Requirements for Control Strategies of Grid Connected Converters in the Future Power System

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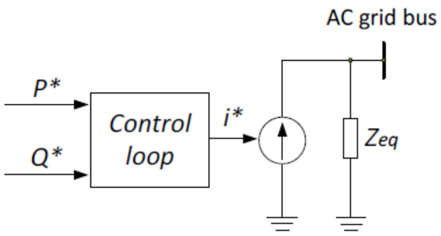
Highlights

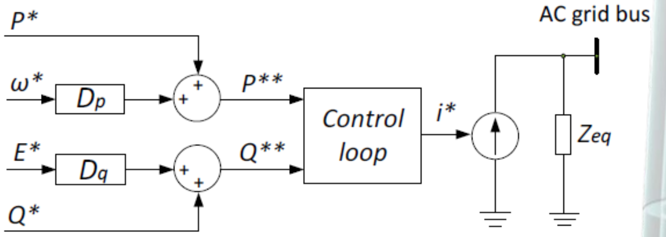
- Current grid-feeding converter-based generation has proven to run stably even in systems with very low inertia
- Grid-forming converters are still at an infant stage of development, examined mostly in isolation and predominantly through simulations
- Concrete evidence is required to define a needs-case for introducing any new technical requirement

Paradigm Shift in Power Systems

Grid-Feeding Concept

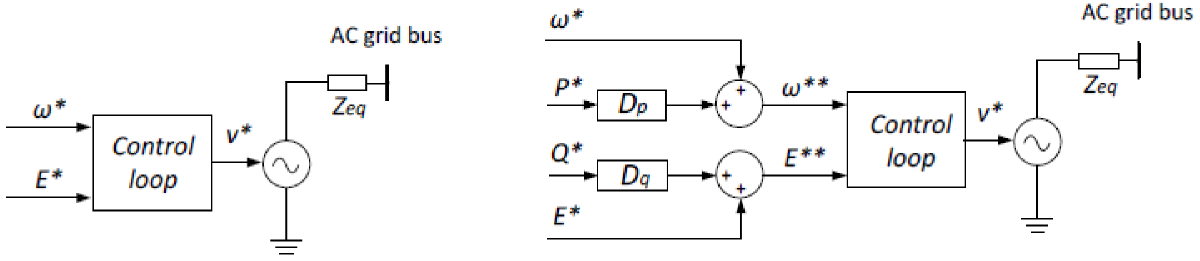
- Simplified scheme of a standard control structure of a grid-feeding converter





Grid-Forming Concept

- Simplified scheme of a standard control structure of a grid-forming converter



- Virtual Synchronous Machines[1]:
  - Behave as a controlled voltage source behind an impedance
  - Operate in extremely low fault levels, in islanded conditions
  - Be able to provide black-start capabilities
  - Synchronize to the grid without a dedicated unit

[1]A. J. Roscoe, M. Yu, A. Dysko, C. Booth, R. Ierna, J. Zhu, and H. Urdal, "A VSM (virtual synchronous machine) convertor control model suitable for RMS studies for resolving system operator/owner challenges," 15th Wind integration workshop (LSI), Vienna, 2016

Current Status

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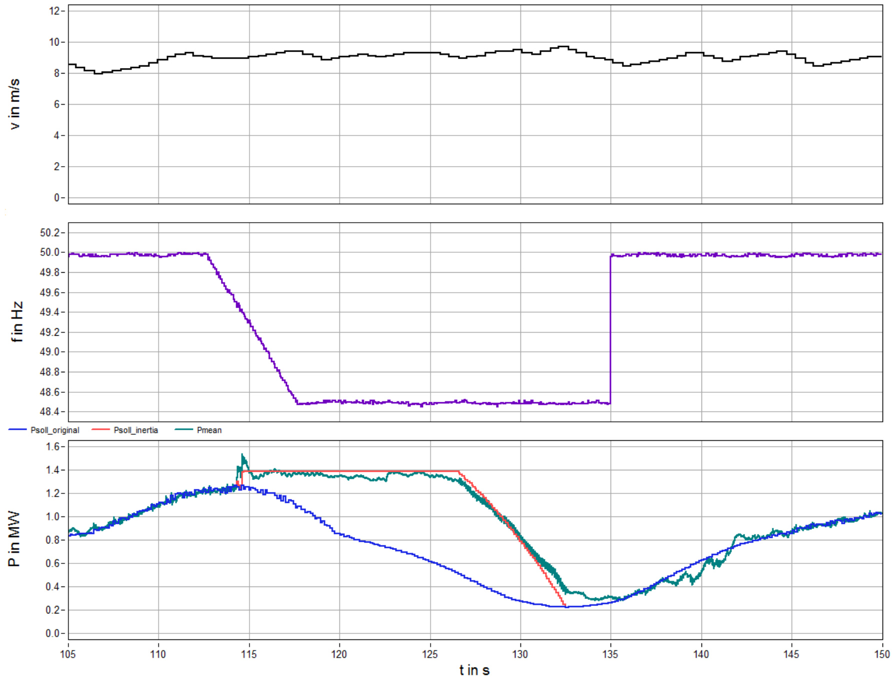
Inertia Emulation

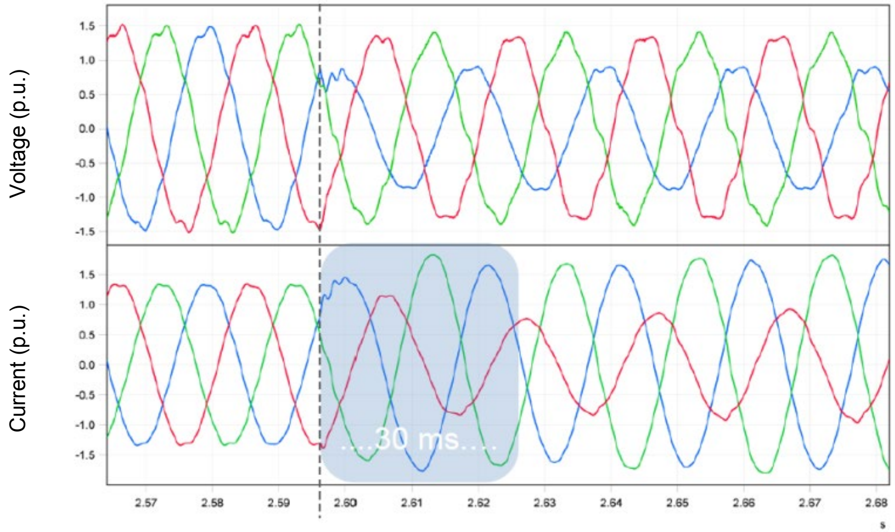
- Provides fast frequency control, helping to substitute inertial response of synchronous generators
- Extraction of kinetic energy stored in rotating mass
- Temporary increase of active power output by an adjustable percentage of nominal active power output
- Rise time of hundreds of ms
- Can be activated for e.g.10 – 15s



Has this capability been considered in the studies?

Fast Fault Current Injection

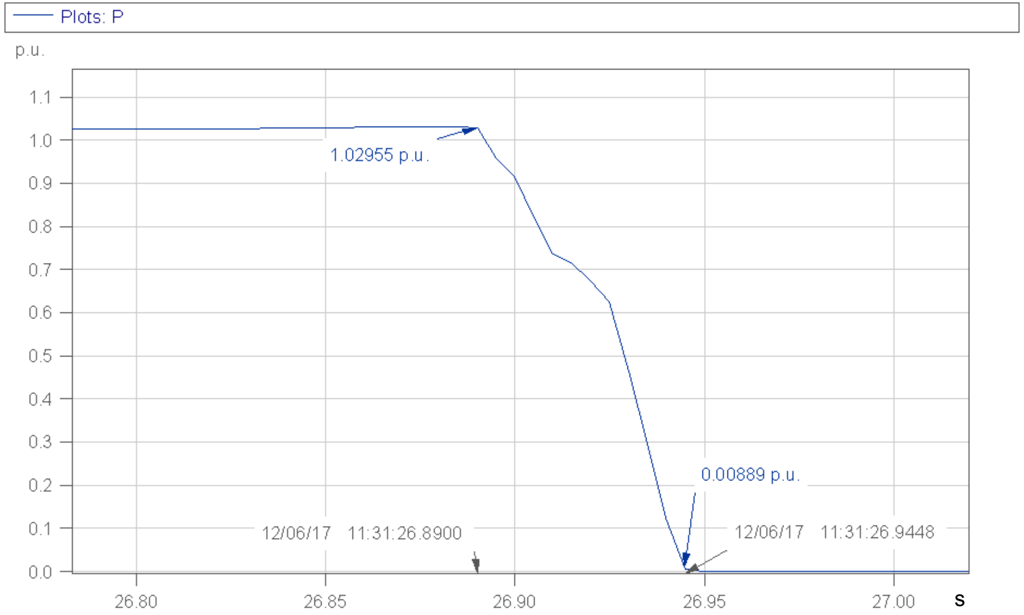
- Variety of Fault Ride Through modes available
- Rise time of the current: below 30ms
- Performance in line with the German VDE AR-N-4120 TAR Hochspannung
- Validated simulation models



What are the FFCI characteristics of “grid-feeding” converters assumed in the studies?

Rapid Downward Control

- Active power output can be reduced to 0 within less than 100ms
- Can prove useful in contingencies (e.g. system splits)



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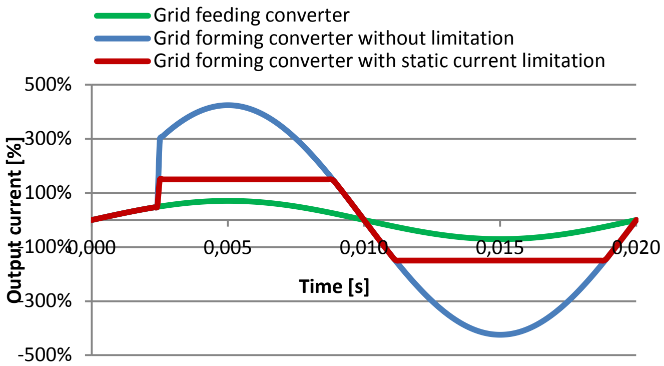
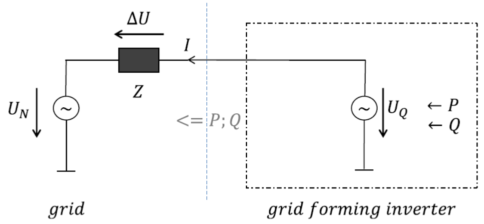
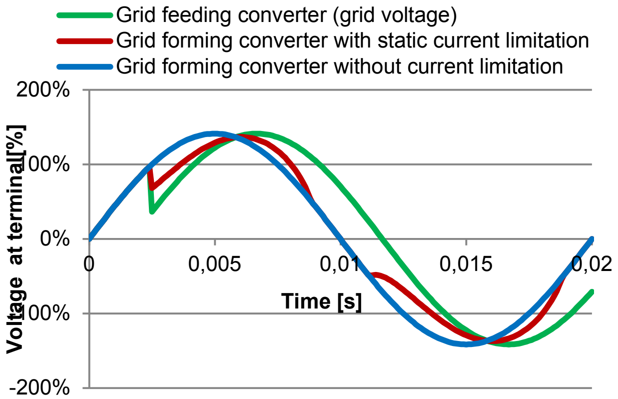
Impact on Transient Response

- The grid-feeding converter does not respond instantly, introducing a phase shift in voltage
- The unlimited grid-forming converter responds instantly without any phase shift
- The limited grid-forming converter responds instantly, but current is limited, distorting the voltage waveform



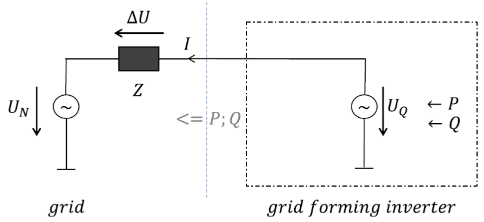




Equipment Oversizing

- Oversizing of the converter
- Possible oversizing of the mechanical system
- Addition of energy storage
- Changes in the WTG's internal design

Phase angle at rated power	Transient current at phase shift and operational point			
	15° P=0 %	15° P=100 %	30° P=0 %	30° P=100 %
5° (ΔU=10.2 % U_N)	266 %	351 %	523 %	606 %
15° (ΔU=27.2 % U_N)	100 %	196 %	196 %	289 %
30° (ΔU=53.3 % U_N)	51 %	150 %	100 %	192 %
45° (ΔU=78.6 % U_N)	35 %	130 %	68 %	159 %



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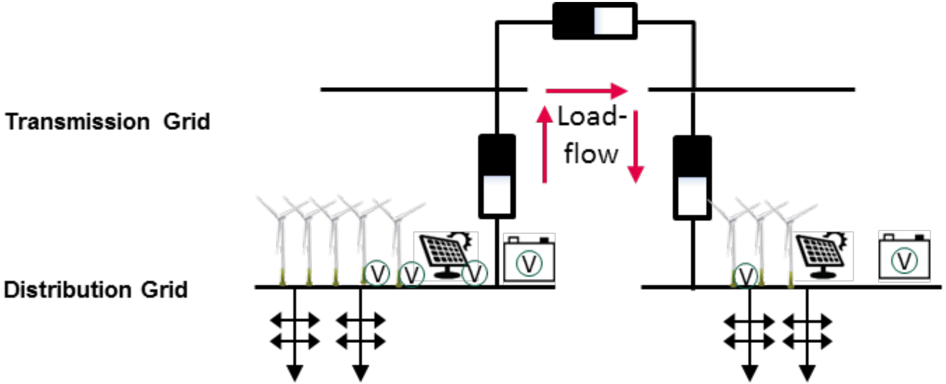
Risk of Unintentional Islanding

- Grid-forming converters will attempt to keep the voltage and frequency reference constant or stable
- Unintentional islanding might be the result
- Protection systems might need to be redesigned



Some Final Thoughts

- Studies should be run in **appropriate simulation platforms** that capture the very first ms of a **credible** event
- There **should be allowance for synchronous generators to become more flexible**
- **Financial aspects** need to be considered in parallel to the technical analysis of the performance of the future power system and its components

Some Final Thoughts

- Performance requirements should be **quantifiable**, **fully detailed**, **applicable at the point of connection** and **technology agnostic**
- We are **not opposed** to new technical requirements


Turn barriers
into
climbing walls