Aggregation methods for renewable infeed profiles in energy system models

Project Workshop

WeatherAggReOpt: Entwicklung von Aggregations- und Reduktionsmethoden zur Implementierung disaggregierter Einspeiseprofile erneuerbarer Energien in Energiesystemmodellen
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Developing methods for (partial) aggregation of renewable infeed profiles in energy system models while minimizing the influence on the overall results of such models.

Consideration of temporal, spatial and technological aggregation.

Main tasks:
- Theoretical work regarding optimal (dis-)aggregation
- Dedicated workpackages on spatial, technological and temporal aggregation
- Evaluation and testing of developed methods in pre-existing energy system models
**Methods and approaches**

**Project WeatherAggReOpt**

- **Temporal aggregation**
  - Analytical approach using stylized optimization models
  - Statistical analyses regarding effects of temporal aggregation

- **Spatial aggregation**
  - Analysis of weather data
  - Impact of spatial aggregation

- **Technological aggregation**
  - Aggregation of investment choices based on value components
  - Aggregation of PV units

**Testing**

- Construction of a reference test model
- Implementation and testing of methods in large-scale electricity market models
Analytical approach for temporal aggregation

Temporal aggregation (UDE)

- **Highlights**
  - Inspired by problems of scenario aggregation in the field of stochastic programming
  - Solution quality of the model based on aggregated time series compared to the solution of the original problem
  - Analytical results derived for a simplified version (peak-load-pricing)

- **Methodology**
  - Original (non-aggregated) problem → Corresponding reduced problem → Meta problem
  - Application (analytical, numerical) utilizing the peak-load-pricing model

Temporal aggregation (UDE)

Results

- With N technologies, 2^N + 1 time segments sufficient to replicate capacities, energy quantities & prices
  - if appropriately selected and in a single node model without operational constraints (“peak-load-pricing model”)

- Separate consideration of the time step with the highest residual load
  - much higher shadow price in this timestep has an important impact on overall cost
  - True also for models with endogenous renewable generation capacities as well as to multi-region cases

Further work on multi-region settings

- Scarcity of transmission capacities impacts possible aggregation
  - Case distinction: non-binding vs. binding transmission constraints: one common or multiple supply stacks

- Description of the infeed distribution over different residual load levels required – with storage also, relative position of time segments matters

WP 5: Temporal aggregation and reduction of renewable infeed profiles aus EE-Anlagen
Temporal aggregation (ISE)

- Using 2 statistical tests: **Randomization** and **Jackknife-method**
- Randomization of hours in days, hours in months, days in months, days in years, weeks in year
- Randomization of hours in months
  - **More short term storage** and the storage volume of the **long term storage decreases** by around 85 %, but is consistent over the model runs
  - **PV expansion decrease** by 50 % (PV more expensive than Wind in the scenario)
- Randomization of days in months
  - Storage volume of **long term storage decreases** by 25-40 %
  - **PV expansion decreases** by 25 %
  - Results are more spread than in other randomization
- Randomization of days in years
  - **PV expansion decreases by 80-90 %** due to the elimination of the seasonal structure
Effects of temporal aggregation – Impacts of extreme events based on statistical analysis

Temporal aggregation (ISE)

- **Jackknife-method**
  - systemically leave out observations
  - Remove a day from the dataset and calculate the results
  - Repeat for each day in the dataset

- **Results:**
  - The exclusion of periods with low capacity factors for wind/PV have the highest impact on the model results
  - The impact becomes greater when there is a cluster of low generation days or weeks
  - The observation with the lowest capacity factor has not necessarily the biggest impact
Spatial Aggregation (ISE)

- Selection of Weather Dataset:
  - Merra-2 (NASA)
  - CFSv2 (NCEP)
  - ERA5 (ECMWF)

  ERA5 was selected based on the following criteria:
  - Longest observation period
  - Windspeed on 100m as parameter
  - Higher resolution than the Merra V2 Dataset
  - Weather model of the newest generation
Problem formulation:

- **Differences** between various module types, small regarding efficiencies, especially with high irradiance
- **Differences in module orientations** potentially more important

Analyses & results:

- 11 different module orientations calculated and tested in model runs
- Differences between profiles are too small to make up the discrepancies in full-load-hours
Spatial and technological aggregation based on value components

Problem formulation:

Multiple investment choices e.g. location and technology type for wind energy to be aggregated for large-scale system models

Approach:

I. Definition of value components

II. Computation of the value components

1. Choice of adequate scenarios
2. Define investment choices as objects for the clustering algorithm
3. Calculate value components for various scenarios

III. Aggregation of investment choices in limited number of clusters

4. Predefine cluster numbers using hierarchical clustering
5. Aggregation of investment choices

➢ cf. presentation by Arne Pöstges
Outlook

- Three months until end of project

Some ongoing work, notably:
- Time series aggregation in a detailed electricity market model
  - chronological time-period clustering
  - adopted the large European electricity market model JMM (Joint Market Model)
  - test and compare different designs of chronological time period clustering
- Test of the developed methods in existing large-scale models

Outlook:
- Use of the developed approaches for system studies
- Adaptive disaggregation?
Thank you for your attention!