



ESIG Spring Workshop 2021

Session 3: Grid Forming Inverter Research Landscape

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GFM – new?

- ~ Inverters with Grid-forming capabilities (GFM) are available on the market
- ~ Technically possible, typically bound to BESS

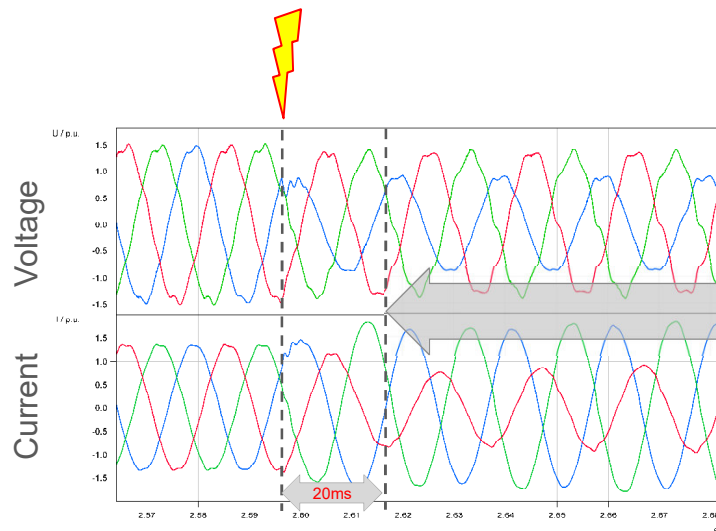


But

- ~ PV- and wind-turbines with GFM are not available on the market
- ~ On purpose, reasons:
 - ~ It is not required, nor is it paid for
 - ~ It is incompatible to MPP tracking
 - ~ It is incompatible with today's grid codes (anti islanding, FRT)
 - ~ Implementing it costs significant money (R&D, CAPEX, OPEX)

GFM – GFL – what's the difference?

- ~ In the very short term performance, prior to a Grid Following (GFL) inverter detecting the position of U-phasors from the external grid: state of the art: <1 cycle



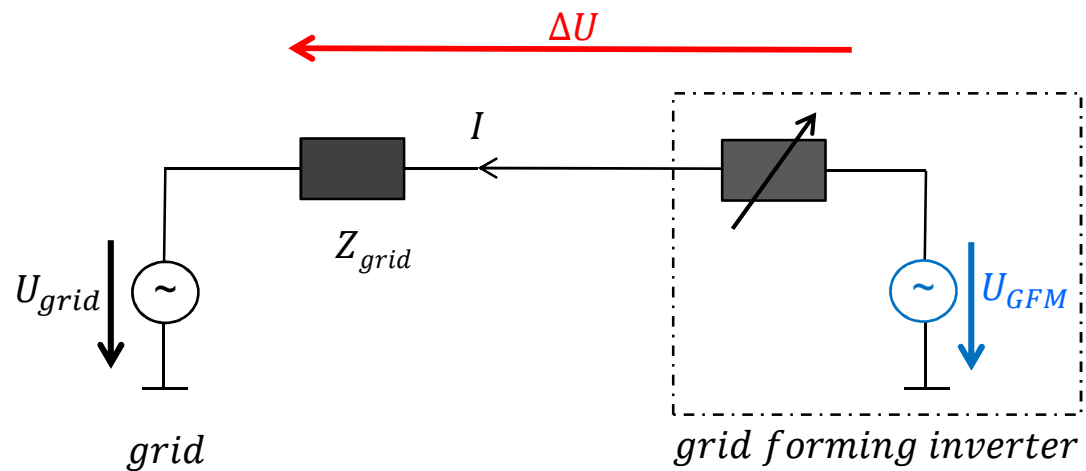
Grid Following inverter facing unsym. fault
Field measurement at LV terminals

Beyond that point in time GFM and GFL have

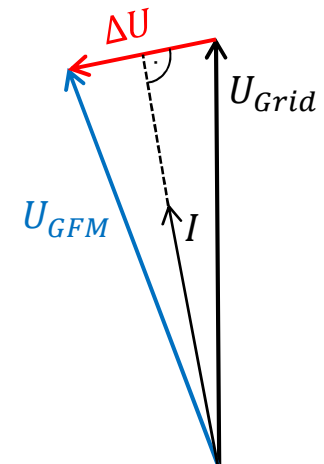
- ~ same physical limitations (current and power/energy)
- ~ same capabilities to implement a “power system supportive performance”

Question: Is this initial ~1st cycle the topic we need to fix to ensure power system stability at high IBR penetration?

Assume we have a GFM

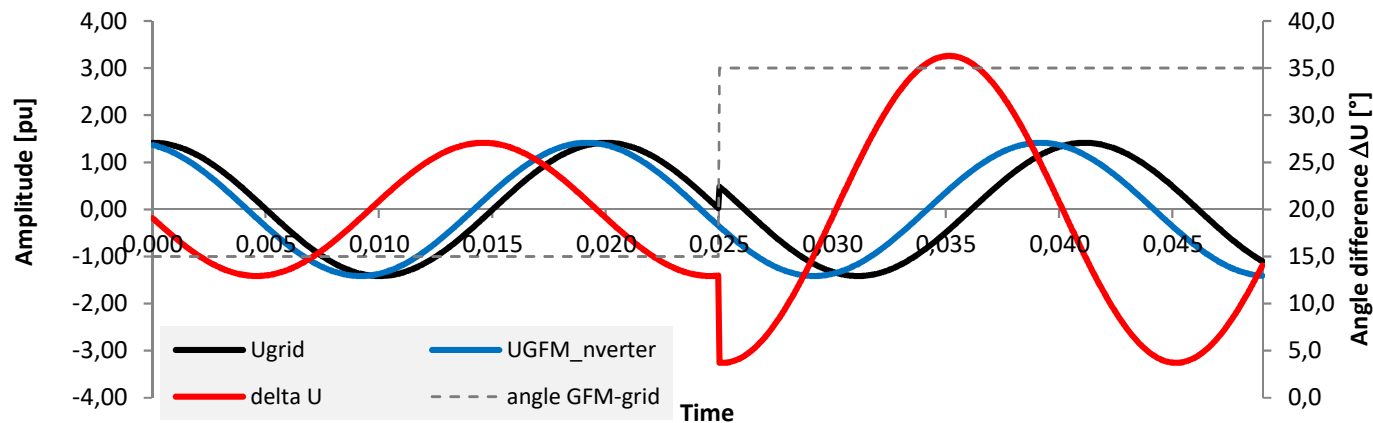
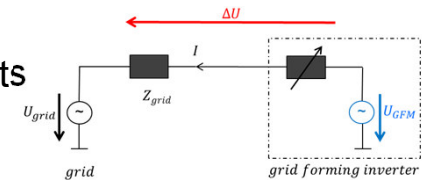


$$U_{GFM} = \Delta U + U_{Grid}$$



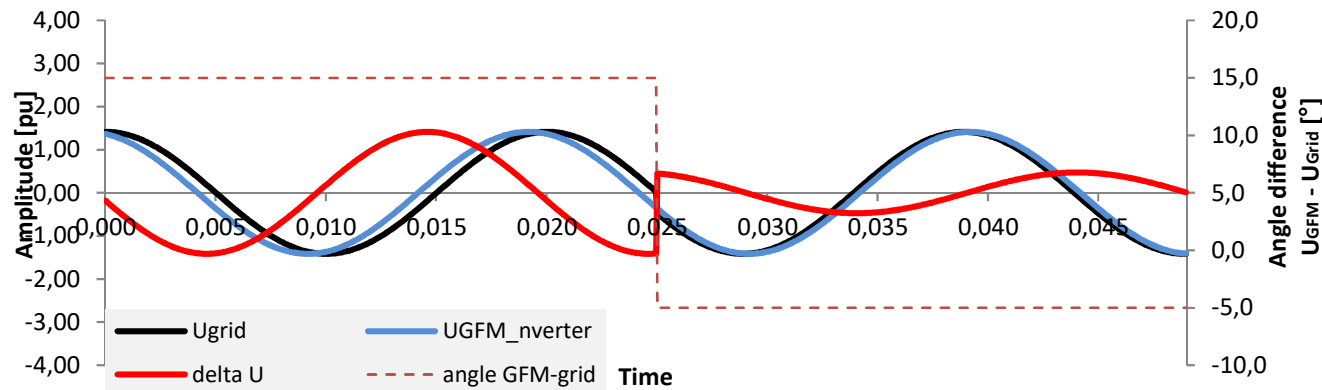
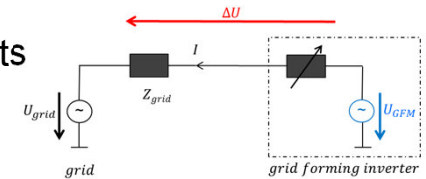
GFM and grid incidents

- ~ A GFM Inverter connected to the grid. No matter what is feeding the GFM
- ~ Initial situation: $f_{\text{GFM}} = f_{\text{grid}}$, $\Delta\varphi$ set to stable infeed, ΔU and resulting I within limits
- ~ Incident on the grid $\Rightarrow 20^\circ$ phase jump
- ~ Consequence:
 - ΔU step $\uparrow$ and I step $\uparrow$ potentially exceeding limits (depends on Z , I_{max} ...)
 - Power buffer available to maintain that operation for Δt ?
 - When & how to return to steady state?
- ~ In a WEC: Requires BESS/Supercap and/or WEC has to withstand severe mechanical stress



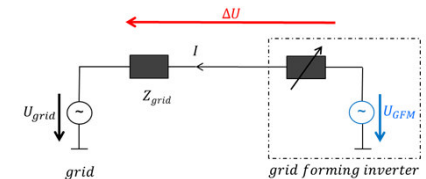
GFM and grid incidents

- ~ A GFM Inverter connected to the grid. No matter what is feeding the GFM
- ~ Initial situation: $f_{GFM} = f_{grid}$, $\Delta\varphi$ set to stable infeed, ΔU and resulting I within limits
- ~ Incident on the grid $\Rightarrow -20^\circ$ phase jump
- ~ Consequence:
 - ΔU step $\downarrow$
 - I step $\downarrow$
- ~ In a WEC: Chopper could be used



GFM and grid incidents

- ~ The challenge is not to build an inverter with GFM as such. The challenge is rather: “If it is a GFM, how shall the power system supportive performance look like in detail?”



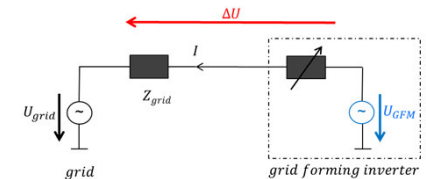
- ~ i) How much overcurrent capability?
- ~ ii) How much P_{buffer} resp. E_{buffer} ?
- ~ iii) How to limit current? (keep sinus shape of current or accept trapezoid cutting?)
- ~ iv) How to do best system-supportive transition from GFM to GFL (and back)
- ~ v) How to avoid unintentional islanding, as an IBR with GFM is perfect to keep any island stable?



If we need it, who should do the GFM job?

- ~ It is all about money:
 - ~ i) How much GFMs do we need in a power system?
And where?
 - ~ ii) Which players are most predestinated for GFM?
 - ~ iii) Which ones can do it at lowest overall cost?
 - ~ iv) How to organize this service lean and safe?

Most questions are “power system questions”.



Thank you

Making **BESS** with GFM?

Possible, with much less effort than PV or WEC



Making **PV** with GFM?

Possible, but with significant effort



Making **WECs** with GFM?

Possible, but with highest effort of all power electronics-options, due to mechanical impact

