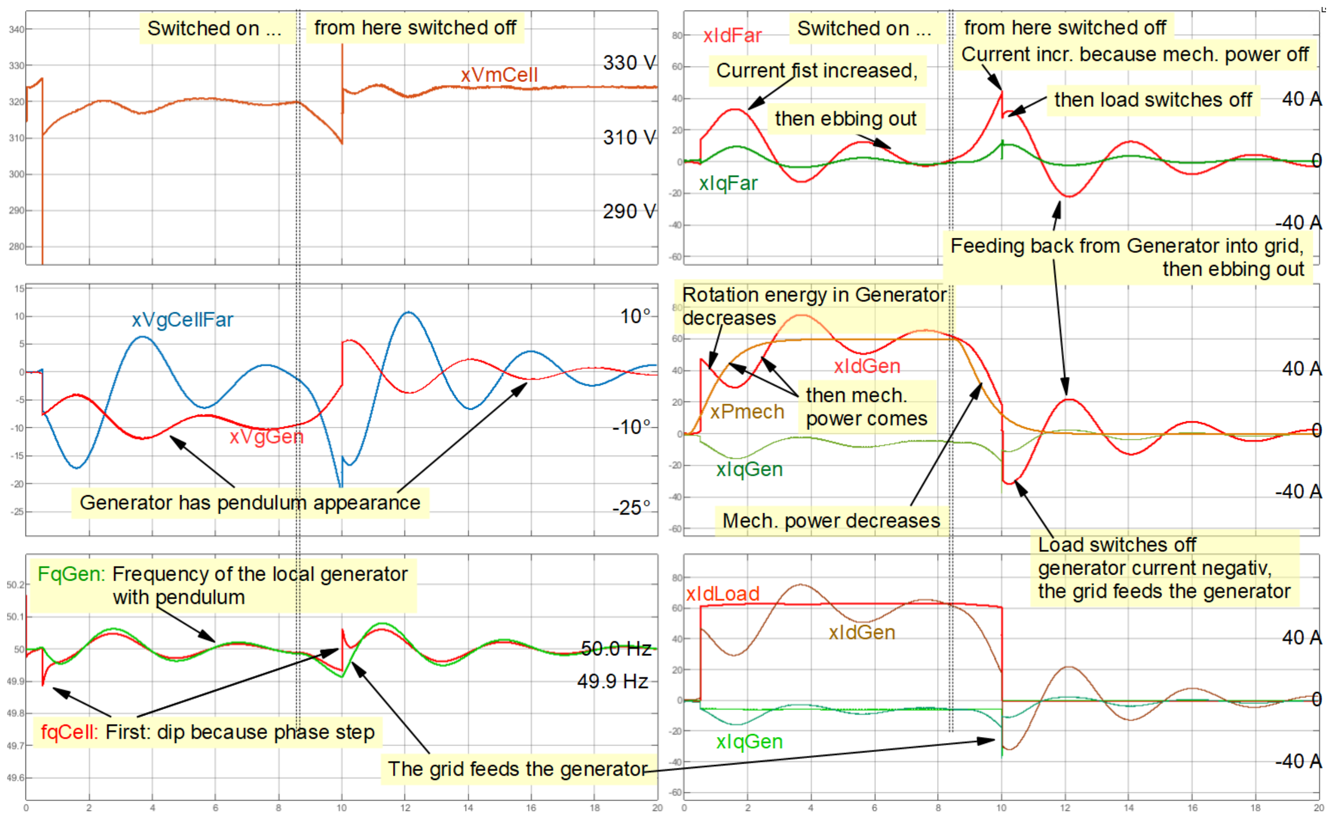

Figure 5: switchOnWithGenPwr-20sec.png

All in all a possible situation ... used in the past.

3 For the example: Use a power bank for the normal load sequence of the heating furnaces

Now new technologies should be used. The farmer has installed a solar panel plant and has bought a power bank with a converter for 60 kW, sufficient for two heating furnaces of his business enterprise.

First, for this specific application, a set value is supplied to the converter of the power bank if the heating furnace should be switching on. But, the set value is realized as ramp. A ramp is usually recommended to change power supplying to suppress shocks in the power flow.

3.1 Behavior of current and reference values in the first second

But switching on the heating furnace is a shock. Of course a better solution may be using a specific converter also for that to create a ramp for the heating power. But on the other hand 30 kW immediately switching on/off is not too much, the grid should have resilience for that. This article should offer and explore such situations.

Another power step situation is sometimes also close a switch gear to another grid segment. If both angles and voltages are exactly equal, then closing does not force a power step. But usual the angles are floating (it should be synchronized, closing during synchronization), and hence there are differences. A difference of 10°, it is only 300 ms during synchronization with a frequency difference of 0.1 Hz, forces often the full power of the feeder.

But have a look switching on the heat furnace:

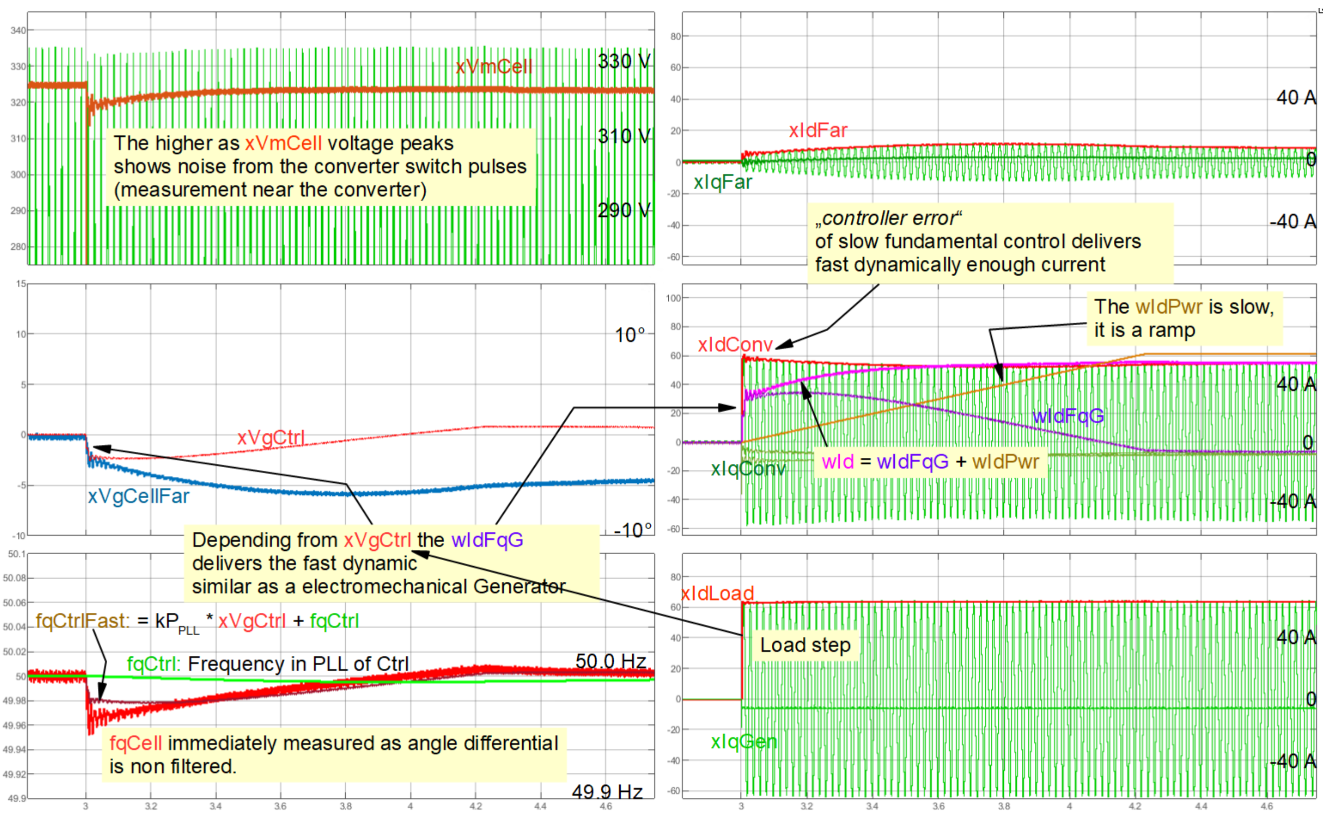

Figure 6: load2sec-Ctrl-fP-Pwr.png

The ramp to for the set or reference value of the converter is shown as brown curve in right mid diagram in figure 5. It has a growing up time of 1.2 seconds till the end value.

But if the load is switched on, the amount of current comes from the converter though the reference value is zero in this moment. Only a small part comes from the outer (national) grid. Why is it so?

The converter is controlled in the so named „*fundamental mode*”. The converter driving signals are not changed fast during one period of the voltage (20 ms), only the fundamental values are changed. The measured current values are averaged with 10 ms or 20 ms to divide the measured values in the parts „*positive sequence current*” in d and q coordinates (direct and squared, **Idq**), „*negative sequence current*” (**Idqn**) and direct parts (**Iab0**). The „*positive sequence current*” is the active and reactive current. The „*negative sequence current*” describes a deviating current from the normal three-phase sequence. This is especially important for unbalanced loads such as one-phase loads, two-phase or one phase shorten and such one. Last but not least, the DC current is also separated and controlled to avoid DC currents in the system, which are unfavorable for the converters. This separated control of the components is only possible with the averaged values.

But it means, the converter acts uncontrolled in a really less time range, in the first milliseconds. The time of controlling (the time where the error is reduced to 37%) is here ~200 ms. The controlling cannot be more fast, it gets else unstable because of the high dead time of the average filters. This effect is now very usefully for load steps. In the first periods the converter behavior is pure electrically. The output impedance of the inverter is responsible for limiting the uncontrolled current rise. This is important for shorten or overload situations. But in this case the load is not to high. The converter supplies it.

Without the violet part of the reference value **wIdFqG** in the right mid diagram the current will be decreased by controlling to the ramp reference value. This forces the difference from the outer grid, and this resulting current from there is high.

The **wIdFqG** comes from the temporary frequency deviation or more exact from the suddenly angle deviation because of the load step. The cause (measurement) for that can be seen in the mid and bottom left diagram as

- **xVgCtrl**: This is the angle deviation of the measured grid voltage from the currently constant (filtered) rotating angle.
- **fqCtrlFast**: This is the fast detected frequency of the measured grid voltage which is used as input for the rotating angle PLL (Phase Look Loop control or filter for the angle)
- **fqCell**: This is the independent measured fast frequency of the grid voltage in the cell.

The **fqCell** is built outside of the controller, only for comparison. All three values have a deviation due to the load step, which can be used to form a reference value for the current control to increase the current in response. This is done shown in the violet value **wIdFqG** in the mid right diagram. This value increases the delivered current from the converter independent of the outside given reference value wIdPwr with the brown ramp. With this value the current from the outer grid remain less.

But this **wIdFqG** decays to zero after a small time (1 second) because the internal reference angle is oriented to the outer voltage, depending of parametrization of the PLL for the reference angle of the controller. Hence the coming **wIdPwr** is important for the longer current supply. This is basically similar as the behavior of a mechanical generator: The load step opens an angle between the rotor and the magnetic field in the generator which increases the current supply. But then the rotor converges to the magnetic field and the supplied current be lesser. A mechanical force is necessary (instead the **wIdPwr**) to remain the angle situation.

Next page have a look on the full time behavior:

3.2 The whole situation with given reference value for the power

The next image shows the whole situation. It is the same simulation run as in Figure but with the full time of simulation.

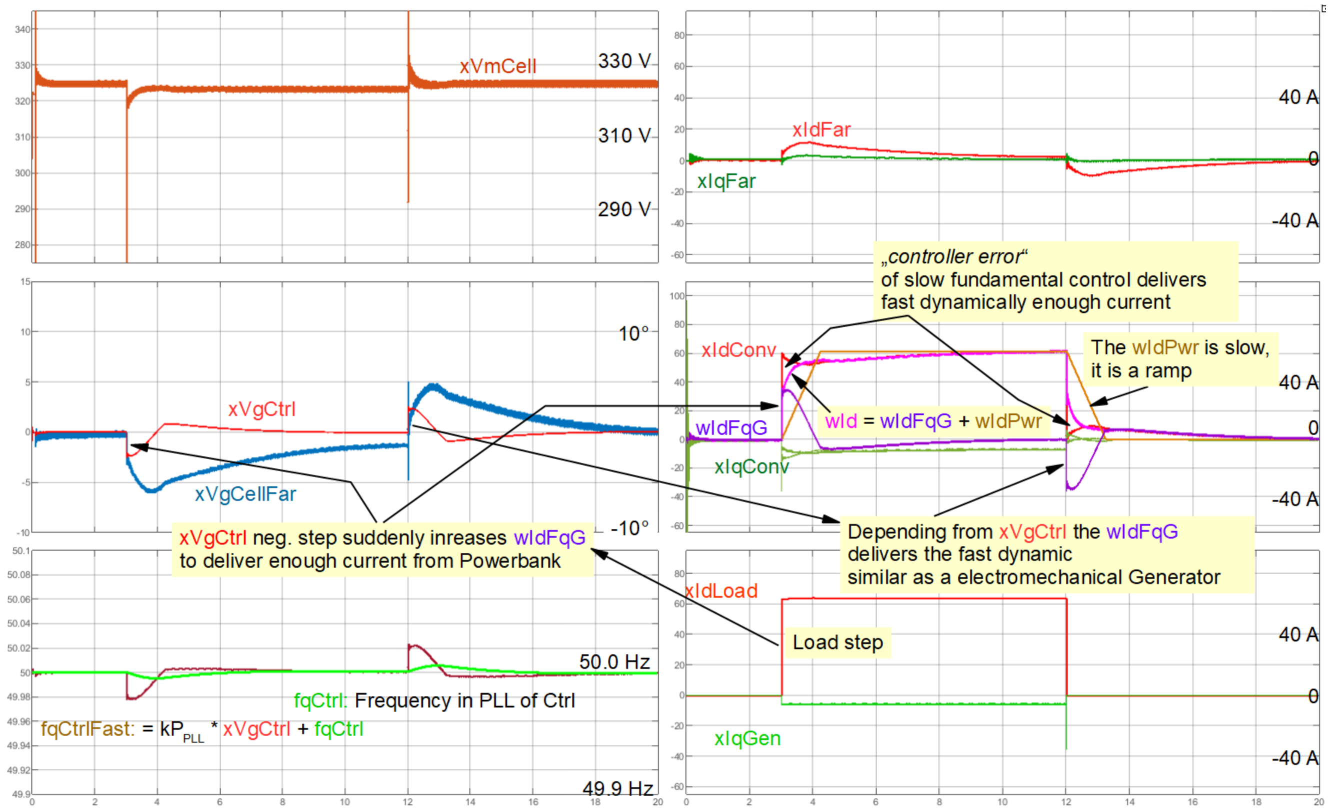

Figure 7: load9sec-Ctrl-fP-Pwr.png

The signals of figure 6 are visible here from the time t=2.9 sec till t=4.7 sec, only the steady state signals are shown here. The oscillating signals are two much.

On time t=12 sec the revers process is done, the load is switched off. Because the ramp is slow again, the converter of the power bank feeds a little power back to the grid in the first second, but only 10 A in maximum.

All in all the result is some more better as with the rotating generator, because the pendulum effects are not given. The converter is more fast and determined. But the fast feeding effects are also proper in the same way as with the rotating energy.

3.3 How the deviation of the angle is gotten

The first question may be how the fast frequency (brown line **fqCtrlFast** in above image, diagram left bottom) is gotten. This signal is similar as **xVgCtrl** red in the left middle diagram. The question may be interesting, because usual converter control uses the f-P characteristic to control the active power. If the input frequency is fast (not smoothed) and the f-P characteristic has no ramp functionality or a fast ramp, then the behavior is similar (not so proper) as using the angle deviation itself. See also todo chapter

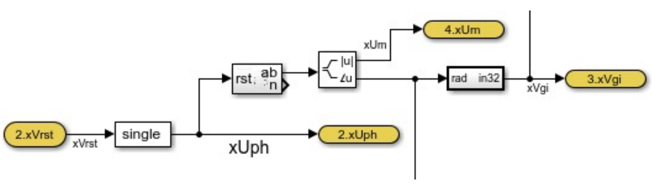

Figure 8: Simulink/x3UlmessPrep_Vltg.png

We should have a look the PLL, the Phase Look Loop control for the reference angle inside the controller works. The input of the PLL control shown in Figure 9: Simulink/PLL.png is the difference **xgErr** of the currently measured angle **xVgi** in Figure 8 to the reference angle itself **yGref**. The **xVgi** is gotten from the 3-phase voltages after a Clarke transformation to orthogonal coordinates **ab**, and then build a rotating angle from it via an actan2 operation. This angle is converted to an integer value of 32 bit

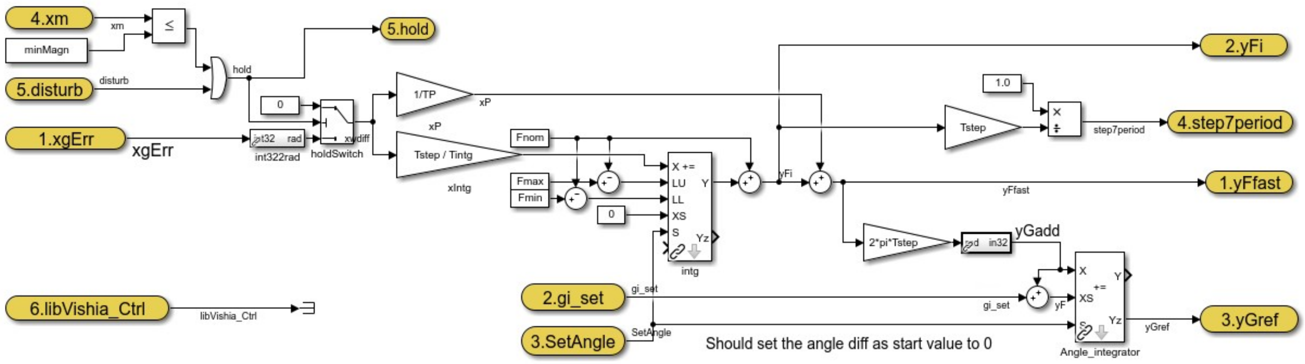

Figure 9: Simulink/PLL.png

Exact this xgE

The functionality is, the reference angle **yGref** should follows the (less smoothed) input angle, but in a longer smoothing time. The angle itself is incremented as integer wrap around `0x7fffffff` over `0x80000000` without any additional effort right below with the given value on input of the integrator. It is a value of `0x100000000` divided by the number of steps in a grid period (here ~ 400), means approximately `0x00A3D70A`. This value results of the frequency given as nominal **Fnom** = 50 Hz calculated with **2*π*Tstep** as radiant value converted to the integer range. If the **xgErr** is near 0, it means the grid voltage is not disturbed, it is stable. If the grid angle changes against the normal flow, a less proportional part is immediately added to the increment of the reference angle, also presented as fast frequency change for the **yFfast**.. This proportional part is also necessary because only the integral part will be oscillating else. The factor is **1/TP**, TP = 2 sec. It means that for a **xgErr** = `-0.1 rad` a temporary frequency change of `-0.05 Hz` is added. This is 1/1000 of the nominal frequency or `~0x29f0` added to the angle increment. It means if this difference remains, the reference angle needs 1000 steps or 2 seconds to adjust this angle step. But of course, because the **xgErr** depends linear from the **yGref** itself, this is a T1-smoothing functionality. The angle step is adjusted in the 2 second smoothing time to 37% (1/e). But because of course the closing control reduces the angle difference **xgErr** also because of its influence to the measured voltage in the grid, the resulting time of deviation is lesser, as seen in the images of measurements as **xVgCtrl**.

The integrator in the PLL is necessary because of a deviating frequency. Without it, an angle difference will be remain if the frequency is not exact nominal 50 Hz. The integrator value plus the nominal frequency is outputted as slow frequency **yFi**, which is used to turn the f-P characteristics.

The PLL contains also a monitoring of the voltage magnitude and an **disturb** input. On a short current situation firstly the disturb comes because of over current, and then the magnitude is usual lesser. In this situations with limited times the input angle measurement is worse because of the deviating voltage curve forms. That's why it should not be used to influence the reference angle in a worse kind. Hence the angle error is set to 0 for further calculation, the reference angle remains changing in steady state mode.

Last not least at start of the converter the angle can be immediately set by a proper measurement angle as start state. For that the set inputs are given.

It is also **important that the input angle** to build the angle difference **xgErr is smoothed**. That is done by using a filtered **ab** signal for the voltage. The filter is an o*rthogonal band pass* which is described in https://vishia.org/emc/html/Ctrl/OrthBandpass.html. It means small fast disturbances of the measured angle are supressed.The filter time is ~ 2 ms, very short for the fundamental control, but it does not shift the currently incrementing angle in the phase of the measurement voltages (other than a simple smoothing filter).

4 Controlling of the power bank with power to the outer grid

The last chapter has shown an example with manually given reference values for the power. But this is not commonly usable, only for the particular situation.

Usual power stations controls their power supply by the given frequency (f/P-characteristic) for the active power and by the voltage (U/Q-characteristic) for reactive power. But this is not automatically satisfying. Additionally the f/P-characteristic is shifted for the amount of Power for the nominal frequency, depending on experience, rules and consultation between different power supplier or by agreements with the market. This is valid for the power supply from the power station itself. The whole national wide grid balances differences.

For a cellular grid this is not useful, because the necessary manual agreements, consultation etc. for volatile load situations are too many effort to do. The difference is, there is not a high power station, there are many power supplier which should not be tuned all. The primary renewable energies should used as possible. The power bank converter is the compensator for the volatile differences between supply and usage of energy. The difference power gotten from and feed back to the outer grid should be constant, less or a part of agreement, consultation and rules.

Do not control the power production itself with such agreements. A better idea is to measure the power (voltages and currents) from and ot the outer grid and use this values to additional control the power bank converter for inner balance. This means that the powerbank converter should consume or feed so much power that the values in the outer network correspond to the desired ones.

The power should be measured on the connection point and transmitted to the power bank converter control unit. That may be a distance till 1 km in the power plant. The transmission is possible for example by a Single Pair Ethernet solution which can be used for this distances with 10 Mbit/s transmission rate which is enough. Building the reference value for the inner current control is a superior controller as cascade to the inner current control.

4.1 Set value and a symmetrical high load

The Figure 10: wiFar20_Load60A-6-10.png right side shows the outer current control with a meaningful load step.

On t=0.4 sec A set value of -20 A is given to the far current control. As result the reference value **wIdFar** as output of this controller increases. Because the current **xIdfar** comes slowly, the reference value increases first as a higher value up to 120 A. The reason for that is, that similar, because of the deviation of the measurement angle **xVgCtrl** another reference value **wIdFqG** decreases to negative values. The sense of this value is seen on t=6 sec and also in the Figure 6: load2sec-Ctrl-fP-Pwr.png and follow, it is for reaction of a load step. Both reference values are summarized. The **wIdFqG** is anytime only temporary because the measured angle **xVgCtrl** decays always back to zero on stable load situation (it is the deviation of the PLL, see chapter before).

But all in all at t=0.4 sec the reference value of the inner current control reaches wId as sum of both reaches 20 A. Hence the converter feeds 20 A, and because there is no other load, this is the feed back to the outer grid.

On t=6 sec a meaningful load of 60 A comes. Because the impedance to the outer grid is ~10 times higher than the inner impedance of the converter, the amount of the current will be feed by the converter. Only 6 A comes from the outer grid, which reduces the feed back current.

Now, the same mechanism is occurring as described in the chapters before with for a suddenly load step: The deviating angle **xVgCtrl** forces a reference value **wIdFqG** for the inner current control. That is fast but only for approximately one second. As second part the **wIdFar** increases because of reduced **xIdFar**. The stable state is reached again with the increased **wIdFar**, no controlling error for xIdFar and a stable additional load.

It means if the load situation or also a feeding situation in the grid cell is changing, the superior controller for the current (power) to the outer grid gives always the proper reference value for the converter current due to the set value for the outer current (to the national or outer grid). It is important of course that this superior controller has a integration part (It's a PID control)

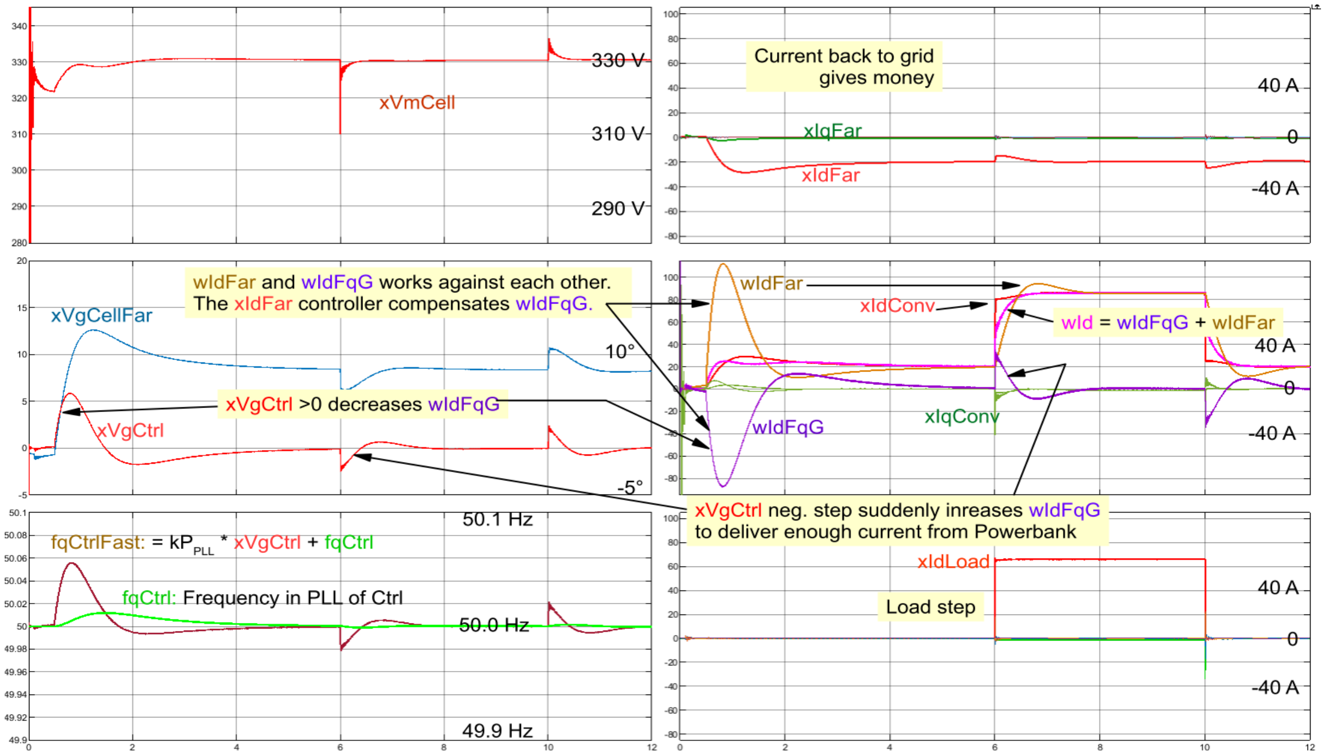

Figure 10: wiFar20_Load60A-6-10.png

But what about the situation if

- The power bank will be empty
- The inner supplied power in the grid cell is higher as the used power and the power bank will be fulfilled.
- A feed back of power in the national grid is set, but all other grid cells do also feed back power, and there is no usage of that power.

The first two points requires the changing of the set value for the feed back power, of course, if the power bank will be get empty or full. But also the produced power in the grid cell can be reduced if the power bank get full. And also there should be mechanism to reduce the power consumption if the power is too less in the grid cell and also from outside no power should be used. This is discussed in the chapter todo.

The last point should be also regarded. It is the same as usual in power feeding of power stations: The amount of power is not given as constant, instead it depends on the frequency. If the frequency is higher as a given value, the power produced, or here feed back to the national grid, is reduced. Vice versa, if the frequency goes down, the power is increased. That is usual part of the contract of power delivering. It means if there are only grid cells, and some grid cells needs power, the frequency is go a little bit lesser so that other grid cells increase its power delivery, and vice versa. If the produced power is to high at all, and no consumer can be activated (for example hydrogen producing plant), then the frequency goes higher in all grid cells which should be used as a signal to reduce the produced power for example from the solar panels. The sum of power should be constant at all.

It is also important to regard power consumption. If the power bank goes empty and no additional power can be gotten from outer because of low frequency, consumers which are possible to switch off should be switched off. That can be heating, which can pause for a defined time, or also car loading with non prior contract (should be cheaper). But this is also a political topic.

4.2 Behavior on a one phase load or fault

High power unsymmetrical loads in a grid are not typically. All higher power equipment are usual connected with three phases which are symmetrically used. Consumers in private houses are typical one phased, but all three phase are distributed to all houses, so that an averaging is given. Only for smaller power consumption a non balanced or unsymmetrical load may occur.

But the unsymmetrical load can be appear on faults. The grid should has a resilience for that.

For one phase faults it is important to regard, that the neutral connector which is the star point of a transformer is usual only available on the lower voltage sides, on end consumer. For distribution usual the transformers are used in delta-connection with only 3 connectors. Also the converter (for this model) has a delta transformer winding on its converter side.

If a one phase fault occur one of the delta winding are feed with the necessary current. The one phase fault results in a negative sequence current on side of the converter and also on side of the distribution grid.

For the example model the cell voltage has a neutral connector, the transformers to the converter and to the outer grid are switched to star winding. The converter and the outer grid itself has a delta winding connection.

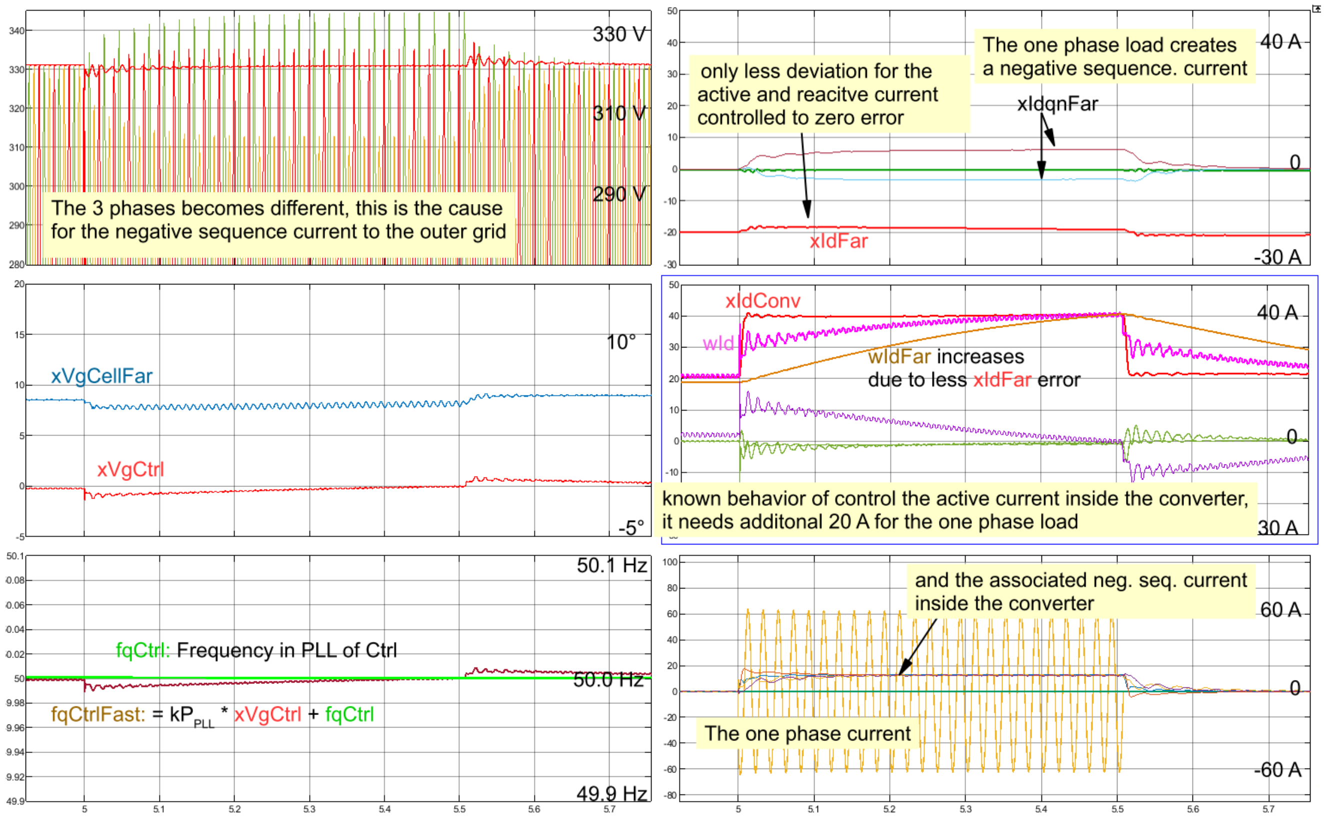

Figure 11: wiFar20_TNloadTN60A-5.png

The image Figure 11: wiFar20_TNloadTN60A-5.png shows a one phase fault or load. The outer grid is fed back with 20 A as in the example before. The one phase fault forces differences in the three phase voltages as shown in left top diagram. The load is high, and a voltage difference of 20 V is admissible in such a situation. It depends on controlling parameter.

The one phase load needs ~ 20 A as active current for the 60 A for the one phase. This is fed by the converter additional, the control of the outer grid current and before the angle deviation forces the necessary reference value for wIdq inside the converter.

The outer grid is driven with also less negative sequence currents (phase differences). But this is only caused by the voltage phase differences. It is not able to control it to zero. But because the outer grid is connected with a higher impedance, the current is some more lesser than inside the grid cell.

A two phase load or fault is similar in the behavior.

For this situation it is interesting what's happen if the outer grid is not connected (island situation) or if the current to the outer grid is not controlled. For the last case after a time the grid cell gets its current form outer for the whole active load for three phases because nobody changes the reference value for the active current of the powerbank converter. The frequency is relative stable because of the outer grid connection. But because of local angle deviation it needs a time. This is shown on the next diagrams:

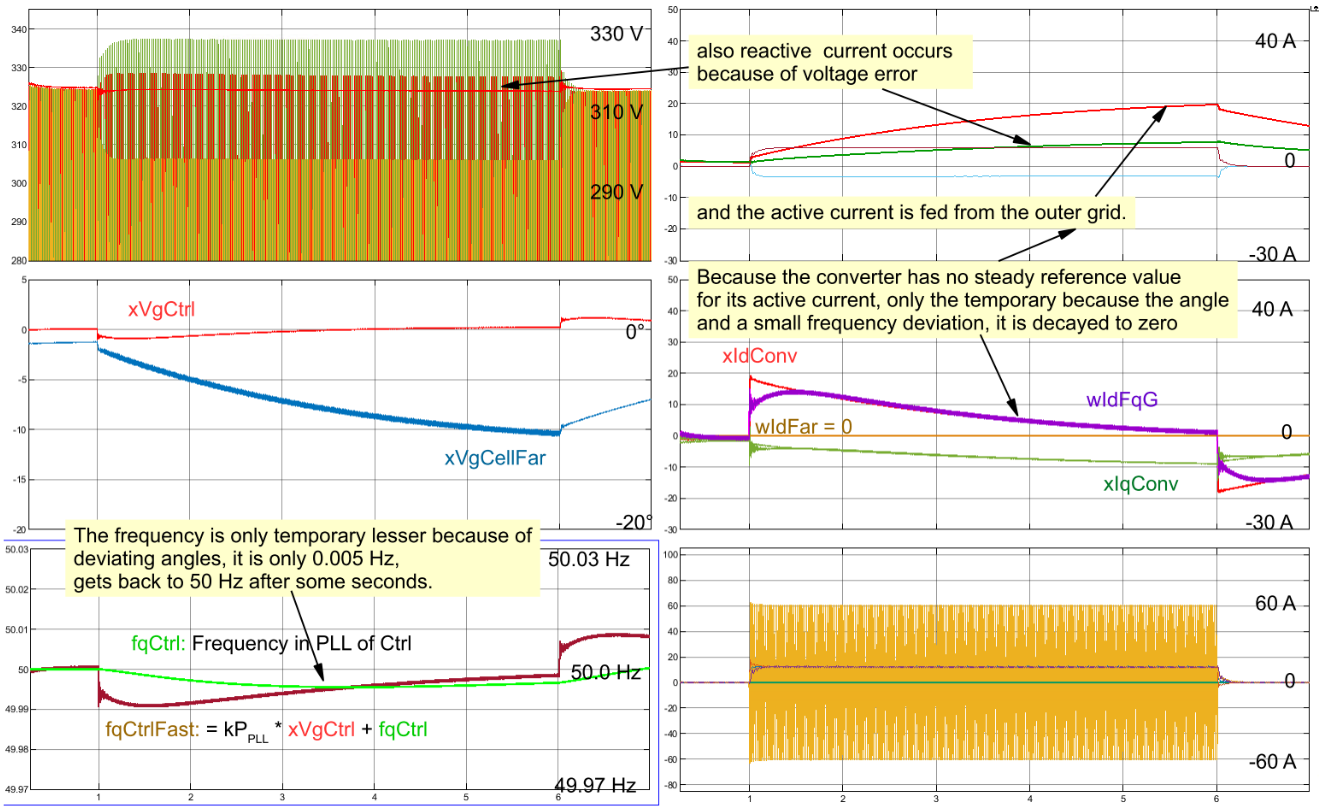

Figure 12: wIfarOff_TNloadTN60A-1-6.png

As you see, in the first seconds of fault, the converter feeds the grid cell due to the behavior of the deviating local angle as described in 3.1 Behavior of current and reference values in the first second page 10. But after a time where the local angle deviation in the PLL of the controller goes back to zero, the whole active power is gotten from the outer grid. That is usual not recommended, but the outer grid current control is switched off here.

You see also a frequency deviation. But this is less (0.005 Hz) and only temporary due to the shifting angle **xVgCellFar** between the cell voltage and the outer grid voltage.

4.3 One phase load or fault in island situation

The problematic is similar as a load step in island situation, so both can be seen here. The behavior of the converter control is discussed more elaborately.

TODO... 2023-06-29