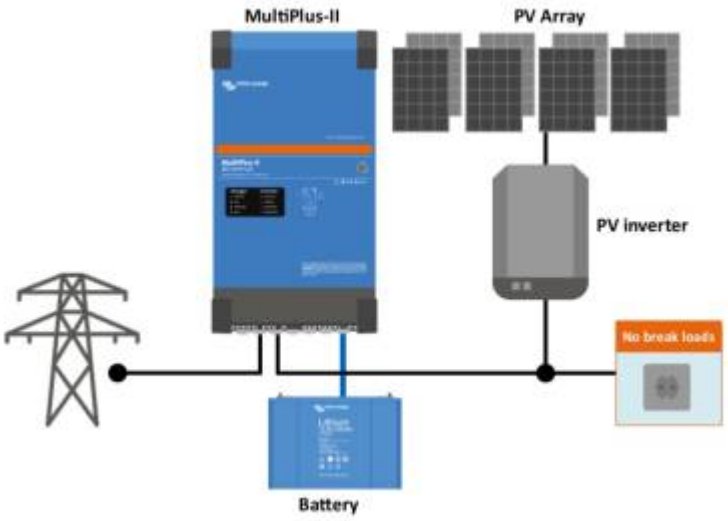
AC-coupling and the Factor 1.0 rule

1. Introduction to the AC-Coupling concept

Already familiar with the concepts of AC-coupling and regulating PV inverter output power by frequency shifting? Skip to the requirements and limitations:

1. Factor 1.0 rule chapter
2. Minimum battery capacity chapter
3. Requirement of adding DC-Coupling (MPPT Solar Chargers)

1.1 What is AC-coupling?



In an AC-coupled system, a grid-tied PV inverter is connected to the output of a Multi, Inverter or Quattro. PV power is first used to power the loads, then to charge the battery, and any excess PV power can be fed back to the grid.

When the Multi or Quattro is connected to the grid, this excess PV inverter power will automatically be fed back to the grid.

When the Multi or Quattro is operating in inverter-mode, disconnected from its AC input, it will create a local grid: a micro-grid. The PV Inverter will accept this micro-grid and will therefore operate even during a black-out. The PV power can even be used to charge the batteries: when there is more PV power available than used by the loads, the power will automatically run through the inverter in reverse direction and charge the batteries. It is necessary to regulate that power to prevent overcharging the batteries as well as overloading the inverter/charger. This is where 'frequency shifting' comes in to the picture, see next section.

Highlights:

- AC-coupling is available in single-phase, split-phase and also three-phase systems.
- Victron Multis and Quattros can prevent feeding back PV power to grid.

- Systems with only a grid-tied PV inverter will fail when there is a grid black-out. A micro-grid system will continue to operate, and even keep using solar power.
- It is also possible to run a AC-coupled micro-grid on a generator
- Most brands of PV inverters can be used for these systems, they need to be setup to support frequency shifting, often called the island-mode or micro-grid mode. For SolarEdge settings, see Integrating with SolarEdge, for Fronius settings, see AC-coupled PV with Fronius PV Inverters & for reading and controling ABB/Fimer inverters, see AC-coupled PV with ABB/Fimer PV Inverters.
- To read out SMA inverters, see AC-coupled PV with SMA PV Inverters.
- If power will be fed back into the grid an anti-islanding device may have to be added to the system, depending on local regulations.

1.2 What is frequency shifting?

Frequency shifting is used to regulate the output power of a Grid-tie PV Inverter, or Grid-tie Wind inverter, by changing the frequency of the AC. The MultiPlus (or Quattro) will automatically control the frequency to prevent over charging the battery. See also the chapter 'Example & background'.

For how to configure, see chapter 4.

2. The Factor 1.0 rule

The max PV power must be equal to or less than the continuous output power at 25 °C of the inverter/charger

2.1 Rule definition

In both grid-connected and off-grid systems with PV inverters installed on the output of a Multi, Inverter or Quattro, there is a maximum of PV power that can be installed. That maximum is the continuous output power of the inverter/charger at 25 °C, as stated in its datasheet.

A MultiPlus-II 48/3000 is rated 2400 W continuous at 25 °C, so the maximum is 2400 Wp of installed solar power. A Quattro 48/8000 is rated 6400 W, so the maximum is 6400 Wp. For paralleled units, add the continuous ratings of the individual units.

2.2 Example and background

To understand the background, consider the following situation: the PV inverter is at full power, supplying a big load. The Multi is in inverter mode. Then, suddenly and at once, this load is switched off. At that moment the PV inverter will continue operating at full power until the AC frequency has been increased. Increasing this frequency will take a very short time, but during that time all power will be directed into the batteries as there is no other place for it to go. This causes the following:

- When batteries are (nearly) full, the battery voltage will spike, possibly causing the Multi to switch off in DC over-voltage alarm.
- The same spike will cause the AC output voltage of the Multi to spike, as these two are directly related, and when the spike on the battery voltage is high and fast enough, the Multi can never

regulate its PWMs down fast enough to prevent the spike on AC. This spike can damage the PV inverter, the Multi and also any connected loads and other equipment.
- Another problem is that the Multi starts charge current protection.
- In the best case it might switch the grid inverter off immediately by setting the AC frequency to the disconnect frequency as configured in the assistant.

It is no problem to overpower the grid inverter by installing more solar panels. Some people do this to increase the generated solar power in winter time or rainy weather. Refer to the PV Inverter datasheet to maximum allowed installed PV power. Two times the inverter nameplate rating or even more is not uncommon!

2.3 Charge current limit

A question frequently asked is how PV power up to the full continuous output rating can be allowed, since the charger inside a 3000 VA Multi is not 2400 W but closer to 2000 W? The explanation lies in the fact that it will regulate. In other words: when there is too much power coming in, causing the charge current to exceed the limit, it will increase the output frequency again and will keep regulating the AC output frequency to charge with the limit.

An example, MultiPlus-II 48/3000, with 2400 W of solar power coming out of a PV inverter:

1. When the Multi is connected to the grid, all 2400 W can be fed back to the grid through the Multi, no problem.
2. In case the Multi is not connected to the grid, the 2400 Wp is more than the charger in a Multi 3000 VA can handle. The charger is around 2000 W. Therefore the grid inverter assistant will automatically increase the frequency to reduce the output of the grid inverter, to match maximum charge current.

2.4 Should you look at the total PV array, or the PV inverter rating?

The mentioned 2400 Wp and 6400 Wp is the Watt-peak which can be expected from the solar system. So for an oversized PV array, where the total Watt-peak installed PV panels exceeds the power of the PV Inverter, you take the Wp from the inverter. For example 7000 Wp of solar panels installed, with an 6000 Watt PV grid inverter, the figure to be used in the calculations is 6000 Wp.

And for an undersized PV array, where the total Wp of installed PV panels is less than the installed PV grid inverter, you use the Wp from the PV panels in your calculation.

3. Minimum battery capacity

Besides the relation between installed PV Power and the continuous output power of the inverter/charger, it is also important to have a sufficiently sized battery. The minimum battery capacity depends on the type of battery, lead or lithium.

Note that, besides the minimum battery capacity, the mentioned sizes are often also the most economical battery size. In case used for self-consumption purposes that is. In case the goal is to increase autonomy, of course installing a large battery increases the system autonomy in case of a

grid failure.

3.1 Lead batteries

1 kWp installed PV power requires approximately 5kWh of lead acid battery:

- 100 Ah at 48 Vdc
- 200 Ah at 24 Vdc
- 400 Ah at 12 Vdc

Each additional 1 kWp of AC PV will require an additional proportional 5 kWh increase in lead acid battery storage.

3.2 Lithium batteries

1,5 kWp installed AC PV power requires 4.8 kWh of battery storage:

- 100 Ah at 48 Vdc
- 200 Ah at 24 Vdc
- 400 Ah at 12 Vdc

Each additional 1.5 kWp of AC PV will require an additional proportional 4.8 kWh increase in battery storage.

4 Requirement of adding DC-Coupling - MPPT Solar Chargers

Not required for Energy Storage Systems in Germany or other reliable grid situations.

Required for offgrid systems as well as backup systems that need to overcome extended grid failures.

Reason: recover from deadlock situation of AC-Coupling only situation.

There is no Factor 1.0 limit that applies for DC coupled PV through a Victron MPPT. Nor is there a specific minimum amount of battery storage capacity, though please follow battery manufacture specifications for maximum charge rates. A rule of thumb is C10 (10% of Ah capacity in A) for lead acid batteries, and C2 (50% of Ah capacity in A) for lithium batteries.

5 Software configuration

Multis and Quattros with factory settings will not shift the AC output frequency to regulate charge current. When setting up an AC Coupled system, install either the ESS Assistant (for grid-connected systems) or the PV Inverter Support Assistant (for off-grid systems).

The Inverter RS will automatically shift frequency without any additional configuration required when a surplus/back-feed of AC is detected on the AC-output.

Other options, all deprecated, are:

1. Self-consumption Hub-2 v3 assistant
2. Hub-4 Assistant in combination with the PV Inverter support Assistant
3. Use the Inverter period time settings on the Virtual switch tab.

Monitoring

See Connecing a PV inverter section of the GX manual.

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