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

Current Status

Blessing
Curse
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?
State-of-the-art Electrical Performance of WPPs

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)

Has this capability been considered in the studies?
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

<table>
<thead>
<tr>
<th>Phase angle at rated power</th>
<th>Transient current at phase shift and operational point</th>
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<tbody>
<tr>
<td></td>
<td>15° P=0 %</td>
</tr>
<tr>
<td>5° (ΔU=10.2 % Uₙ)</td>
<td>266 %</td>
</tr>
<tr>
<td>15° (ΔU=27.2 % Uₙ)</td>
<td>100 %</td>
</tr>
<tr>
<td>30° (ΔU=53.3 % Uₙ)</td>
<td>51 %</td>
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<tr>
<td>45° (ΔU=78.6 % Uₙ)</td>
<td>35 %</td>
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Implications of Grid-Forming Converters

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