Whiteboard Edition!

ESIG Spring Technical Workshop

Grid-Forming Definition

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Functional Definitions

(“borrowed” from upcoming P&E article)

Grid-Following: *Most inverter based resources currently in service rely on fast synchronization with the external grid (termed Grid-Following) in order to tightly control their active and reactive current outputs. If these inverters are unable to remain synchronized effectively during grid events or under challenging network conditions, they are unable to maintain controlled, stable output.*

What technology uses Grid-Following?

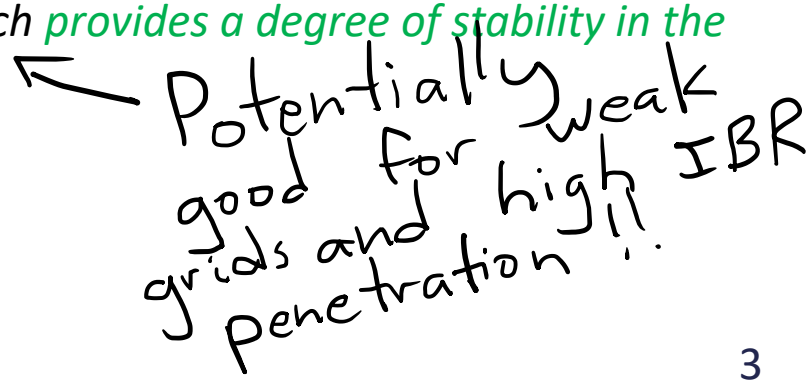
- *Current generation wind turbines*
- *Current generation transmission connected PV*
- *DER*
- *Most BESS applications*
- *LCC HVDC*
- *Most VSC HVDC*
- *Current generation STATCOMs and SVCs*

Functional Definitions

(“borrowed” from upcoming P&E article)

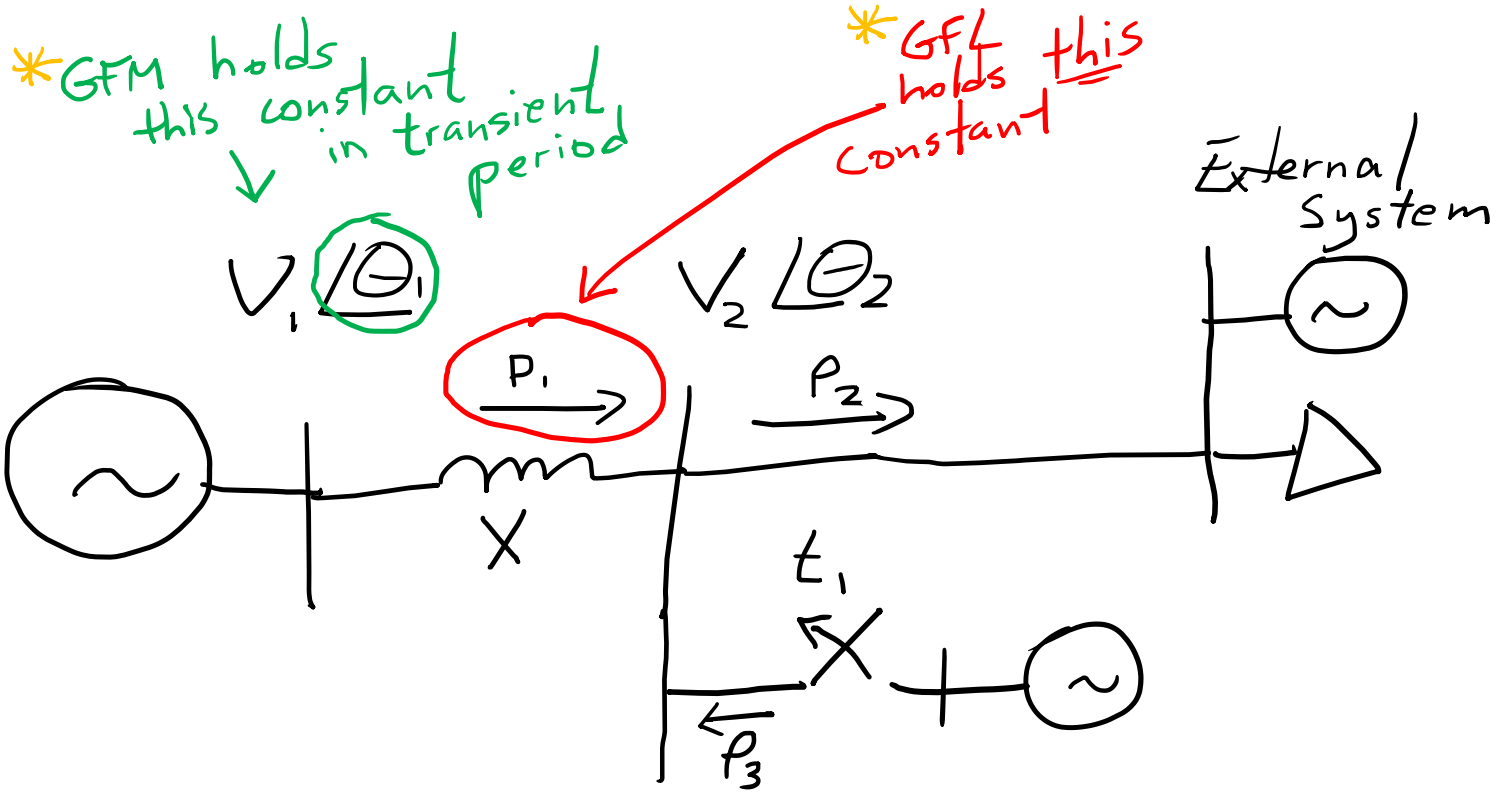
Grid-Forming: *Grid-Forming resources do not require very fast synchronism with the external grid to produce a predictable output. Instead of output currents being their primary control objective, they maintain control of an internal voltage phasor.*

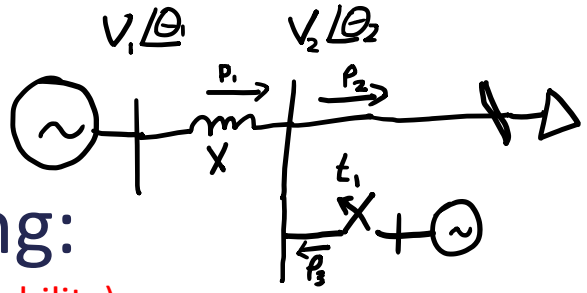
In some applications (eg. Black start or microgrid applications), this voltage phasor is held relatively constant, allowing the plant to operate in an island as the sole frequency determining element. In other applications (eg. bulk grid connected applications), the voltage phasor may be controlled to maintain synchronism with other elements and also control active and reactive currents. There are many ways to implement this type of control, but common to all of them is a constant voltage phasor in the sub-transient to transient time frame, which provides a degree of stability in the controls during challenging network conditions.



What does this look like on a whiteboard??

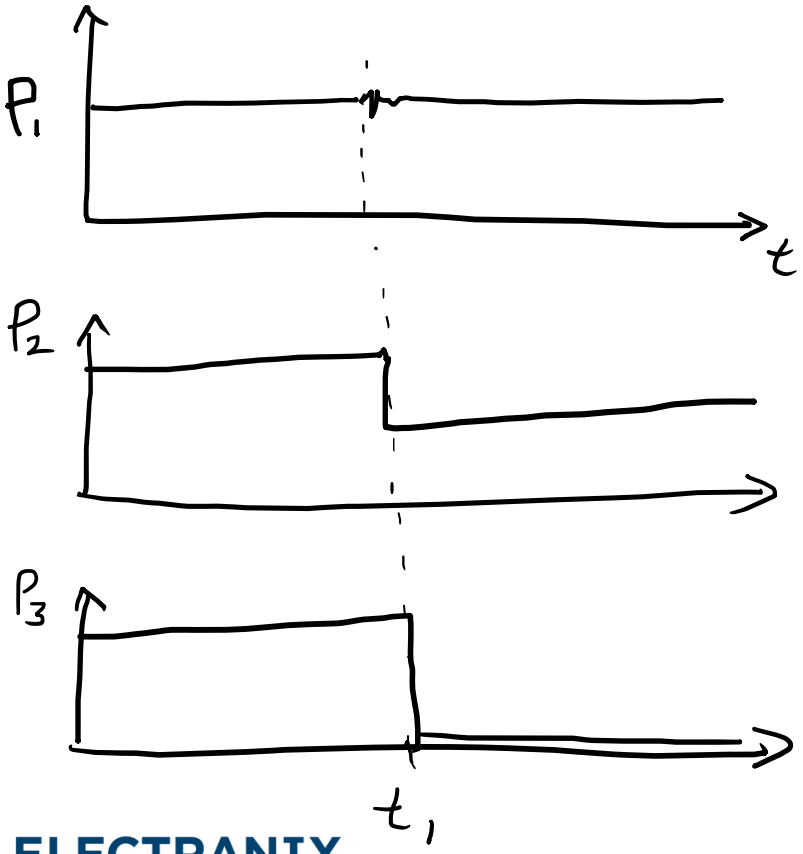
* (simplified to a level which will possibly enrage experts and is borderline inaccurate?)





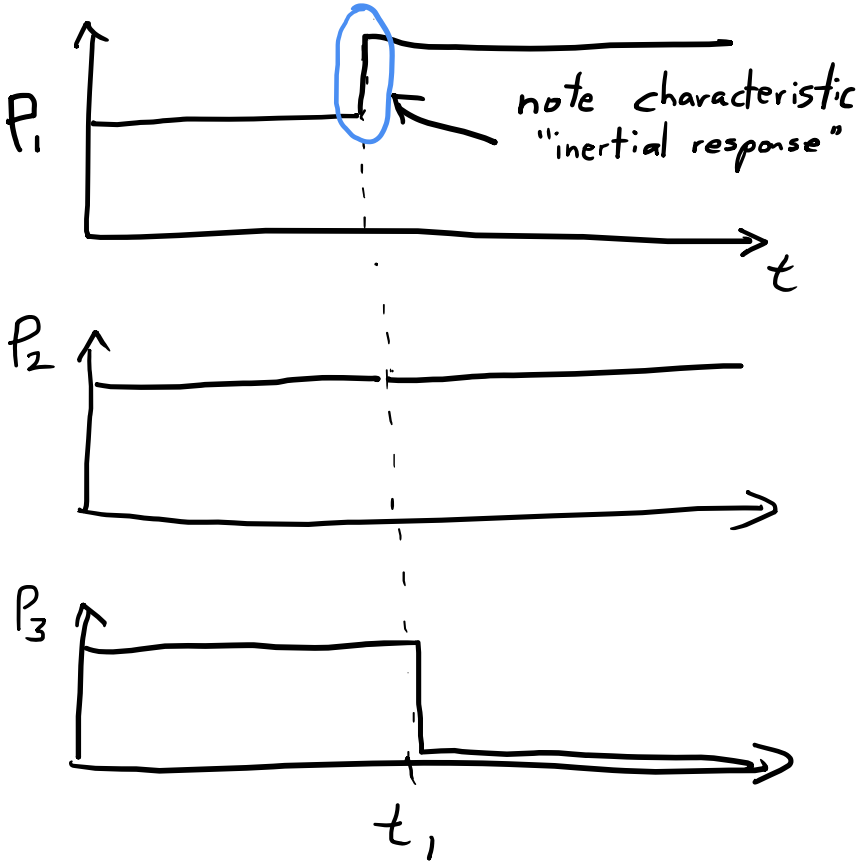
Grid-Following:

(Neglecting weak-grid instability)



Grid-Forming:

("Island" or Locked-Frequency Mode)



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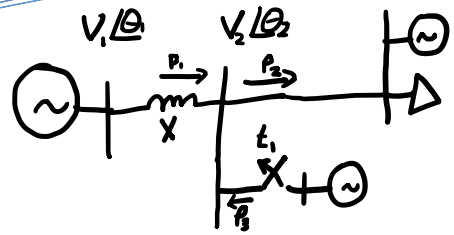
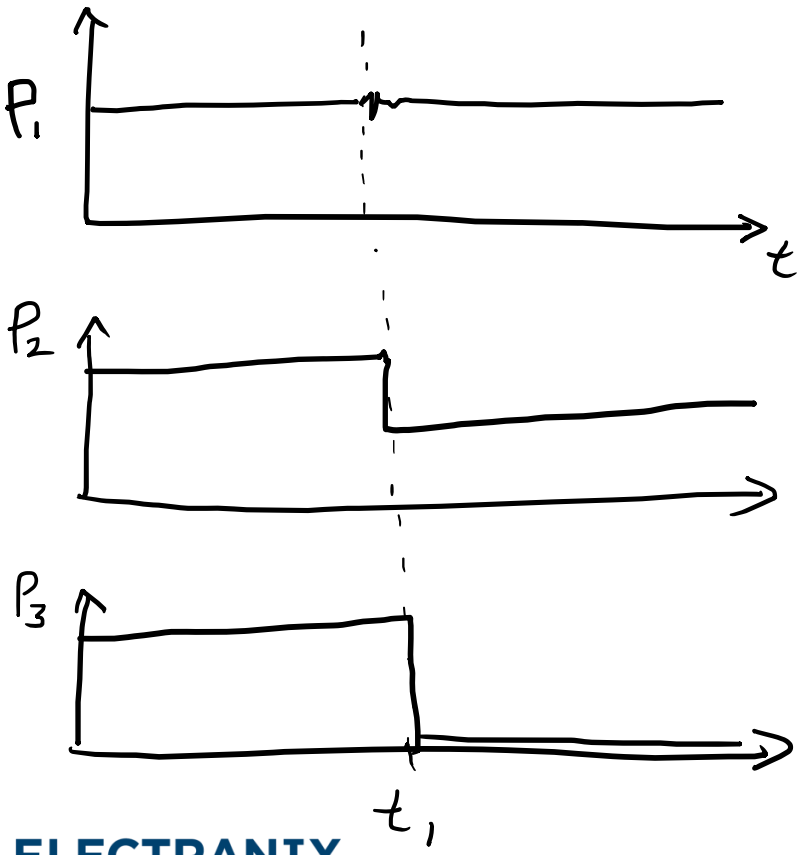


Adding power-control/grid-synchronization

Grid-Following:



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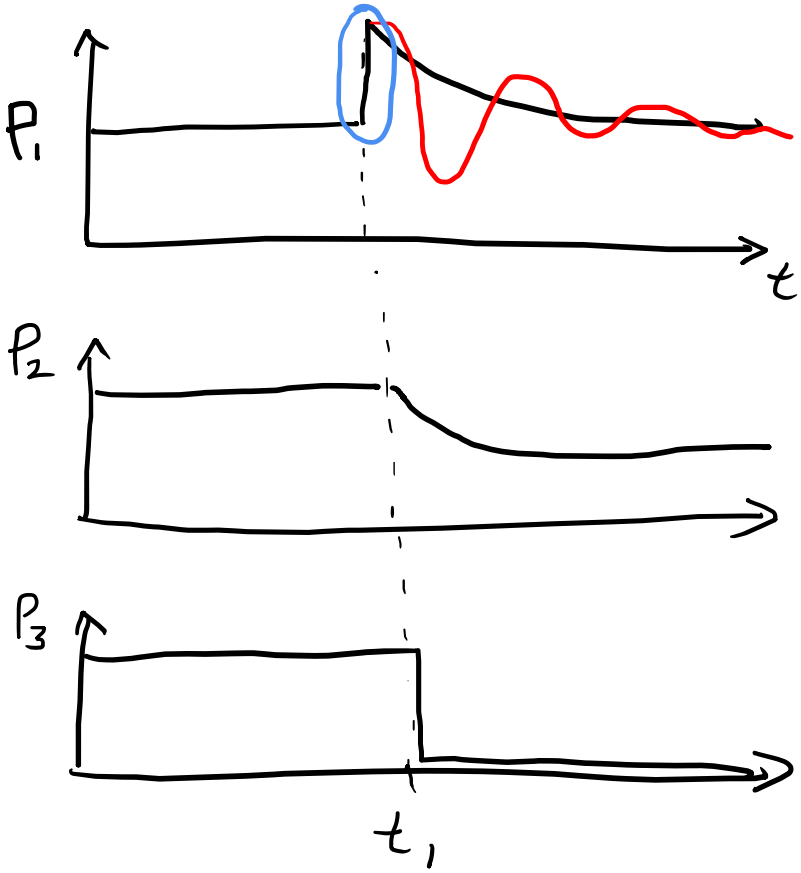

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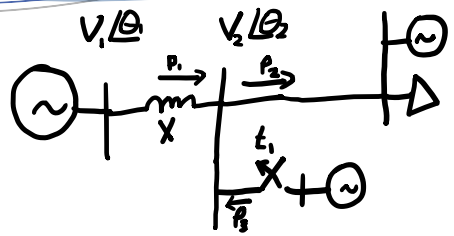
Adding Power Control/Grid Synchronization

Adding frequency-droop control



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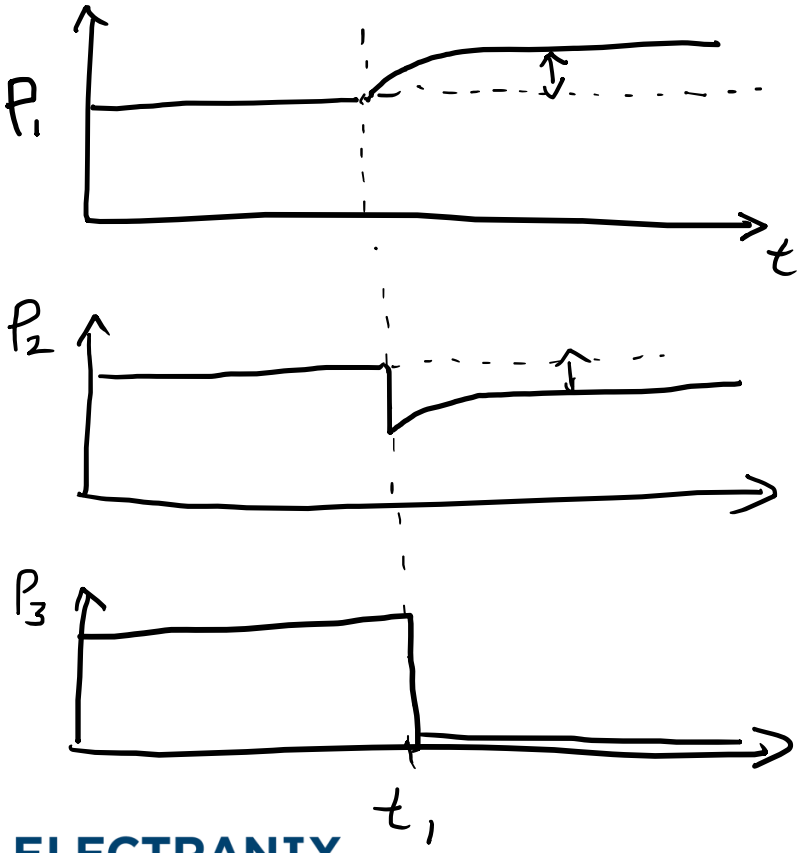

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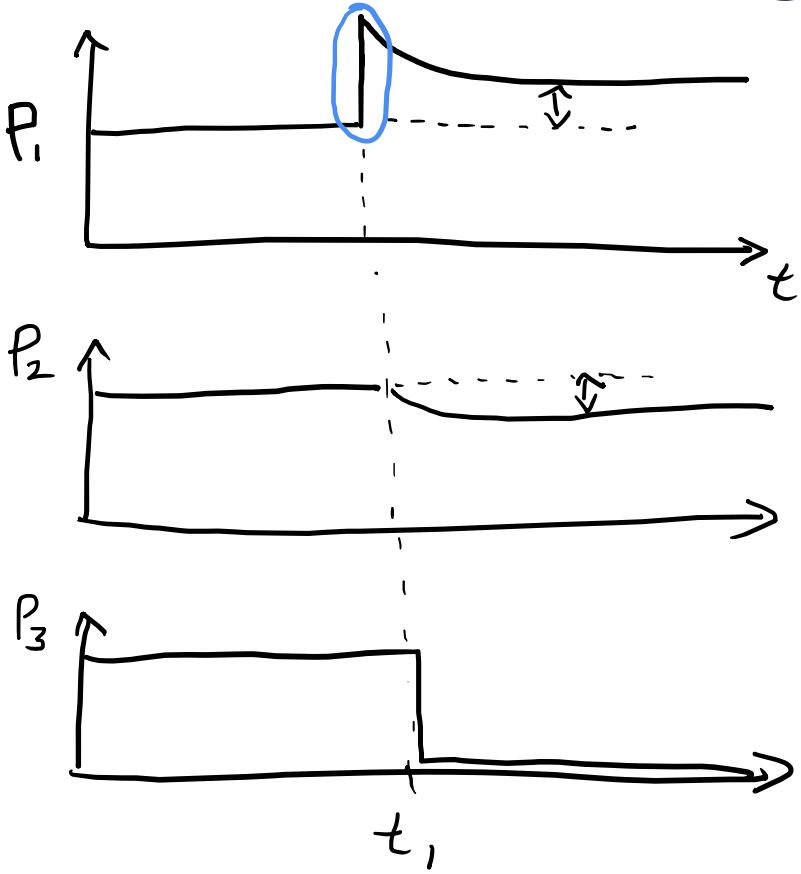

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So what does this *really* look like?

- Of course, as usual, *IT DEPENDS*.
  - Are you at an energy, current, or voltage limit in the IBR?
  - Are you at a power-flow or voltage limit in the system?
  - What else is around to interact with or oscillate against?
  - How will you handle faults and transitions between islands and grid-connected modes?
  - How good is the OEM at control design?
  - How do you implement the frequency control?

There are many variations of both grid-forming and grid-following converter controls, and both are subject to physical constraints, including voltage, current and energy limits, and external power system limits. Additionally, both are dependent upon careful control implementation to operate in a desired way.

Other terms for Grid-Forming :

- Island mode
- *Grid-firming mode* ⇒ Garth Irwin's term
- **Virtual synchronous machine mode**
- Black-start mode
- Microgrid mode
- Self-sync mode
- Voltage source mode or constant voltage mode
- **Delayed voltage synchronization (PLL) mode**
- Offshore wind VSC-HVDC rectifier mode

GFM… what's next?

- The technology exists, and works, so start building them! The question for every BESS should be: "Is this an application for GFM?"
- More work needed on the system level. Large studies needed to understand how to leverage the technology. These studies have a research element, and will take time to complete, so don't wait until there's a panic.
- We need to be very careful about introducing new modes of instability
- GFM applications for non-BESS/HVDC?

Mr. Grid F. Inverter Profile:
"I bring the magic!"

About me: Initially resistant to change but willing to consider an alternate perspective given some time. Sometimes prone to making mistakes in situations not previously encountered, but open to correction and improvement. Definitely in it for the long term.