Towards 100% renewable systems

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

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iea wind

Contents

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

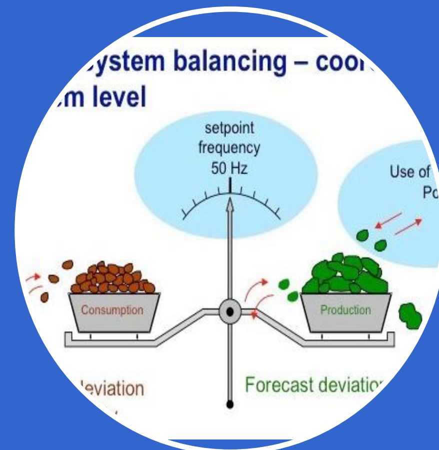
VIBRES – Variable Inverter Based Renewable Energy Sources

ENERGINET

Challenges

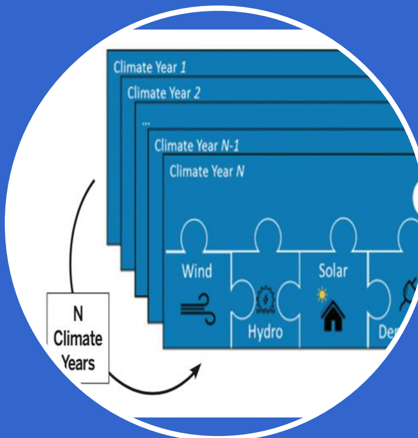
Stability

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

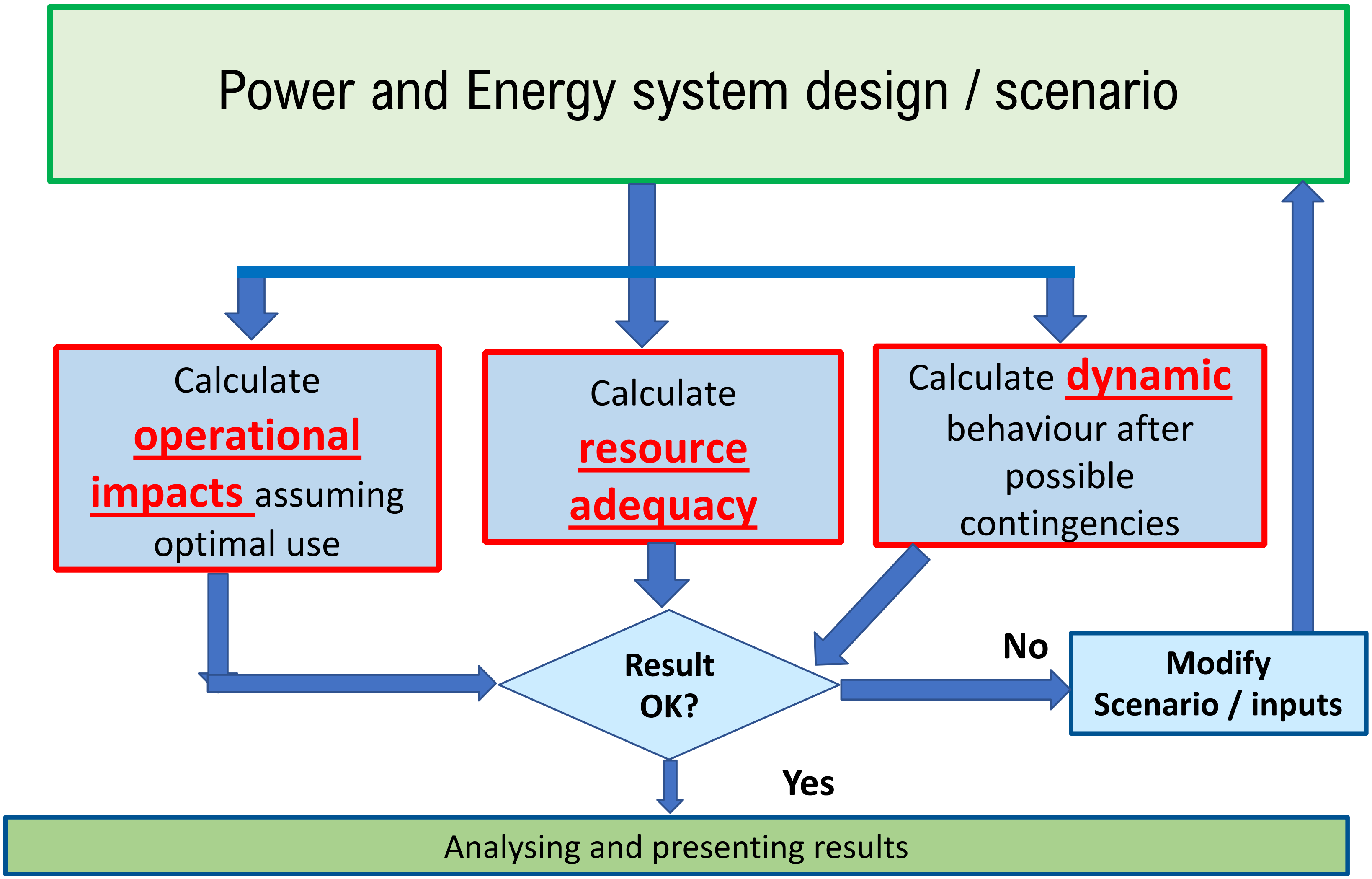
Towards 100% renewables

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/

Task 25
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Large Amounts
of Wind Power

Thank You!!

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