Towards 100% renewable systems

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

Hannele Holttinen, Operating Agent Task25

Partner, Recognis

TEM#113 Net Zero Systems, 8 April 2024, Dublin

iea wind

Contents

- Challenge with wind/solar dominated systems
- Status and Gaps in simulation model tools
- Recommendations for studies

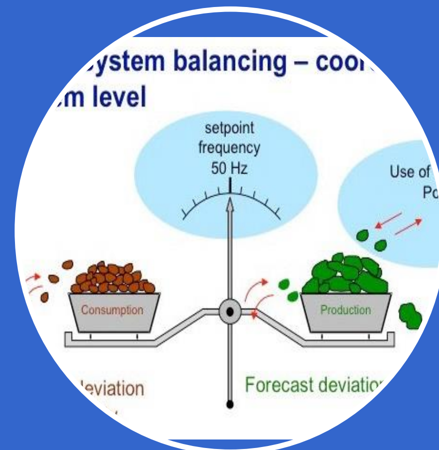
VIBRES – Variable Inverter Based Renewable Energy Sources

ENERGINET

Challenges

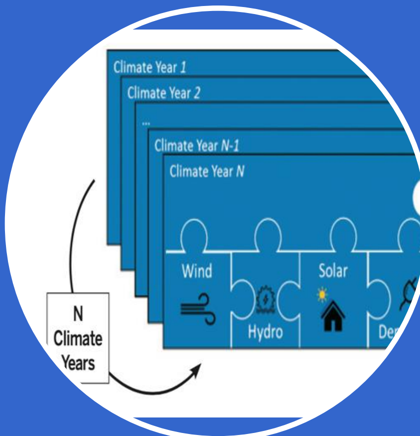
Stability

At times 100% inverters: non synchronous operation- resilience for disturbances and external events; control interactions



Short term balancing

Demand and supply in balance – flexibility challenge



Long term balancing

Increased weather dependency. No more fixed load paradigm – new planning tools for storage and demand side

seconds, minutes, hours, days seasons/years

Transmission is an enabler – easier for larger systems

More complexity and amount of data is exploding - digitalisation

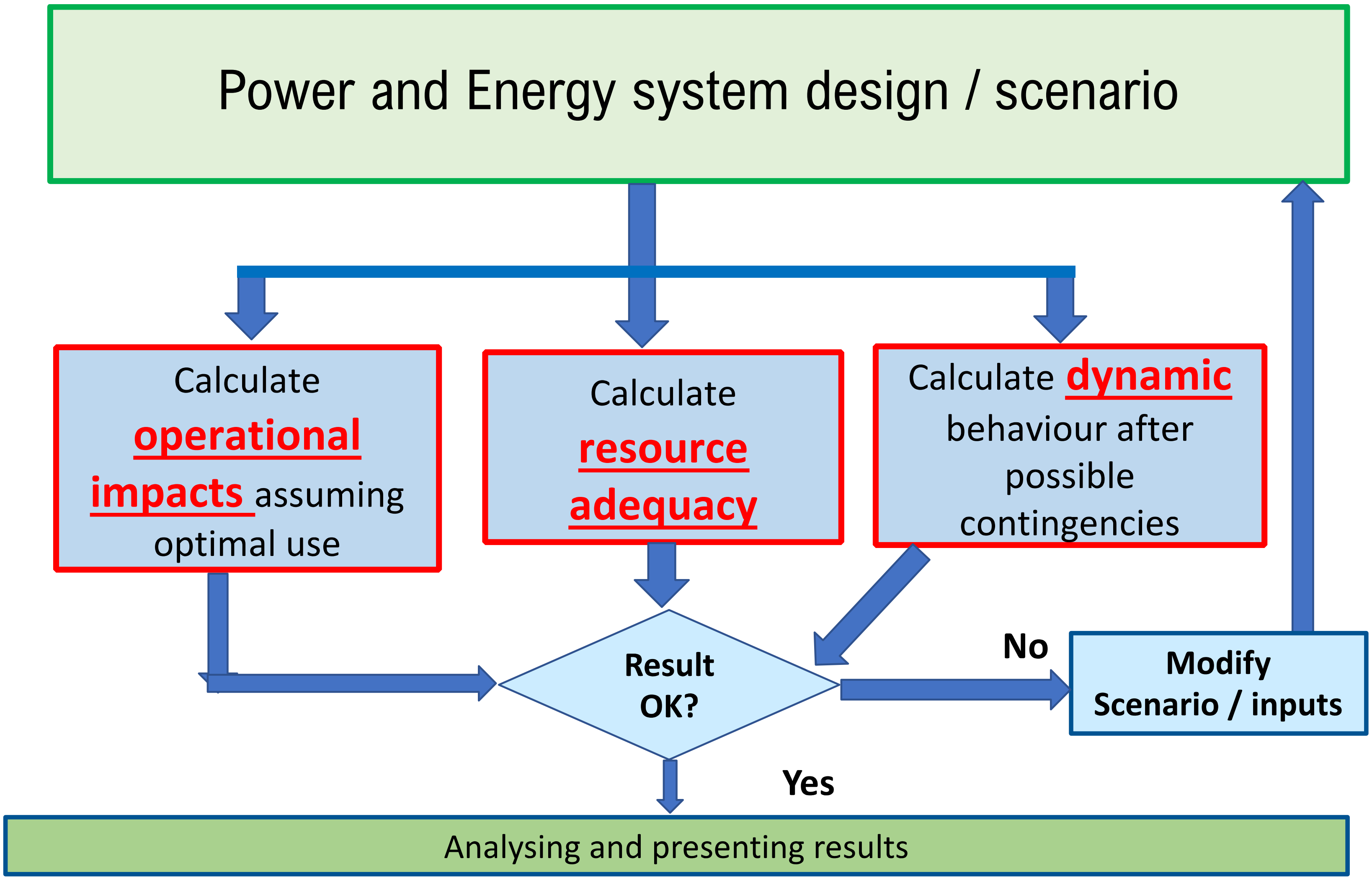
Towards 100% renewables

1. 100% VIBRES region that is part of a larger non-100% VIBRES synchronous power system
   - Challenge of balancing, efficient sharing of electricity and reserves with neighbouring areas. Highlights importance of how neighbouring regions presented in model tools
   - Also potentially local aspects of stability
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

Gaps in planning and operational models

- Insufficient consideration of 3 sub-problems of reliability, flexibility and stability
  - New constraints in existing models or the ability to link models with more detailed analytical tools
  - No need to be complex, but must address costs and constraints that impact dispatch (or investment) decisions. Setting up approximations with offline studies
- Increasing need to consider energy sector coupling
  - requires that not only the 'production' side of a generator modeled, but also the fuel storage and consumption side, as the fuel might be delivered by, or have alternative uses in, a different sector
- Increasing weather dependency – more data
  - Scheduling models need data for decades to capture this

System impact studies (integration studies)



Recommendations: Future scenarios with capacity expansion

Demand and storage

- Improve representation of demand flexibility, energy storage and sector coupling to obtain better future price predictions for systems with high VIBRES

Short-term balancing

- Include short-term balancing in order to see the impact of VIBRES forecast uncertainty on the optimal capacity mix

Grid

- Improve representation of grid limitations and stability constraints
- Include expansion costs for optimal VIBRES capacity in different areas

Markets

- Improve models to account for operational practices reflecting future system needs and services, such as price signals for end-users and revenue sufficiency.

Recommendations: adequacy

New adequacy metrics

- Reliability target - which critical loads must be served
- Use multiple adequacy metrics for risk: EUE Expected Unserved Energy and LOLH Loss-of-load Hours

Future load projections

- Include new electrification loads that are different from the current loads
- climate change impacts on demand profiles

Chronological models

- To be able to include load and storage flexibility
- Flexibility adequacy metrics to ensure flexibility

Inter-annual resource variability

- Energy reliability
- Improve data, and sensitivity to capture extreme events and include climate change impacts

Neighboring areas

- Include import possibilities in times of scarcity
- Recent model developments using Monte Carlo

Recommendations: UCED

Grid and stability constraints

- Include grid location detail and grid enhancing technology capturing bottlenecks and curtailments
- For stability constraints include inertia limits; sufficient frequency reserves; sufficient equipment in relevant locations for voltage stability

Probabilistic models

- Deterministic and probabilistic assessment approaches for risk-based operation, using new optimization methods and advances in computation

Wind and solar resource

- Temporal and spatial detail, long datasets
- Forecast uncertainty integrating weather-dependent parts of the system in multiple decision cycles

Loads and storage

- Other relevant energy sectors – flexibility and constraints
- Energy storage and price-responsive loads: model constraints relating to service availability, more detailed models of distributed resources /distribution systems

Markets

- Include market options, like products for flexibility trading at different time intervals

Recommendations: Stability

Cases for analyses
- High wind and solar share, large exports across an area, lower headroom for conventional generation.
- Worst case scenarios and foreseen operational conditions

Component models
- Validated wind/PV/BESS models
- Consider variety of control options available for wind plant/PV/BESS, grid forming where needed
- Load models, also for power electronic loads

System services
- Accurate modelling of system services, greater detail than for UCED simulations
- Protection systems

Model tools
- Update existing positive-sequence fundamental frequency planning models for more advanced functionality (FFR,..)
- Identify limiting conditions to predict control stability and fast interactions, when EMT-based models are necessary.

Types of stability studies
- Frequency stability
- Voltage stability
- Transient stability
- Rotor angle stability
- Resonance stability
- Converter-driven stability

Depend on on the system studied

Summary of recommendations

Larger areas

- the entire synchronous system for stability
- sharing of resources for balancing and adequacy purposes

Complexity

- increasing computational burden capturing VIBRES detail
- higher resolution for larger areas, with extended time series for weather dependent events

Demand and storage

- new types of (flexible) demand and storage,
- further links through energy system coupling

Model integration

- integrated planning and operations methodologies, tools and data. Greater overlap btw operational and planning time scale models
- Flexibility needs and plant capabilities within adequacy, and stability concerns for operational UCED

Cost vs. risk

- reliability interface needs revisiting
- evolution of flexibility and price responsive loads

Based on IEA WIND Task 25 articles and RP16 Ed-3 (in review)

- **”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
- **“Recommended Practices for Wind/PV Integration Studies”** IEA Wind RP16 Ed.2 available in https://iea-wind.org/

Thank You!!

Hannele Holttinen

Hannele.Holttinen@recognis.fi

+358 40 5187055

recognis

The IEA Wind TCP agreement, also known as the Implementing Agreement for Co-operation in the Research, Development, and Deployment of Wind Energy Systems, functions within a framework created by the International Energy Agency (IEA). Views, findings, and publications of IEA Wind do not necessarily represent the views or policies of the IEA Secretariat or of all its individual member countries.