2017-05-10 FACHTAGUNG FLEXIBILITAET IN DER ELEKTRIZITAETSWIRTSCHAFT

Towards more flexible supply of electricity

A summary of ongoing work across CIGRE's study committees

Dr. Alexandre Oudalov, Market Innovation, Power grids division

Agenda

1. Why do we need a more flexible power system?
2. Which technologies can contribute to system flexibility?
3. What are the open technical questions and how are they addressed by CIGRE?

Towards more flexible supply of electricity

Why do we need a more flexible power system?

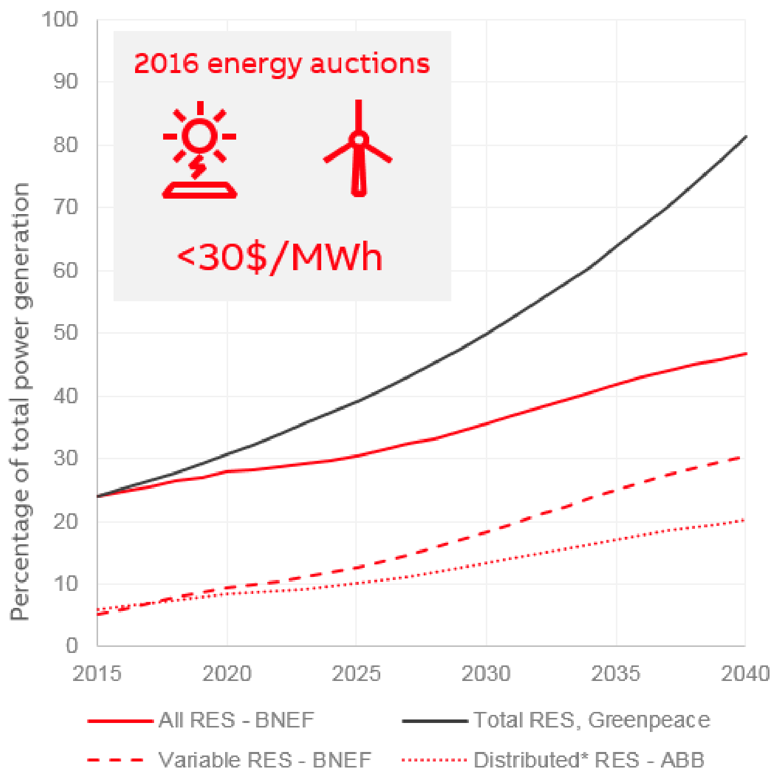
Power system flexibility is the ability to respond to changes in supply and demand

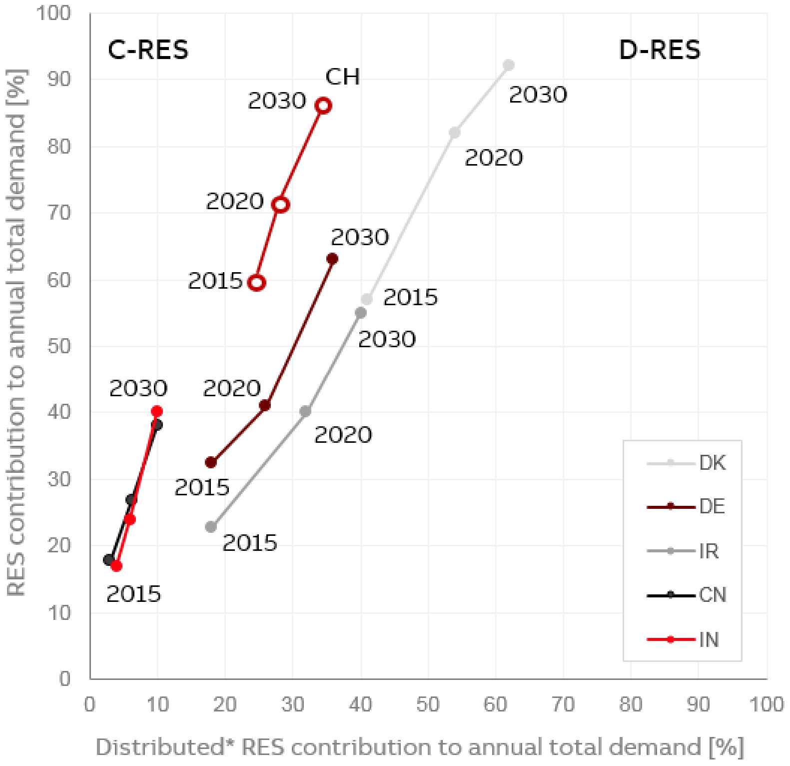
Power balance tipping towards renewables, driven by policy and sharp reduction in technology cost (spend the same, get more).

Main growth in variable renewables (V-RES) such as wind and solar.

Two growth paths:

- Mainly centralized renewables (C-RES).
- Mainly distributed* renewables (D-RES).





* Power generation units <50 MW.

Towards more flexible supply of electricity

A more time-variant system in the future

Hourly variation

The 2012-15 time-series for wind and solar are scaled such that future annual energy supplied by these sources can cover 50% of the annual demand.

It is assumed that the German demand will not change in the future (in line with governmental projections). The 2014 demand time-series is used as future demand.

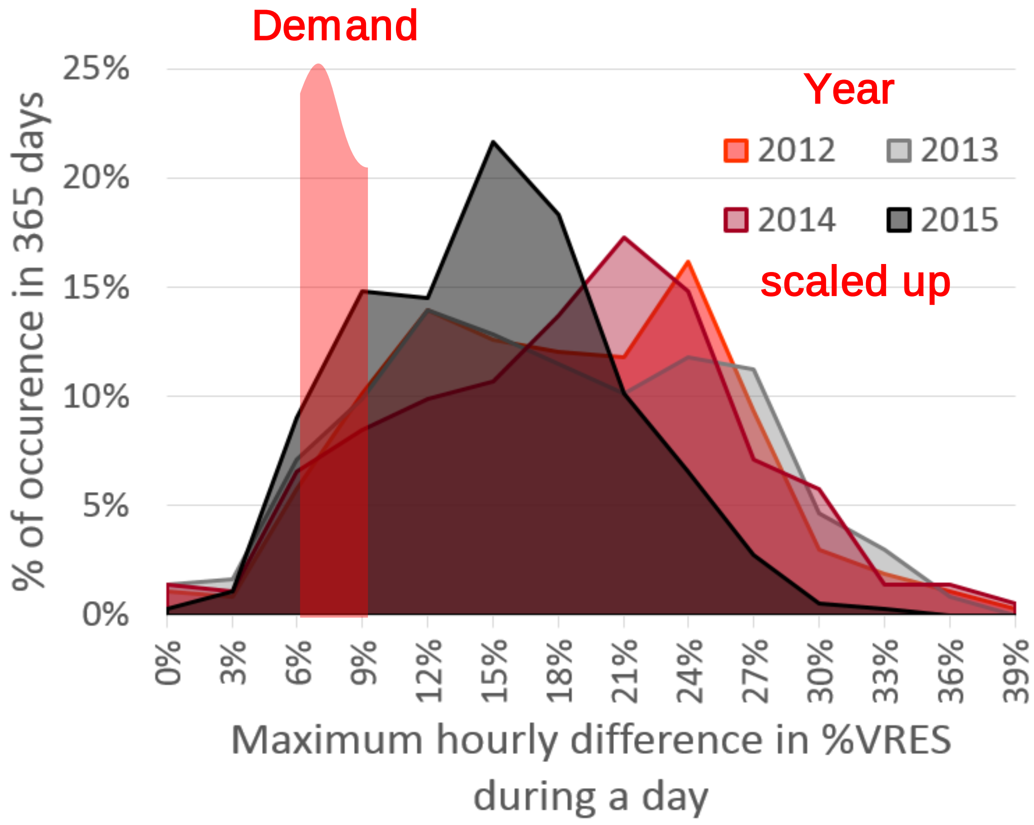
Hour-to-hour variation of V-RES share is calculated in each day as:

$$\left| \frac{P(t_{h+1})_{V-RES}}{D(t_{h+1})} - \frac{P(t_h)_{V-RES}}{D(t_h)} \right|$$

where t_h is the hour of the day, P is the power supplied by the V-RES, and the D is the demand.

Compare to: maximum hour-to-hour change in demand is ~6-10%

1 billion € re-dispatch cost in 2015 in DE



Results are based on statistical analysis of German power system. Time series for 2012-15 are provided by Agora Energiewende: https://www.agora-energiewende.de/de/themen/-agothem-/Produkt/produkt/76/Agorameter/

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A more time-variant system in the future

Daily "mileage"

Daily "mileage" is a sum of total hourly changes in a day and it is calculated as:

$$\sum_{h=1}^{24} |P(t_{h+1})_D - P(t_h)_D|$$

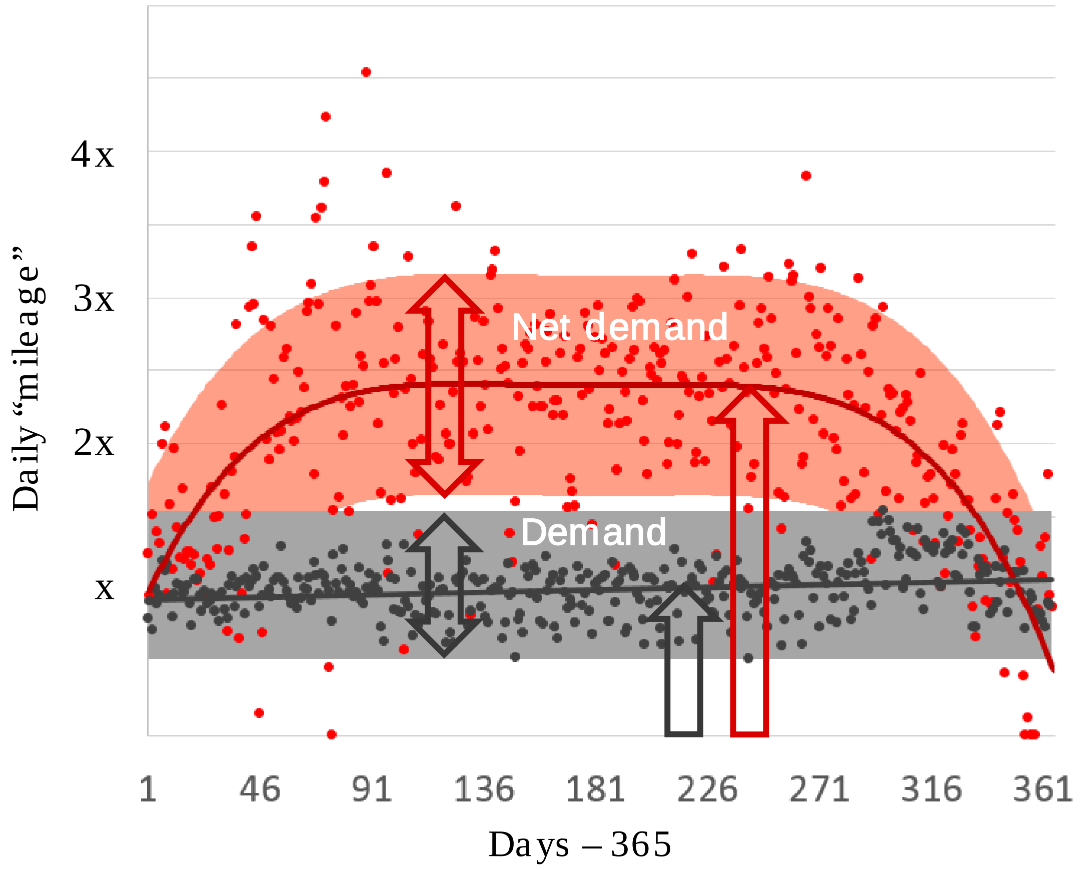
where D can be demand or "net demand" ("net demand" is a difference between the demand and the V-RES).

Future net demand demonstrates:

– larger daily mileage variability (as much as 1.5 times)

– larger average mileage (more than 2 times)

compared to demand (especially in spring, summer and fall seasons).



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A more time-variant system in the future

Daily variation (minimum vs. maximum)

The difference between minimum and maximum V-RES share in each day is calculated as:

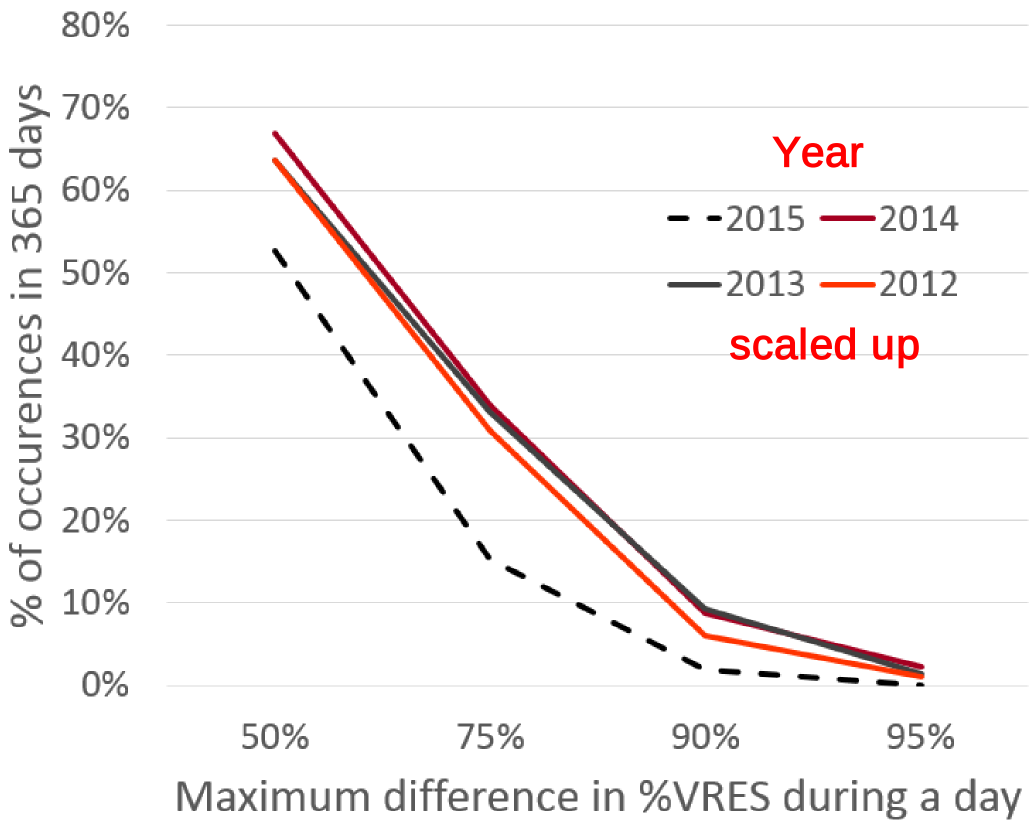
$$\frac{P(t_{h_i})^{Max}_{V-RES}}{D(t_{h_i})} - \frac{P(t_{h_j})^{Min}_{V-RES}}{D(t_{h_j})}$$

where $i, j = 1 \cdots 24\ hr$

- 67% of the time (244 days) more than 50%, and
- 9% of the time (33 days) more than 90%

daily difference in V-RES share occurs.

Compare to: the difference between minimum and maximum demand during a day (wrt the daily maximum) is 18 – 35%. It occurs 88% of the time i.e. 320 days.



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A more time-variant system in the future

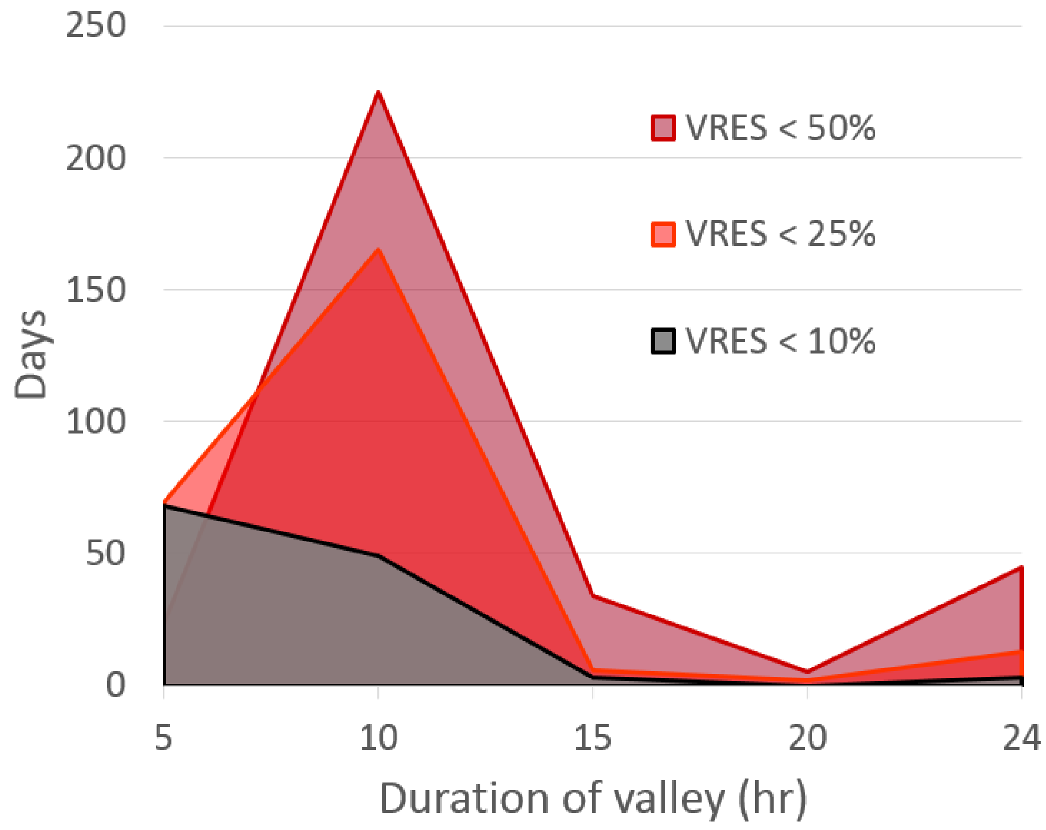
Duration of the “valleys”

The frequency of consecutive low V-RES shares is referred to as “valley”.

Most often occurring low-shares:

- Less than 10% V-RES shares are observed for 5 hours in a row in 68 days.
- Less than 25% V-RES shares are observed for 10 hours in a row in 165 days.
- Less than 50% V-RES shares are observed for 10 hours in a row in 225 days.

Note that in 45 days less than 50% V-RES shares are observed for 24 hours in a row.



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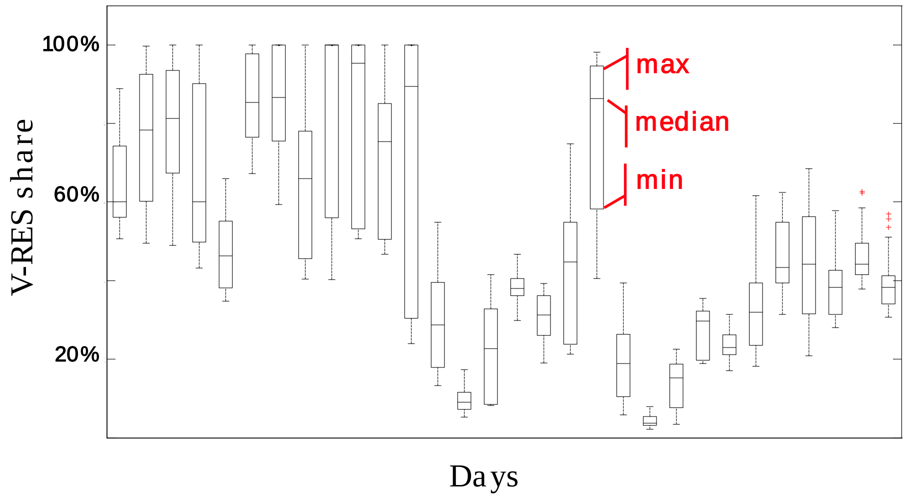
A more time-variant system in the future

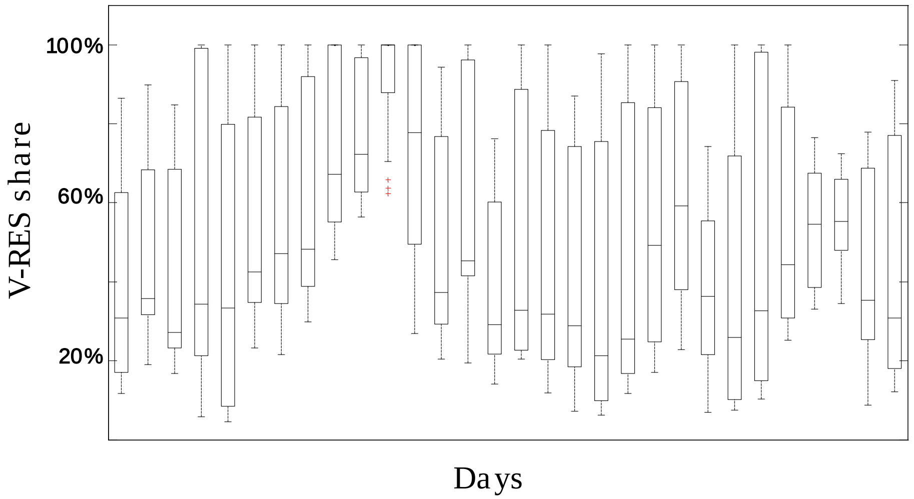
January



Each box contains hourly V-RES shares with median value for that day.

Lack of sun and large changes in wind availability result in high variability in January not only daily but also from day-to-day.

May



Compared to January, due to abundance of sun, high V-RES shares are observed in May in majority of the days.

However, large daily variations are noteworthy.

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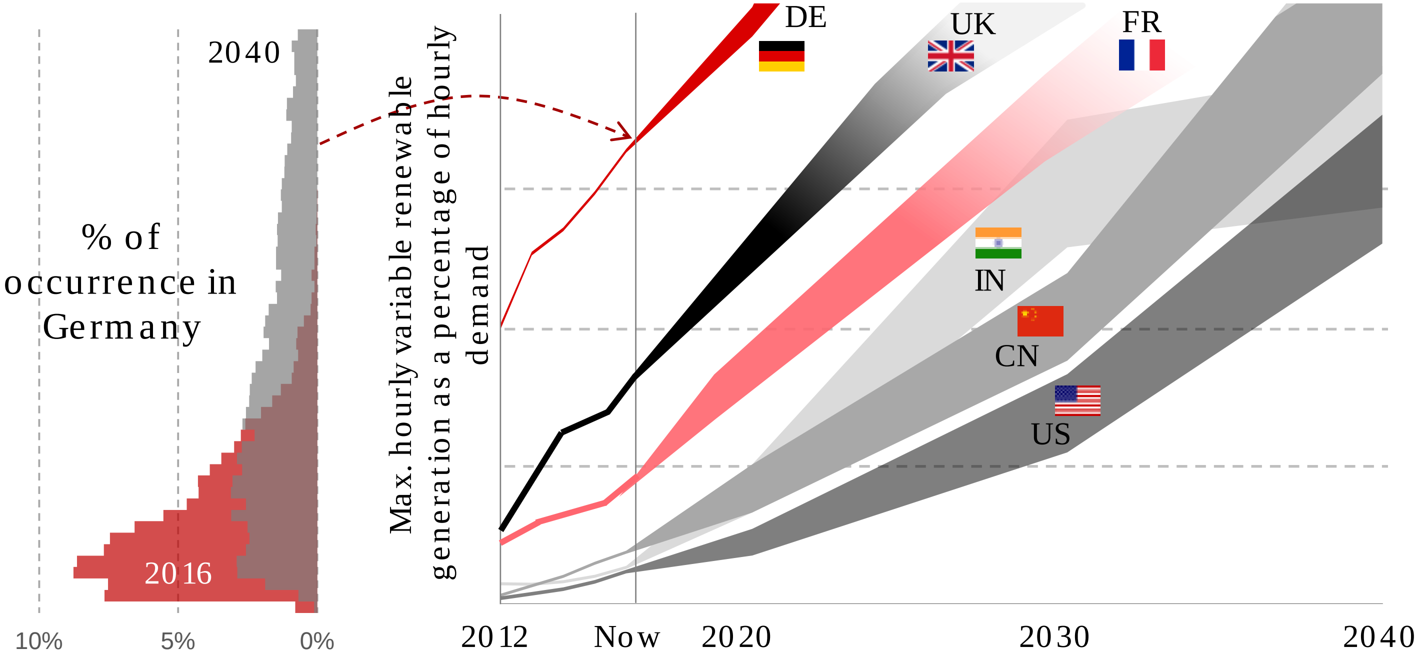
What may happen when large amount of variable renewable sources is online?

Technical challenges renewable energy adopters encounter



Short circuit capacity & V-RES utilization

System inertia & grid voltage

Grid capacity & reserve

Conventional operation

Increasing system flexibility is a key for the reliable operation of future power systems with high levels of V-RES

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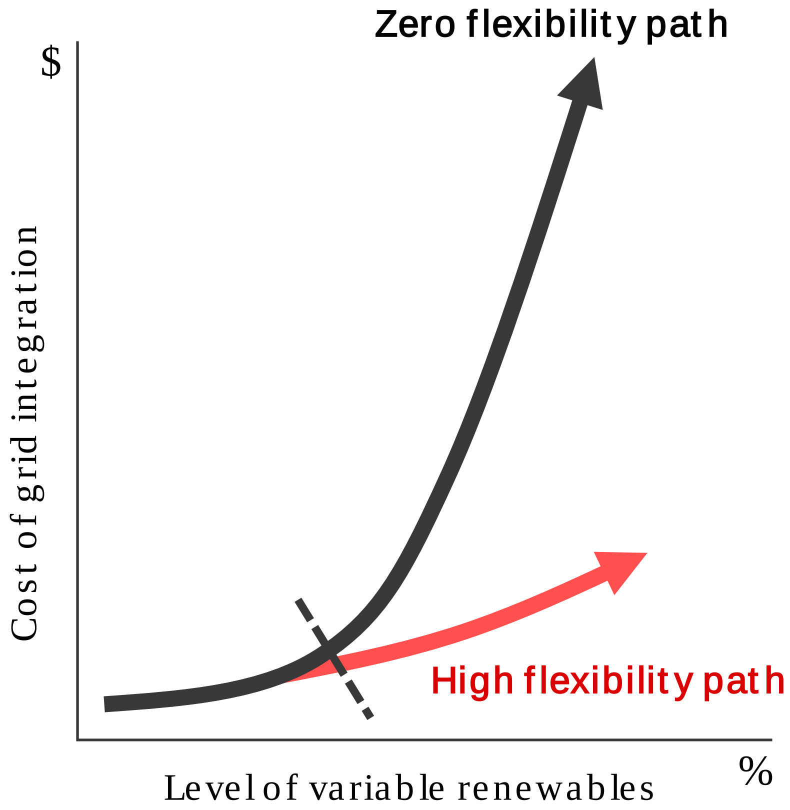
Need for more flexible system: impact on cost



Flexibility vs. variable generation

Today's levels of power system "flexibility" can handle lower shares of behind-the-converter V-RES.

Economic and seamless integration of higher shares of V-RES require significant increase in the level of today's grid flexibility.

How can we raise system flexibility?

Generation	Fast ramping (up/down) generation Generators with quick and low-cost start-up Distributed under-utilized energy resources (storage, EV charging infrastructure)
Demand	Fast responding flexible customers (lowering the amount of demand or shifting the time of consumption)
ICT	Protection system adapting the settings to changing grid conditions (e.g. reduction in inertia or short circuit capacity) Advanced Metering Infrastructure Reliable communication infrastructure with minimum latency

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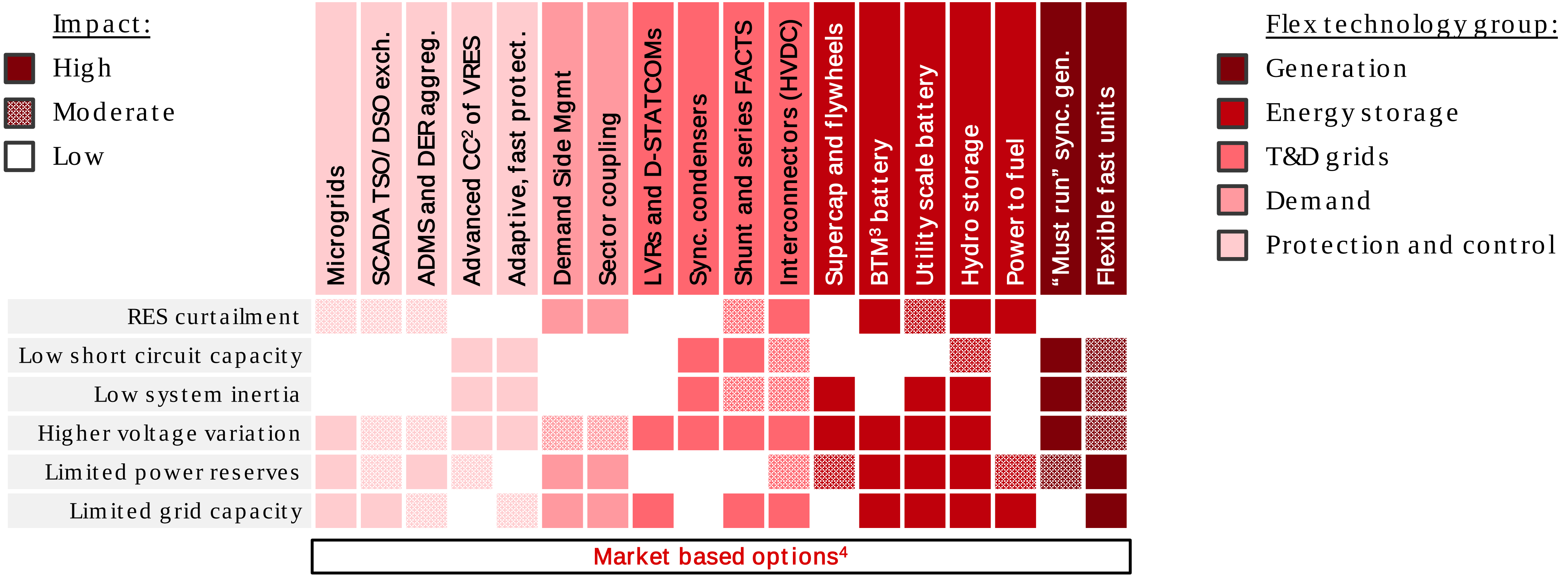
Technology options[1] at different system level



1. Not exhaustive list
2. Converter controlled
3. Behind the meter
4. Wholesale energy market, ancillary services, capacity markets, p2p retail markets, etc.

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How the questions related to power system flexibility are addressed by CIGRE?

What is CIGRE?

CIGRE is a non-governmental and non-profit int'l association founded in 1921.

It aims to facilitate knowledge and information exchange about electricity production, transmission and distribution across regions.

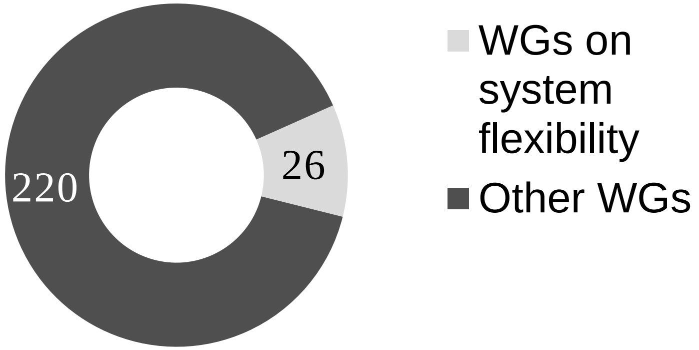
Key figures

10'100+ individual and 1200+ collective members from more than 80 countries.

CIGRE has approximately 60 National Committees, representing over 95% of its members.

16 Study Committees are focused on equipment, systems, materials and ICT.

Working expert groups



Working Groups (WG) are the main work engine of CIGRE.

Currently there are 240+ WGs with ~3'800 experts from almost 70 countries.

We identify 26 WGs which address questions related to power system flexibility needs and solutions.

Source: CIGRE

Active working groups related to power system flexibility

Selected examples

WG number	Title	Convener	Start date
A1.54	Impact of Flexible Operation on Large Motors	John Doyle (IE)	27/09/2015
B5/C4.61	Impact of Low Inertia Network on Protection and Control	Ray Zhang (UK)	17/01/2017

Impact of Flexible Operation on Large Motors

CIGRE Working group A1.54

Background

Conventional power plants are increasingly required to operate flexibly to facilitate larger penetration of V-RES.

Cyclic operation including operating at minimum load, and fast ramp up/down have all become normal for many power plants.

Cyclic operation results in more starting and stopping of auxiliary drives and this can result in a number of mechanisms which lead to deterioration of electric motor components.

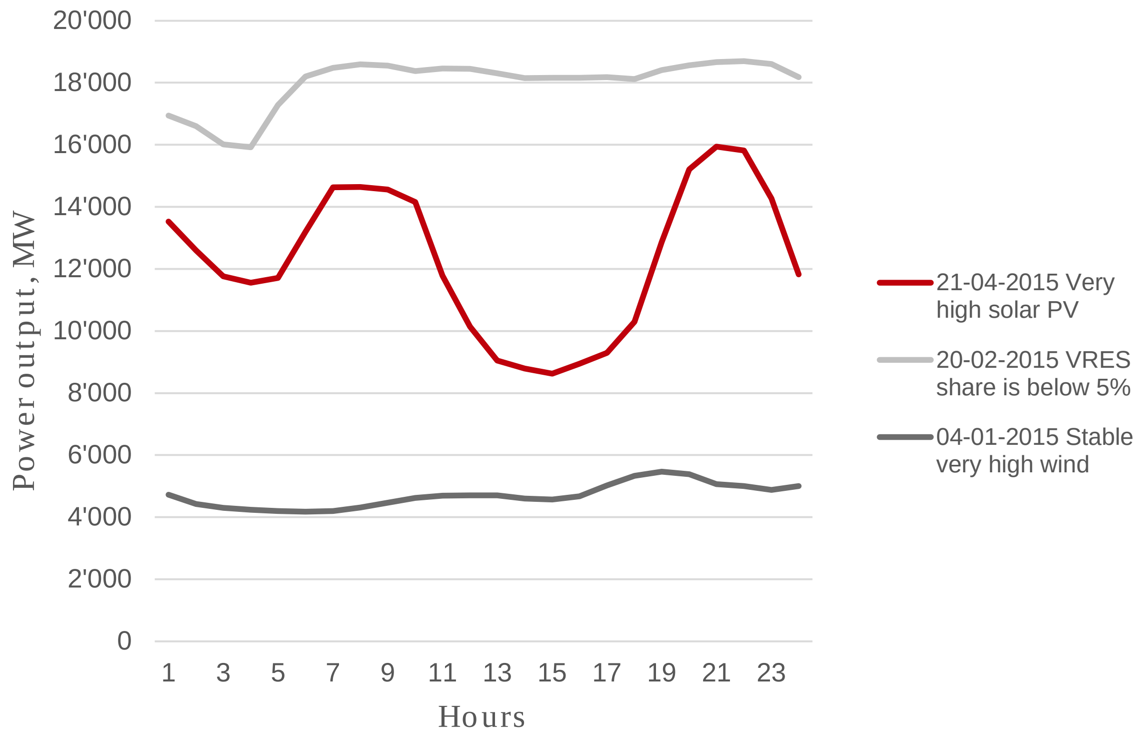
Typical failures that have been attributed to cycling operation include material fatigue arising from:

– Torque stresses on rotors during starting and stopping.

– High starting currents causing thermal and electromagnetic effects.

Mr. John Doyle from EBI Int'l (Ireland) is in lead.

Hard coal dispatch in Germany



Source: CIGRE TOR A1.54, Dataset for 2015 German power production and consumption is provided by Agora Energiewende: https://www.agora-energiewende.de/de/themen/-agothem-/Produkt/produkt/76/Agorameter/

Impact of Flexible Operation on Large Motors

CIGRE Working group A1.54

Scope

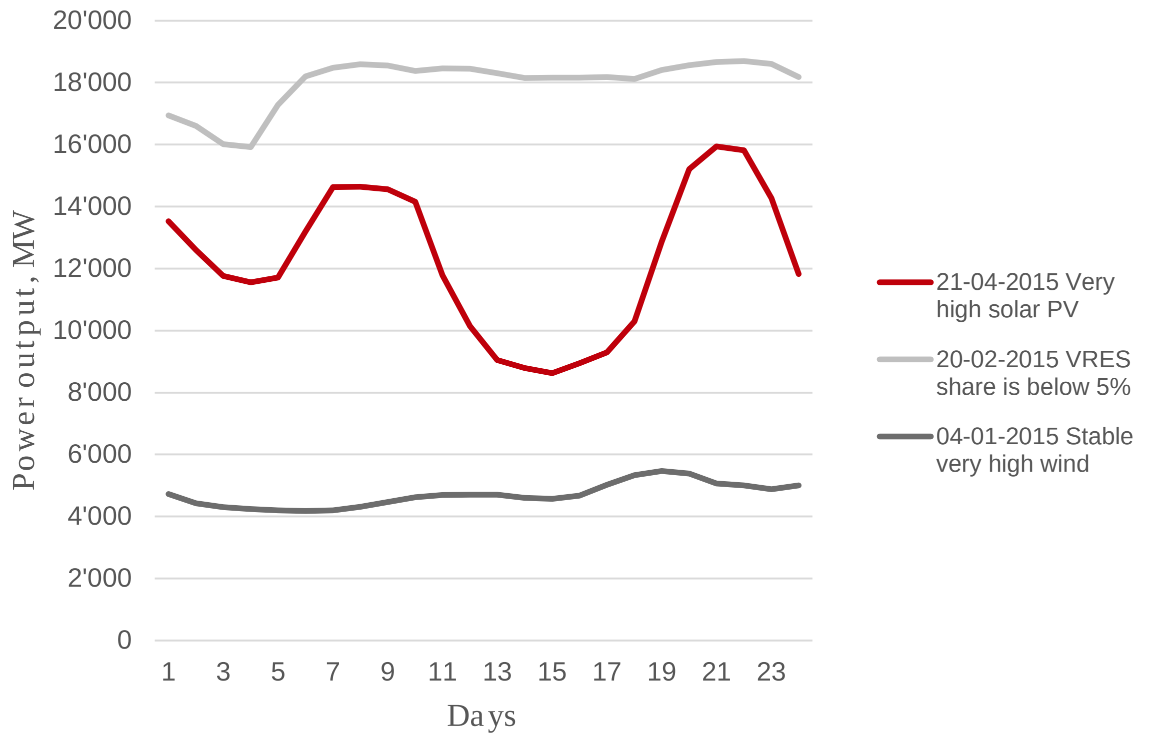
Update work done in WG A1.19 "Motor Failure Survey". Collect inputs from relevant stakeholders via a questionnaire.

Review international standards, application guidelines, design trends.

Review effectiveness of motor testing and commissioning, monitoring, diagnostics, and maintenance in relation to impact of cycling operation.

Make recommendations on application, design and maintenance.

Hard coal dispatch in Germany



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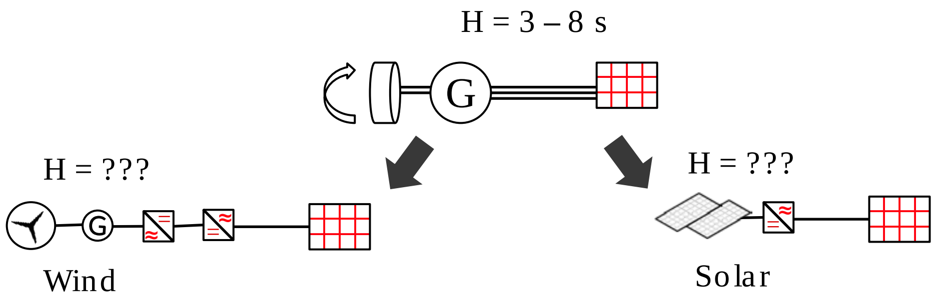
Impact of Low Inertia Network on Protection and Control

CIGRE Working group B5/ C4.61

Background

High penetration of behind-the-converter V-RES will reduce the inertia of the power network significantly, which is threatening power system stability.



In these conditions, the schemes adopted by traditional protection may not be suitable for certain faults.

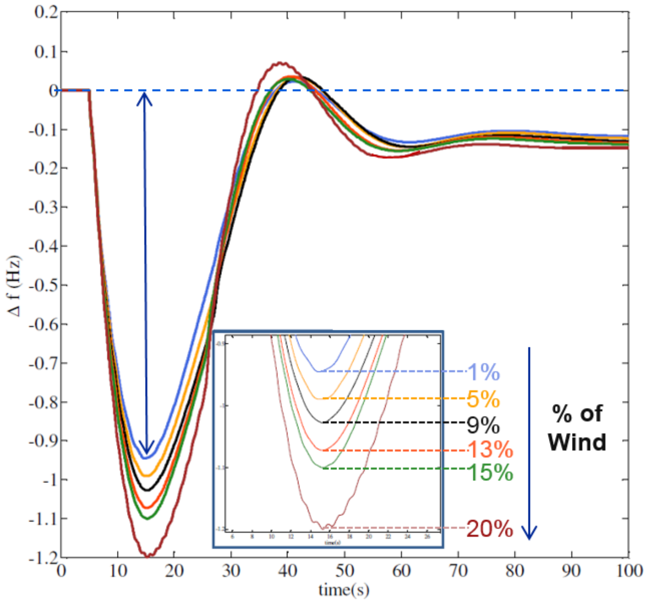
The WG shall consider the challenges of protecting electrical networks with reduced system inertia and changed fault characteristics.

Prof. Ray Zhang from National Grid (UK) is in lead.

Low inertia: what does it mean for the grid stability?

Increasing presence of V-RES is leading to changes in ROCOF and frequency nadir following a disturbance.

Example: frequency response of the Nordic system to tripping of a 750 MW generator.



Source: CIGRE TOR B5/ C4.61, H.R. Chamorro et al. Wind Power Impact on Power System Frequency Response. 2013

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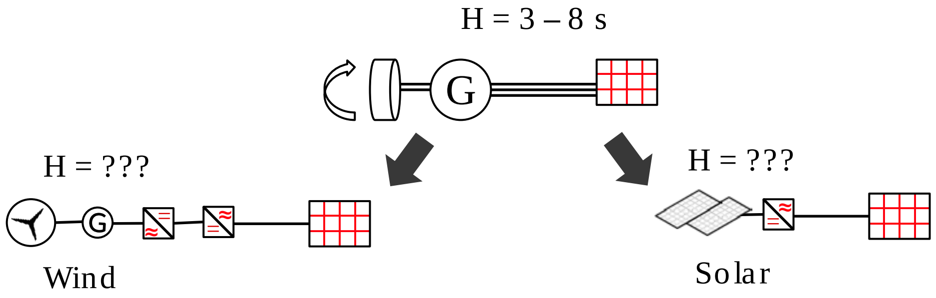

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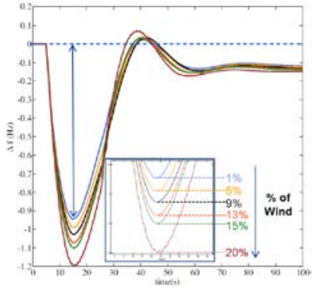

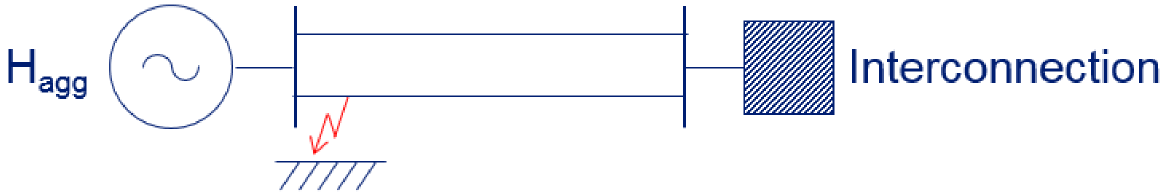

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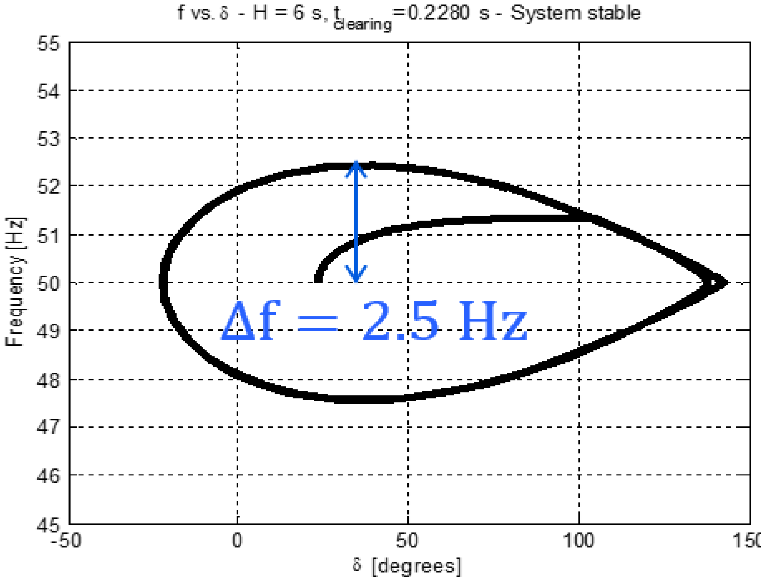
Impact of Low Inertia Network on Protection and Control

CIGRE Working group B5/ C4.61

Inertia reduction: what does it mean for the grid?

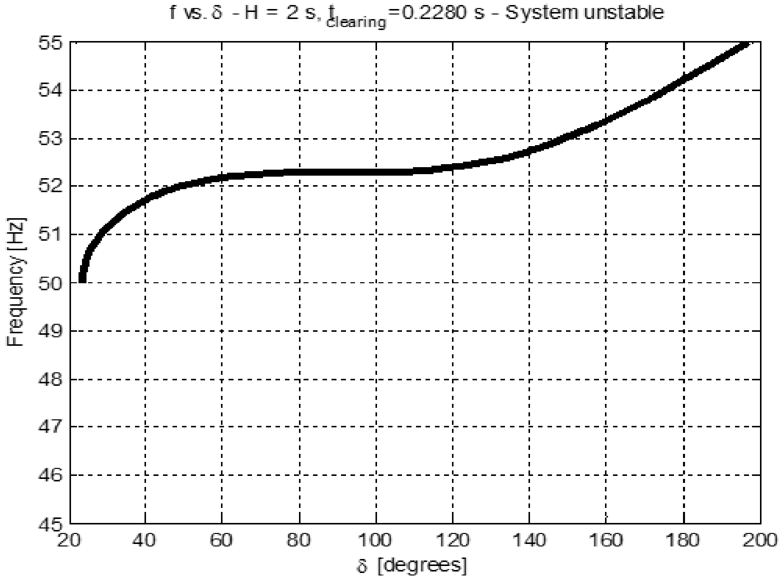
For aggregated inertia H_{agg} = **6 sec** (scenario w/ out V-RES) **CCT is 228 ms**.

We reduce H_{agg} to **2 sec** due to ~55% of instantaneous V-RES presence.



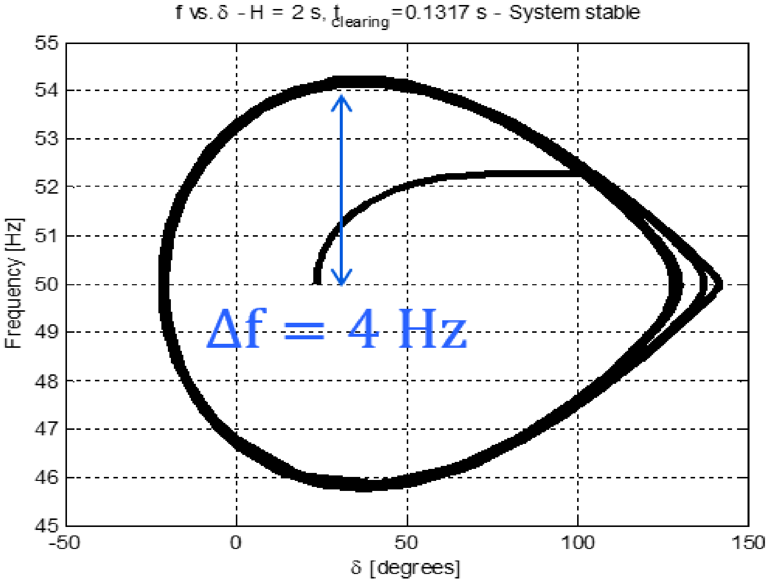
For H_{agg} = **2 sec**, if a disturbance is cleared after 228 ms the system is unstable.

The fault has to be cleared much faster to maintain a stable operation.



For H_{agg} = **2 sec** the CCT must stay below **130 ms** (40% faster).

In order to keep **Δf** = 2.5 Hz the fault must be cleared even faster, at most in **73 ms**.



Source: ABB analysis

Impact of Low Inertia Network on Protection and Control

CIGRE Working group B5/ C4.61

Scope

Explore methods of mathematical modelling for power electronics components to simulate transient fault phenomena for protection studies and tests.

Analyze fault characteristics in presence of V-RES and how they affect traditional protection schemes, including site experience and simulation methods.

Research how the reduced inertia affects the system stability margins and the protection mechanism of detecting the loss of stability under disturbance.

Investigate countermeasures or new schemes for protection and automation to adapt to this evolution of power grids.

Fault interruption time

Fault CCT evolution: from today ≈ 150-250 ms to future <75 ms.

Fault interruption time limits of traditional breakers: 40-75 ms.

Relay	Mechanics	Electric
10 -15 ms	22-40 ms	10-18 ms

Where is a potential for time reduction?

- Relay time (new fault detection methods, advanced signal processing, etc.)
- Mechanical time (faster mechanics, solid-state breakers, etc.)

Another alternative is to use adaptive protection system (settings, functions).

Source: CIGRE TOR B5/ C4.61, ABB analysis.

Key take away messages

1. Increasing proliferation of variable renewable energy sources (V-RES) will present challenges to grid operators.
2. While low levels of V-RES can be easily accommodated now, future very high levels of V-RES shares will require a paradigm shift in the way we operate our grids.
3. Various technologies may enable seamless integration of high shares of V-RES without jeopardizing reliability and security of the power grids thanks to effective exploitation of digitalization.
4. CIGRE actively carries out analyses related to evaluation of power system flexibility needs and solutions in different Study Committees. More than 20 working expert groups provide technical recommendations on product and system levels.

ABB