Aggregation of Temporal Representation of High-Resolution, Fundamental Flow-based Market Coupling Input Data to Identify Typical Market Scenarios

A Systematic Evaluation and Selection of Relevant Cluster Algorithms

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Agenda

1. Setting the scene
2. Methodology
3. Main findings
4. Conclusion & Outlook
Setting the scene

(Abstract) process chain of transparent, model-based, quantitative studies

- Selection of required parameters, e.g. fluctuating system elements
- Due to computational limits selection of representative data
  - key issue: adequate representation of spatial and temporal variability

- Data-driven, fundamental, cost-optimizing modeling of system variables

- Optimal investment in generation and transmission capacity

- Interpretation of results for derivation of policy recommendations

What if the recommendations are based on low-quality, imprecise model results?

- Underrepresentation of variability → Overestimation of role of renewable energy
  → Underestimation of system integration cost

Focus of Master's thesis

Martin Kittel @ ENERDAY 2018

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Setting the scene

Research objectives

- Identification of a minimal, yet representative set of market situations in the CWE electricity markets in 2016
- Systematic evaluation of the impact of aggregation techniques on market situations and on model outcome

Key problem: aggregating intra-annual time resolution of fundamental market data

- Capturing temporal and spatial variability of load and variable renewable generation (VRES) patterns
Setting the scene

Relevant aggregation approaches

Aggregation approaches

Random selection

Heuristic selection

Content related systematics

External validity indices

Cluster analysis

Hierarchical

Partitional

Related work

Complexity

source: own illustration
Methodology I – Exemplary clustering

Iterative Procedure

- Six observations: \{A, B, C, D, E, F\}
- Logical final cluster partitioning
  - C1 = \{A, B\}
  - C2 = \{C, D, E\}
  - C3 = \{F\}

Cluster representation

- Centroid: x
- Medoid: D
Methodology II – Cluster dimensions

3-dimensional scenario space: 260 scenarios

Cluster representation

Cluster algorithm

Number of Clusters

Source: own illustration
Methodology III - Overview

Fundamental input data of CWE region for 2016
- Demand
- VRES Generation

Cluster analyses (Python)

Cluster validation

(preliminary) Market scenarios

Input error metrics
- $\text{RMSE}_{\text{cl}}$
- Variability
- Correlation

Output error metrics
- Total system costs
- CostE
- L1-distance
- $\text{MAE}_{\text{PDC}}$
- $\text{RMSE}_{\text{PDC}}$

Fundamental input data of CWE and non-CWE countries for 2016
- Demand, VRES Generation
- Power plant stack
- Fuel & CO$_2$ prices
- FBMC parameters

ELTRAMOD (GAMS)
NTC $\rightarrow$ FBMC

source: own illustration
Main findings

Cluster dimensions

- Most efficient cluster algorithms achieve similar performance
  - WARD (hierarchical algorithm)
  - K-Means (partitional algorithm)
- Ambiguous results regarding cluster representation
  - Centroid-based representatives closer resemble original data
  - Medoid-based representatives capture greater deal of temporal and spatial variability
- Number of clusters
  - Research objective comprises adverse requirements → minimal in number vs. representativeness of set of scenarios
  - $K = 15$ based on K-Means
  - $K = 20$ based on WARD

Facilitation of reduction to 4 salient cluster scenarios

- $K = 15$ based on K-Means
- $K = 20$ based in WARD

for both centroid- and medoid-based representation
Example of representative market situations

Original load time series in DE

Result: 15 clustered load situations in DE based on K-Means (medoids)

source: own illustration
Conclusion & critical appraisal

Conclusion

- Contribution in terms of comparison of large number of configurations of cluster analyses, thus empirically derived findings
- Provides holistic aggregation approach for deriving and selecting typical market situations in energy system modeling

Shortcomings

- Disruption of diurnal structures are inherited to representative market scenarios → Inadequate consideration of intertemporal constraints
- Order of representative hours remains unclear
- Output error metrics highly dependent on shortcomings of applied modeling framework
  - Methodological simplifications on technological resolution
  - Structural congestion and generation curtailment
Outlook

- Refinement, extension and elimination of shortcomings of developed approach
  - Adequate aggregation unit (entire days comprising multiple hourly or multi-hourly time-slices)
  - Determination of order of representative market situations
  - Clustering of all time-dependent data

- Reduction of temporal resolution of input data is inevitable in the context of sector coupling
  - Key issue: consideration of variability of fluctuating system elements
  → underestimation of variability can lead to tremendous distortions of model results
Relevant Literature


Thank you for your attention!

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