Reliable Grid Integration of Wind Power Plants

Grid Code Compliance and Lessons Learned

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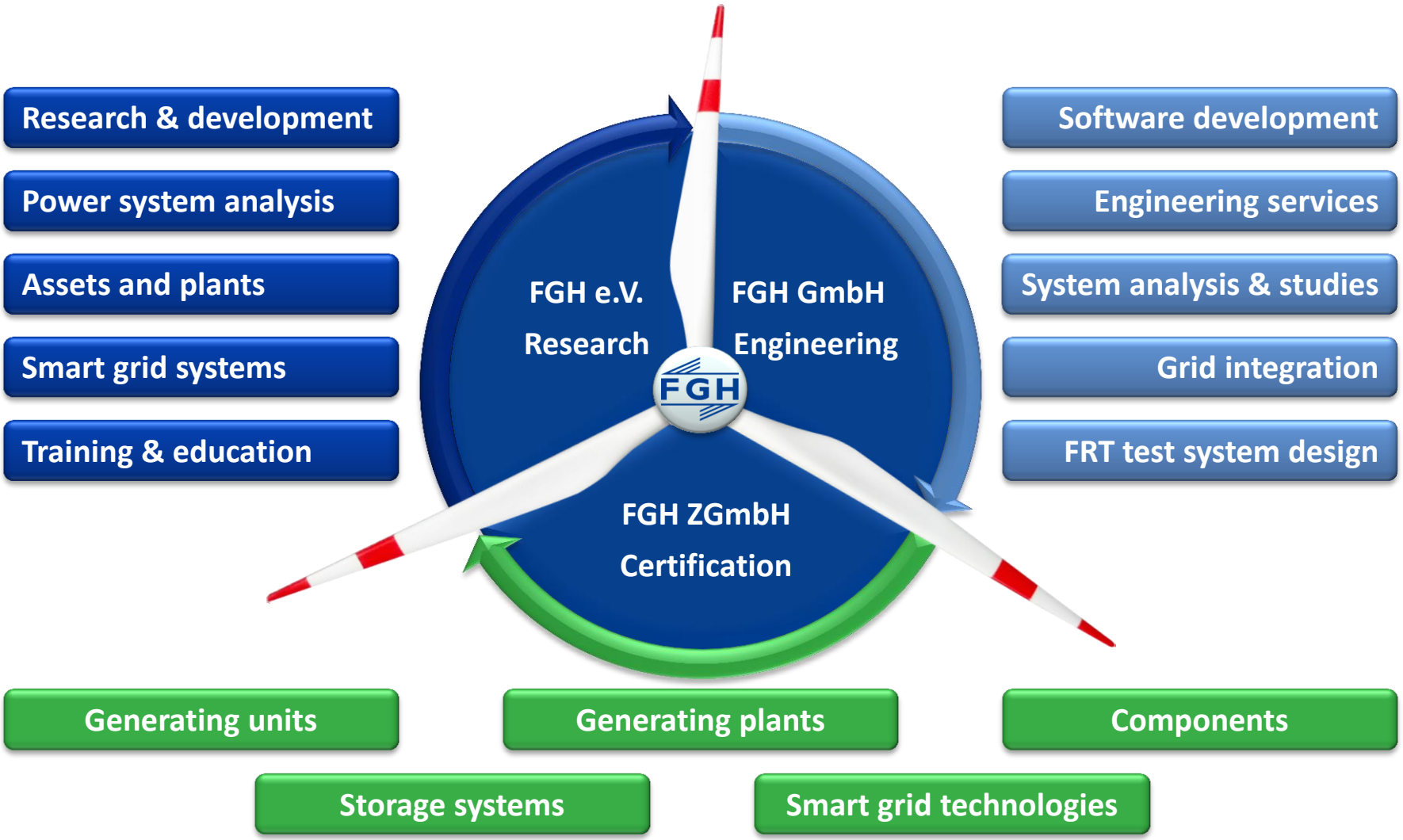
FGH at a glance

3 key partner for customized solutions in electrical power engineering



Agenda

Grid Code Compliance of Wind Power Plants

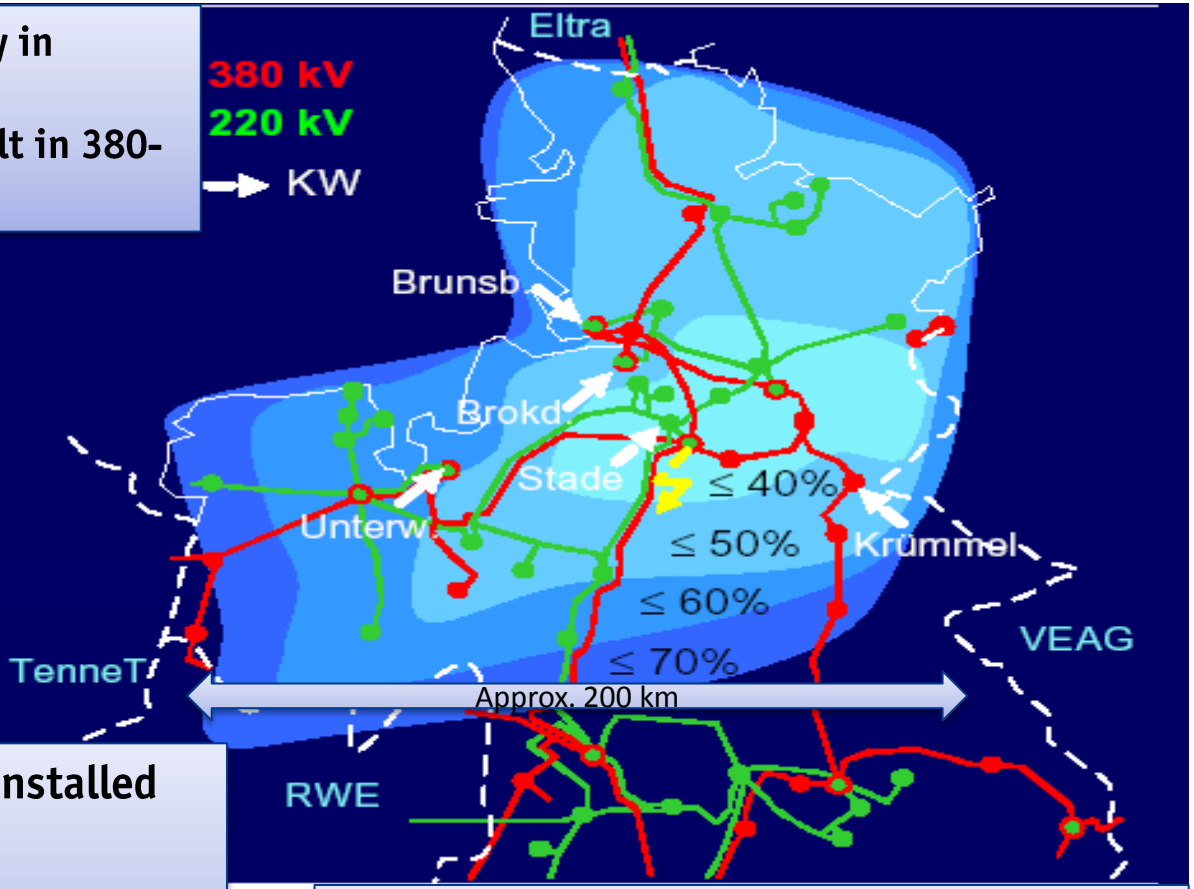
- **Background and Motivation**
- Status Quo in Turkey
- Compliance Process
- Lessons Learned
- Outlook

Background

Essential ancillary services at significant wind power penetration

Study in 2001 on system stability in Northern-Germany:
Voltage dip during a 3-phase-fault in 380-kV substation

U_{Rest}	P_{WEA}
≤ 40% U_n	170 MW
≤ 50% U_n	1130 MW
≤ 60% U_n	2160 MW
≤ 70% U_n	2700 MW



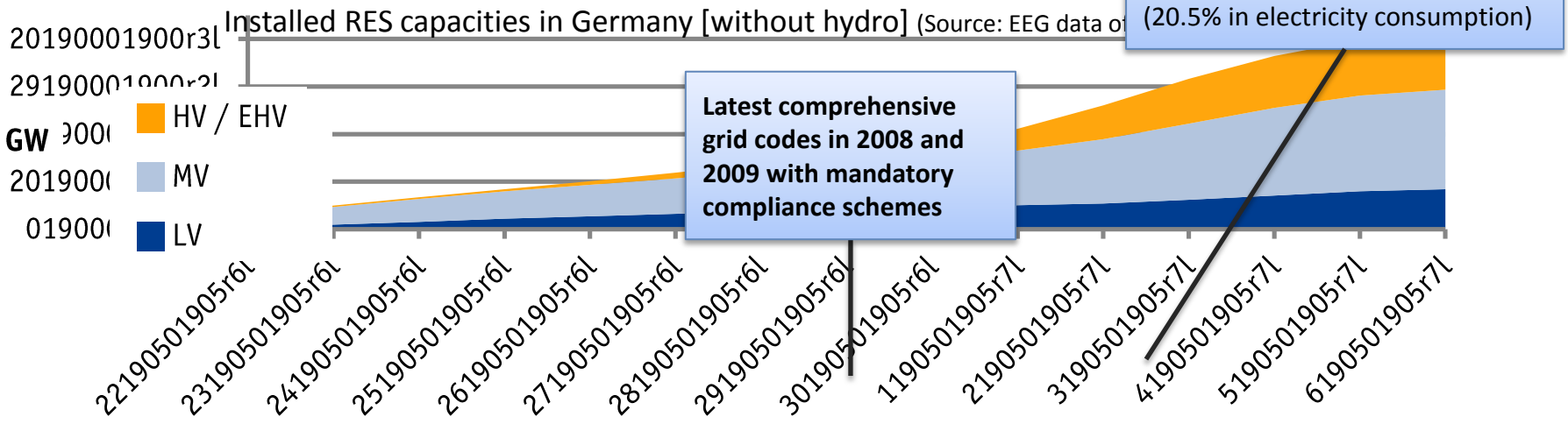
⇒ **Automatic shutdown of installed WTGs at <80% Un (no LVRT capability)**

⇒ **Loss of about 3000 MW**

⇒ **Nevertheless: Partial Blackout in Europe in 2006 due to similar case**

Motivation – Developments at RES Penetration

Example: Paradigm Shift in Germany



Basic requirements until 2002:

- Power quality in normal operation
- Fast disconnection in fault conditions

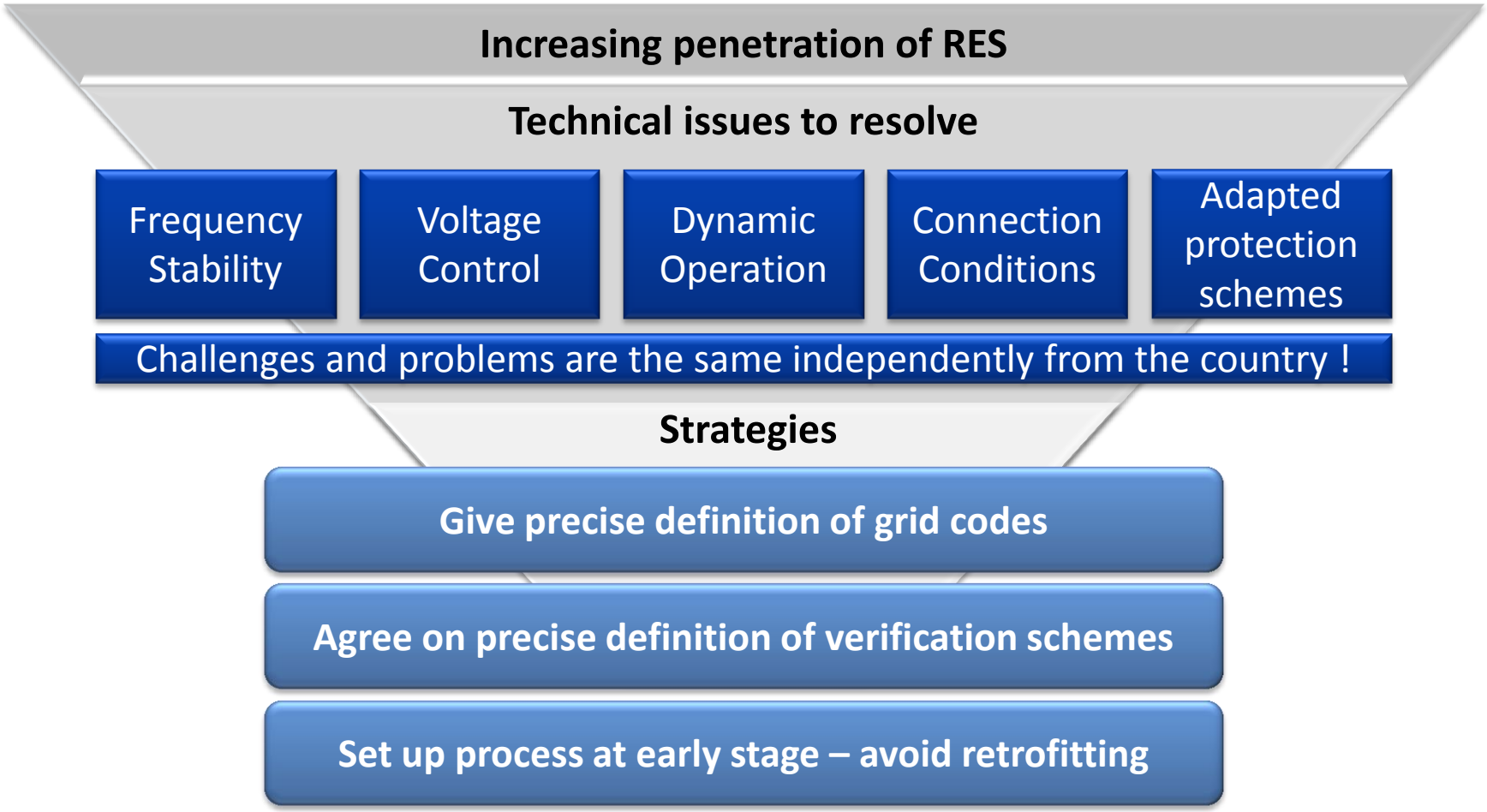
In the following upcoming years
Enhanced Ancillary Services in normal & fault conditions, i.e.

- Flexible reactive power supply, including control schemes
- Active power reduction at over-frequencies (50.2 Hz problem)
- FRT-capabilities including dynamic voltage support

Once requirements are determined, compliance verification is crucial

Basic Challenges of Grid Integration

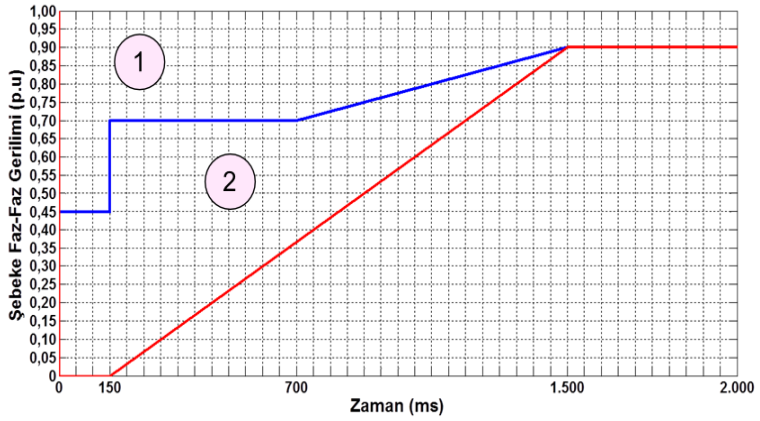
Scope and Findings



Situation in Turkey

Annex 18 of Turkish Grid Code includes mature requirements

LVRT



Voltage Control

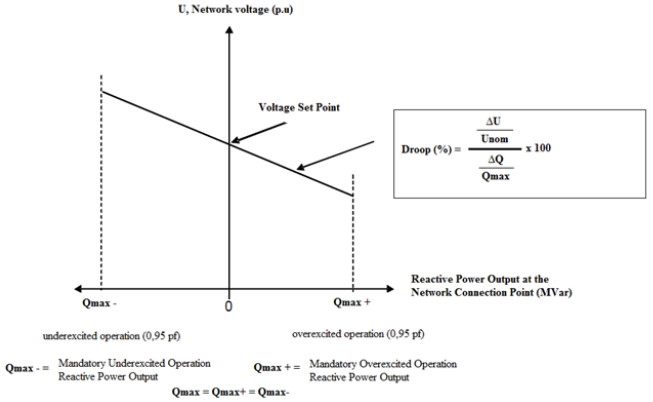


Diagram E.18.6.1 – Reactive Power Support Curve from wind Generations

Reactive Power Supply

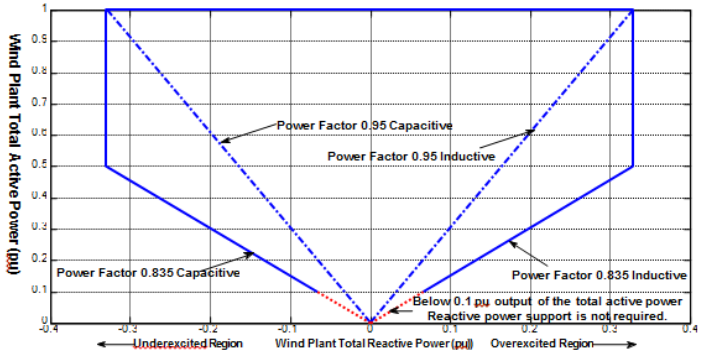
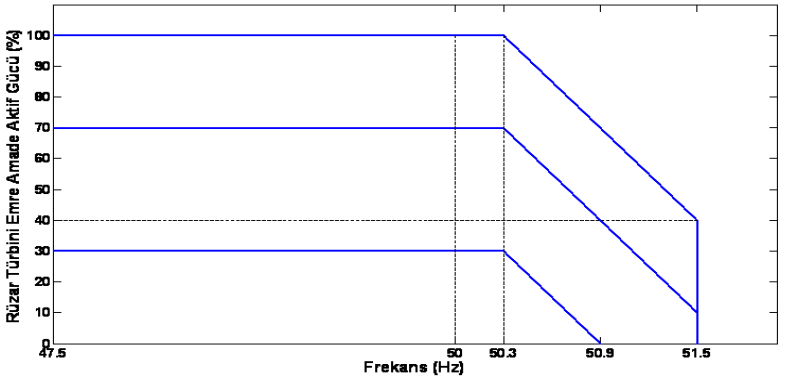


Diagram E.18.5.1 – Reactive Power Capacity

Frequency Control



Situation in Turkey

Compliance with Turkish Grid Code

- Power Quality Assessment Reports required
  - In accordance with IEC 61400-21, prepared by ISO 17025 accredited authority with measurements made according to the IEC 61400-12

➔ Good approach with quality requirement and independent third-party

➔ However only referring to the single wind turbine

- Static and dynamic models of WTGs requested for system analysis

➔ Definitely needed, but no validation scheme in terms of accuracy

- Compliance studies for entire plants

➔ Very crucial study, but lacking quality criteria thus limited reliability

- Compliance testing at commissioning
  - Newly requested by TEIAS for farm installations

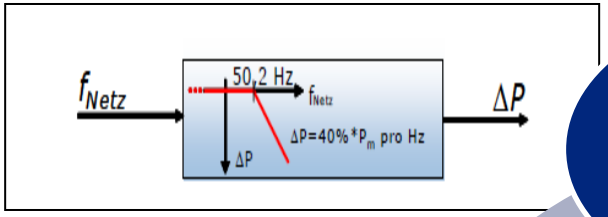
➔ Verification of control functions, parameter initialization, protection settings

➔ **Improvements for a reliable and standardized compliance process recommended**

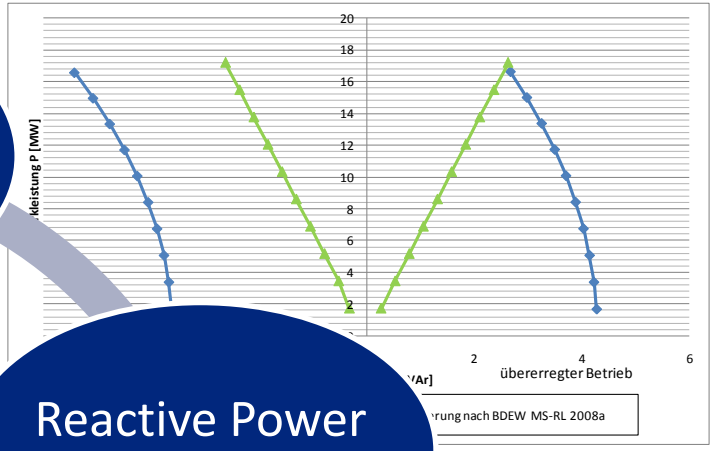
blackout in Turkey on 31/03/2015

Advanced Grid Code Compliance Evaluation

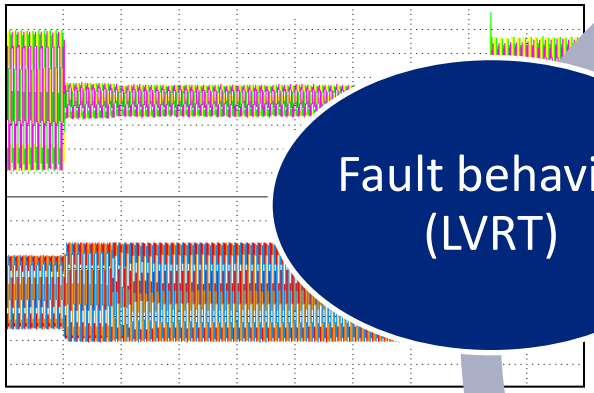
Overview and scope



Active Power Control

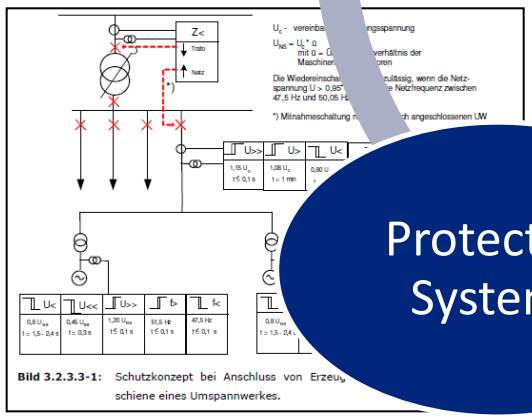


Fault behavior (LVRT)



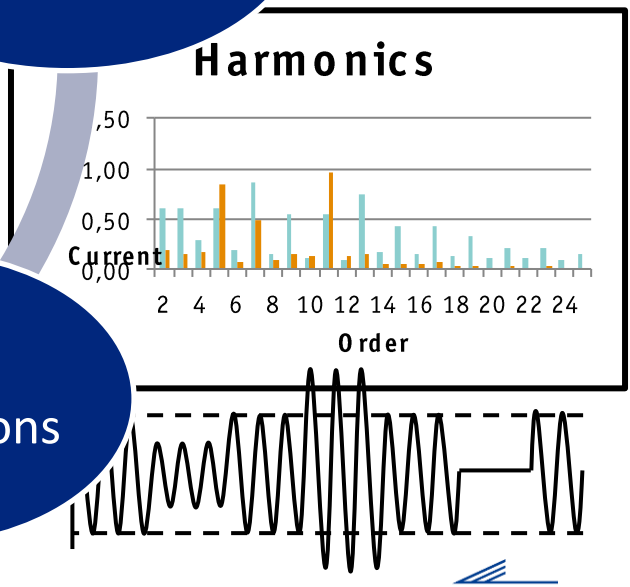
Reactive Power Supply

Evaluation of:



Protection Systems

System Perturbations



Proposal: Standardization of Compliance Process

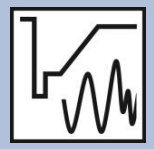
Generating Unit

Unit Certificate

Reliable testing standards

- Active Power Control
- Reactive Power Control
- System Perturbations
- Protection Settings

Unit Model



Unit field testing

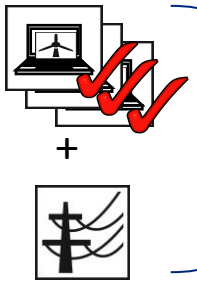
Validation = Analysis of deviations between unit model and field test results (P, Q, Ir) according to pre-defined accuracy level

Calculation of WPP characteristics

Reliable validation standards

Reliable standards for WPP calculation

Validated Model



Simulation of dyn. performance during voltage dips (LVRT)

Comprehensive compliance tests acc. to grid code requirements at PCC

Plant Certificate

Lessons Learned – Standardization

Benefits for the parties and effective solution

- The standardization is a win-win situation for both parties involved to solve asymmetric information efficiently and effectively

System Operators

- Effect of grid connection must be analyzed
- Do not know about every specific characteristics of farms but minimum level of performance must be ensured
- **Quantity of projects makes the commissioning of third parties mandatory**
- **Rely on proven quality of expertise by e.g. accredited certification body**

Wind Farm Operators

- Requirements identified within process of project development and recommendations during planning process
  (risk reduction in terms of project initiation)
- Enabled to provide verification of grid code fulfillment, therefore no time delays
  (risk reduction in terms of grid connection)
- Additional or subsequent re-investments avoided during commissioning
  (risk reduction in terms of costs)

➔ **Bottlenecks for grid connection of RES avoided**

➔ **Efficient instrument to stimulate fast integration**

➔ **Objective assessment**

Lessons Learned – Experiences

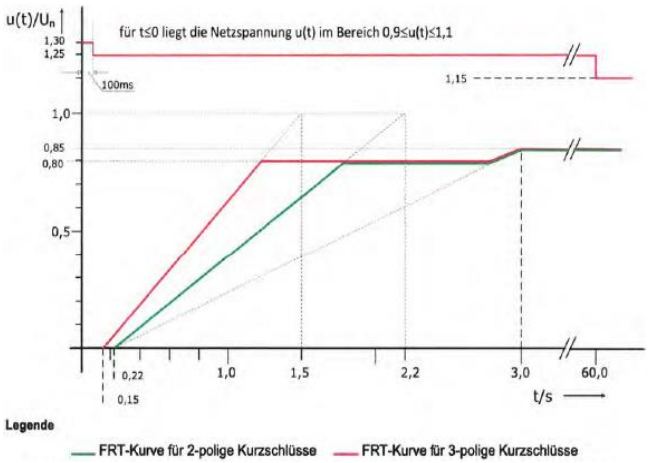
Recommendations on grid integration of RES

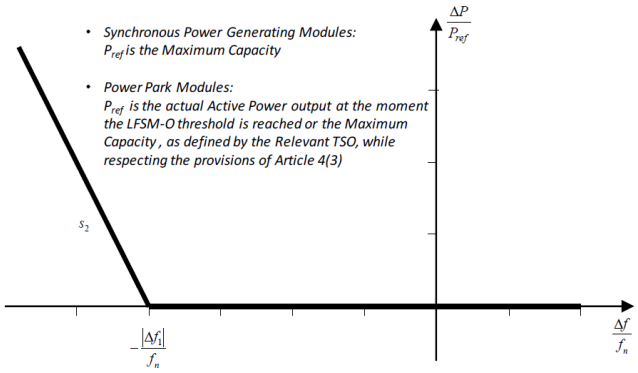
- Experiences from other countries have shown
  - Validated models with defined simulation quality are essential for stability analysis
  - Detailed representation of wind farm is needed for correct verification of protections
  - Advanced compliance schemes for RES increased power system's stability significantly (reliable prediction of impacts in critical situation). **Verification is essential!**
  - Subsequent changes in the design can be investigated and impacts be analyzed
  - **Retrofitting is economically disadvantageous!** (e.g. LVRT capability, 50.2 Hz)
  - Standard-complying manufacturers **maintained and empowered market positions**
- Key drivers for successful integration
  - Close cooperation and collaboration of system operators and RES sector
  - All players take over responsibility in terms of systems services and their application
  - Adequate incentives for grid code fulfillment and for the provision of system services
  - Well-defined, transparent and accepted compliance schemes at early stage
- Build up international cooperation on these issues
  - Exchange experiences, participate in standardization and learn from lessons of others

Outlook on Challenges

There is still a long way to go

- High-Voltage-Ride-Through (HVRT)
- Primary Reserve at Underfrequency
- Synthetic Inertia
- Black Start Capability
- Islanding
- Storage Systems
- Virtual Power Plants
- Automation and Communication





➔ **Dynamic process with continous adaption**

➔ **Ensure security of supply and system stability**

➔ **Guidelines for successful implementation essential**

Thank you for your attention!

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