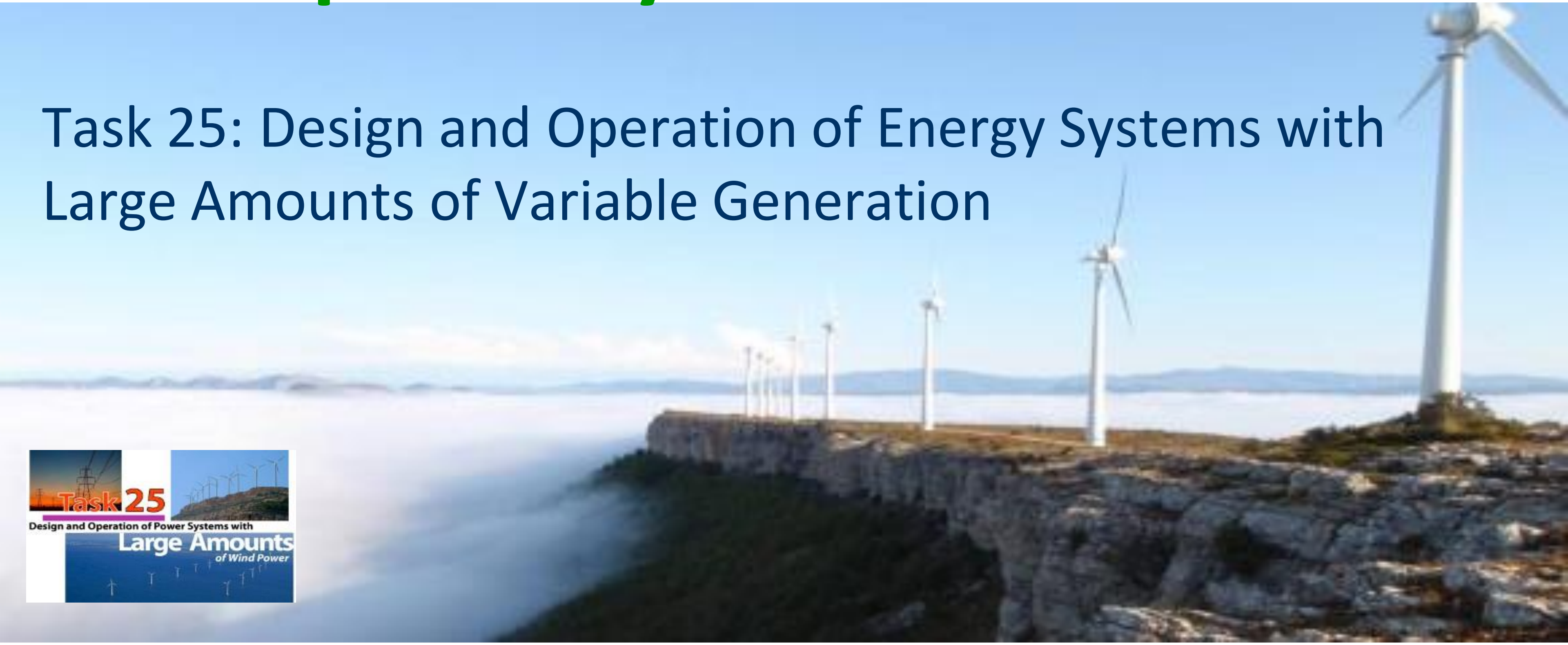
Experience in stability issues of future power systems



Task 25: Design and Operation of Energy Systems with Large Amounts of Variable Generation

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WESC2021 Task 25 Minisymposium, 25 May, 2021

IEA Wind Task 25 – Best practice of VG integration

- Started in 2006, now 17 countries + WindEurope participate to provide an international forum for exchange of knowledge
- State-of-the-art: review and analyze the results so far (Jan 2019)
- Formulate guidelines- Recommended Practices for Wind/PV Integration Studies (RP Ed.2 July 2018)
- Fact sheets and integration study time series (wind, solar, load…)

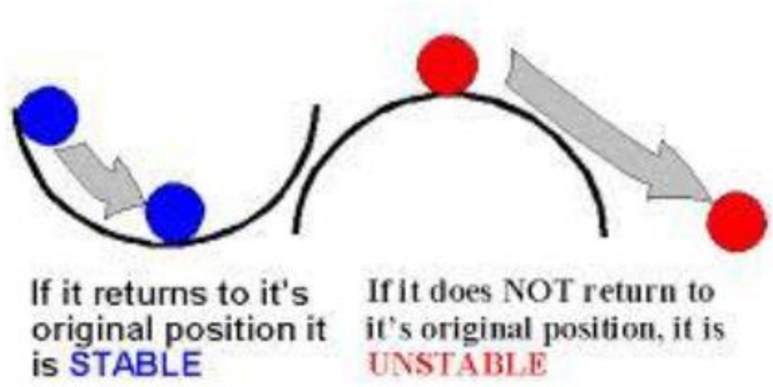
https://iea-wind.org/task25/ *(old web: https://community.ieawind.org/task25)*

Contents

- 100% renewables, and 100% VIBRES
  - Planning, Balancing and Stability Challenges for power system
- Focus on Stability
  - experience

VIBRES – Variable Inverter Based Renewable Energy Sources

In addition to energy produced, some power plants need to produce ‘glue’ to keep the power system resilient to disturbances – keeping it stable



Towards 100% renewables

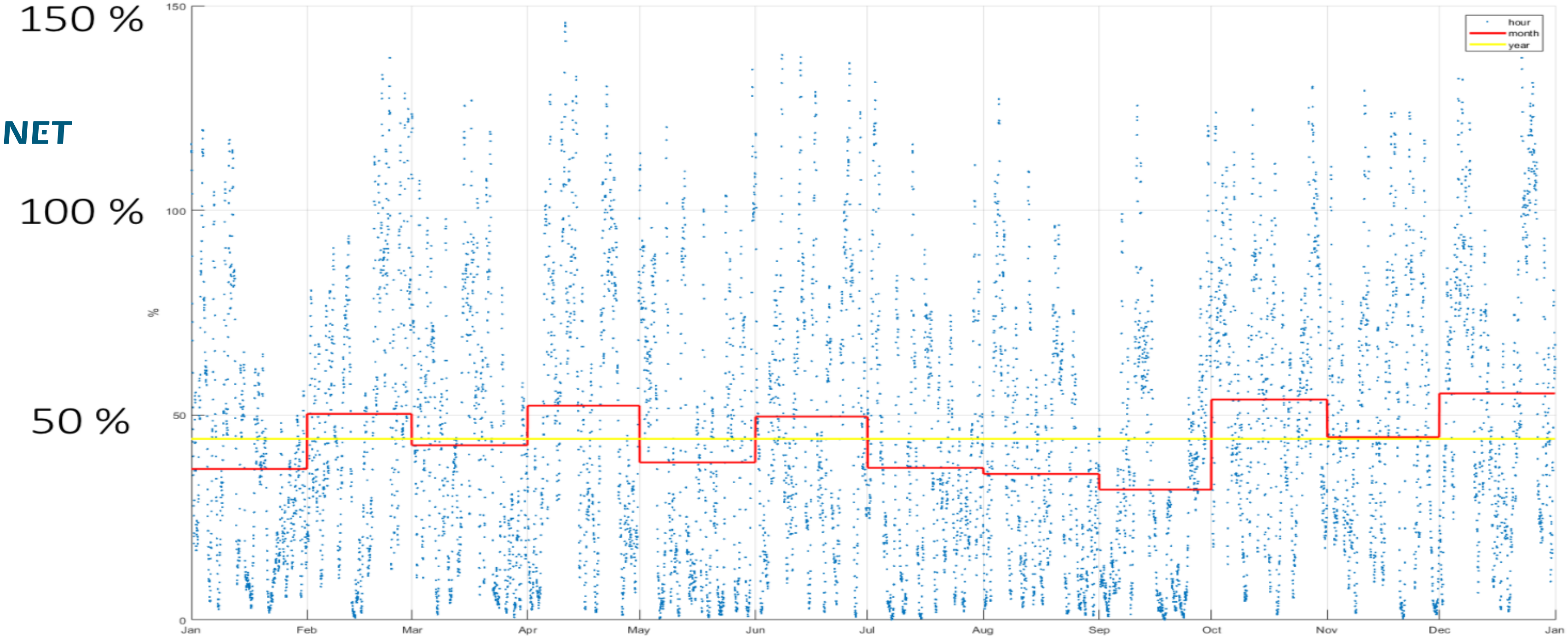
1. 100% VIBRES region that is part of a larger non-100% VIBRES synchronous power system
   – challenges are about balancing, local aspects of stability and efficient sharing of electricity and reserves with neighbouring areas. Highlights importance of how the neighbouring regions are presented in studies
2. A synchronous system getting closer to 100% VIBRES for short periods of time
   – a challenge on top of these: system-wide stability issues
3. 100% yearly energy from VIBRES
   – a challenge on top of these: the adequacy issue, to meet high demand at low VIBRES contribution

High share of VRE operation for extended times before

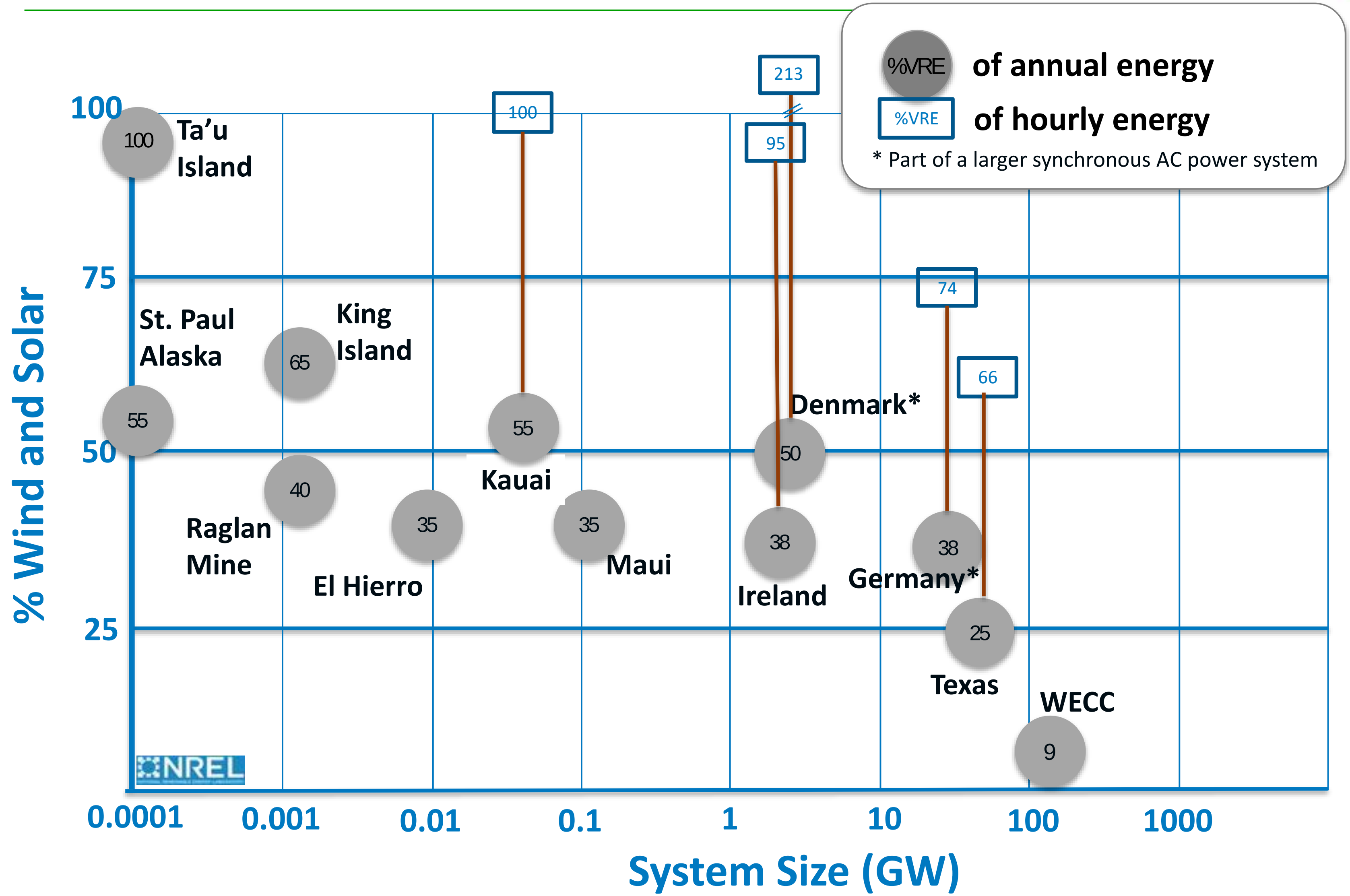
Instant 100% will be faced already when less than 25 % on average

Example DK 2017 43 % on average

ENERGINET



Experience is growing

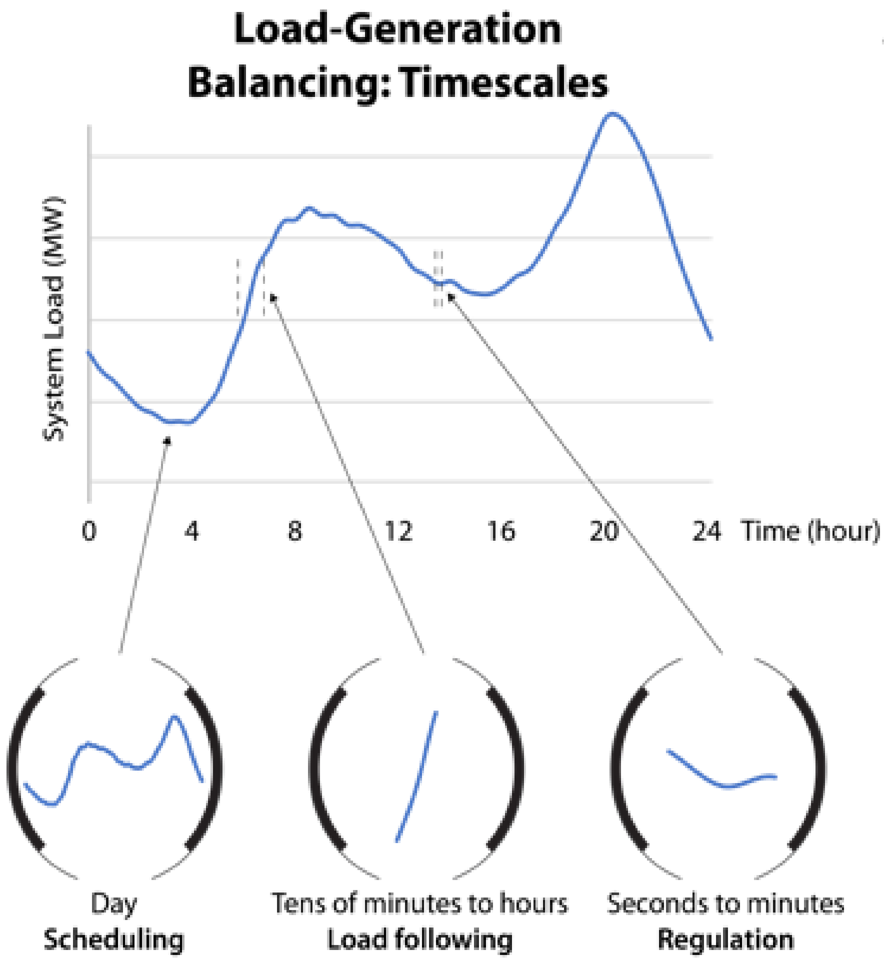


Transition to a (nearly) 100% annual VIBRES system gradually during the next decades

Planning – resource adequacy

- Resilience
  - More data to capture all weather related extreme events
  - integrated planning and operations tools and data. Greater overlap btw operational and planning time scale models
- Cost versus risk: reliability interface needs revisiting
- New metrics, not just LOLP as load not fixed
  - energy system coupling, flexible loads and storages: how to take to models to assess adequacy

Balancing - flexibility

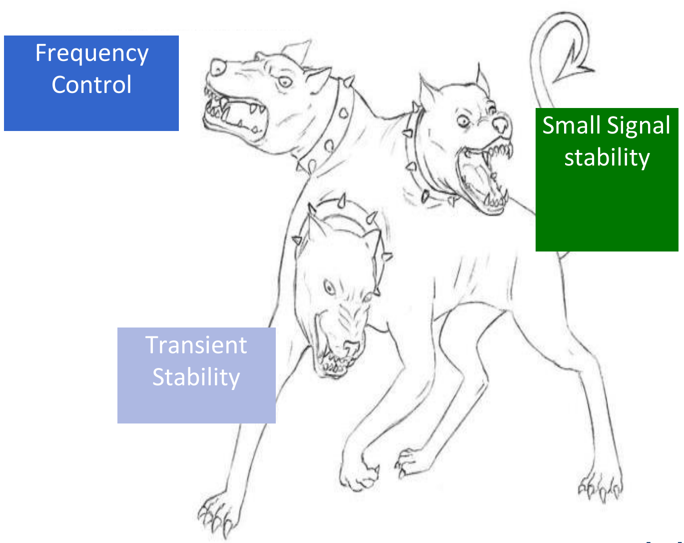


- Operational challenge: increased need for balancing in all time scales
- Also new flexibilities available, from VIBRES, from loads, from storages
- So far changes in operational practices have given more flexibility than VIBREs have increased

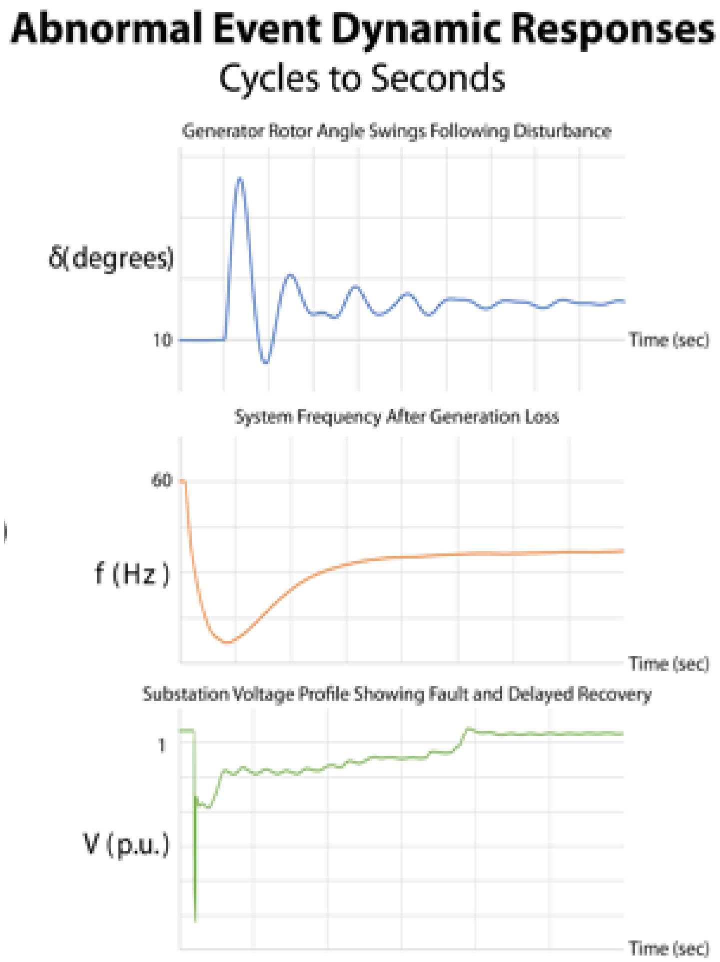
100% renewables studies so far look at days/hours time scale balancing

Stability challenges

- small signal stability
- frequency stability (inertia/fast responses)
- voltage stability

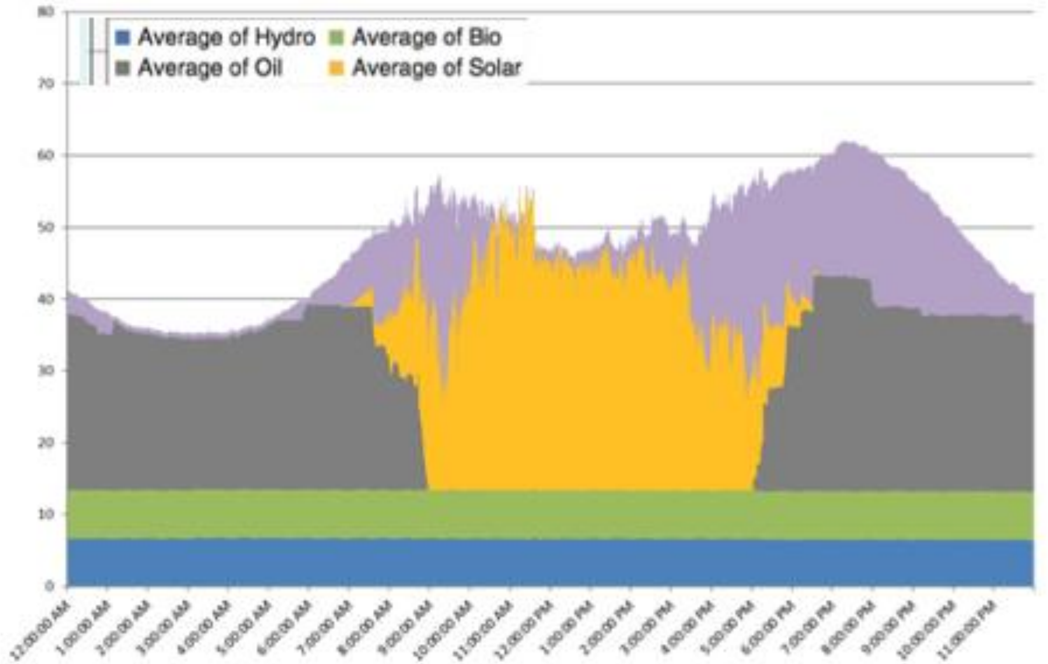


Source: Nick Miller



Small island power system: Kauai in Hawaii

- quick-start diesel reciprocating engines
  - fast reserves (start up in minutes); one engine operating in synchronous condenser mode: inertia and system strength
- PV/battery hybrids for fast response
  - (cloud events on the order of seconds) hold 50% of the real-time output as spinning contingency reserve.

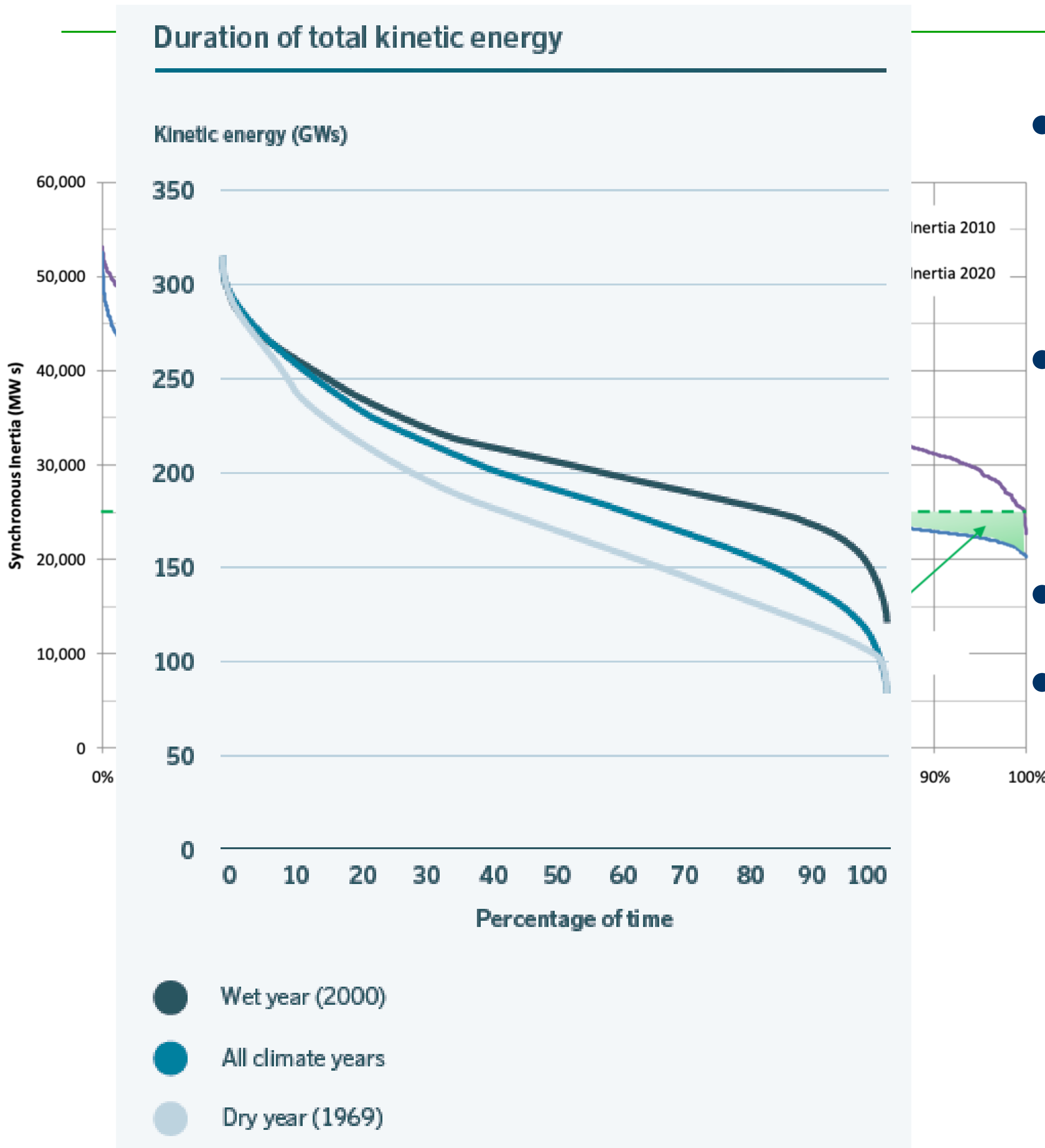


KIUC system dispatch on 3/14/20 with 8 hours of 100% renewables operations. Purple shows PV/battery hybrid output. (Source: Brad Rockwell, KIUC).

Issues with stability: Wind and solar power plants' response to fault situations

- Wind power plant Fault-Ride-Through to grid codes since 2005, when German and Spanish studies showed that they could become a maximum tripping event for the European power system (>3 GW)
- For solar power plants, the so called 50.2 Hz issue in Germany – all roof top PVs had same setting
- Southern California Aug 16, 2016 Blue Cut Fire event resulted in 700 MW solar PV power plant tripping → mitigation (NERC, 2017).
- South Australia storm with >5 consecutive faults

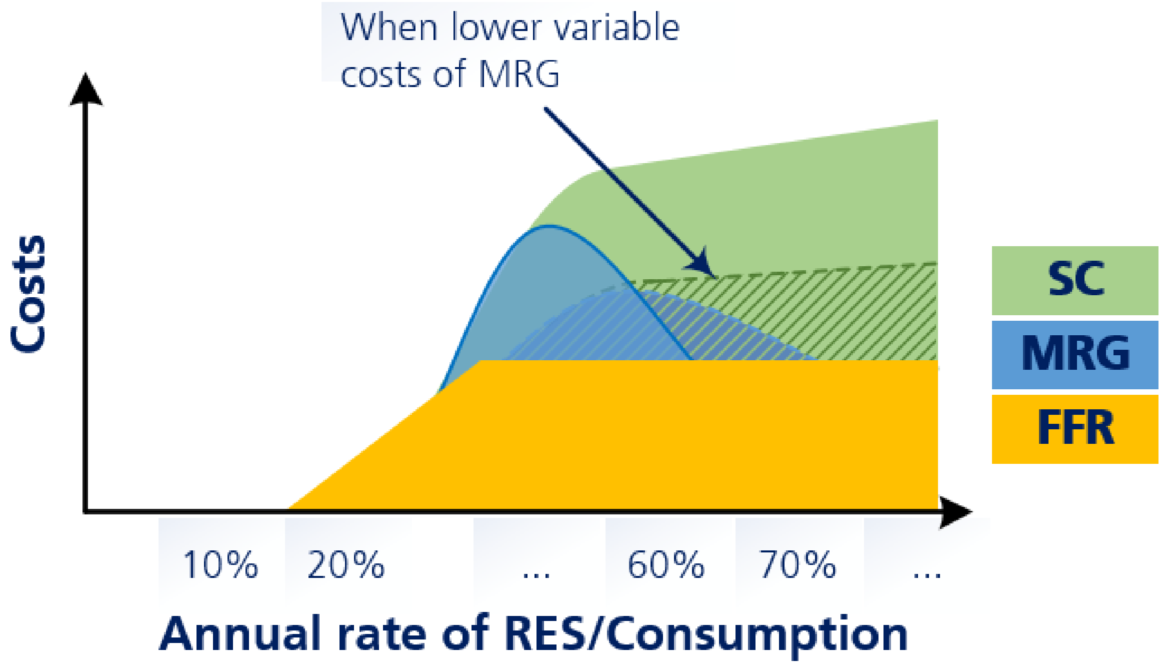
Frequency stability, inertia



- Inertia—maintaining grid stability through physical response
- Ireland: aiming for 40% share in 2020 – study 2010
- Nordic study for 2025
- Real-time (day-ahead) estimators for inertia in use in Ireland, GB, Nordic and Texas power systems

Supporting frequency stability

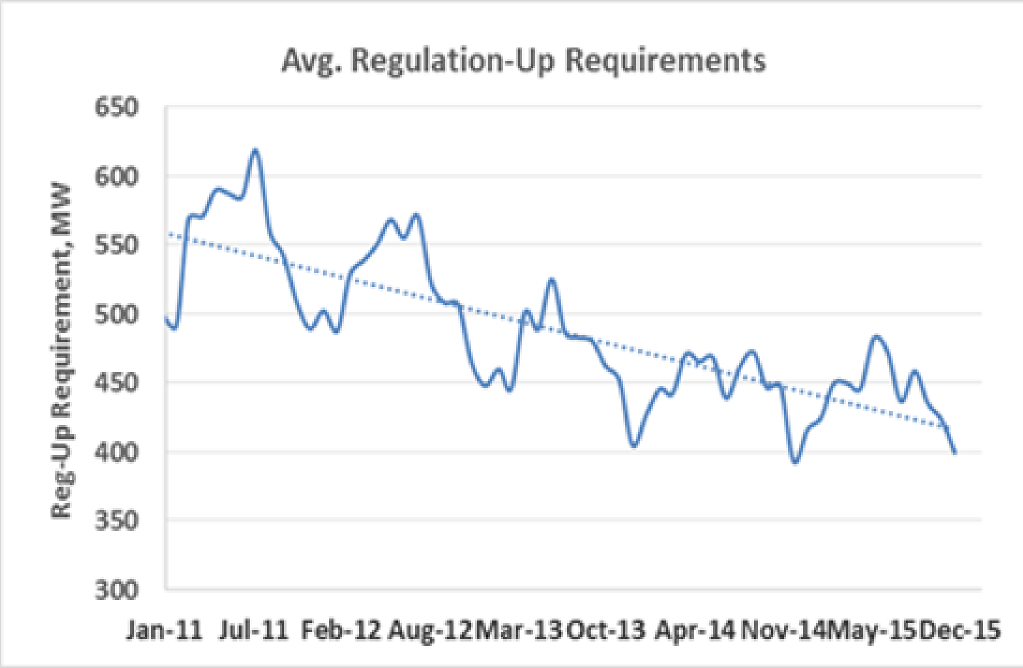
- Maintain inertia by keeping synchronous machines running (MRG) or other sources of synchronous inertia (SC, synchronous condensers)
- Speed up frequency response Faster primary frequency response (on synchronous machines), Fast frequency response (FFR)



Source: EdF (Primes et al 2019)

Faster response is more valuable

- ERCOT, Texas: FFR (0.5s) High wind, low load: 1,400 MW of FFR provides same response (and reliability impact) as 3,300 MW of PFR
- Hydro Quebec event 28 Dec, 2015, frequency nadir of 59.08 Hz, wind power plants response contributed to the recovery of the system frequency



Texas experience, less need for fast frequency support after wind power plants provide good response (Source: Julia Matevosjana, ERCOT)

Voltage stability - Ireland

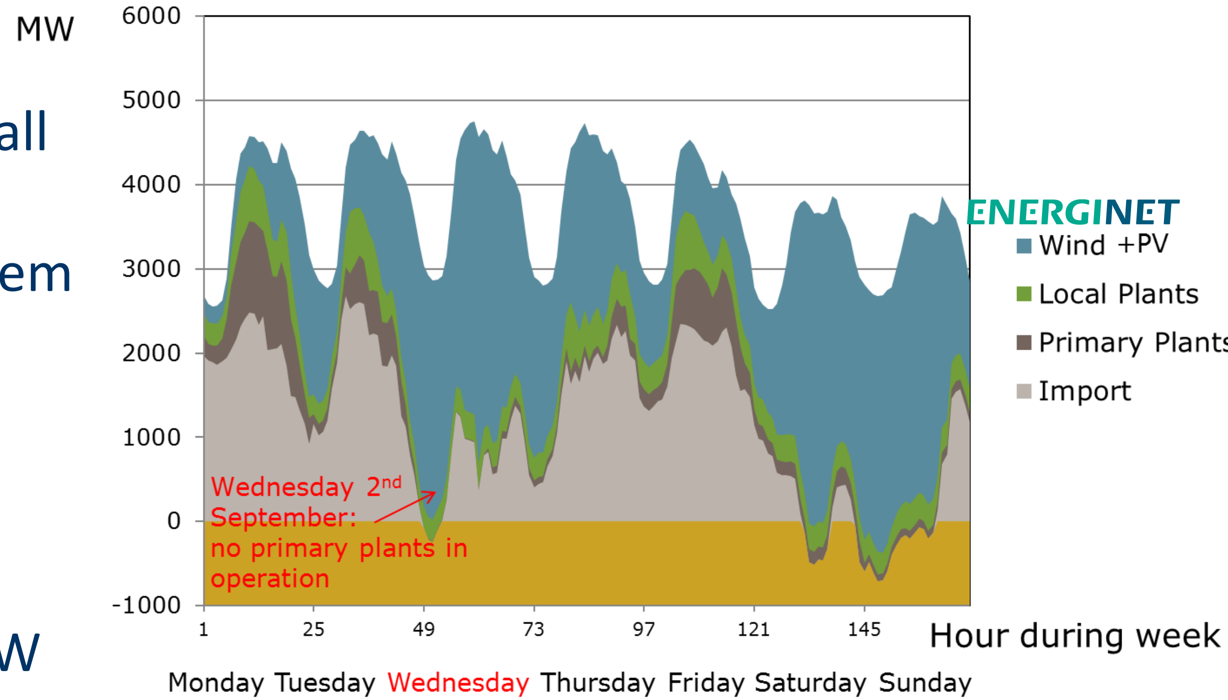
- Constraint of min 8 large synchronous machines on-load at all times must be relaxed to reduce curtailing wind energy
- Disperse location of wind farms (with different capability characteristics), combined with increasing installation of HV cables
- Voltage Trajectory Tool for control room for intra-day and day-ahead time horizons

Denmark operating the system without central power plants

First time in 2015 and several times since then, all central power plants shut down. The necessary system support from:

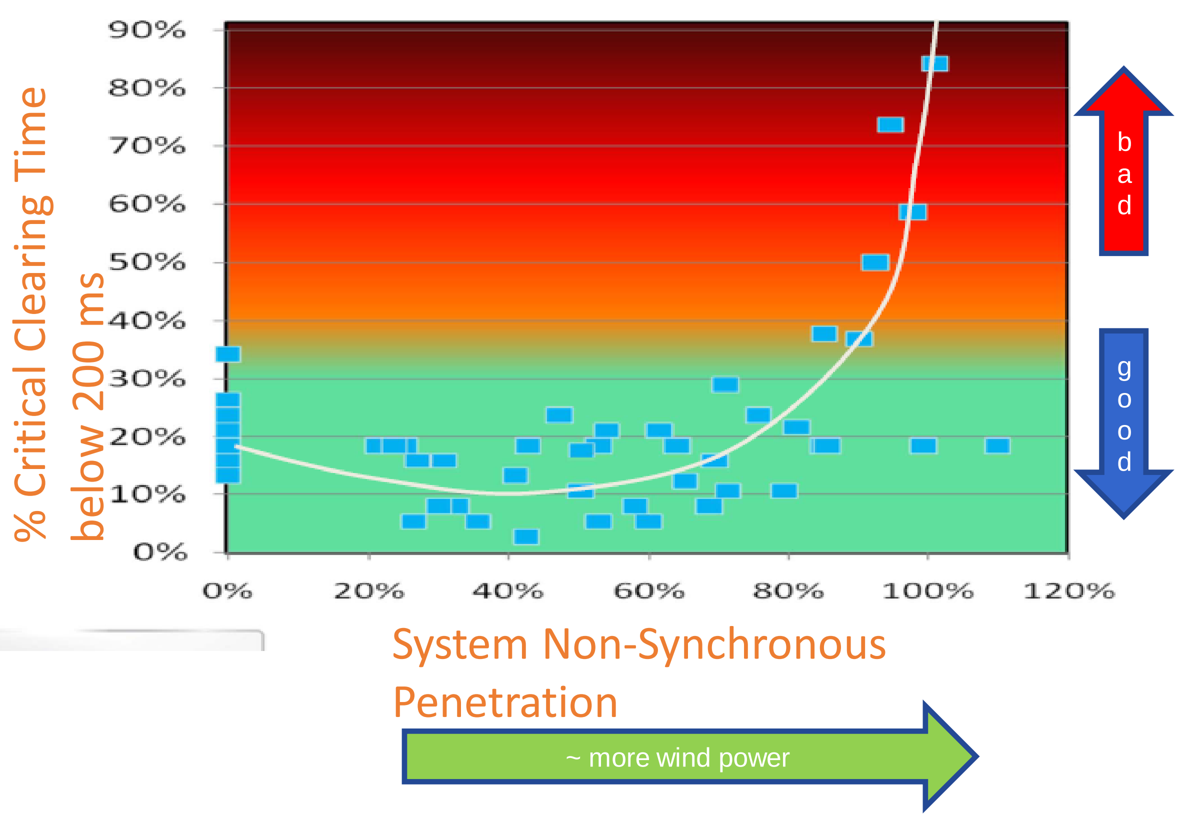
- HVDC link: 700 MW Denmark-Norway
- synchronous compensators 4 in DK-W and 2 in DK-E
- and small scale power plants

2nd September 2015 without central plants
- hourly dispatch 31 August – 6 September 2015



Ireland study: current power systems ok for 80-90% wind

- Transient stability (as measured by critical clearing time) first slightly improves, until around 80-90%, where instability becomes a big issue.



EIRGRID GROUP

Towards 100% VRE operation

- Make inverter behavior “better”
  - Grid forming inverters and Virtual synchronous machines
- System needs – what exactly is needed in different operational situations, and how much
  - Operational paradigms for asynchronous operation
  - Degrading grid strength impacts: short-circuit analysis and protection coordination
  - Essential reliability services today and in future

Based on IEA WIND Task 25 collaborative publications

- Summary report **”Design and operation of energy system with large amounts of variable generation”** to be published fall 2021
- ”**Towards 100% Variable Inverter-based Renewable Energy Power Systems**” by Bri-Mathias Hodge, C Brancucci, H Jain, G Seo, B Kroposki, J Kiviluoma, H Holttinen, J C Smith, A Estanqueiro, A Orths, L Söder, D Flynn, M Korpås, T K Vrana, Yoh Yasuda. WIREs Energy and Environment vol 9, iss. 5, e354 https://doi.org/10.1002/wene.376
- “**System impact studies for near 100% renewable energy systems dominated by inverter based variable generation**” by H Holttinen; J Kiviluoma; D Flynn; C Smith; A Orths; P B Eriksen; N Cutululis; L Söder; M Korpås, A Estanqueiro, J MacDowell, A Tuohy, T K Vrana, M O’Malley , IEEE TPWRS Oct 2020 open access https://ieeexplore.ieee.org/document/9246271

- https://www.researchgate.net/project/IEA-Task-25-Design-and-Operation-of-Power-Systems-with-Large-Amounts-of-wind-power

Thank You!!

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MISO RIIA study

- Potential dynamic stability issues due to weak grid increase sharply beyond 20% share of VIBRES
- Frequency response stable up to 60% instantaneous shares of VIBRES
- Small signal stability beyond the 30% VIBRES - can be addressed by specially tuned batteries or must-run units equipped with power system stabilizers. Interconnection-wide small signal oscillations (0.1-0.8 Hz) can appear at high shares VIBRES - strategic locations where power oscillation damping (POD) controllers, batteries, SVC, STATCOM, or HVDC can help.
- Overall, critical clearing time becomes better as large units are displaced, but some locations may observe a decrease and may require installation of new protection techniques or transmission devices