The Power System in the Energy Transition

Operational Challenges and Power Electronics based Solutions

Vinay Sewdien

Technical Secretary, SC C2 System Operation and Control

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2. System operational challenges from the energy transition
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CIGRE AT A GLANCE

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CIGRE’s Strategic Directions

1. Future Power System

2. Environment and Sustainability

3. Best use of Existing Systems

4. Unbiased Information for all Stakeholders

CIGRE’s Domain of Work

A focus on current pressing challenges:

- *Renewable energy sources*
- Growing environmental requirements
- *Limitations to build new transmission infrastructures*
- Architecture of networks and systems
- Maintaining the existing power systems
- *Transmission of large amounts of power over long distances*
- Cyber security
- *Intermittency of renewable power generation*

CIGRE’s Domain of Work

Group A – Equipment:

A1 Rotating electrical machines
A2 Power transformers and reactors
A3 Transmission and distribution equipment

Group B – Technologies:

B1 Insulated cables
B2 Overhead lines
B3 Substations and electrical installations
B4 DC systems and power electronics
B5 Protection and automation

Group C – Systems:

C1 Power system development and economics
C2 Power system operation and control
C3 Power system environmental performance
C4 Power system technical performance
C5 Electricity markets and regulation
C6 Active distribution systems and distributed energy resources

Group D – New materials & IT:

D1 Materials and emerging test techniques
D2 Information systems and telecommunication

SC C2: Scope

The scope of the SC C2 covers the technical, human resource and institutional aspects and conditions for a secure and economic system operation of power systems in a way that complies with requirements for network security, against system disintegration, equipment damages and human injuries, and security of electricity supply.

The SC is encouraging ***young members*** and additional members from DSOs to participate in its activities in order to prepare the energy transition with an integrated end-to-end power system.

More information on how to get involved? Contact your SC C2 national representative:

Mr. Carlos Vanegas

cavanegas@XM.com.co

SC C2: Technical Directions

The activities of the SC are aligned along the following main Technical Directions:

1. Real-time System Operation and Control

2. System Operational Planning and Performance Analysis

3. Control Centre Infrastructure and Human Resources for System Operation

SC C2: Structure

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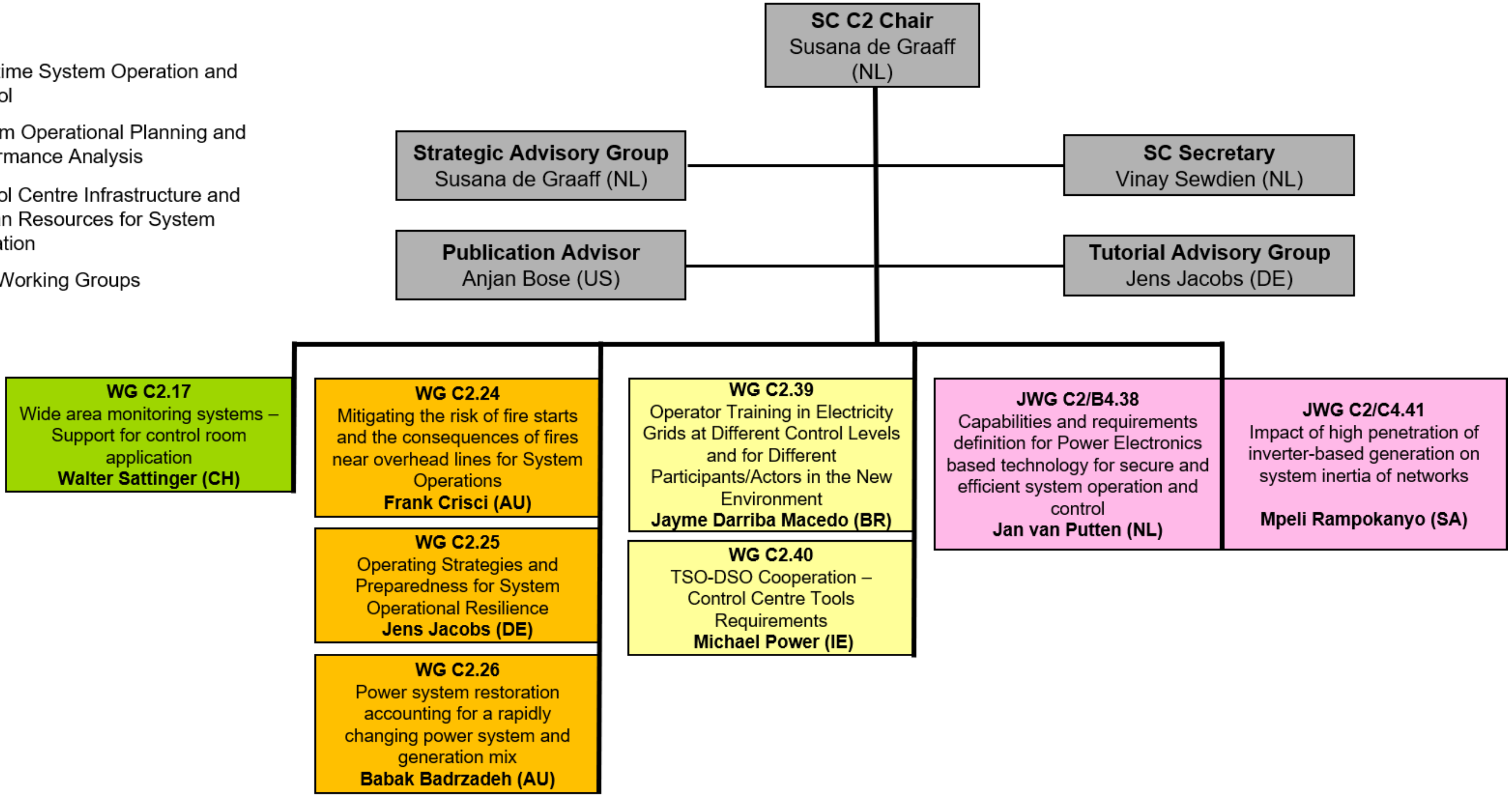
- 🟩 Real time System Operation and Control
- 🟧 System Operational Planning and Performance Analysis
- 🟨 Control Centre Infrastructure and Human Resources for System Operation
- 🟪 Joint Working Groups



SC C2 Chair
Susana de Graaff (NL)

Strategic Advisory Group
Susana de Graaff (NL)

SC Secretary
Vinay Sewdien (NL)

Publication Advisor
Anjan Bose (US)

Tutorial Advisory Group
Jens Jacobs (DE)

WG C2.17
Wide area monitoring systems – Support for control room application
Walter Sattinger (CH)

WG C2.24
Mitigating the risk of fire starts and the consequences of fires near overhead lines for System Operations
Frank Crisci (AU)

WG C2.25
Operating Strategies and Preparedness for System Operational Resilience
Jens Jacobs (DE)

WG C2.26
Power system restoration accounting for a rapidly changing power system and generation mix
Babak Badrzadeh (AU)

WG C2.39
Operator Training in Electricity Grids at Different Control Levels and for Different Participants/Actors in the New Environment
Jayme Darriba Macedo (BR)

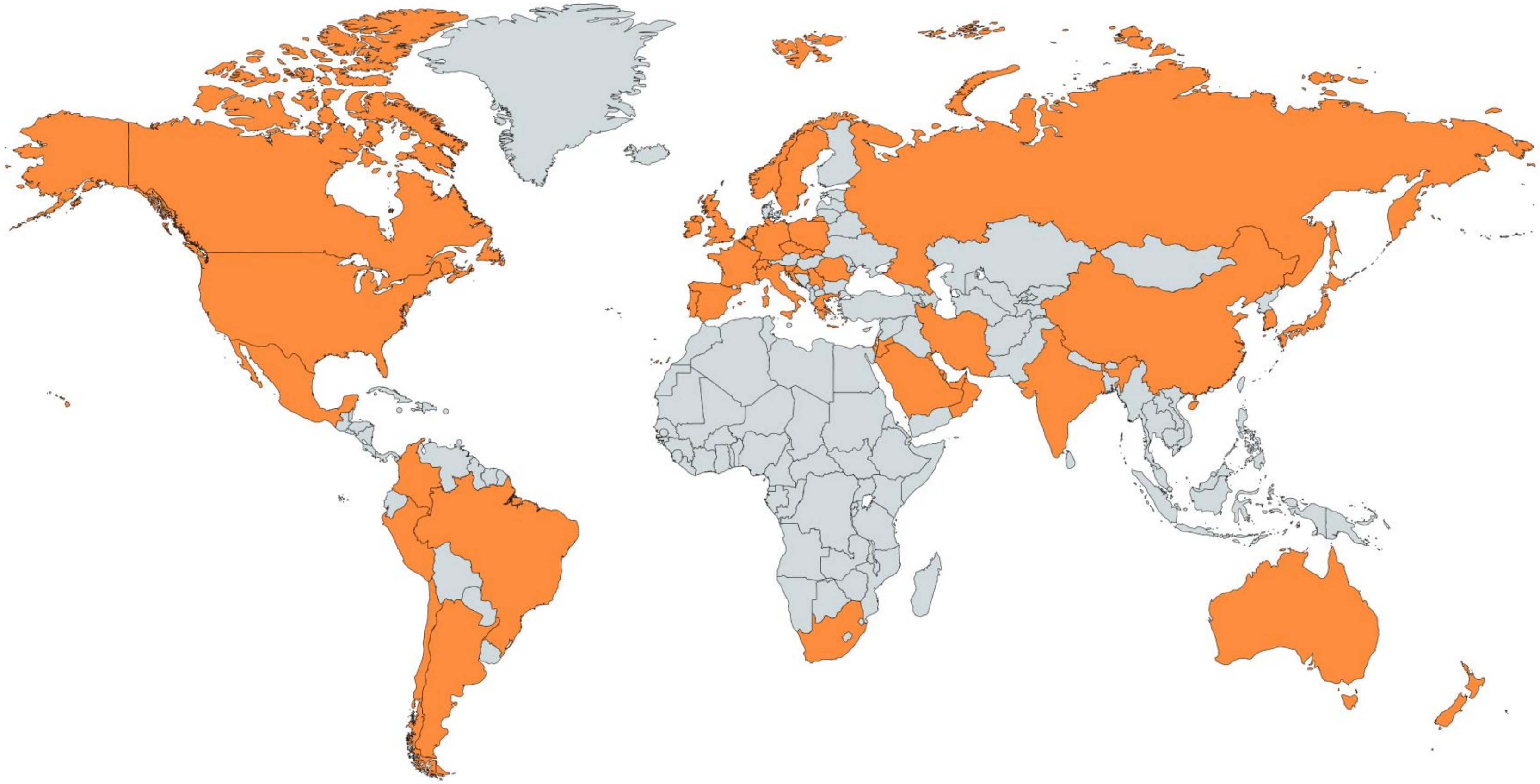
WG C2.40
TSO-DSO Cooperation – Control Centre Tools Requirements
Michael Power (IE)

JWG C2/B4.38
Capabilities and requirements definition for Power Electronics based technology for secure and efficient system operation and control
Jan van Putten (NL)

JWG C2/C4.41
Impact of high penetration of inverter-based generation on system inertia of networks

Mpeli Rampokanyo (SA)

SC C2: Members



- 27 Regular Members
- 15 Observer Members
- 170 experts
- 39 countries

SC C2: Additional Information

The website of SC C2 contains plenty of information on the activities, active working groups, publications, etc.

Website: https://c2.cigre.org/

SYSTEM OPERATIONAL CHALLENGES FROM THE ENERGY TRANSITION

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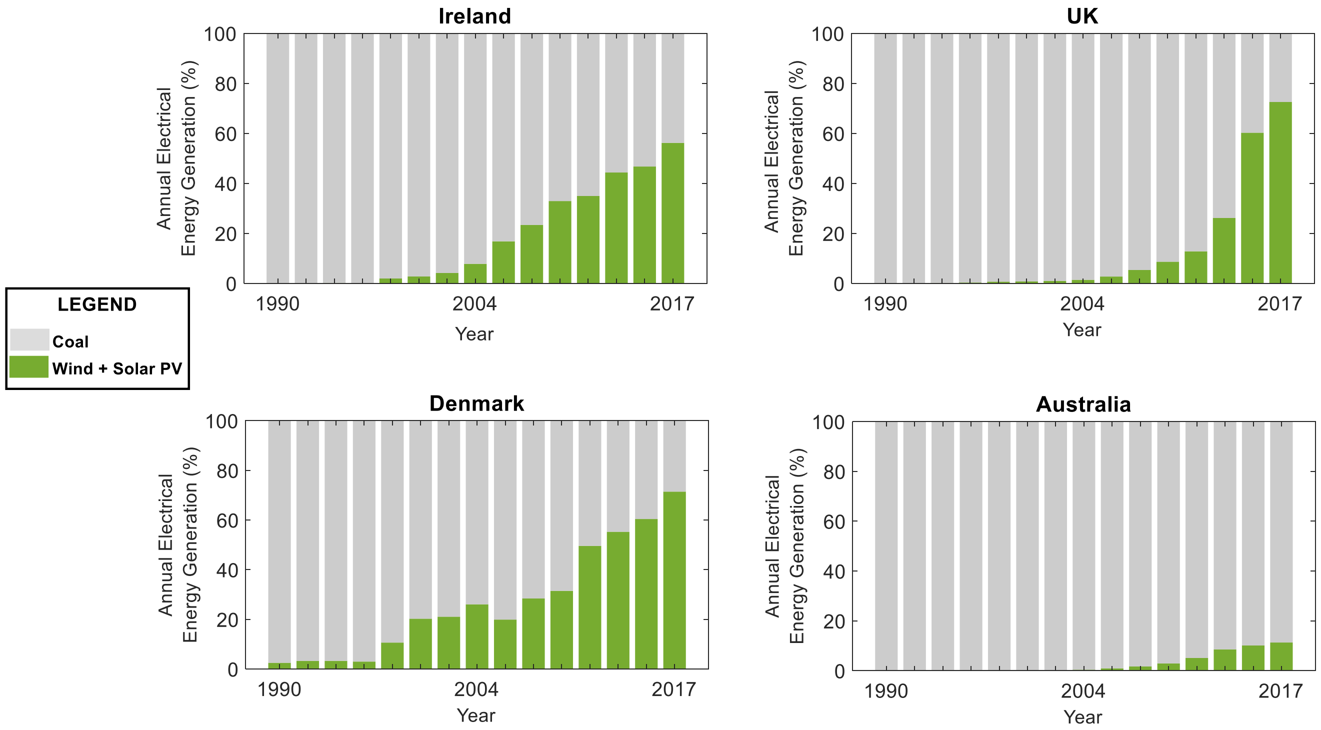
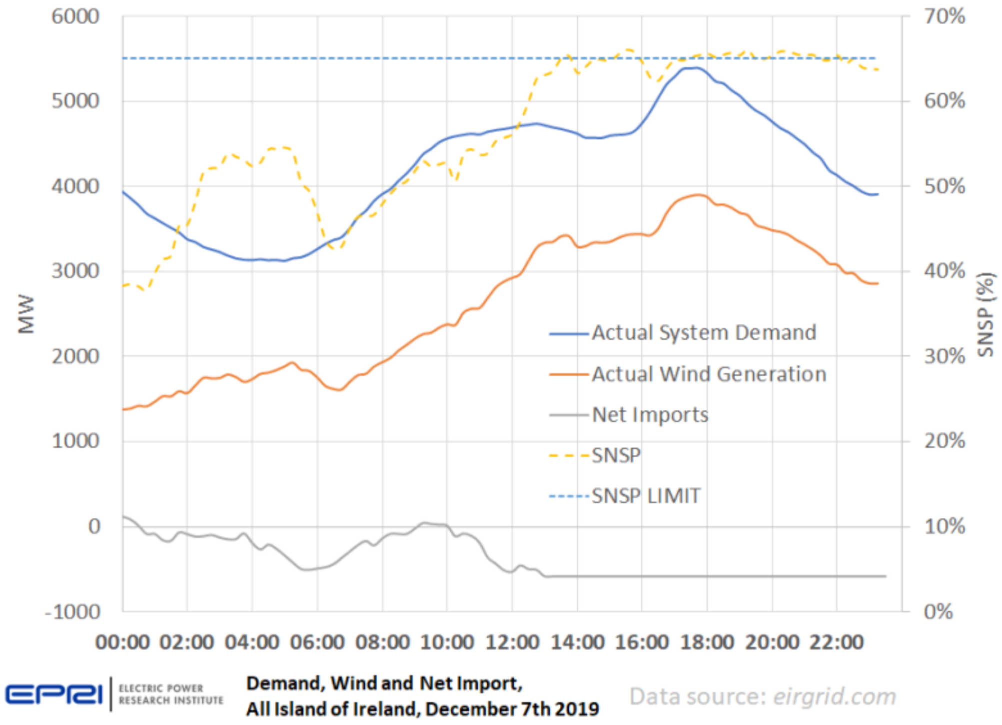
System Operational Challenges from the Energy Transition

Overview of Generation Development

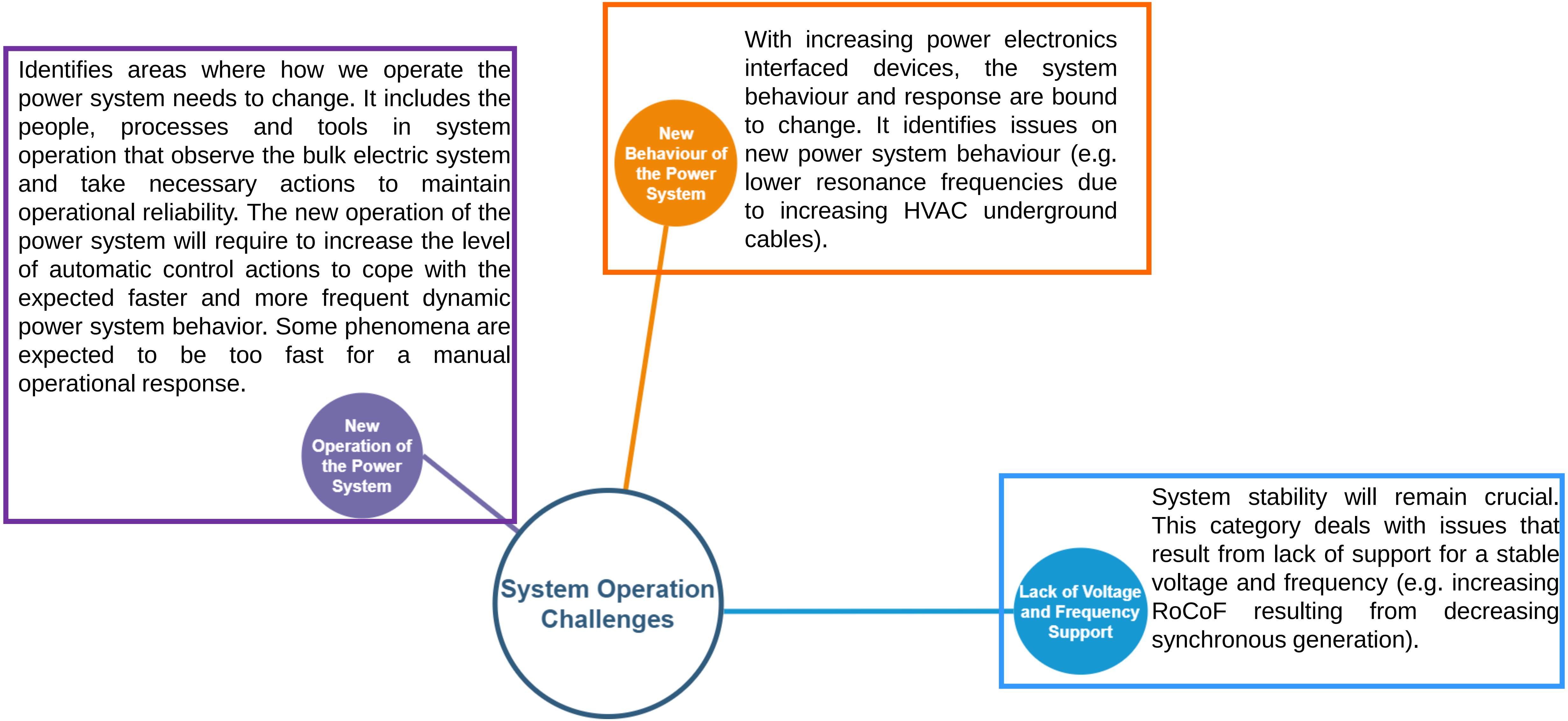


Annual electrical energy production coming from coal and combined wind and solar PV for Ireland, UK, Denmark and Australia. Values are normalized using the sum of these three sources. Other fossil fuel and renewable energy sources are not considered in the figure.



Demand, wind and net import of All Island of Ireland on 7 December 2019

System Operational Challenges from the Energy Transition



System Operation Challenges

New Operation of the Power System

Identifies areas where how we operate the power system needs to change. It includes the people, processes and tools in system operation that observe the bulk electric system and take necessary actions to maintain operational reliability. The new operation of the power system will require to increase the level of automatic control actions to cope with the expected faster and more frequent dynamic power system behavior. Some phenomena are expected to be too fast for a manual operational response.

New Behaviour of the Power System

With increasing power electronics interfaced devices, the system behaviour and response are bound to change. It identifies issues on new power system behaviour (e.g. lower resonance frequencies due to increasing HVAC underground cables).

Lack of Voltage and Frequency Support

System stability will remain crucial. This category deals with issues that result from lack of support for a stable voltage and frequency (e.g. increasing RoCoF resulting from decreasing synchronous generation).

System Operational Challenges from the Energy Transition

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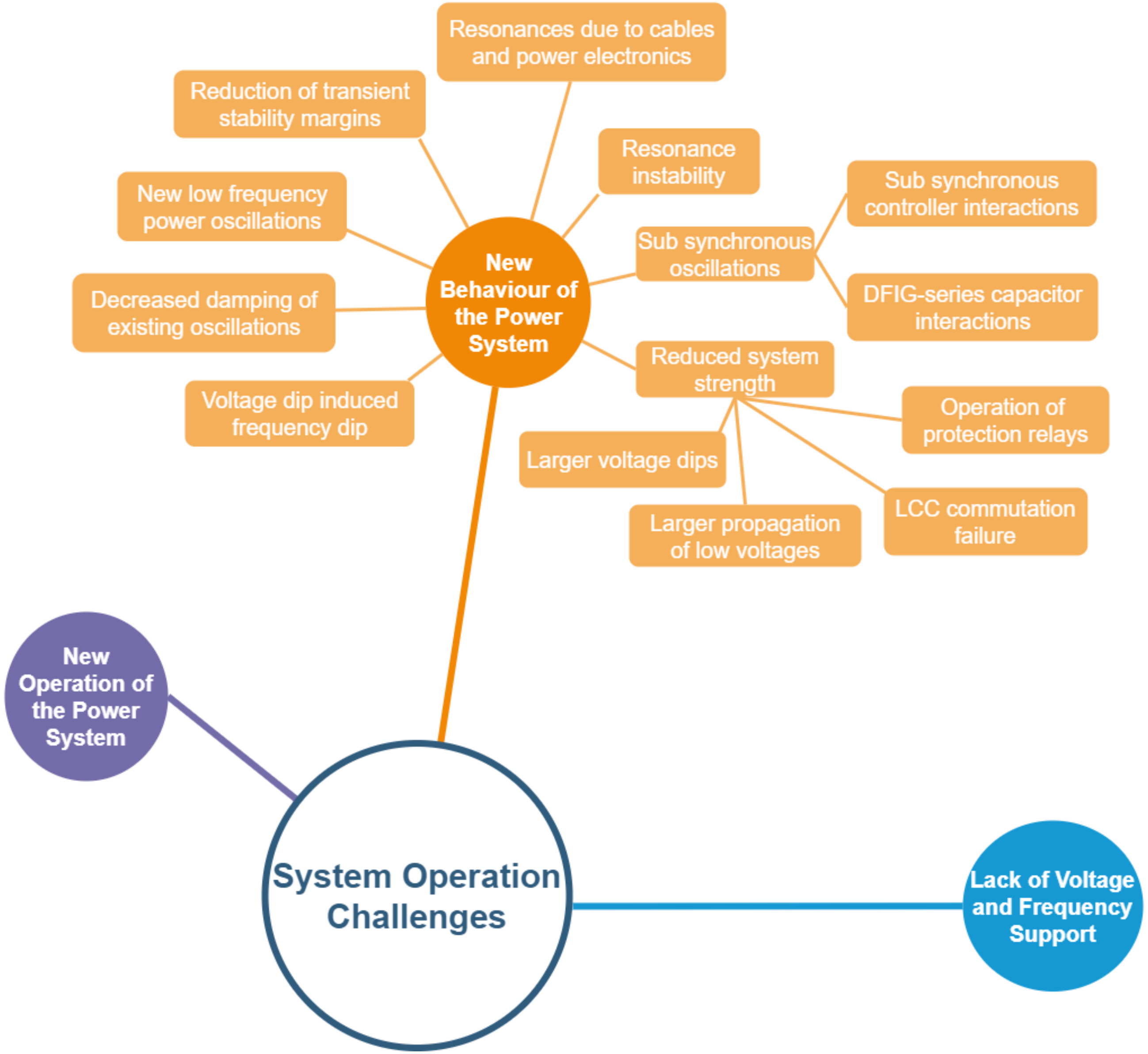

System Operational Challenges from the Energy Transition

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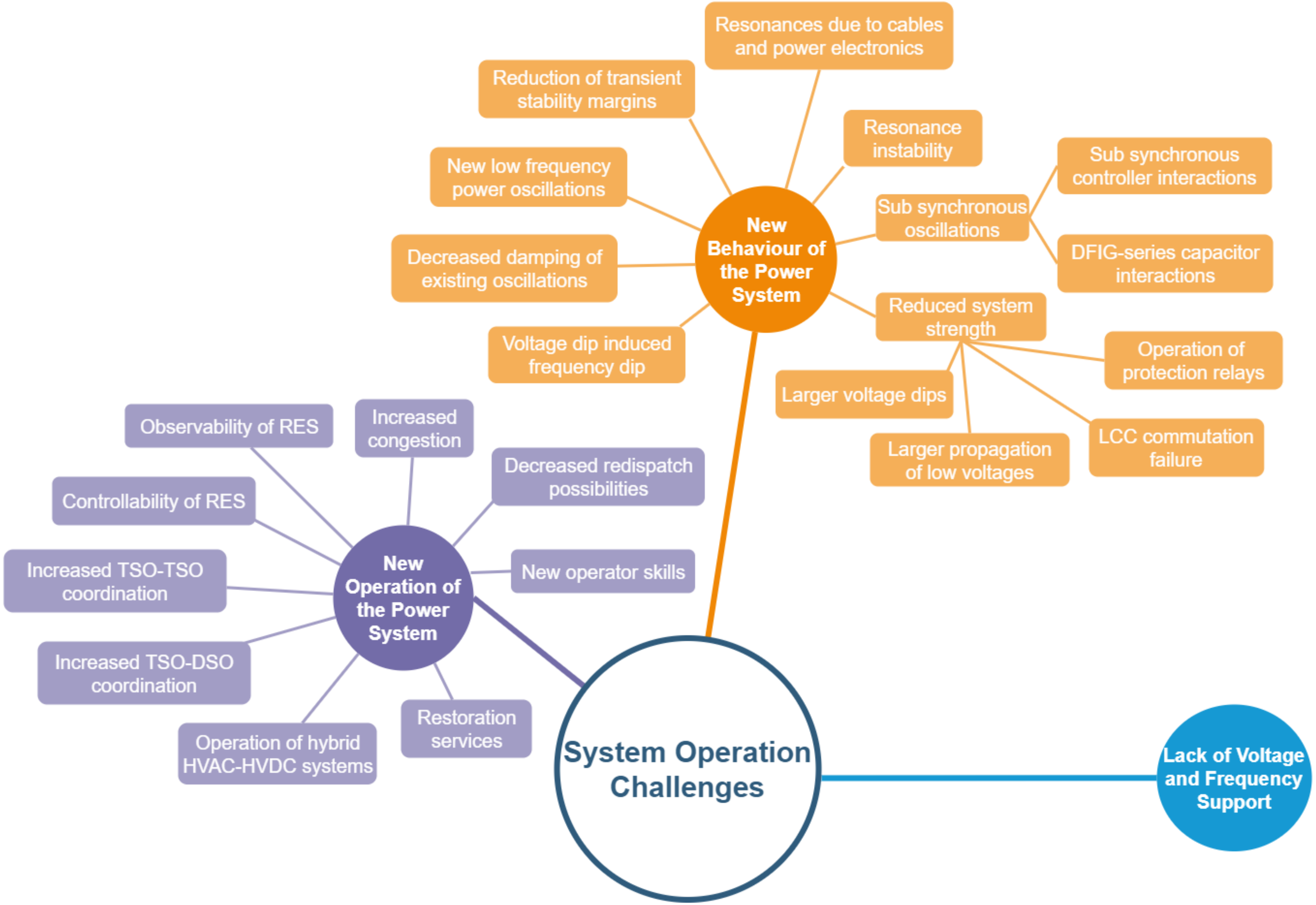


System Operation Challenges

New Behaviour of the Power System

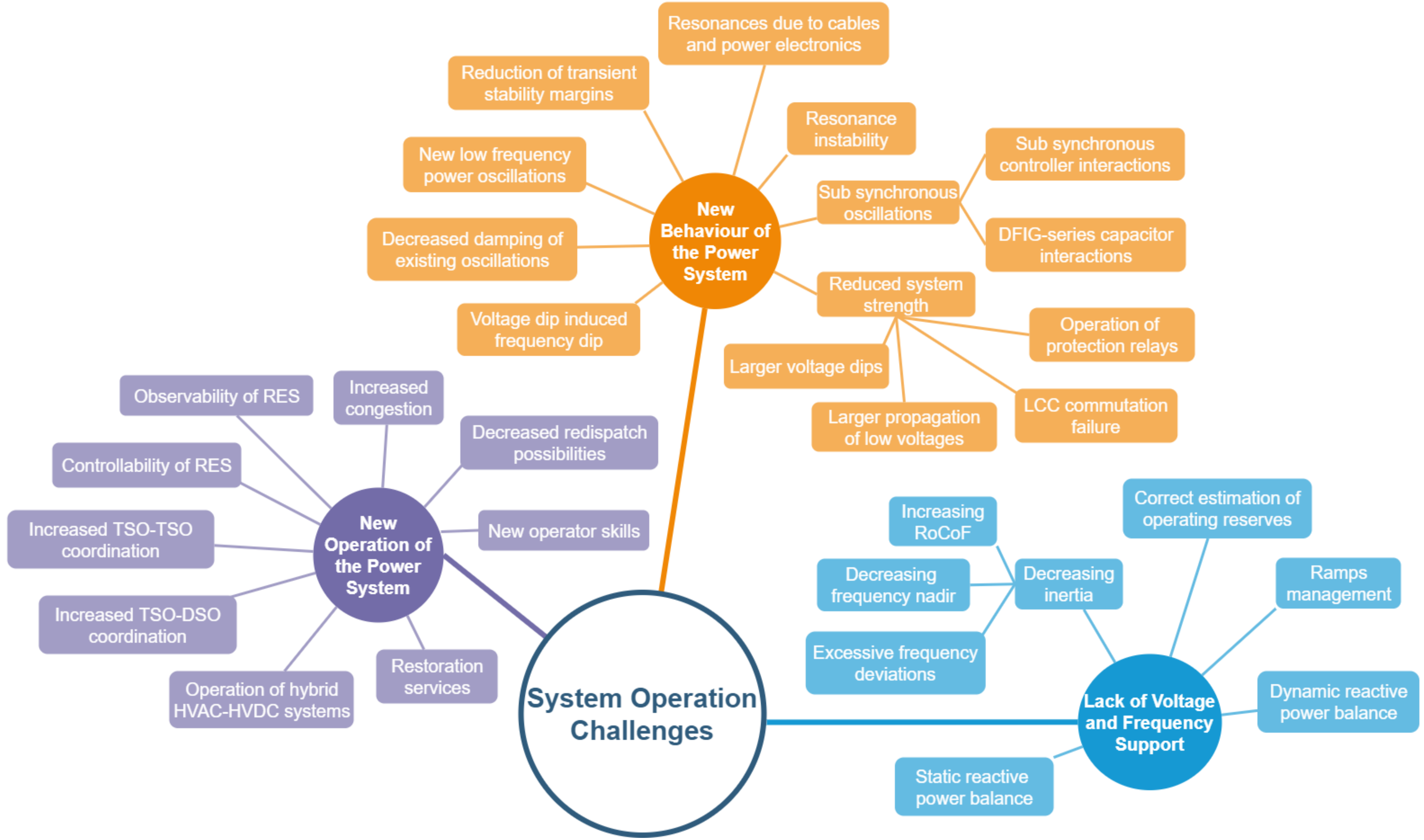
- Resonances due to cables and power electronics
- Reduction of transient stability margins
- Resonance instability
- New low frequency power oscillations
- Sub synchronous oscillations
  - Sub synchronous controller interactions
  - DFIG-series capacitor interactions
- Decreased damping of existing oscillations
- Reduced system strength
  - Operation of protection relays
  - Larger voltage dips
  - Larger propagation of low voltages
  - LCC commutation failure
- Voltage dip induced frequency dip

New Operation of the Power System

- Observability of RES
- Increased congestion
- Decreased redispatch possibilities
- Controllability of RES
- New operator skills
- Increased TSO-TSO coordination
- Increased TSO-DSO coordination
- Operation of hybrid HVAC-HVDC systems
- Restoration services

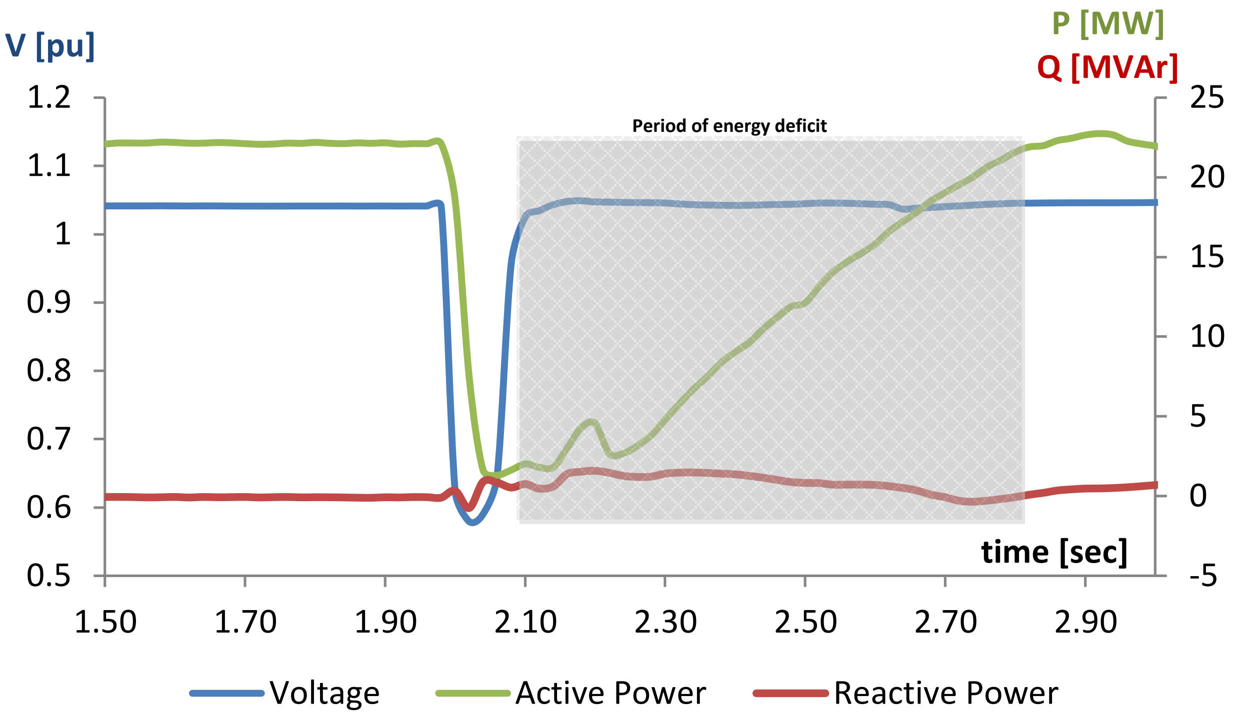
Lack of Voltage and Frequency Support

System Operational Challenges from the Energy Transition



New Behaviour of the Power System

Example: voltage dip induced frequency dip in Ireland



Energy deficit caused by slow recovery of wind generation following a network disturbance

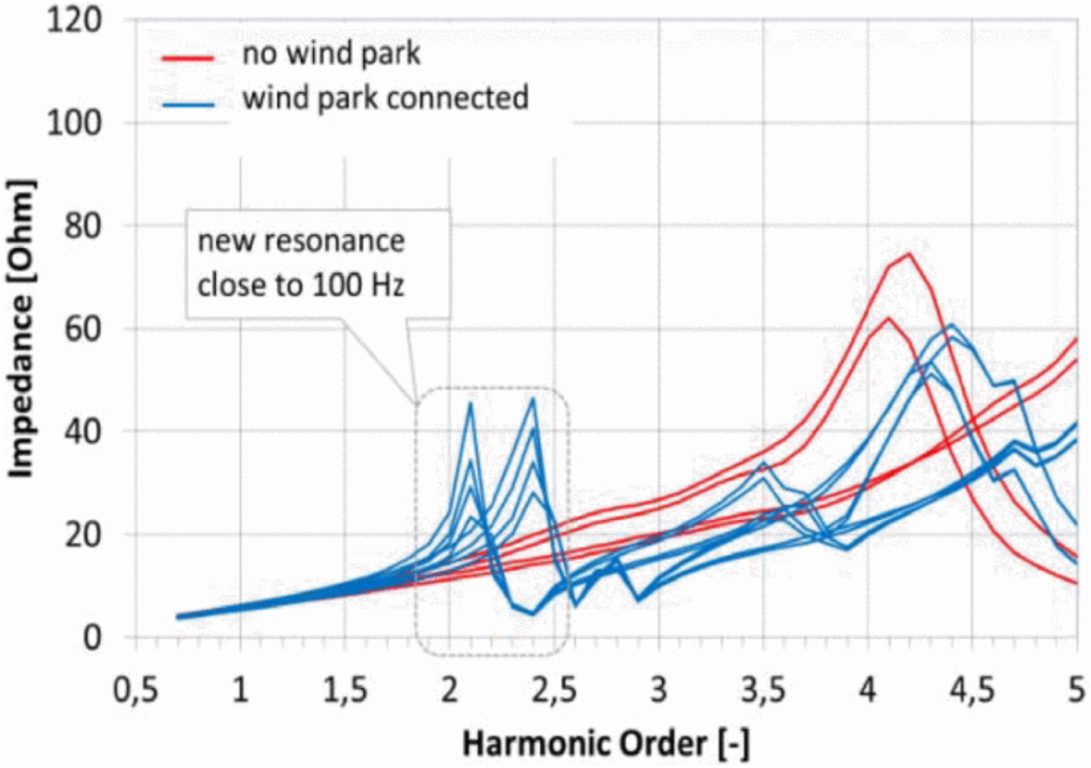
Reference:
S. Almeida de Graaff, Z. Emin et al., “Effects of Increasing Power Electronics based Technology on Power System Stability: Performance and Operations,” CIGRE Sci. Eng. J., vol. 11, pp. 5–17, 2018.

This issue refers to the recovery phase of the active power of wind turbine generators after short-circuit events.

This active power recovery may be slow in order to limit the mechanical stress on the drive-train: during the grid fault, active power cannot be supplied to the grid. Wind turbines without the capability to dissipate active power for a short time, will immediately be unloaded, which causes mechanical stress.

New Behaviour of the Power System

Example: Resonances due to increasing cables (harmonic frequency scan of the Dutch transmission system)



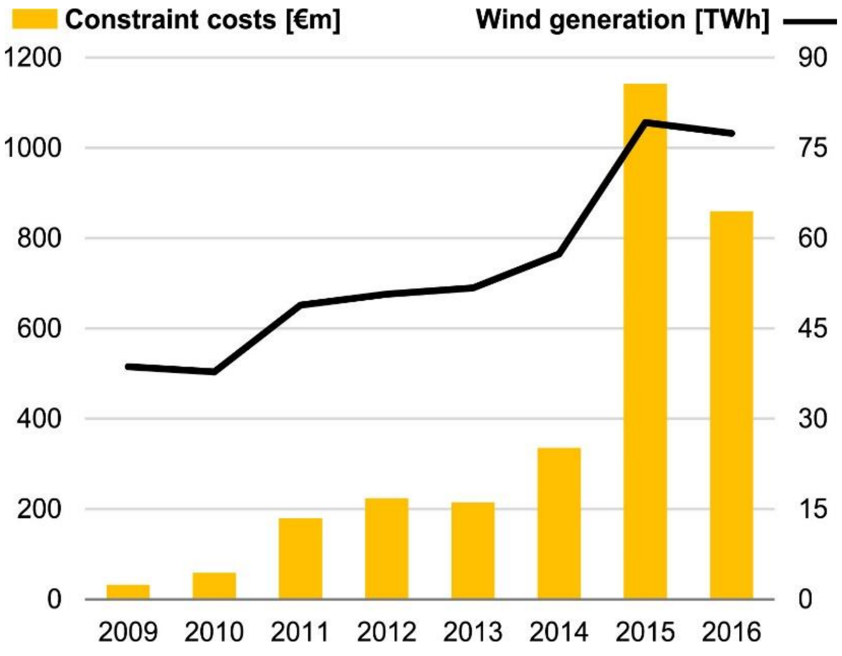
Harmonic frequency scan

Reference:

K. Jansen, B. Van Hulst, C. Engelbrecht, P. Hesen, K. Velitsikakis, and C. Lakenbrink, “Resonances due to long HVAC offshore cable connections: Studies to verify the immunity of Dutch transmission network,” in *2015 IEEE Eindhoven PowerTech, PowerTech 2015*, 2015, pp. 1–6.

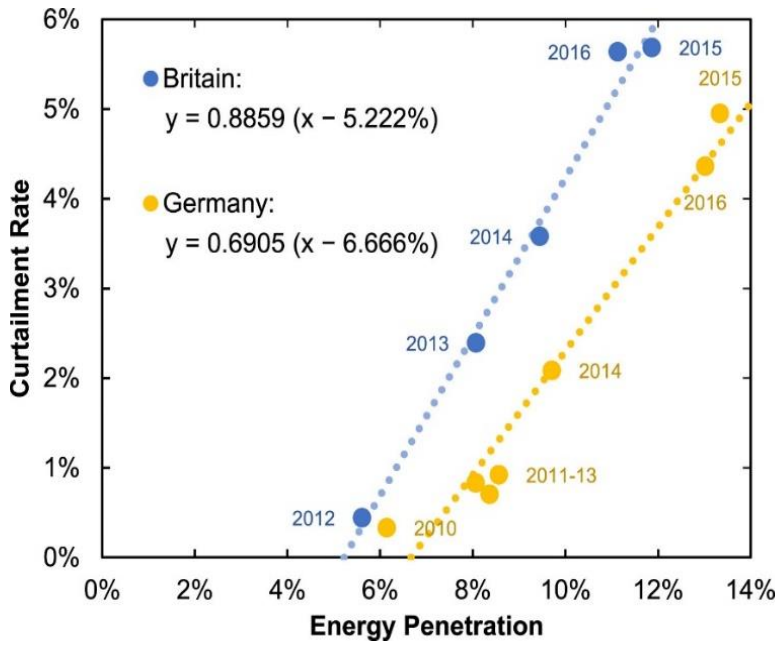
New Operation of the Power System

Example: increased congestion/decreased redispatch possibilities in Germany and UK



Congestion management costs in Germany

Reference:
M. Joos and I. Staffell, “Short-term integration costs of variable renewable energy: Wind curtailment and balancing in Britain and Germany,” Renewable and Sustainable Energy Reviews, vol. 86. Elsevier Ltd, pp. 45–65, 01-Apr-2018

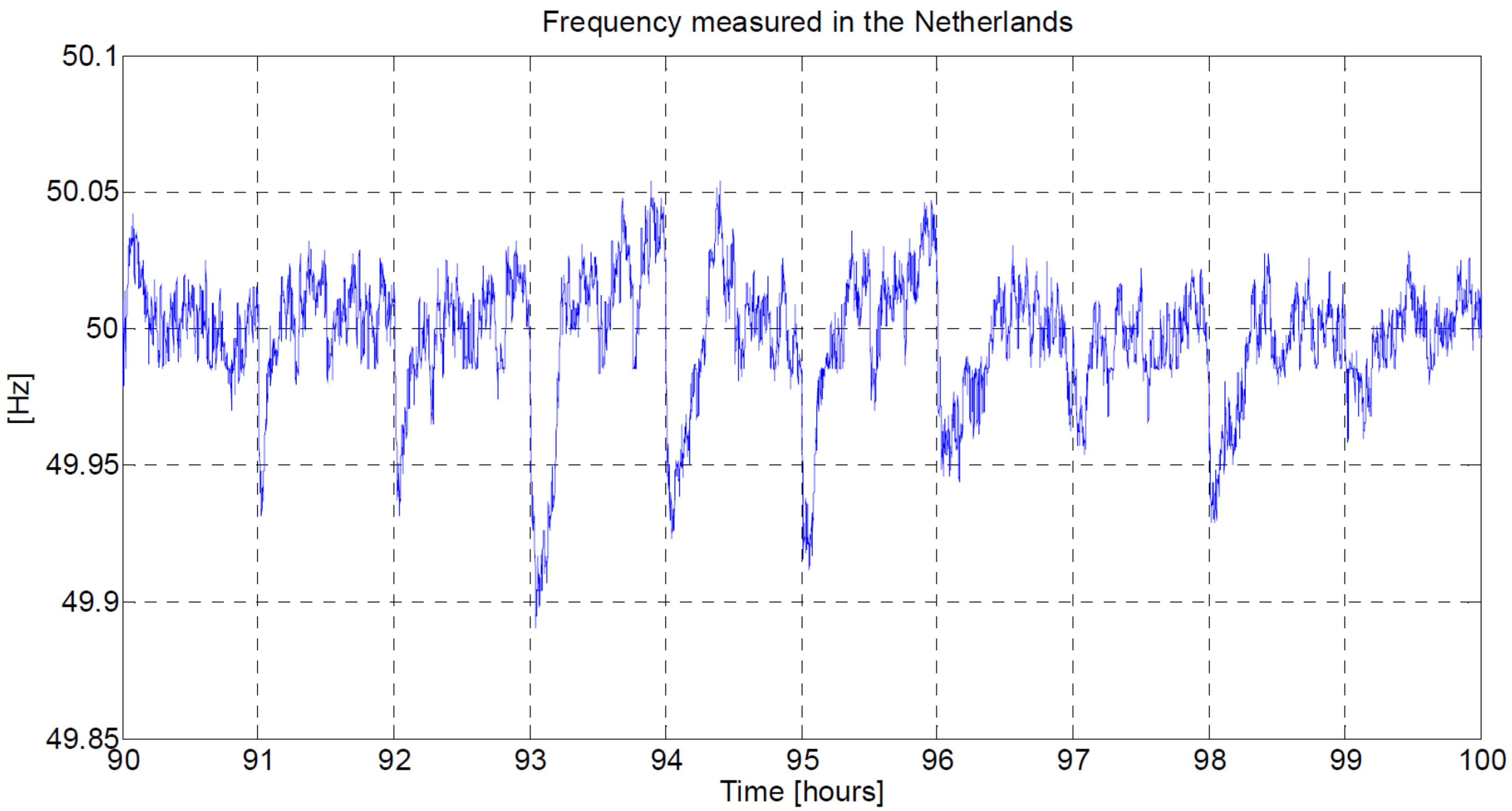


Curtailment rates against penetration levels for wind power in Britain and Germany

Reference:
M. Joos and I. Staffell, “Short-term integration costs of variable renewable energy: Wind curtailment and balancing in Britain and Germany,” Renewable and Sustainable Energy Reviews, vol. 86. Elsevier Ltd, pp. 45–65, 01-Apr-2018

Lack of Voltage and Frequency Support

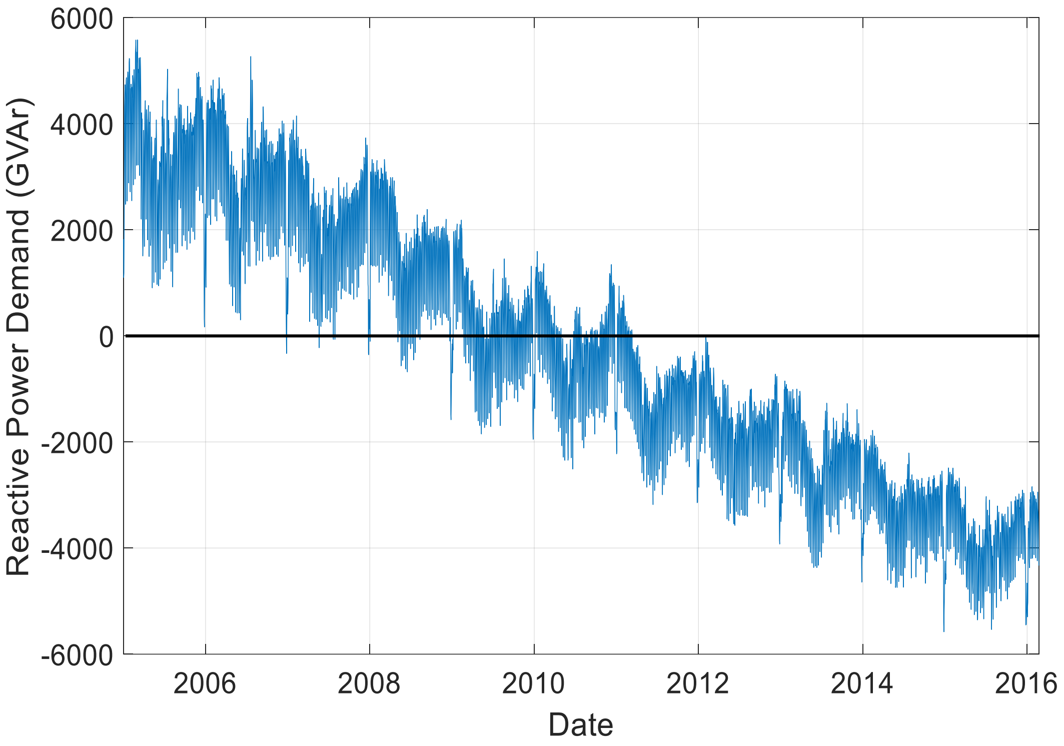
Example: deterministic frequency deviation in the Netherlands caused by X-border schedule exchanges



Reference:
D. Becker Hoff *et al.*, “Storage application for frequency control of hourly cross-border program changes,” in *Proceedings of the 2016 CIGRE Session*, 2016

Lack of Voltage and Frequency Support

Example: static reactive power balance in UK



Daily minimum reactive power demand

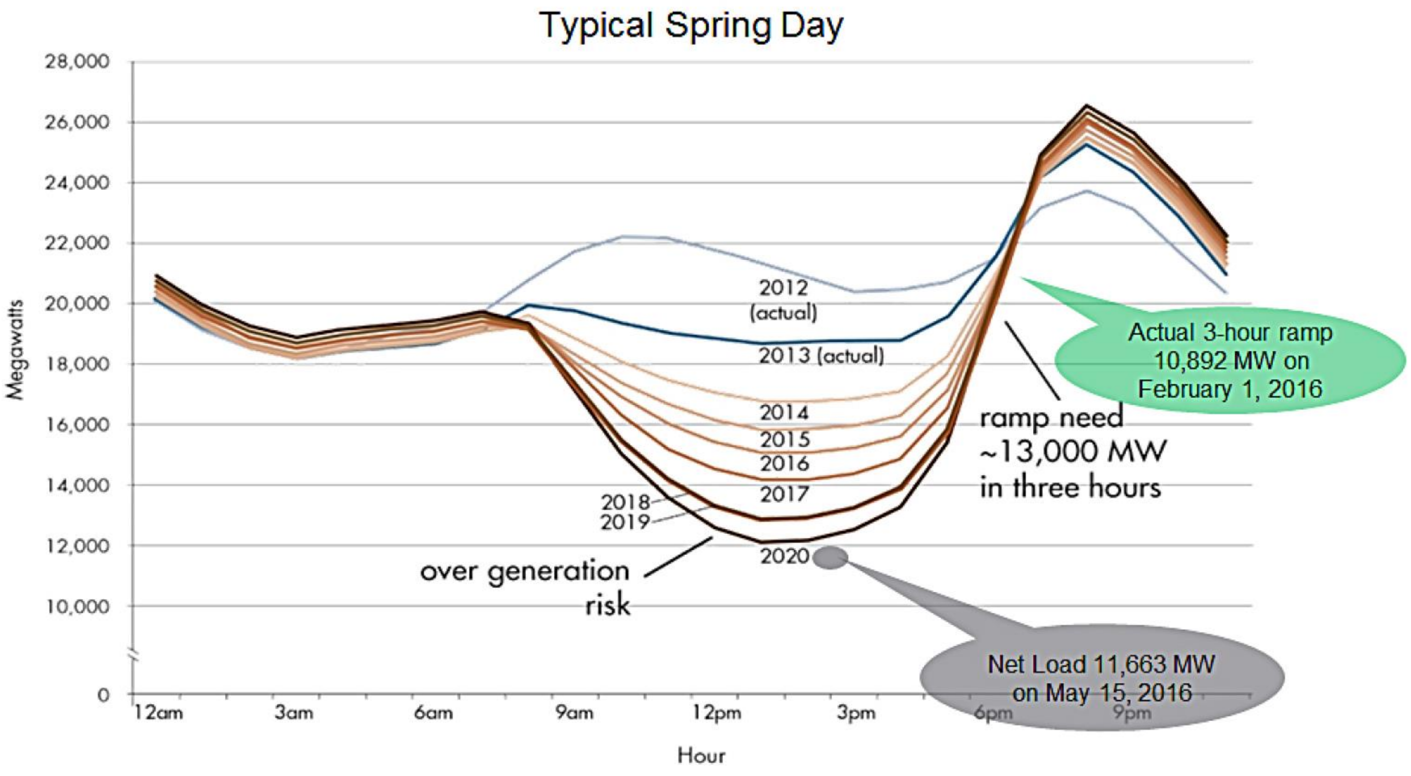
RES connected close to customer loads at medium and low voltages are contributing to a reduction in demand that needs to be supported by transmission and sub-transmission systems at various times of the day.

Operation of transmission lines below their surge impedance loading (SIL), coupled with the increased usage of underground cabling, will result in a surplus of reactive power and an increase in network voltages during these low demand periods. The ability to 'sink' excess reactive power at such times is a growing issue in some networks.

Reference:
National Grid, “System Operability Framework,” Warwick, 2016

Lack of Voltage and Frequency Support

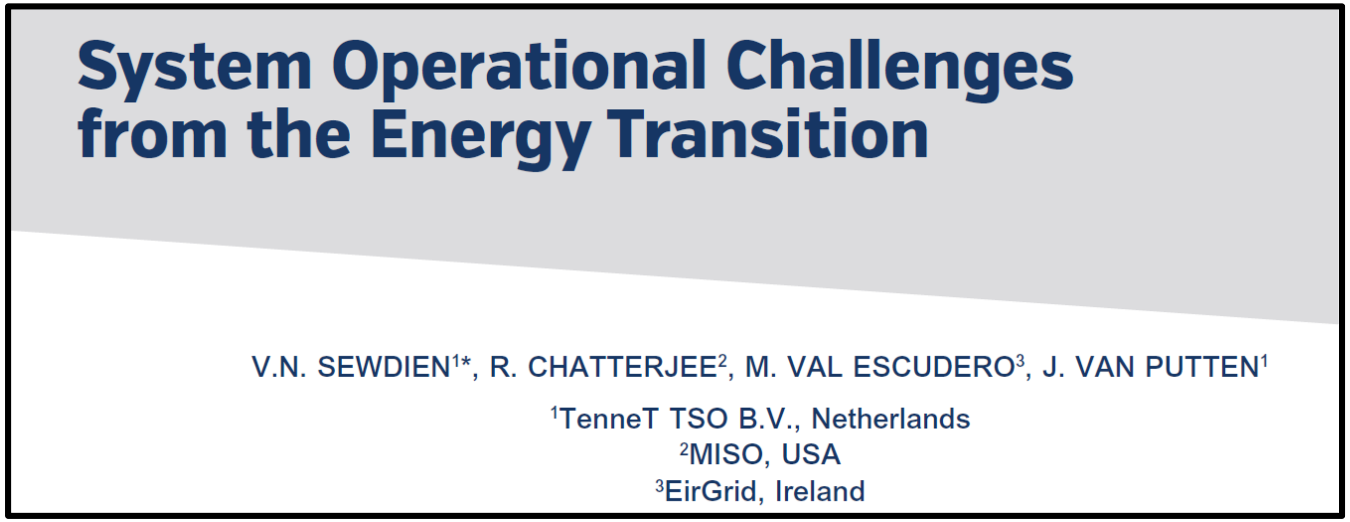
Example: ramp management requirement in California



Net load for a typical Spring day in California

Reference:
Californian ISO, “What the duck curve tells us about managing a green grid,” California, 2016

System Operational Challenges from the Energy Transition



System Operational Challenges from the Energy Transition

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[1]TenneT TSO B.V., Netherlands
[2]MISO, USA
[3]EirGrid, Ireland

CIGRE SCIENCE
& ENGINEERING

Innovation in the Power Systems industry

Engineers and specialists worldwide exchange information and state-of-the-art world practices to enhance knowledge related to power systems in CIGRE's latest publication.

Reference:
V. N. Sewdien, R. Chatterjee, M. Val Escudero, and J. van Putten,
“System Operational Challenges from the Energy Transition,” *CIGRE Sci. Eng.*, vol. 17, pp. 5–20, 2020.

MITIGATION SOLUTIONS

- FACTS based
- non-FACTS based

FACTS BASED MITIGATION SOLUTIONS

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FACTS: Non-Exhaustive Overview of Installed Systems

Region	FACTS
South Australia	SVC
Chile	STATCOM SVC
China	SVC UPFC
Colombia	STATCOM (1) SVC (3)
Gulf Cooperation Council	SVC TCSC
India	STATCOM (7) SVC (1) TCSC (6)
Japan	STATCOM

Region	FACTS
Norway	STATCOM (1) SVC (10)
Peru	STATCOM (1) SVC (11)
South Africa	STATCOM (1) SVC (3)
South Korea	STATCOM (6) SVC (3) UPFC (1)
Spain	OLC (1) SSSC (1)

STATCOM:	Static Compensator
SVC:	Static Var Compensator
UPFC:	Universal Power Flow Controller
TCSC:	Thyristor Controlled Series Capacitor
OLC:	Overhead Line Controller
SSSC:	Static Synchronous Series Compensator

FACTS: Examples in System Operation

STATCOM:

- Compensation of voltage unbalances due to traction loads (South Africa)
- Power oscillation damping (Colombia, India)
- Voltage support (India)

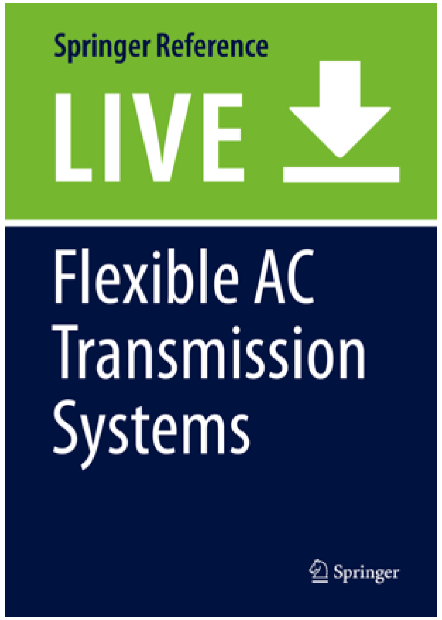
SVC:

- Fast dynamic voltage support to improve large disturbance voltage stability (Peru, Norway)
- Balancing of phase voltages of long non-transposed transmission lines (South Africa)
- Increased power transfer capabilities of transmission corridors (Peru)
- Mitigation of transient overvoltages following HVDC faults (China)
- Mitigation of flicker and harmonics (Peru)

FACTS: Examples in System Operation

TCSC:

- Increased power transfer capability across long lines (India)
- Damping of interarea oscillations (India)

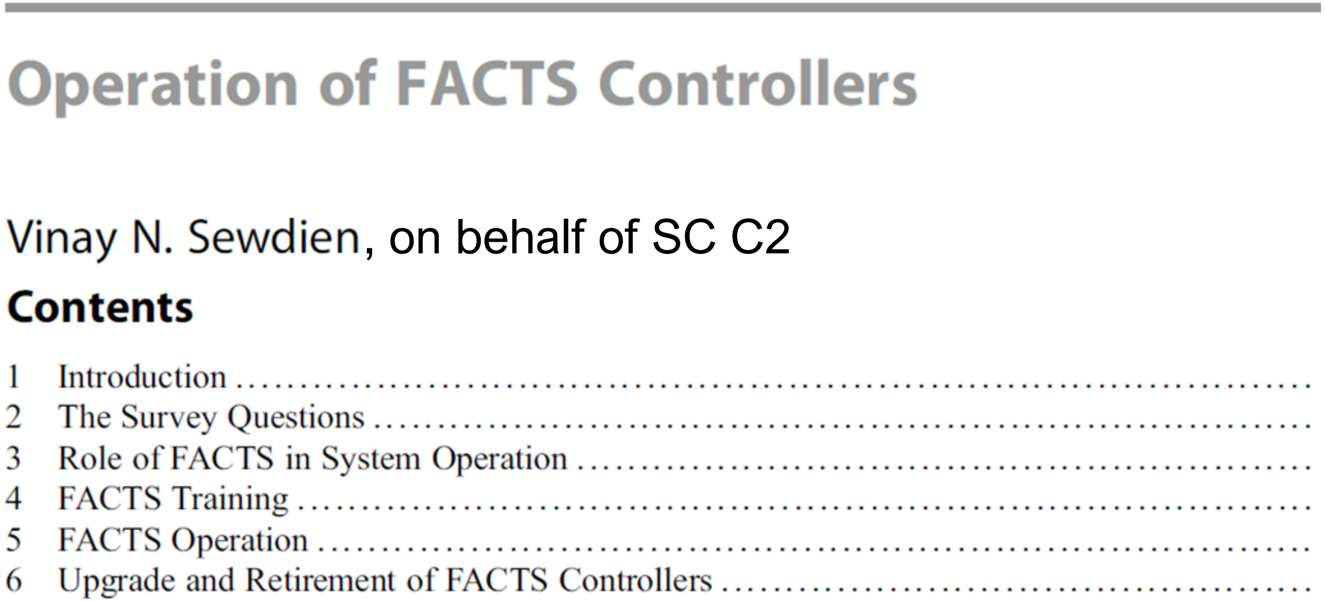


Springer Reference

LIVE

Flexible AC Transmission Systems

Springer



Operation of FACTS Controllers

Vinay N. Sewdien, on behalf of SC C2

Contents

Reference:
B. Andersen and S. Nilsson, Eds., Flexible AC Transmission Systems. Cham: Springer, 2020

NON-FACTS BASED MITIGATION SOLUTIONS

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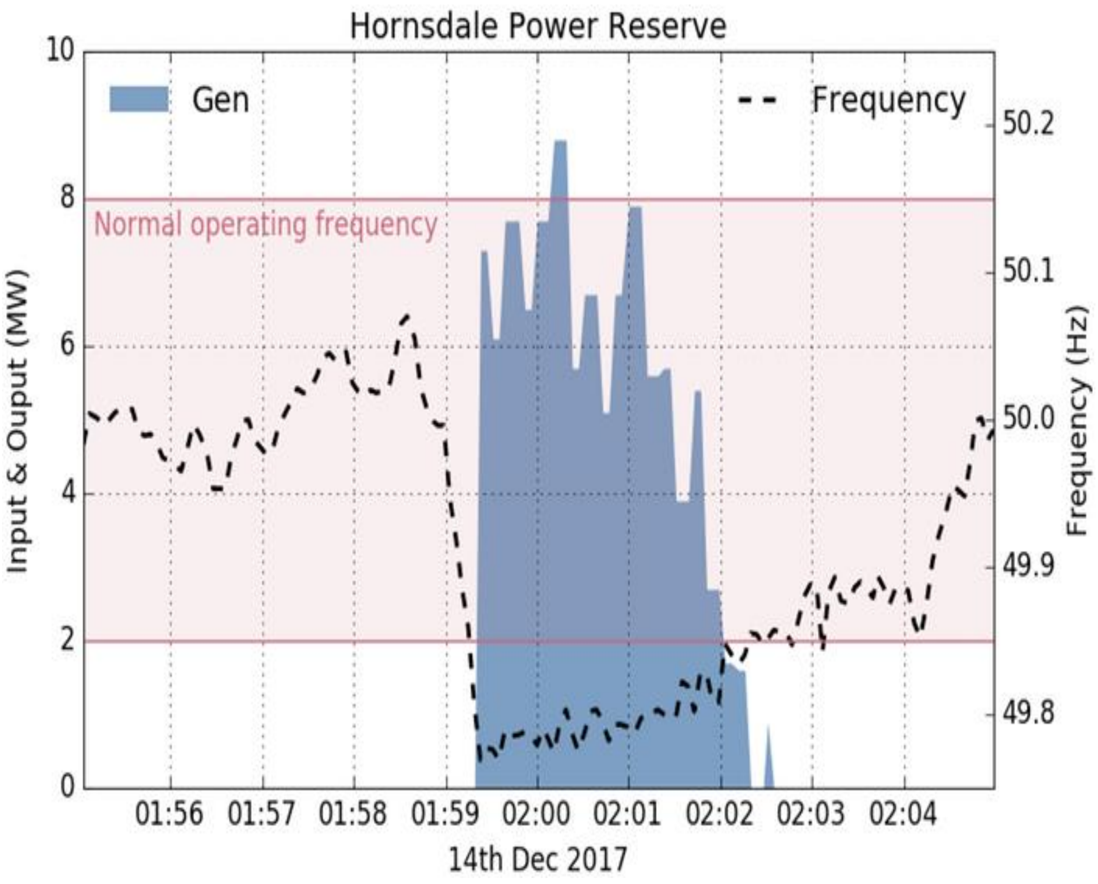
Frequency Support – Example Australia

Battery Energy Storage System (BESS)

In South Australia, there is a 100 MW (129 MWh) BESS installation at Hornsdale, and a 30 MW (8 MWh) BESS installation at Dalrymple.

One of the aims of these batteries is to provide ancillary services (e.g. frequency control).

On 14 December 2017 successful operation was demonstrated. The battery in Hornsdale discharged with millisecond response to immediately arrest the frequency excursion following a trip of a 560 MW coal fired power plant.



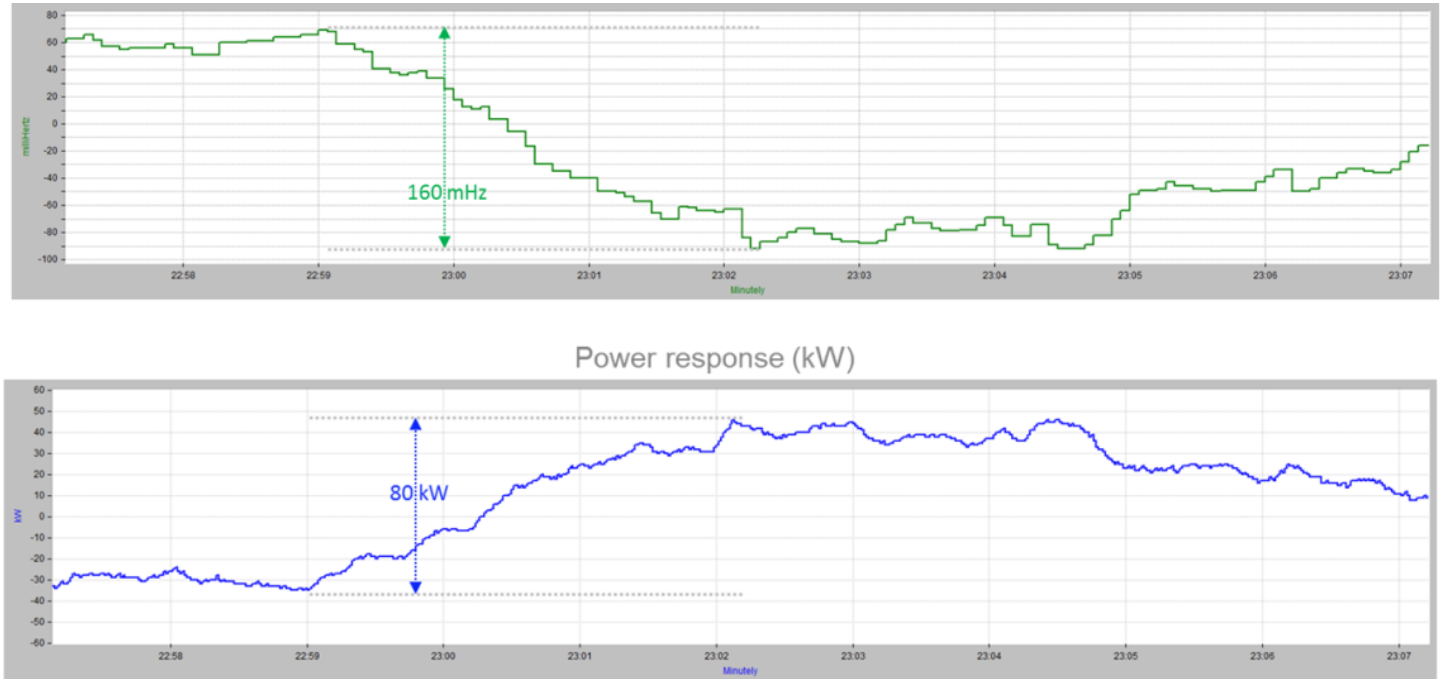
Hornsdale power reserve response to disturbance of 14 December 2017

Reference:
F. Crisci *et al.*, "Power System Restoration – World Practices & Future Trends," *CIGRE Sci. Eng. J.*, vol. 14, pp. 6–22, 2019.

Frequency Support – Example of Netherlands

Pool of assets

In 2016, a pilot project was initiated in the Netherlands with the aim to provide Frequency Containment Reserves by aggregating responses from a pool of assets: electrical vehicles, heat-pumps, Bio-CHPs, battery installations, residential energy storage and wind turbines



Response of FCR pilot assets to frequency deviation

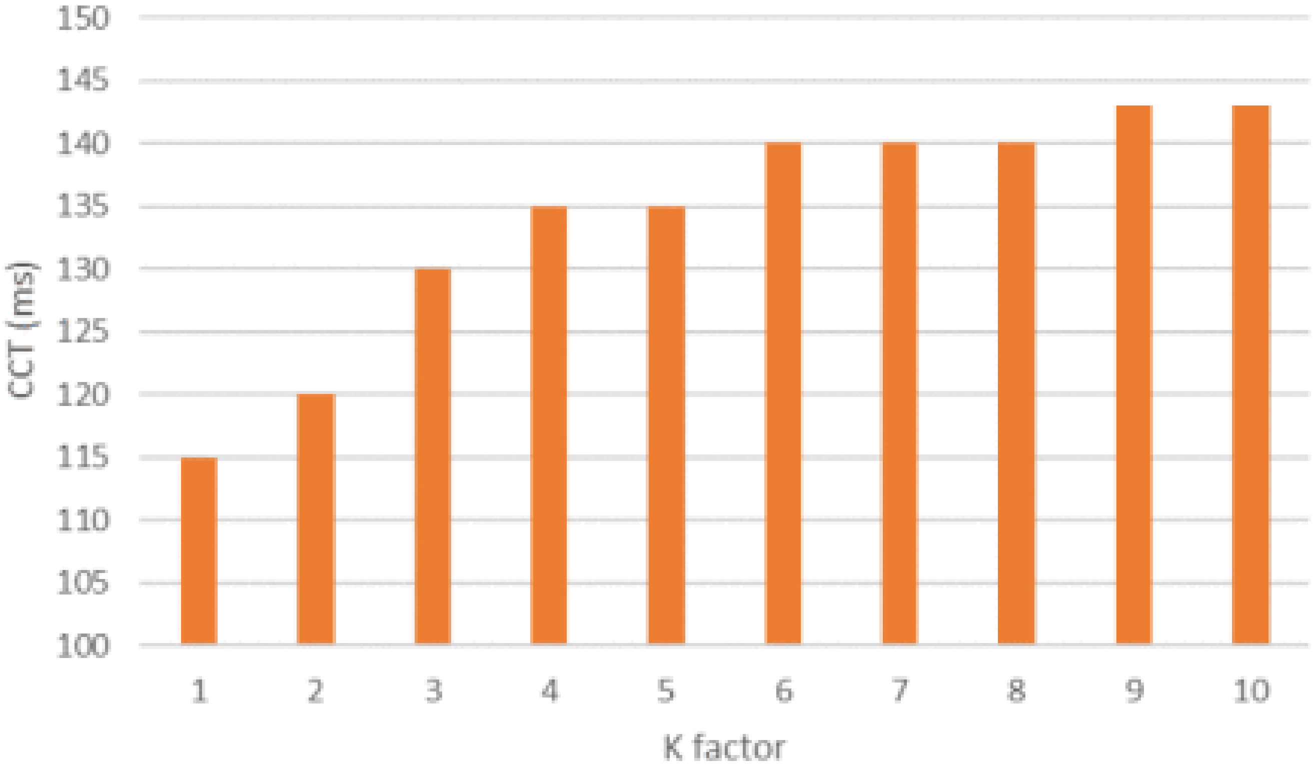
Reference:
D. Klaar, “Pilot projects for ancillary services,” in *Proceedings of the 2018 CIGRE Session*, 2018

Increased Transient Stability Margin

Converter parameter tuning

In an academic exercise, the influence of the reactive power boosting parameter *K* of the converter control on the critical clearing time was investigated.

For a given penetration of power electronics interfaced generation, it was found that the transient stability can be improved by tuning of the parameter *K.*



Improved transient stability (i.e. increased critical clearing time (CCT)) due to tuning of the reactive power boosting parameter *K* in the converter control

Reference:
N. Farrokhseresht, A. A. van der Meer, J. R. Torres, M. A. M. M. van der Meijden and P. Palensky, "Increasing the Share of Wind Power by Sensitivity Analysis based Transient Stability Assessment," *2019 2nd International Conference on Smart Grid and Renewable Energy (SGRE)*, Doha, Qatar, 2019, pp. 1-6.

UPCOMING PUBLICATIONS

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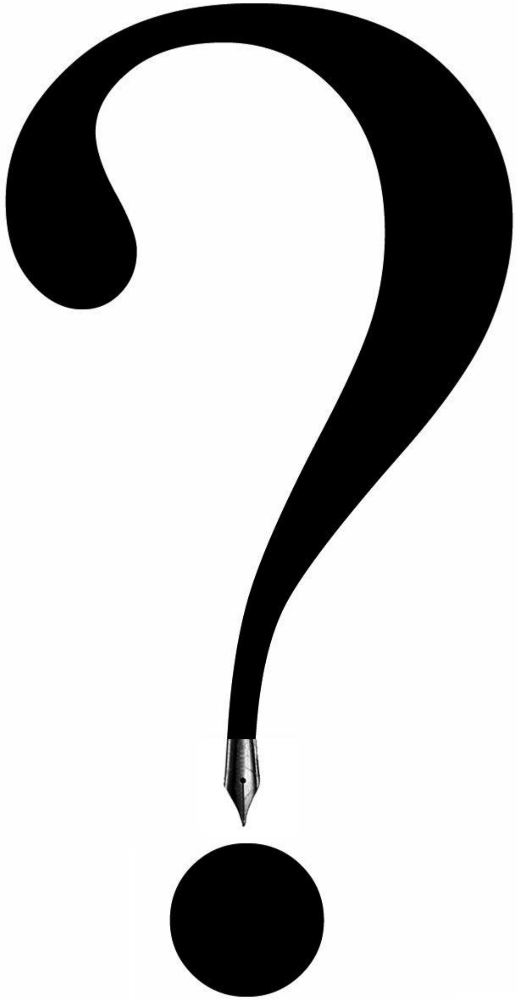
Upcoming Publications

Publications to look forward to in 2020:

- Technical Brochure C2/B4.38 (Q4-2020)
- CSE Paper: Capabilities of power electronics for system operations (Q4-2020)
- FACTS Green Book (Q3-2020)
- Power System of the Future Green Book (Q3-2020)

Questions



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