Testing Renewable Power Plants on High-Voltage-Ride-Through Capability

Grid Code Requirements and Testing Procedure

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FGH – Who we are

Customized solutions in electrical power engineering

Research & development
Power system analysis
Systems engineering
Smart grid systems
Training & education

FGH e.V.
Research

FGH GmbH
Engineering

FGH ZGmbH
Certification

Generating units
Generating plants
Components

Storage systems
Smart grid technologies

Software development
Engineering services
System analysis & studies
Grid integration
FRT test system design
Agenda

- Introduction and Motivation
- HVRT in Grid Codes
- Testing of HVRT Capability
- Experiences from Testing
- Conclusion
Introduction

Current Situation of Fault-Ride-Through

- LVRT capability mandatory requirement for Power Generating Units (PGU) in grid codes
  - Disconnection threatens grid stability
- LVRT testing equipment and procedures have been developed by FGH already in 2003
  - Standardized more than 10 years ago and incorporated in IEC 61400-21
- Today new challenges with further penetration of dispersed power generators
  - Temporary overvoltage in high voltage systems
  - New grid code developments and requirements
  - 2015 in Germany: VDE-AR-N 4120 (110 kV)
Motivation

Relevance of Overvoltage and HVRT

- Overvoltage due to
  - Line capacities combined with load shedding or generation tripping
  - Voltage recovery after fault clearance

- Difference in terms of
  - Time duration (ms...min)
  - Location and propagation

- Example: Incident in Germany in 2012
  - Capacitive voltage boost after 2ph fault with loss of 1.7 GW

→ HVRT capability reduces risk of generation tripping
HVRT in Grid Codes

First requirements can be found

- Result of such incidents:
  - HVRT capability required in recent grid codes (evolution similar to LVRT)
- In focus: VDE-AR-N 4120 specifies dynamic system support of PGUs with LVRT and HVRT capability
  - Up to 130% $U_n$ for 100 ms and 125% $U_n$ until 60 s
  - HVRT capability
- Reactive current injection
  - Grid support -> under-excited
- HVRT also in IT, RSA, AUS, CA
- Discussed and proposed also in USA, DK and India (!)

Source: VDE 4120
HVRT in Grid Codes

HVRT Requirement also in Indian Grid Code Draft

- Central Electricity Authority (CEA) introduced LVRT in connection standards for wind power plants in 2013
  - Wind turbines commissioned after 15/04/2014 must be LVRT compliant
  - Compliance shall be tested and verified by a third party (part of type certification)
- CEA amendments to clarify grid codes for connectivity of wind turbines
  - Latest draft includes HVRT requirement for wind and solar power plants

### TABLE I. CEA HVRT Proposal

<table>
<thead>
<tr>
<th>Overvoltage (p.u.)</th>
<th>Minimum time to remain connected (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.3 &lt; U ≤ 1.4</td>
<td>1</td>
</tr>
<tr>
<td>1.1 &lt; U ≤ 1.3</td>
<td>3</td>
</tr>
<tr>
<td>1.1 or below</td>
<td>Continuous</td>
</tr>
</tbody>
</table>

Source: CEA draft
Testing of HVRT Capability

Equipment design

- FGH development similar to LVRT setup
- Overvoltage with capacitive charging (Ferranti effect)
- Configuration according to grid effects
- Setup in accordance with IEC 61400-21 Ed. 3
- Modular layout, scalable and flexible
- Max. design: 170% $U_n$, 36 kV 8 MVA
Testing of HVRT Capability

Test System

- Examples of the test system layout

Pilot Testing in 2012

Commercial full-scale
Experiences in HVRT Testing

Pilot Projects

- Example: Testing of ENERCON WT with HVRT prototype testlab
- >100 tests, up to 140% $U_n$
  - Modified switching sequence to reach rectangular voltage shape, lower overshooting and transients
  - Saturation effects of transformer cause distorted and limited secondary voltage (max. 124% $U_n$)
  - Electrical design of the test circuit very crucial to avoid resonances or influences in ripple control
- Several test system successfully in operation in certification projects
Experiences in HVRT Testing

Grid Code Compliance

- Behavior of wind turbine according to requirements
  - no disconnection
  - voltage distortion without influence
  - adequate underexcited reactive current
Conclusion

- HVRT is crucial capability and subject to grid codes
  - Justification due to high decentralization or system characteristics (➔ India!)
- Compliance testing and verification is needed
  - Not only to turbines but only based on simulation for farms
- HVRT test systems and procedure available and successful in performance
  - Capacitive overvoltage based on real grid effects
  - Appropriate setup design important to prevent grid repercussion
- Grid codes and testing guidelines shall take saturation effects of transformers into account
  - Max. overvoltage, time duration, fault types
- Wind turbine investigation in terms of control strategies needed
Thank you for your attention!

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