

GFM Converter Application – A Necessity for the Future

Innovative power technology shaping tomorrow's energy systems

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Trends in Energy Sector

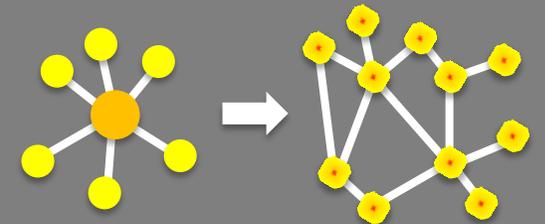
Decarbonisation (defossilization)

- **From fossil fuels to renewable energy sources & storage**
- Concentration of Generation and Demand (solar, wind, ...)
- Electrification of transport, heating and industrial processes



Decentralization

- Location: From centralized to distributed power generation
- Control: From centralized to de-centralized management (prosumers)
- Increasing Distance between Generation and Demand



Energy System Development (transition)

- High loading of transmission lines (dynamic line rating for more flexibility)
- HVDC and Multi-Terminal HVDC for connecting Offshore Wind to the load centers far away
- Change in characteristic of Generation and Demand

Transition to new components



**Conventional
Power Plant**

Different characteristic
Different services
**Different inherent
capabilities**



HVDC valve hall



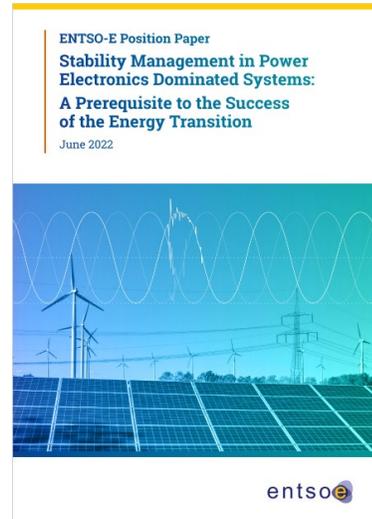
Impact on Stability Management

System Development Risks

Developing the grid with incomplete data or models may overlook **issues like resonances and control interactions**, causing delays in resolving challenges and **hindering the energy transition.**

Technology Risks

Poor communication of technology needs to R&D and manufacturers may result in **unprepared technologies**, leading to further delays and operational risks **affecting the energy transition.**



Industrial Readiness

Operational risks:

Poor stability management can **jeopardize supply quality and reliability**, causing severe damage to assets and leading to incidents like **islanding, system splits, cascading faults, blackouts, and equipment failure.**

Indirect operational risks:

Lack of stability management compels TSOs to increase security margins, raising investment costs, **reducing grid efficiency and transmission capacity**, and **imposing high societal costs.**

Designing the Future Energy System

Power system is still in transition

2050 EU Goal
(Energy Roadmap 2050)

Italian White Night

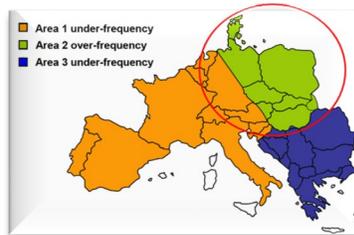


2000

Wind & Solar Integration

2010

Power System Stability issues



2015

Nuclear and Coal Phase Out

2020

Massive Offshore Wind Integration

2025

Most suitable way forward is the collaboration in research projects

Many phenomena still unknown

Keep the future green power system stable



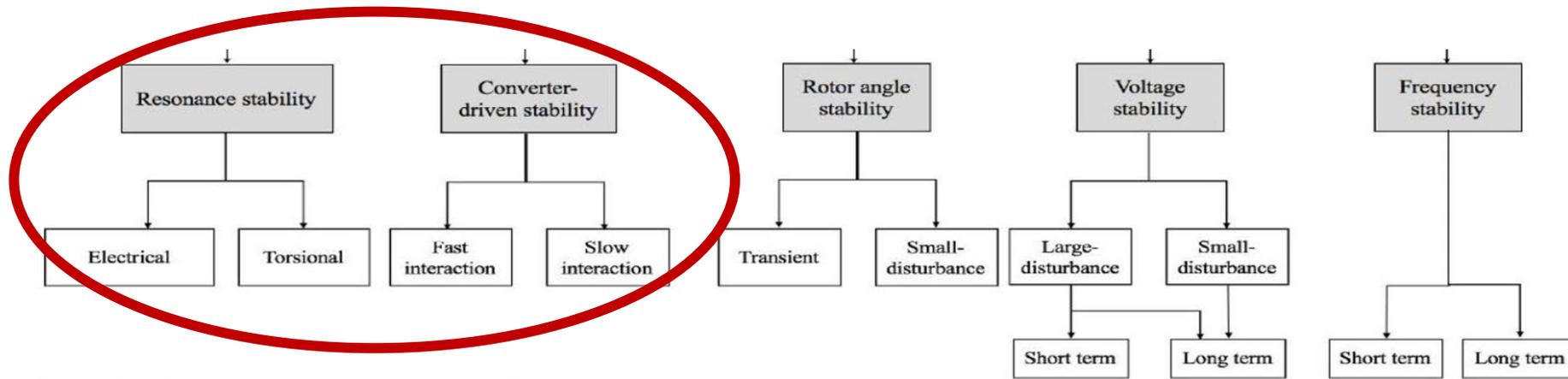
Towards a power electronic dominated power system

TenneT GE Control Area Challenges

- ***Requested installed capacity***
 - [Installed generation capacity](#) in Germany in 2024 approximately **250 GW**
 - Connection requests only about **15%** of that in the TenneT control area!
 - **Very short-term commissioning**
- ***About 100 connection requests for battery storage***
 - Total requested capacity approximately 38.9 GW
 - Focus of commissioning between 2026 – 2028
 - Additionally, numerous connection requests e.g. for electrolyzer
- ***Global System Integrity***
 - CNC 2.0 requirements (on hold) urgently needed
 - **Resonance stability and converter driven stability risks**
 - Risk of cascading effects

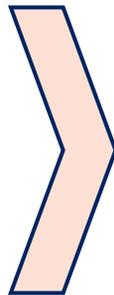


Extended System Stability Criteria



Observed development

- More HVDC systems & PE
- Low inertia and uneven distribution
- High RoCoF and low frequency nadir
- System split is a treat
- Change in of characteristics in generation and demand

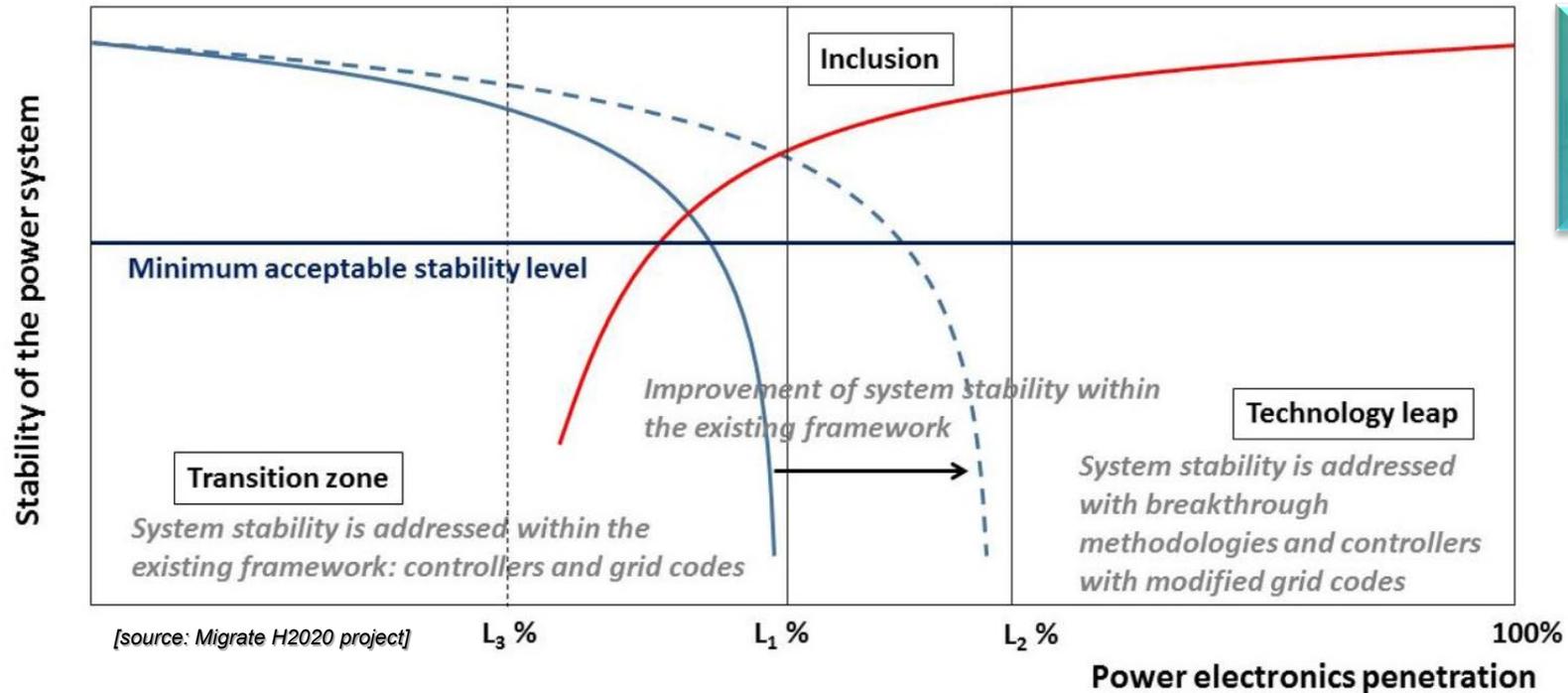


Potential R&I Actions for a future European power system

- Development of tools for assessment and simulation of dynamic behaviour
- Development of procedures for long- mid and short-term planning and real-time operation
- Development of systems for more preventive and curative actions
- Coordinated response Power Electronic Equipment
- Development of resources for further system services needed
- Development of market designs

Stability/integrity of power electronic dominated systems

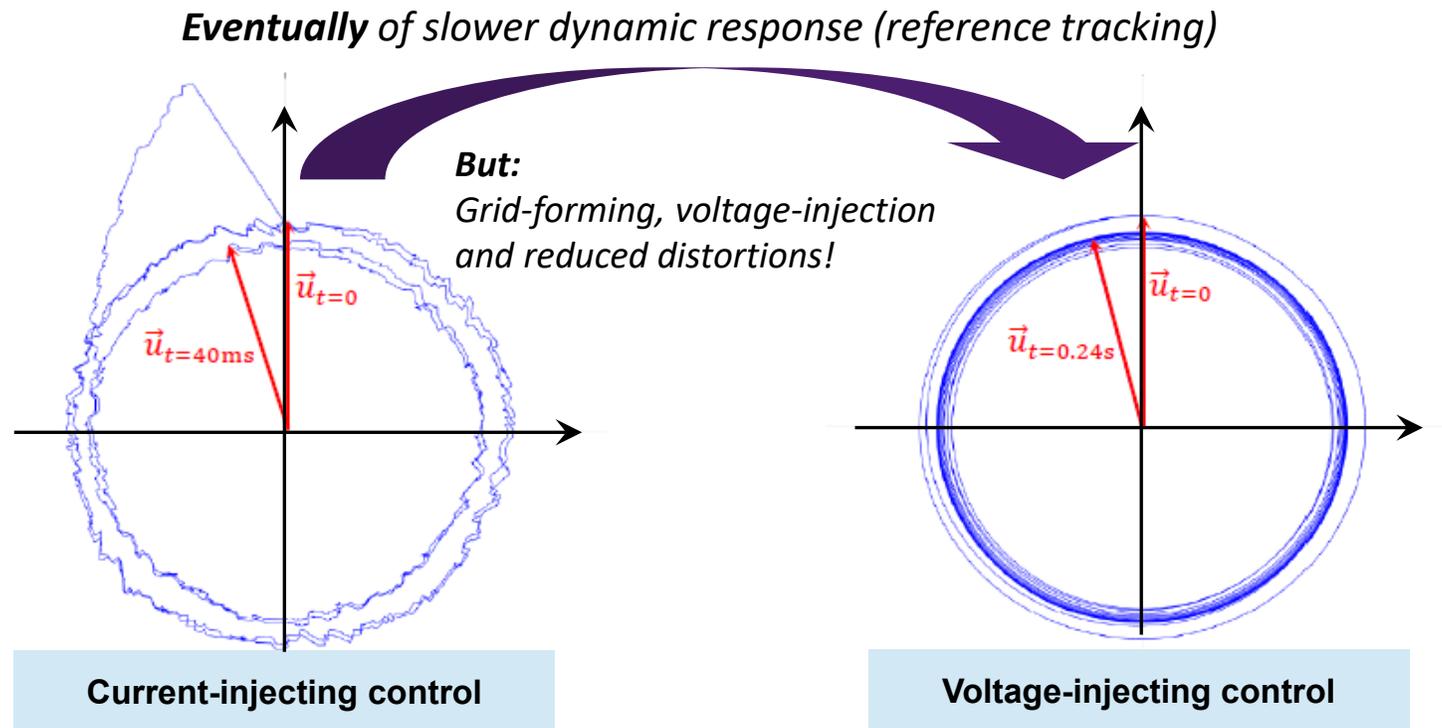
- How to **maximize the amount of Renewable Energy Sources** installed in the system while **keeping the system stable**?
- How to create awareness for **industrial readiness** anticipate future potential problems and challenges?
- Need for new **control/protection** schemes?



Comparison of Grid Following and Grid Forming Controls

Typical time response considering „weak“ grid connection

- Illustration as space vector in stationary coordinates

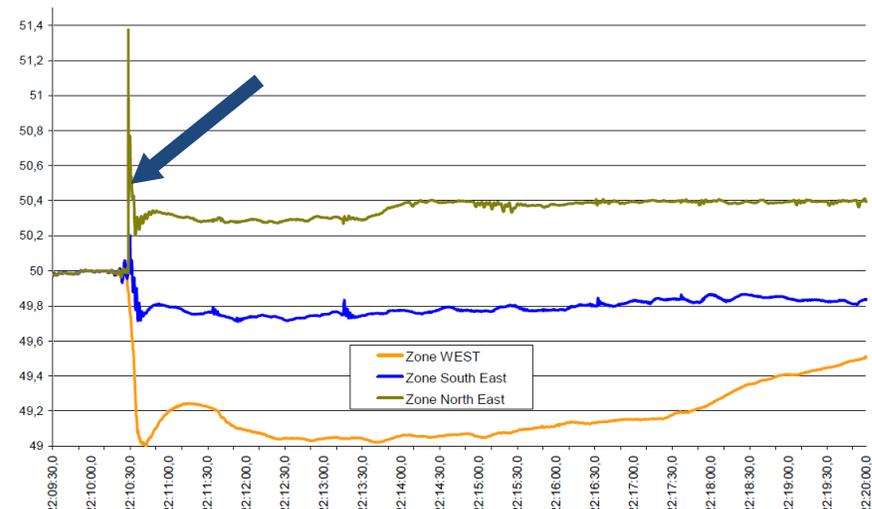
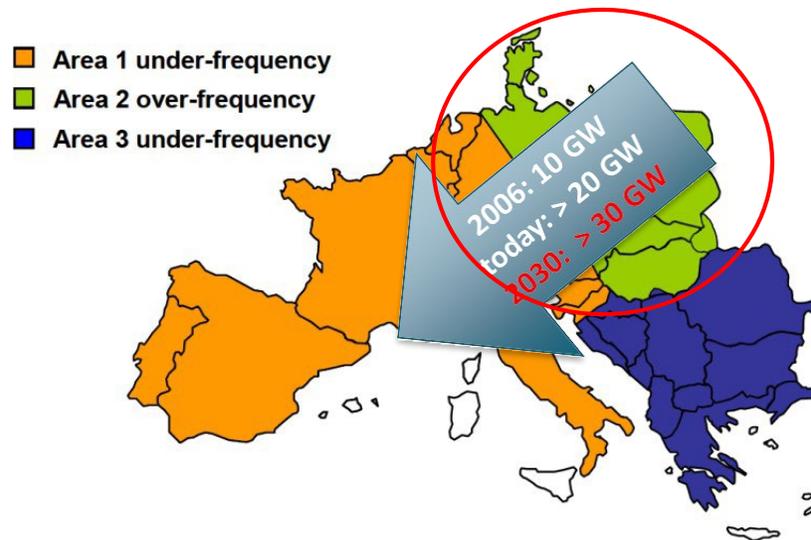


[Source: 4GTSO SUE-Project]

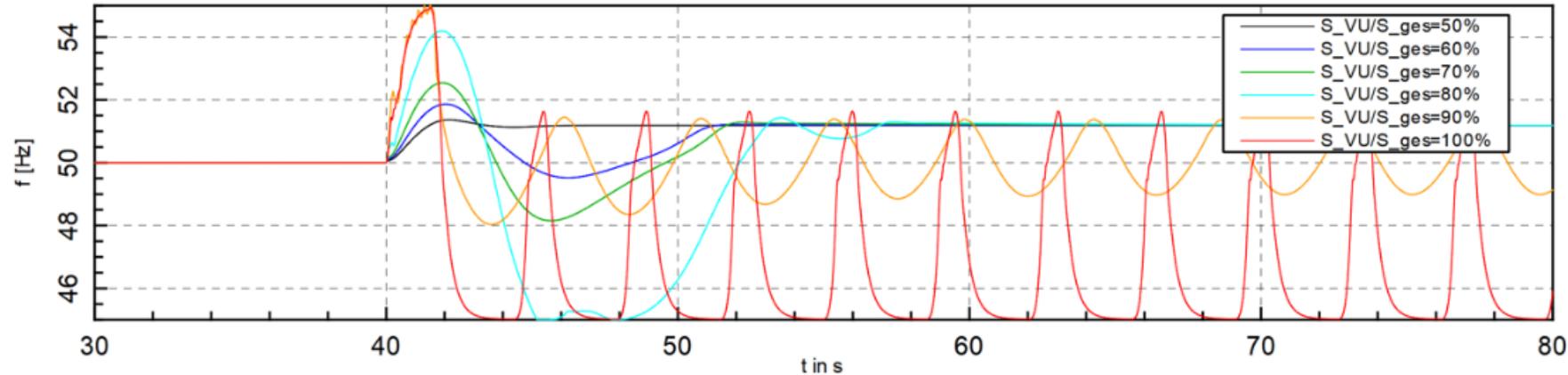
System Split in November 2006

Question: Will we survive the system split from 2006 today and in the future?

- Converter penetration and transmission capacity increased significantly since 2006!
 - as a consequence potential imbalances and RoCoFs increase accordingly!
- Control schemes for active power balancing have to be verified (in particular the reaction time!)
- **A robust system behaviour with converter-based generation has to be ensured!**



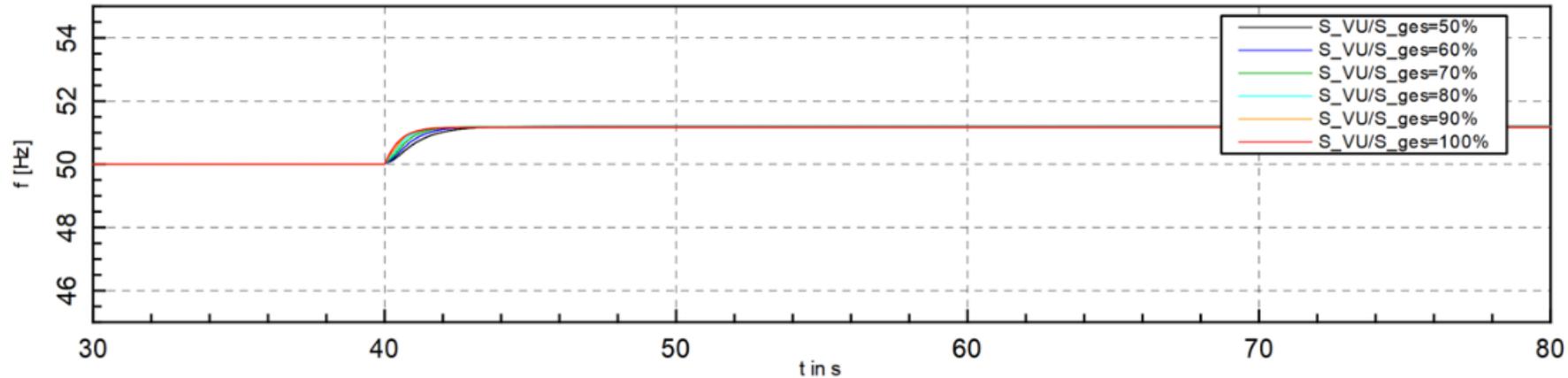
System split scenario in a PE dominated system



- **Generic benchmark grid where conventional generation based on synchronous machines was gradually replaced by converter-based generation**
- At approx. 60 % share of converter-based generation related to the total generation within one area, **system split events cannot be endured**, if a current injection control scheme is applied at the low-level control layer

[source: SUE project of the 4 German TSOs]

System split with near 100% share of PE – GFC concepts



- **Voltage injection control schemes allow for even 100 % share of converter based generation.**
 - **System split events cannot be survived**, if a grid forming control scheme is applied at the low-level control layer

[source: SUE project of the 4 German TSOs]

System Split Scenario Results

Based on conducted studies

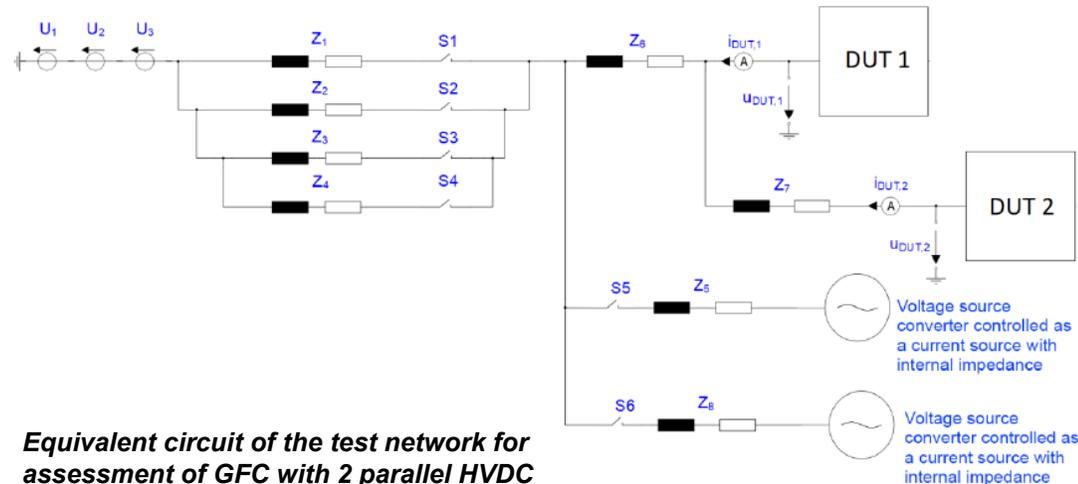
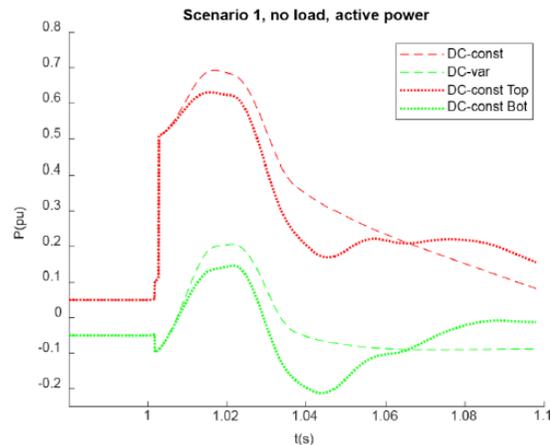
- At **40% installed converter-based generation**, power exchange of **50%** can be handled with **today's converter control schemes**
- At approx. **60% installed converter-based generation** (depending on parameters of current-injecting control) system split scenarios (with **power exchange up to 50%**) are not manageable considering **today's converter control schemes**
- At **80% installed converter-based generation**, power exchange **starting from 10%** are already not manageable considering **today's converter control schemes**



Industrial Readiness – Guideline for Grid Forming Control compliance

German VDE FNN Paper (2020) on grid forming control for HVDC and non-synchronous DC-connected generation units provides a guideline for Grid Forming compliance simulation:

1. Phase steps
2. Frequency change and phase steps
3. Voltage steps
4. Islanding mode



Equivalent circuit of the test network for assessment of GFC with 2 parallel HVDC systems

VDE FNN Guideline

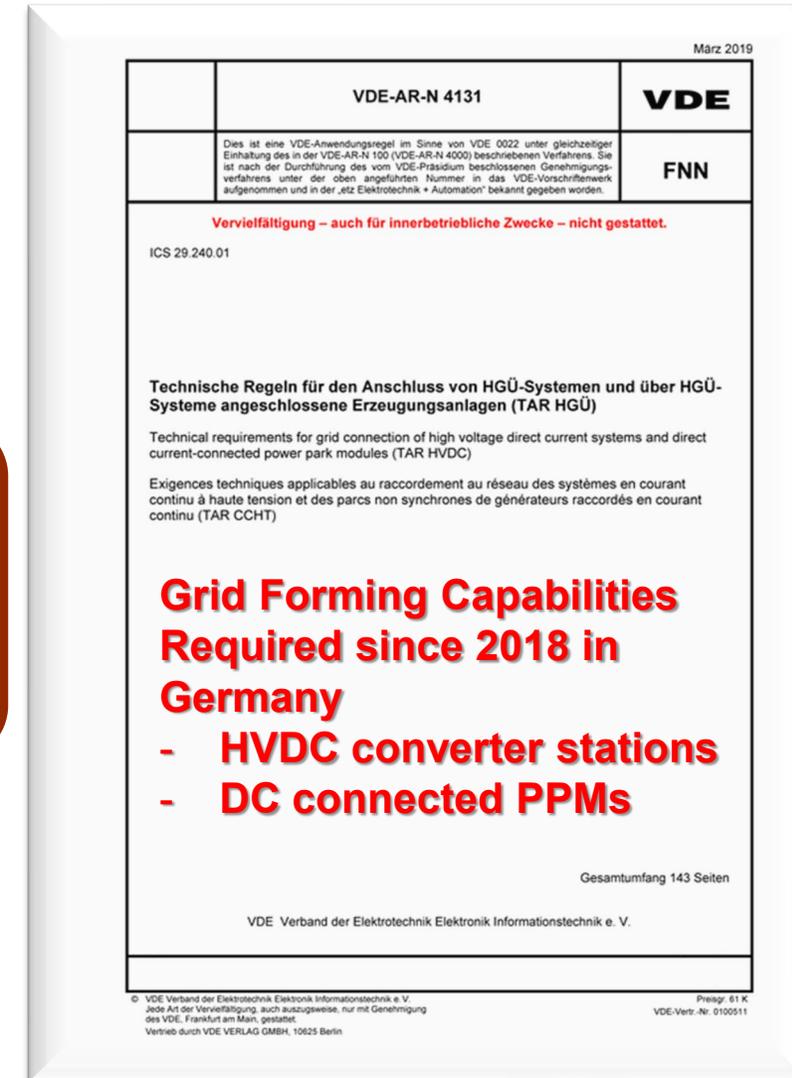
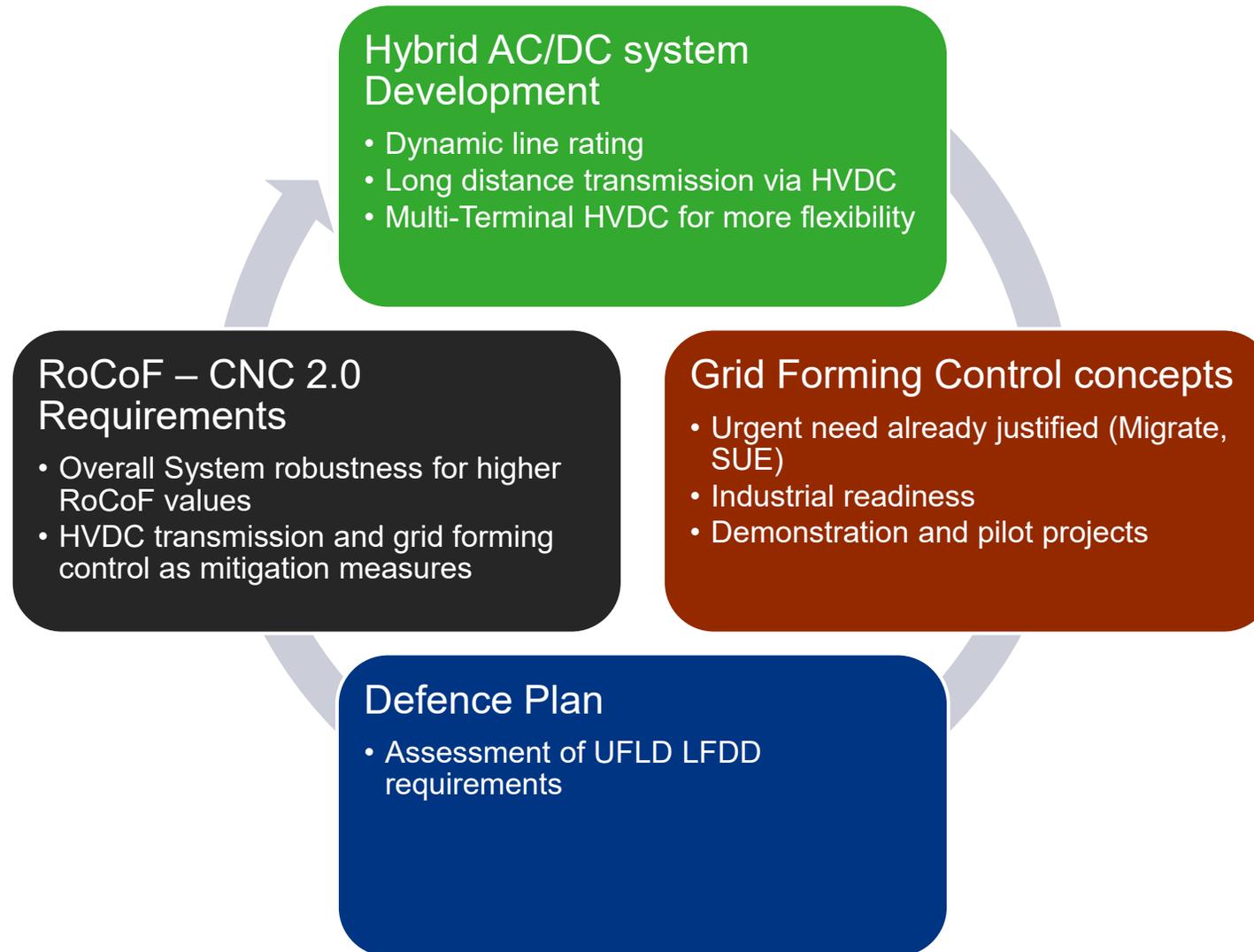
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FNN Guideline: Grid forming behaviour of HVDC systems and DC-connected PPMs

Supplement to VDE-AR-N 4131 for dynamic frequency/active power behaviour and dynamic voltage control without reactive current specification

VDE FNN

Recommendations



Questions?

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