2016 CIGRÉ USNC International Colloquium

Evolution of power system planning to support connection of generation, distributed resources and alternative technologies

# FUTURE SYSTEM CHALLENGES IN EUROPE.

## CONTRIBUTIONS TO SOLUTIONS FROM CONNECTION NETWORK CODES

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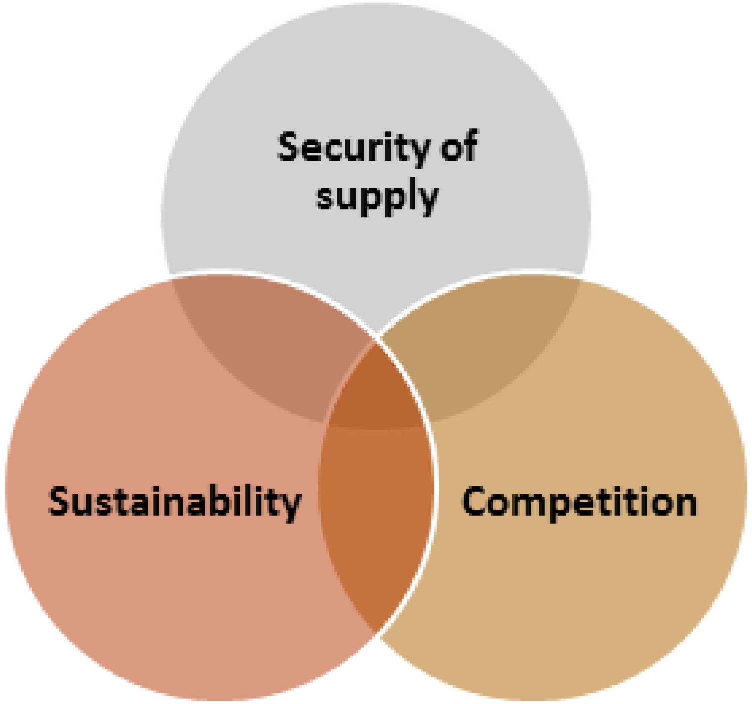
# European energy policy objectives
## The link to the challenges of keeping the lights on in a low carbon future.

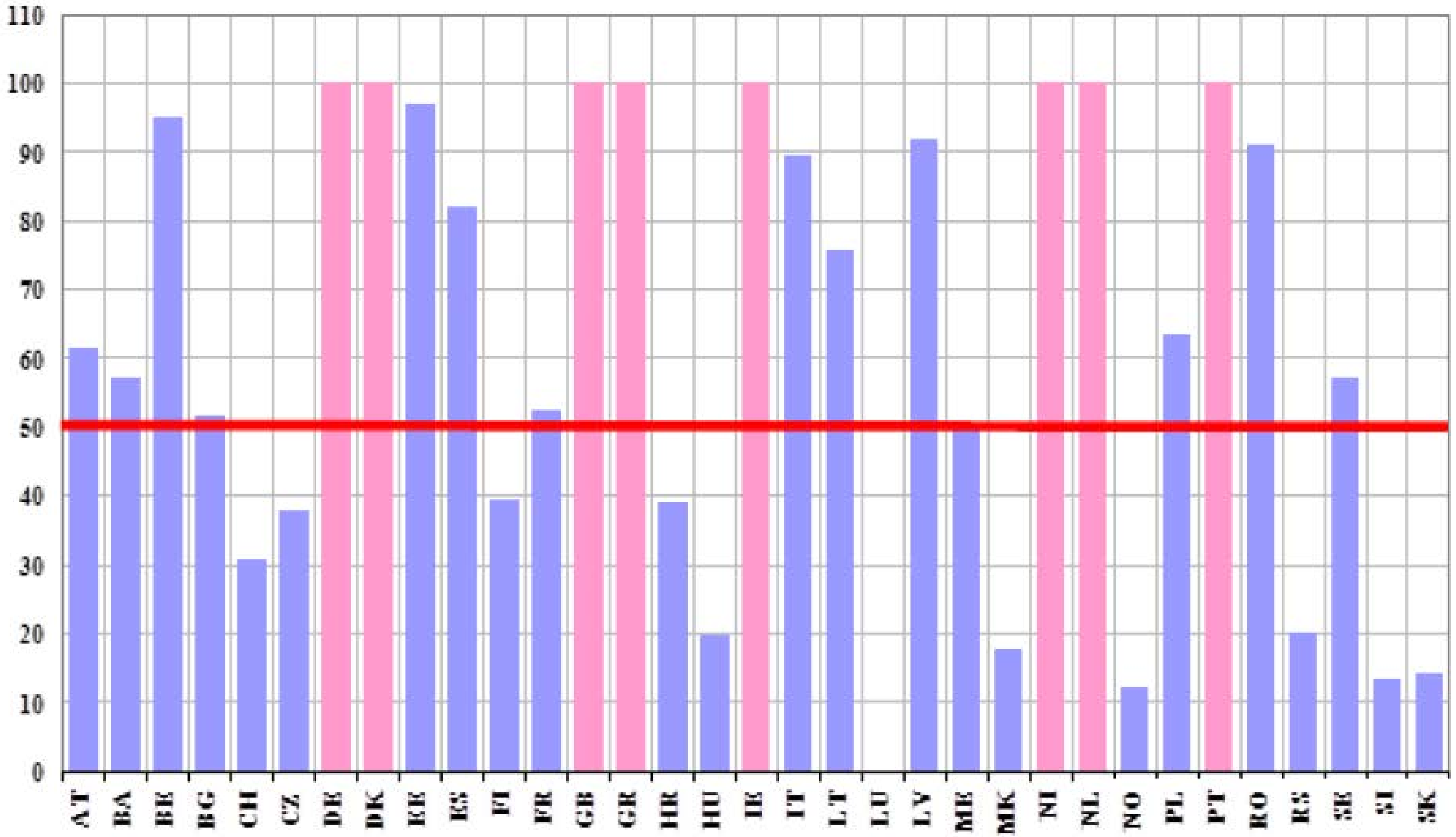
In 2009 “Third package” of the European Commission determined the legislative framework of  the European energy supply business:

- Facilitation of a competitive European internal market at all levels of the electrical energy supply chain - generation, transmission, distribution, wholesale and retail.
- Sustainable integration of renewable energy sources (RES) at large scale to decarbonise the electricity sector and to meet ambitious targets of climate protection.
- Ensuring security of supply to all customers at a high level.




New question:
Can SoS be  achieved even with operation at or close to 100% RES?

# ENTSO-E scenarios (prepared in 2015)
# Energy mix in 2025 – RES Renewable Load Penetration Index (RLPI)



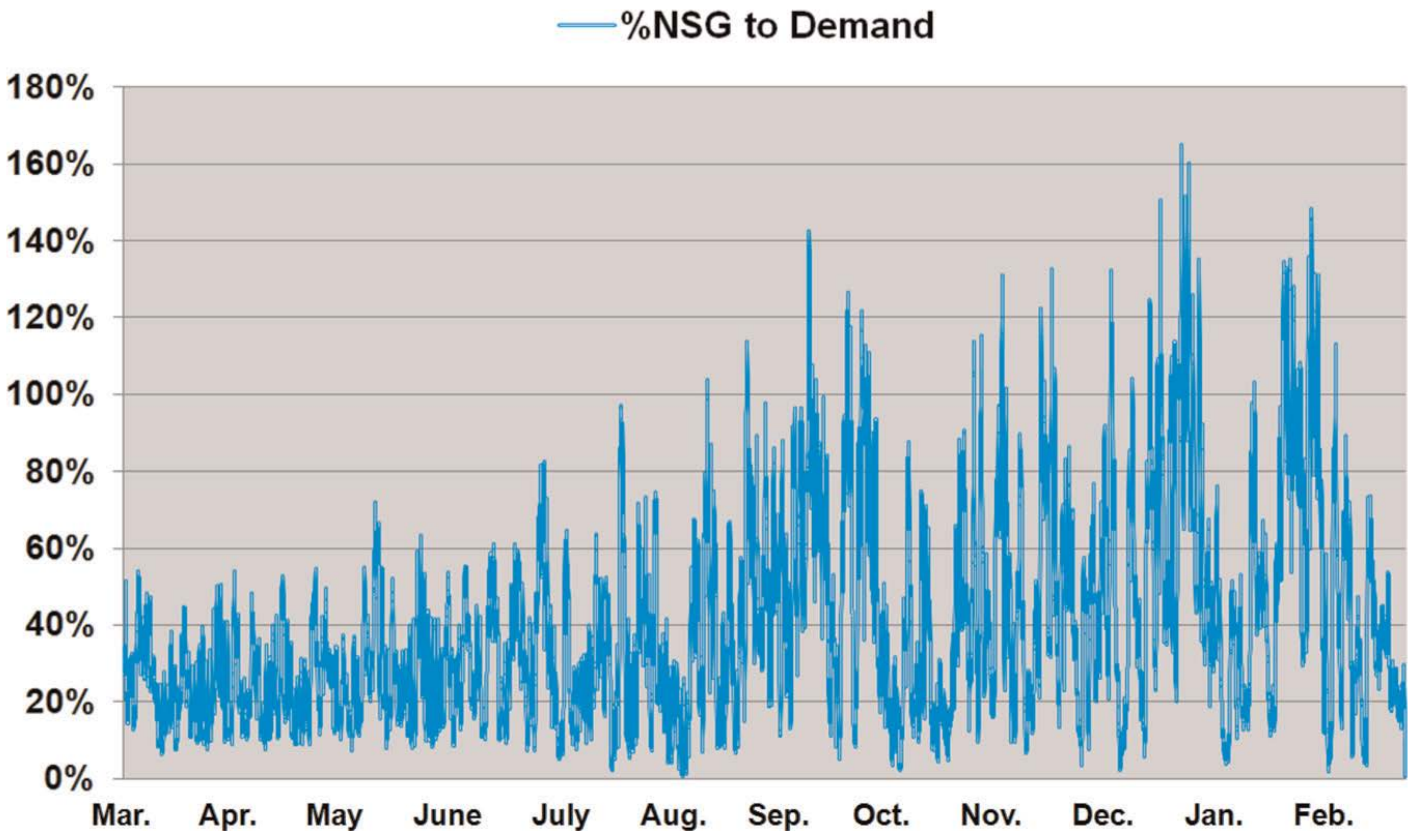

**8 countries reaching full hourly load penetration – without export**

**22 of 33 countries RLPI>50%**

The eight:

Germany (now close to 100%)
Denmark (now >>100%)
Great Britain
Greece
Ireland (large constraints now)
Northern Ireland
Netherlands
Portugal

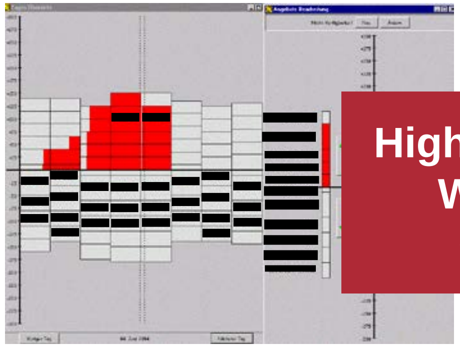
# GB hourly % RES in 2030 – scaled, based on recorded hourly wind & sun Installed wind & PV according to scenario Gone Green




From
0% in August
(calm no wind, night )
to
165% in December
(high wind with low demand at X-mas)

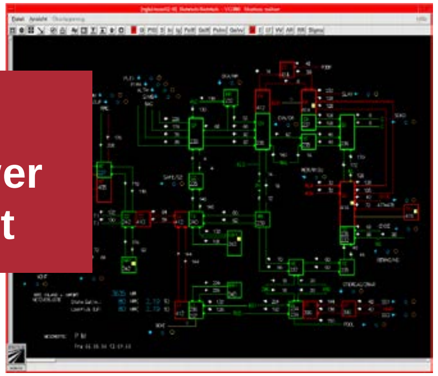
Challenging variability from many view points

# Future challenges overview



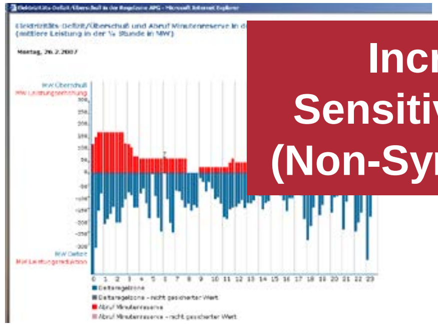
High Penetration of Wind & Solar Generation

Voltage & Reactive Power Management

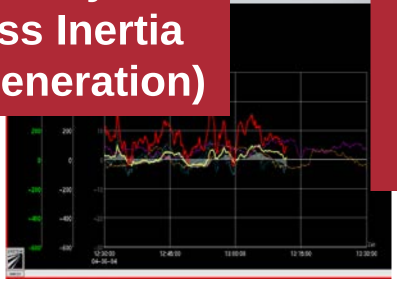


Remote Generation and Market-Driven Power Flows

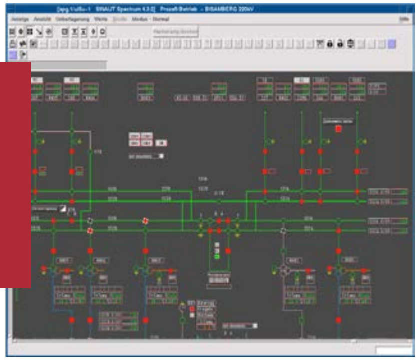
Delays in Grid Reinforcements



Increasing Frequency Sensitivity due to less Inertia (Non-Synchronous Generation)



Priority Treatment of Renewable Generation



# Progress to date
# Capabilities of connected RES

For 10-15 years individual countries with increasing RES (% NSG) have focused on avoiding adverse affects on power systems by:

- Staying connected during and following faults – Fault Ride Through (FRT)
- Replace Q capability of displaced SG – Q requirements and voltage control
- Capability to replace MW reserves of displaced SGs – f management capabilities FSM/LFSM

These capabilities as well as f and V operating ranges are now being partially harmonised across Europe through introduction of 3 Connection Network Codes RfG, DCC and HVDC.

These NCs, are fulfilling many of the needs to prepare for the future.

# System Strength (SS) (I of II)
# Challenge of variability including operating extremely weak system

Ratio of synchronous generation (SG) to non-synchronous generation (NSG) vary.

- If unconstrained, even between the extreme positions:
- 100% SG / 0% NSG strong, familiar
- 0% SG / 100% NSG weak, unfamiliar

System Strength (SS) follows largely these variations. SS can be expressed as:

- Fault level (FL)
- Short Circuit Ratio at Connection Point (SCR)
- Total System Inertia (TSI)

# System Strength (SS) (II of II)
# Challenge of variability including operating extremely weak system

The present portfolio of RES is dominated by power electronic based interfaces.

- Predominantly designed  for electronic equipment preservation
- Not for system needs
- Making minimal contributions to SS in the form of FL, SCR and TSI.

Quantifying challenges for full synchronous areas or even  each country is needed.

- Analysis of different conditions (e.g. Hourly based) for various SS aspects
- With a wide range of future plant mix, preferably including the most extreme position

# New challenges associated with low System Strength

Low total system inertia – impact on frequency management

Keeping in synchronism & new high frequency stability challenge

Lack of fault level for converter stable operation

Lack of fault current for transmission system protections

Lack of system strength for voltage quality of supply

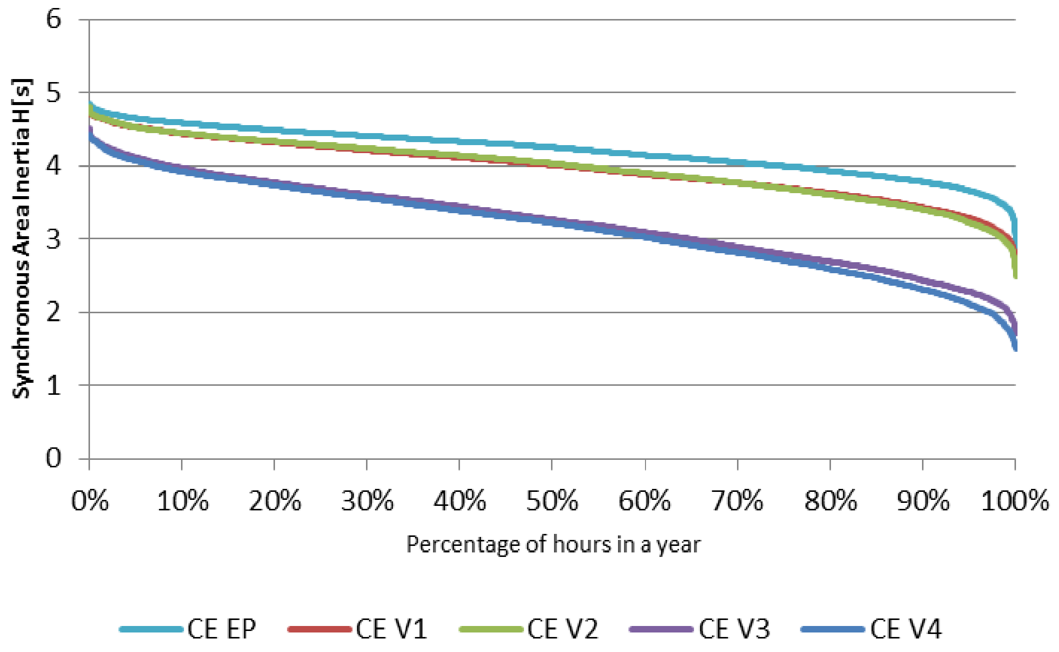
# New challenges associated with low System Strength

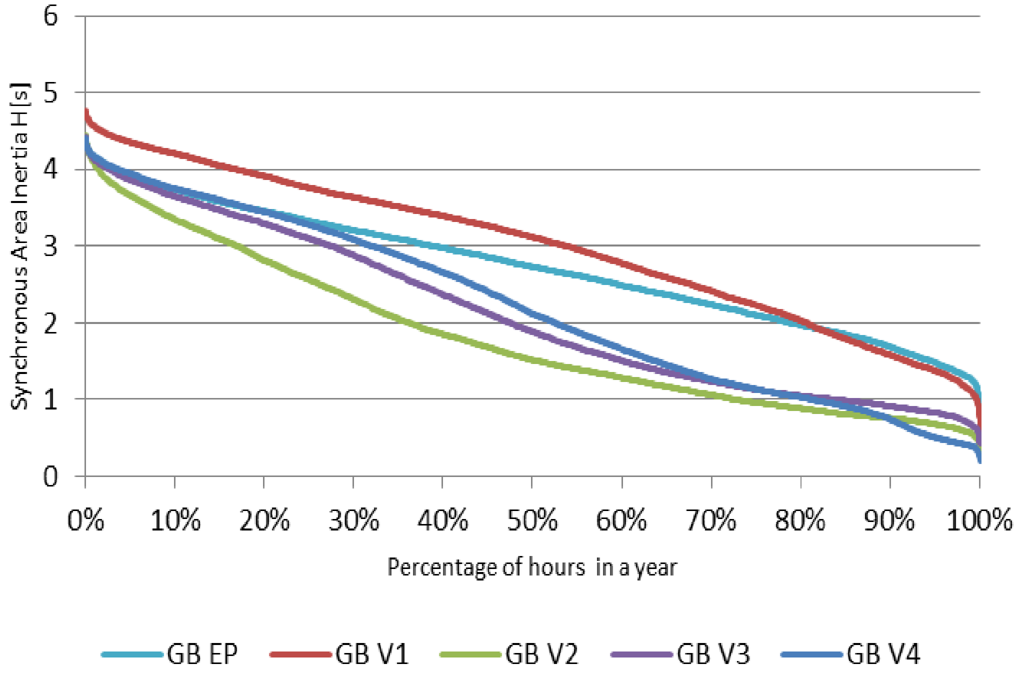
- Low total system inertia – impact on frequency management
- Keeping in synchronism & new high frequency stability challenge
- Lack of fault level for converter stable operation
- Lack of fault current for transmission system protections
- Lack of system strength for voltage quality of supply

# Examples of analysis regarding system inertia Continental Europe (CE) and Great Britain (GB)

## Insight report for TYNDP 2016:

- Estimation of the evolution of system inertia for different TYNDP visions



# Low Total System Inertia (TSI)
# Impact on frequency management

- **TSI in a SG dominated power system, H: typically 5-6s**
- **In future, without contribution from RES, could at times go extremely low. ENTSO-E SO Guide Lines will require regular TSI calculations by TSOs.**
- **A min TSI, possibly around H=2-3s may be needed.**
- **Connection Network Codes require robustness**
  - NC HVDC highest at df/dt (RoCoF) = 2.5Hz/s – stay connected.
- **Contribution to TSI from Power Electronics needed.**
  - R&D has demonstrated that care is needed. SI lead to other instabilities
  - New strategies for converter controllers looks like being needed, e.g. with true voltage source (inner control loop) performance.

# New challenges associated with low System Strength

- Low total system inertia – impact on frequency management
- Keeping in synchronism & new high frequency stability challenge
- Lack of fault level for converter stable operation
- Lack of fault current for transmission system protections
- Lack of system strength for voltage quality of supply

# Conventional keeping in synchronism & new high frequency stability challenge

- **High frequency instability with very high RES penetration – tipping point at 60-70% NSG**
  - Different modeling challenges to classic angular / transient instability dealing with power systems with predominance of SGs.
- **Dynamic simulation move to a new paradigm:**
  - Very high % NSGs (e.g. 70% & above) – high bandwidth converter controllers
- **Control strategy in VSC must be appropriate to mitigate the high frequency instability issue**
- **Very high %NSG require a proportion of "leaders"**
  - Operating on principles different from the dominant PLL controllers, which are effectively "followers" of existing system voltage.

# New challenges associated with low System Strength

- Low total system inertia – impact on frequency management
- Keeping in synchronism & new high frequency stability challenge
- **Lack of fault level for converter stable operation**
- Lack of fault current for transmission system protections
- Lack of system strength for voltage quality of supply

# Lack of fault level for converter stable operation

- HVDC systems continue to use line commutated converters (LCC), although commonly transferring to voltage source converters (VSC)
- LCC traditionally require SCR =>3
- Existing HVDC LCC on systems with a lot of new RES, seeing periods of SCR<<3.
- Further reduction in SCR needs to be managed.
- RES / VSC HVDC converters need to contribute to FL/SCR
- Virtual Synchronous Machine type performance needed soon
- Reduce converter interactions, possibly through limiting the active control bandwidth.

# New challenges associated with low System Strength

Low total system inertia – impact on frequency management

Keeping in synchronism & new high frequency stability challenge

Lack of fault level for converter stable operation

**Lack of fault current for transmission system protections**

Lack of system strength for voltage quality of supply

# Lack of fault current for transmission system protections

- R&D has demonstrated that some protections (e.g. distance protection) may not see any phase-earth faults in a power electronic dominated power system (lack NPS)
- Fast (first cycle) current contribution from RES needed.
- Recent R&D demonstrates that this can be achieved, although it may require a fundamental change in converter control strategy.
- Contributions needed for 3 purposes:
  - A: 0-40ms - for T protection systems, including asymmetric component
  - B: 40ms to fault clearance - aid transient stability
  - C: From fault clearance: - control voltage overshoot on recovery

# New challenges associated with low System Strength

Low total system inertia – impact on frequency management

Keeping in synchronism & new high frequency stability challenge

Lack of fault level for converter stable operation

Lack of fault current for transmission system protections

Lack of system strength for voltage quality of supply

# Lack of system strength for voltage quality of supply

- QoS is dependent upon system strength / fault level (FL)
- Roughly voltage distortion will double if FL is halved
- SGs are sinks for harmonics and unbalance.
- As SGs are increasingly withdrawn (permanently or disconnected during high RES production) consideration is needed to how this beneficial function is replaced.
- To date, TSOs have focused on RES converters not introducing CURRENT harmonics, i.e. not increasing the problem.
- Future, RES converters need to be asked to do more, to contribute to “clean-up” with focus on sinusoidal voltage and not current.
- This has already been done in stand-alone systems, such as marine systems.

# Promising developments

**Research by TSOs in association with Universities show great promise:**

- **Defining penetration limits for system stability (with existing control capabilities)**
- **Demonstrating that changes to power electronic interfaces are possible to:**
  - Mimic the valuable characteristics of synchronous generators (SGs), provide adequate volume of these
  - Deliver different characteristics for aspects of SGs, which are less desirable (e.g. power oscillations) or expensive to deliver (e.g. dynamic breaking).

**Indicates solutions are emerging covering all the new low system strength challenges**

**Allowing the policy makers to contemplate 100% RES, without lowering security of supply**

**Even extend to 100% RES for a full synchronous area (e.g. Ireland and GB)**

**with resilience to continue to support existing standards of security**

**and maybe extend further to survive severe system splits.**

Major challenge: turn the above prospect into reality before it is too late / too challenging / too expensive

# Conclusions (I)

- **RES penetration has increased steadily in Europe**
  - E.g. Germany this summer recorded 88% of demand covered by RES
- **To date focus of TSOs to avoid detrimental performance (FRT), gradually moving to expect RES to contribute to system V & f controls.**
- **RES penetration is expected to increase**
  - 8 countries having hours by 2025 when 100% of demand covered by RES
- **Many new system challenges arise, predominantly linked to reducing system strength.**
  - Rapidly reducing Total System Inertia
  - Low FL affecting potentially transmission protection performance
  - Low SCR affecting stability of converters
  - Potential for high frequency system wide instability
  - Increasing voltage QoS issues

# Conclusions (II)

- **New generation of converter controllers needs to be implemented soon to new RES installations**
- **The “need case” must first be reinforced**
  - In context of Network Codes this is at national level
- **If so, this would allow further development of RES, while keeping the lights on.**
- **Recent R&D demonstrates that we need not fear operation with 100% RES, if we act soon.**

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