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Gefördert durch:
Bundesministerium für Wirtschaft und Klimaschutz
aufgrund eines Beschlusses des Deutschen Bundestages

11th European Openmod Workshop, Vienna, 22-24 March 2023

STAWESOM: STABILITY-AWARE ENERGY SYSTEM OPTIMIZATION MODELS

project funded by the German Federal Ministry for Economic Affairs and Climate Action
Funding period: 2023-2025

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Abstract

- The structure of future energy systems leads to **dynamic stability** challenges
- State of the art ESOMs can only consider simplified **steady-state** power network constraints

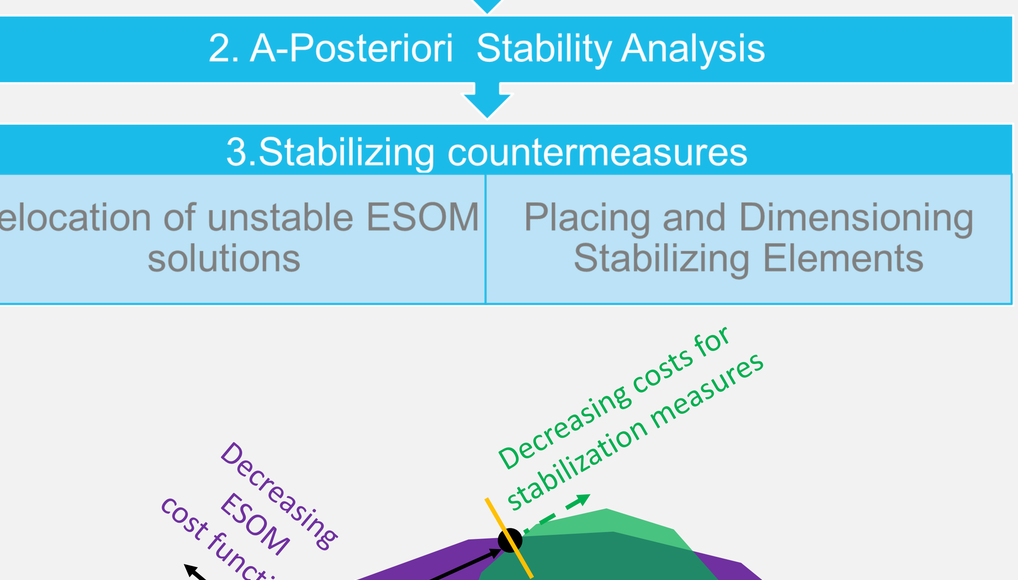
Main Project Goal

- Integrate **stability-constraints** in a simplified way in ESOMs ➔ESOM–results are closer to an optimum that is also **permissible** from a **stability point of view**

Future Power System Structure

Ambitious climate-targets, like net zero in 2050 require a massive changes in the power system structure

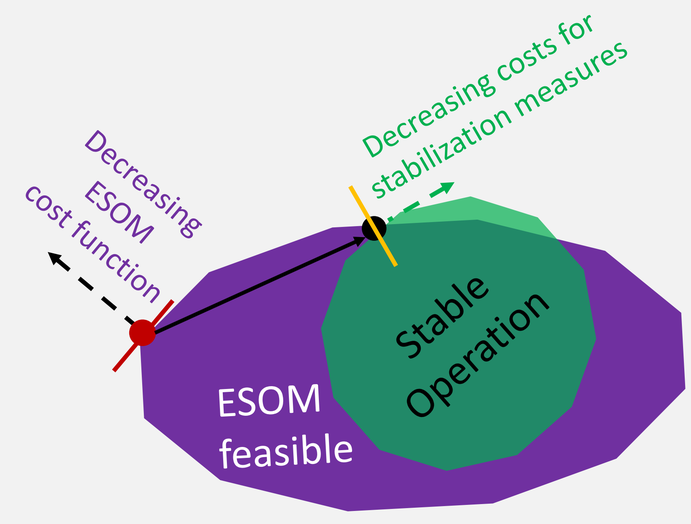
- Sustainable **increase** in renewable energy sources (**RES**)
- **Large** and long-distance **power transmission** from areas with high RES-potential to regions with high energy demand
- **Reduced inherent grid stability** due to reduced synchronous machine-based generation



A-Posteriori Stability Analysis

State-of-the-art sequential process (TYNDP[1], NEP [2])

1. ESOM
2. A-Posteriori Stability Analysis
3. Stabilizing countermeasures
   - Relocation of unstable ESOM solutions
   - Placing and Dimensioning Stabilizing Elements



- Energy System Optimization Model (ESOM) solutions are not designed to be inherently stable or even near to stable solutions
- Sequential processes lead to suboptimal solutions

A-Priori Stability-Awareness in ESOM

- In an integrated process, ESOM has a stability awareness
  - Integration of simplified stability-metrics for a-priori stability prediction
  - Integration of stabilizing elements as new ESOM components

Workflow

Development of a modular dynamic benchmark network model

Steady State,
ESOM Language
REMix [3], PyPSA [4],..

Clustered gird data

Network Snapshots from ESOM

Simulation Models for Power System Dynamics:
Julia based
PowerDynamics.jl [5],
PowerSimulationsDynamics.jl [6]

Spatial and temporal dependent dynamic models for system components
Load, Conventional Generation, Inverter Control Concepts

Dynamic benchmark power network model

Stability metrics

- How to quantify system stability a-priori?
  - Simple regionalized metrics, such as inertia, stability reserve per region
  - For linearized system dynamics:
    - System theoretic system norm such as $\mathcal{H}_2, \mathcal{H}_\infty$
    - Spectral characteristics
- Simplification and Integration in ESOM
  - Restrict the feasibility space
  - ESOM costs integrate “distance” to stable operation
- Application for the identification of stability-critical snapshots and disturbances

Requirements

- Open Source
- Modular
- Interface to relevant open-source Tools

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[1]: 4th ENTSO-E Guideline for Cost Benefit Analysis of Grid Development Projects
[2]: Begleitdokument zur Bewertung der Systemstabilität, Netzentwicklungsplan Strom 2030, Version 2019
[3]: Gils, H. C. et al. (2017). Integrated modelling of variable renewable energy-based power supply in Europe. Energy
[4]: T. Brown, J. Hörsch, D. Schlachtberger, PyPSA: Python for Power System Analysis, 2018, Journal of Open Research Software, 6(1),
[5]: Plietzsch, A. et al. (2022) "PowerDynamics. jl—An experimentally validated open-source package for the dynamical analysis of power grids."
[6]: https://github.com/NREL-SIIP/PowerSimulationsDynamics.jl

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