Capturing the intermittent character of renewables by selecting representative days

Kris Poncelet

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Introduction

- Long-term energy system optimization models:
  - Computationally demanding:
    - Technology rich
    - Large geographical area
    - Long time horizon (e.g., 2014-2060)
  - => Model simplifications:
    - Low level of temporal detail
    - Low level of techno-economic operational detail
    - Low level of spatial detail

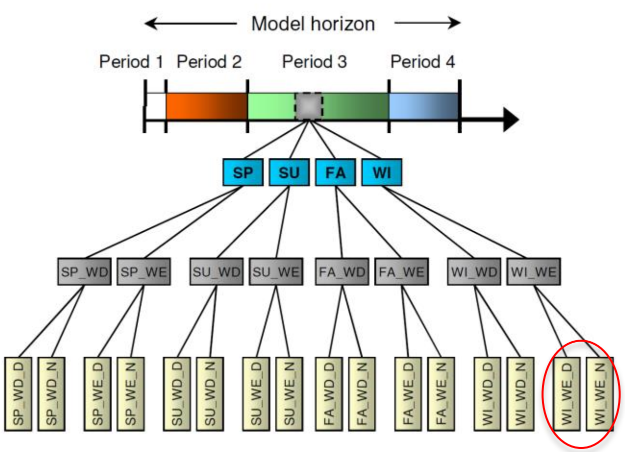
⇒ Overestimation potential uptake of IRES
⇒ Overestimation value of baseload technologies

Underestimation operational costs

Temporal representation

Temporal representation

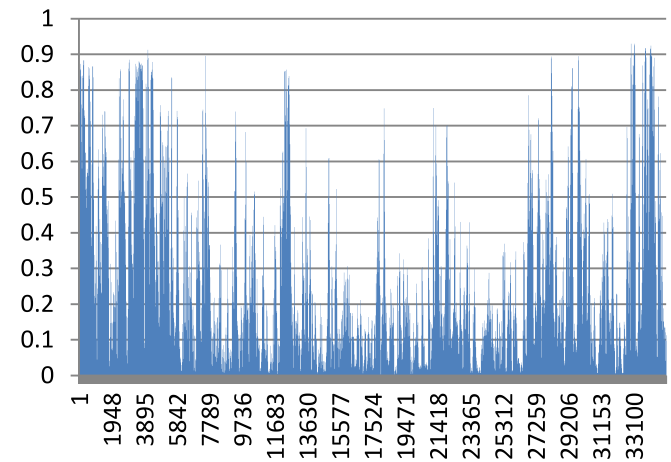
Temporal structure



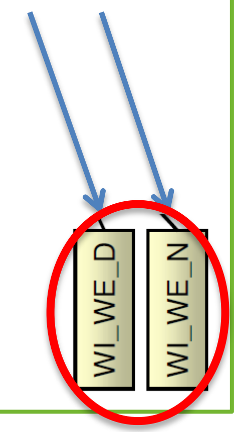
= Property of planning model

Within each time slice, all values are fixed (wind, load, etc.)

Data preprocessing



= Approach used to assign a value (and weight) to each time slice



Data preprocessing

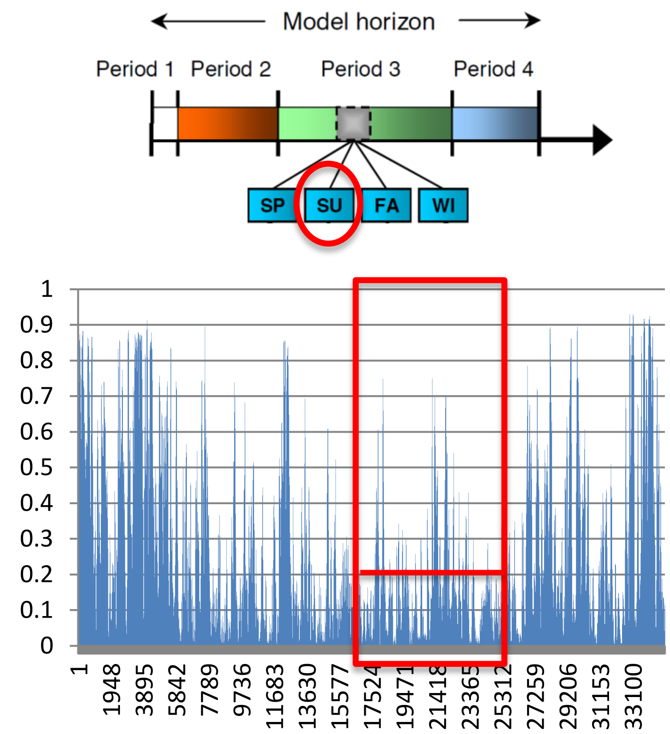
Different approaches:

"Integral"

- Take the average value of all values corresponding to a specific time slice
- Traditionally used, corresponds to energy balance
- Does not sufficiently account for the variability of IRES

"Representative days"

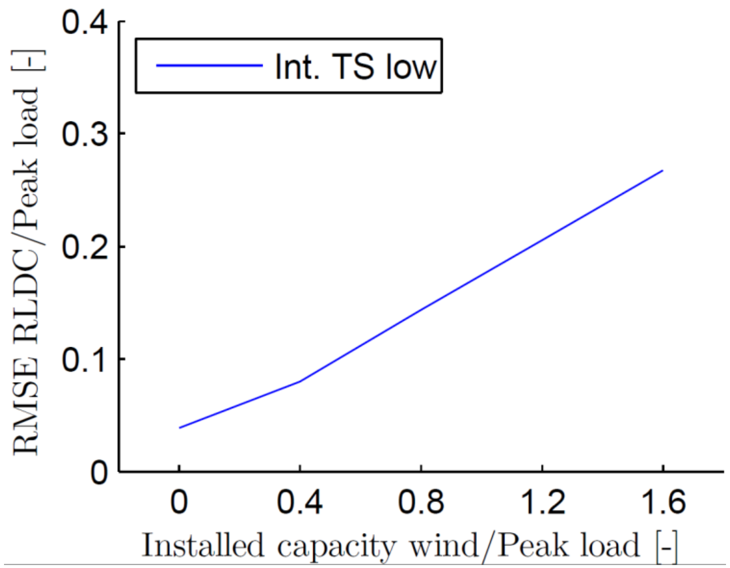
- Each year represented by a small set of representative days (consisting of a number of diurnal time slices)
- => No/less averaging of data



Alternative temporal representation?

Integral Traditional

Temporal representation	Number of time slices Seasonal	Daily	Diurnal	IRES	Total
Integral TS low	4	-	3 (day, night, peak)	-	12
Reference (TS ref)	52	7	24	-	8736

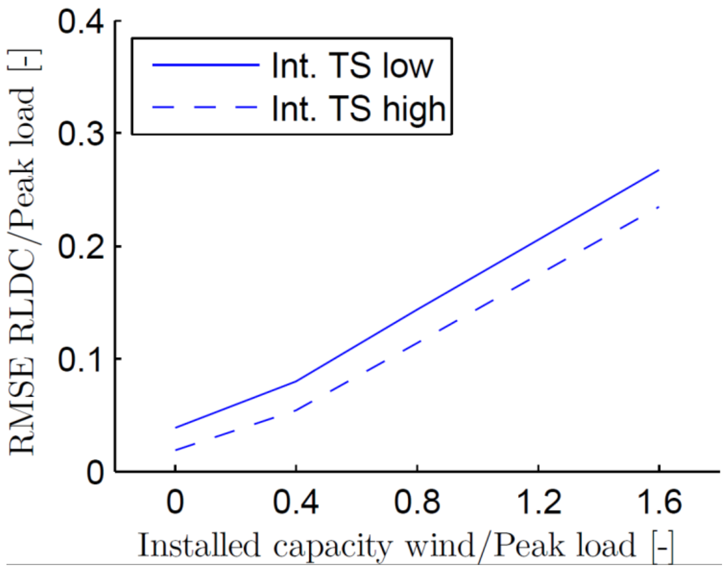


Alternative temporal representation?

Integral Traditional

Temporal representation	Number of time slices: Seasonal	Daily	Diurnal	IRES	Total
Integral TS low	4	-	3 (day, night, peak)	-	12
Integral TS high	4	3 (Weekday, Sat, Sun)	24	-	288
Reference (TS ref)	52	7	24	-	8736

Integral increased # time slices



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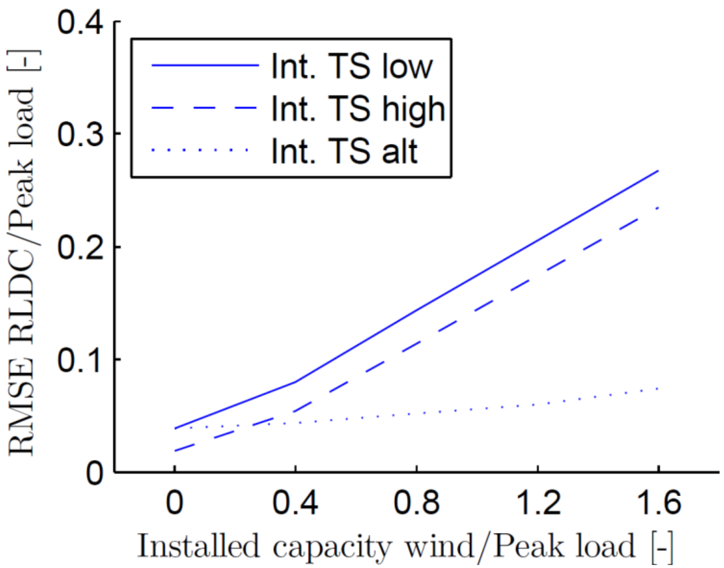
Integral TS alt	4	-	3 (day, night, peak)	3 (high, medium, low)	36
Reference (TS ref)	52	7	24	-	8736

Integral increased # time slices

Integral with separate time slice level for RES availability



Alternative temporal representation?

Integral Traditional

Temporal representation	Seasonal	Daily	Number of time slices Diurnal	IRES	Total
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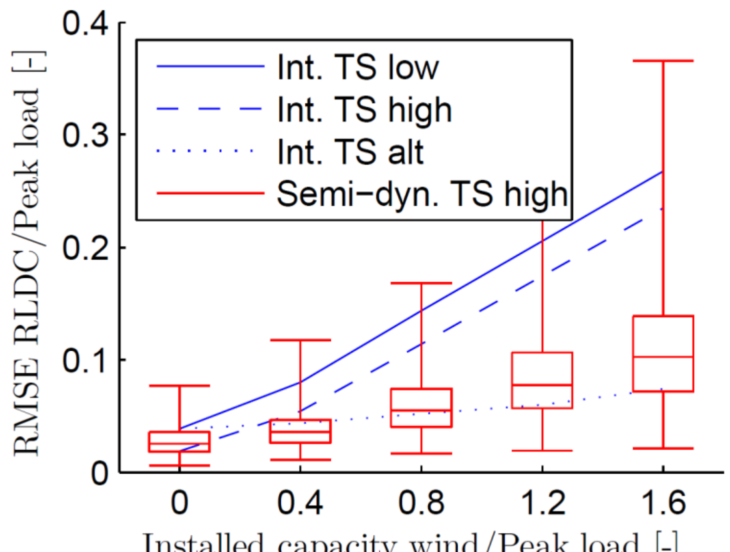
Integral TS high	4	3 (Weekday, Sat, Sun)	24	-	288
Integral TS alt	4	-	3 (day, night, peak)	3 (high, medium, low)	36
Semi-dynamic TS high	4	3 (Weekday, Sat, Sun)	24	-	288
Reference (TS ref)	52	7	24	-	8736

Integral increased # time slices

Integral with separate time slice level for RES availability

Representative days (12)



Alternative temporal representation?

- Integral method with separate time slice level for RES availability
  - Pro's:
    - Low # of TS required
    - Easy to implement
  - Cons:
    - Loss of chronology => storage, ramp rates?
    - Correlation between different regions/resources?

- Representative days
  - Pro's:
    - High accuracy possible
    - Chronology (and correlation) maintained
  - Cons:
    - Higher #TS required?
    - How to ensure that days are representative?

Selecting representative days

Goals:

- Select a set of historical days, and corresponding weights, such that these days are representative for the data-set
- Make optimal use of available #TS => capture as much as possible information

Representative?

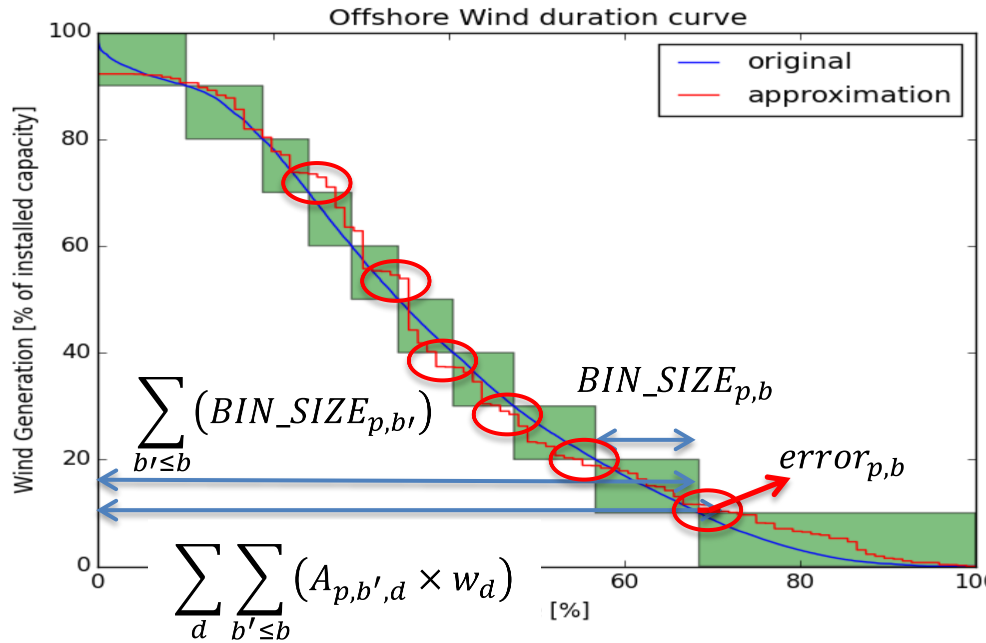
First order (highest priority) — Second order (lower priority)

Aspect	Yearly average value	Distribution	Dynamics			Correlation	
			ST	MT	LT	Between ‘profile types’	Between regions
Important to account for:	Energy yield of different technologies + load	Variability (static) of the load and IRES	Ramping rates, storage	LT storage technologies	Different wind/solar /load years	value of electricity generation in different time steps	value of electricity generation, grid extensions

Optimization approach to select representative days

Aspect	Yearly average value	Distribution
Important to account for:	Energy yield of different technologies + load	Variability (static) of the load and IRES

$$\underbrace{\hspace{6cm}}_{\text{Duration curve}}$$



$$\min_{u_d, w_d} \sum_p W_p \times \sum_b error_{p,b}$$

s.t.:

$$error_{p,b} = \left| \sum_{b'\leq b}(BIN\_SIZE_{p,b'}) - \sum_{d}\sum_{b'\leq b}(A_{p,b',d}\times w_d) \right|$$

Hours in day d, belonging to bin b

- Sum of weights correspond to total number of days in the original profile
- Weight of a day can only be > 0 if that day is selected (integer variable u_d)
- Pre-determined number of days are selected

p: profile (load, wind, PV, etc.)
b: bin
d: day

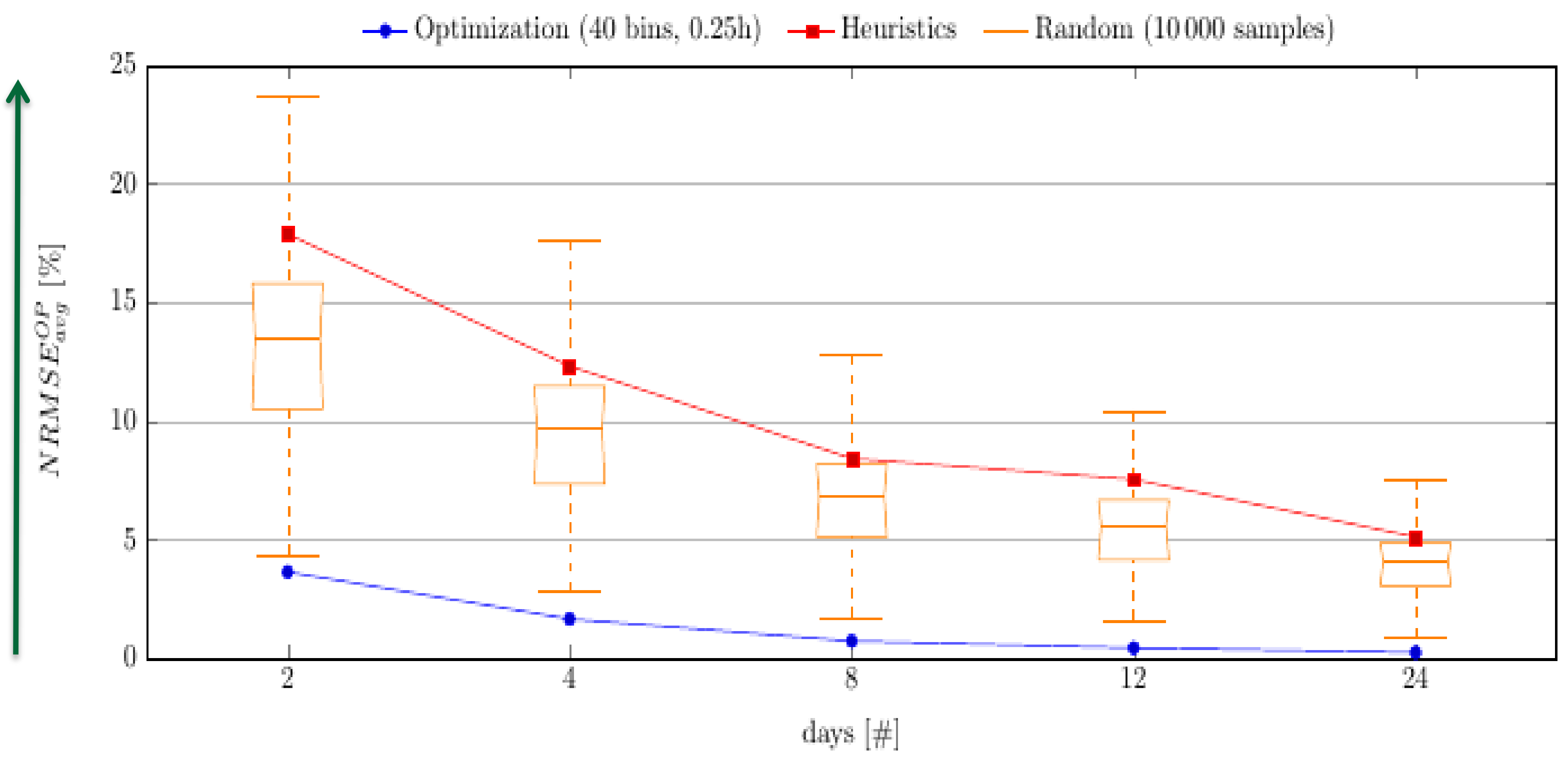
Methodology

- Input = time series for Belgian onshore wind generation, solar generation and load in 2014
  - 3 original profiles (OP)
- 40 Bins
- Select a varying number of representative days
- Quantify error in approximating the duration curves, the dynamics and the correlation
- Compare with simple heuristic approach to select representative days

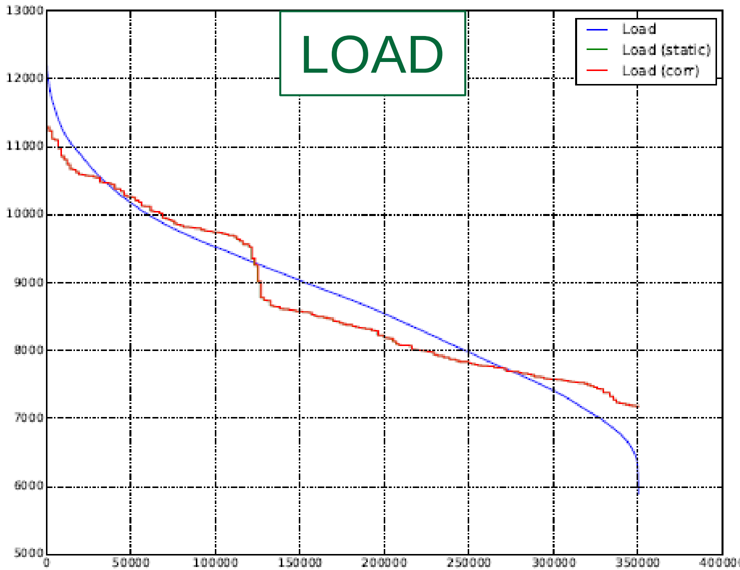
Results

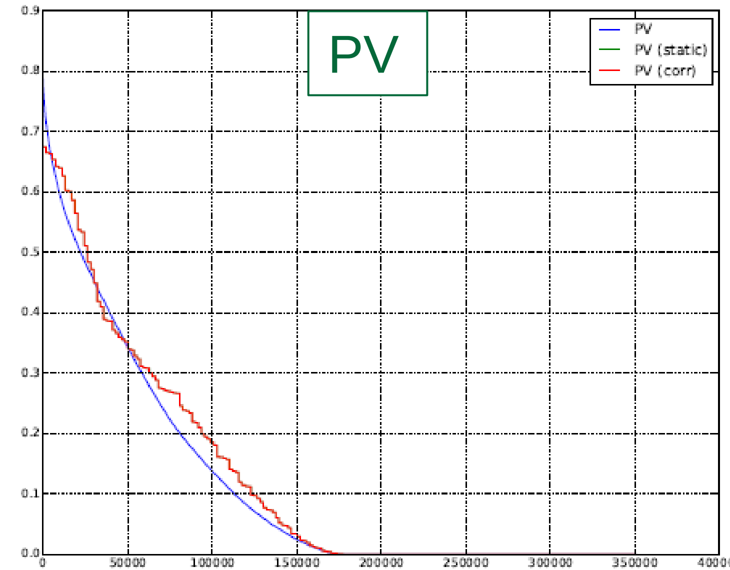
Static aspects (only OP)

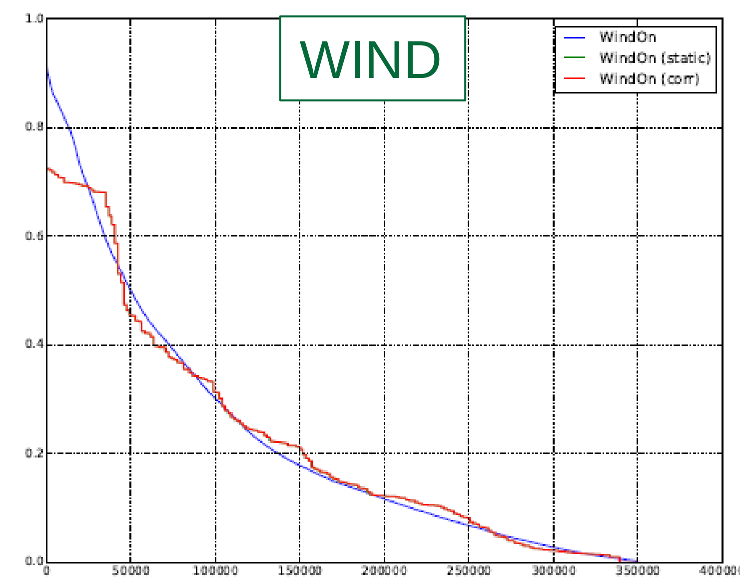
Error in approximating duration curves of the original time series

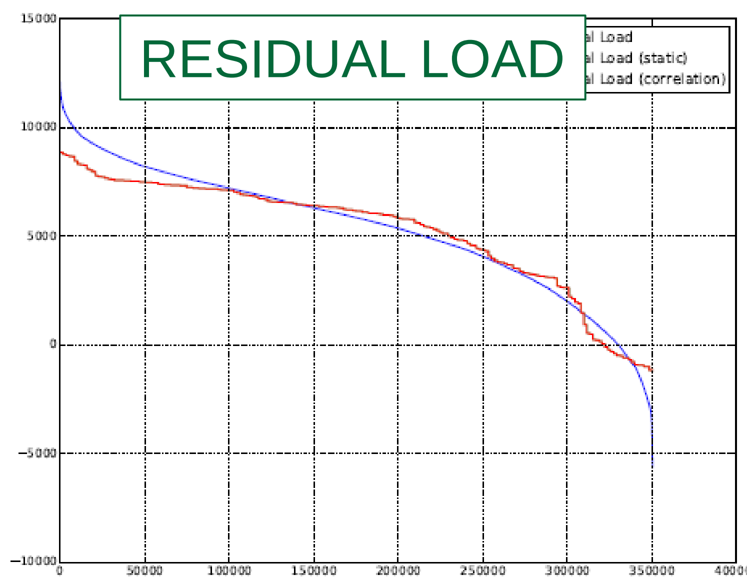


Results – 2 representative days

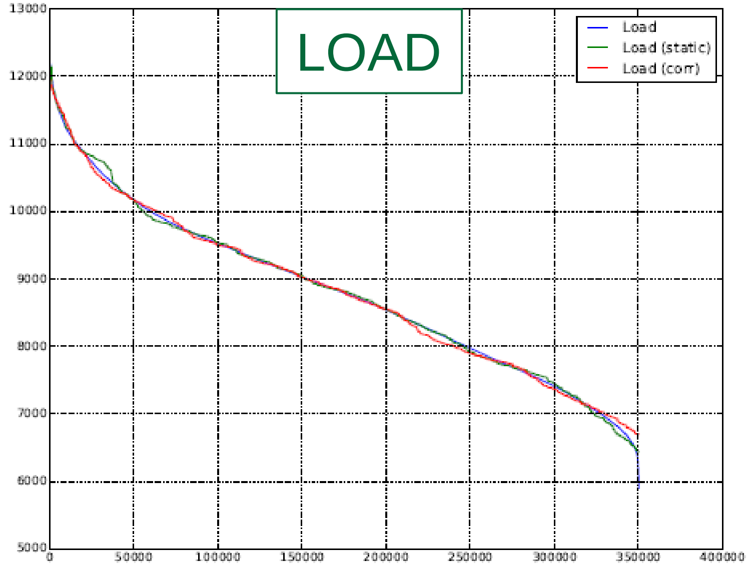


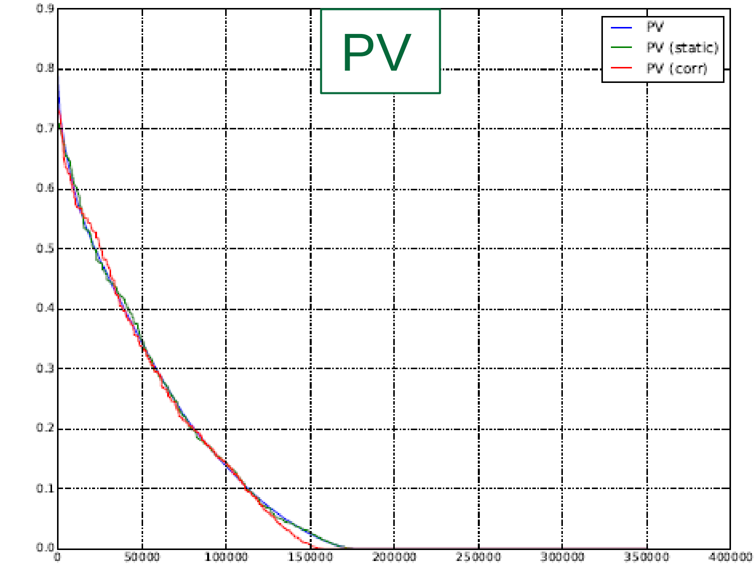


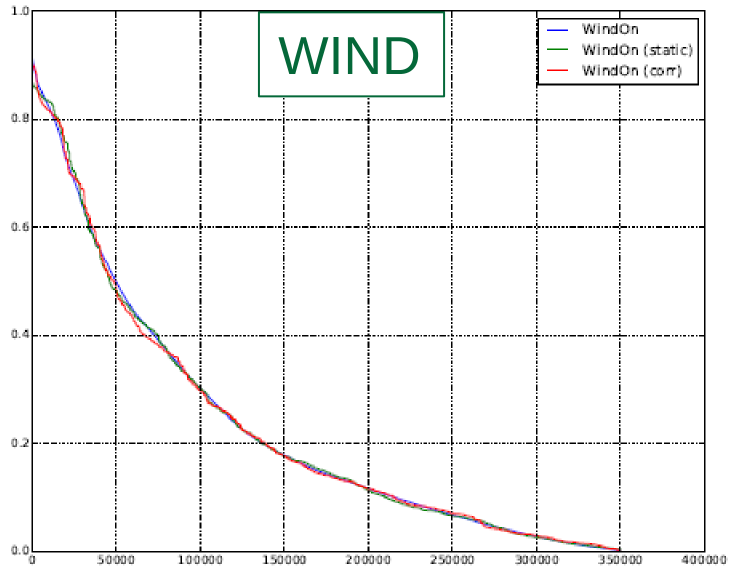


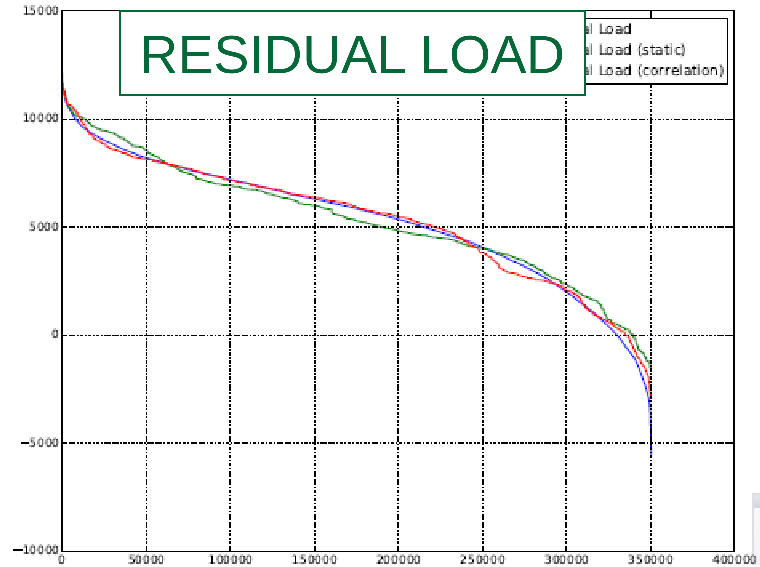


Results – 8 representative days

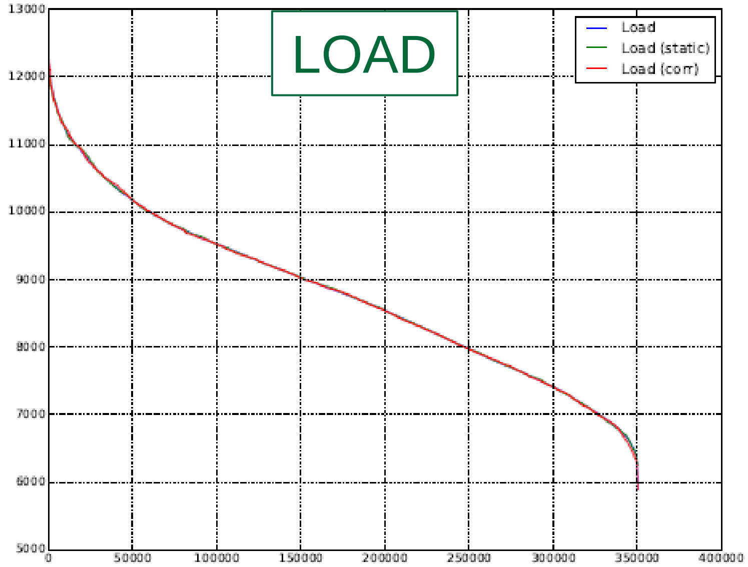


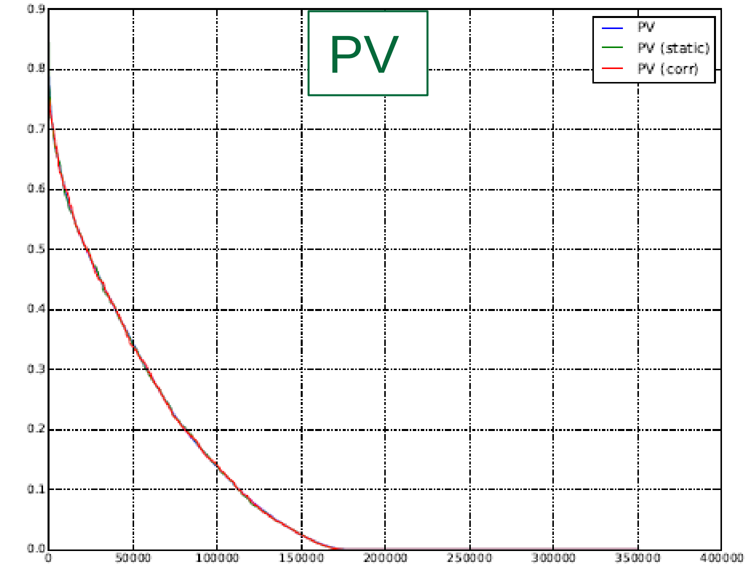


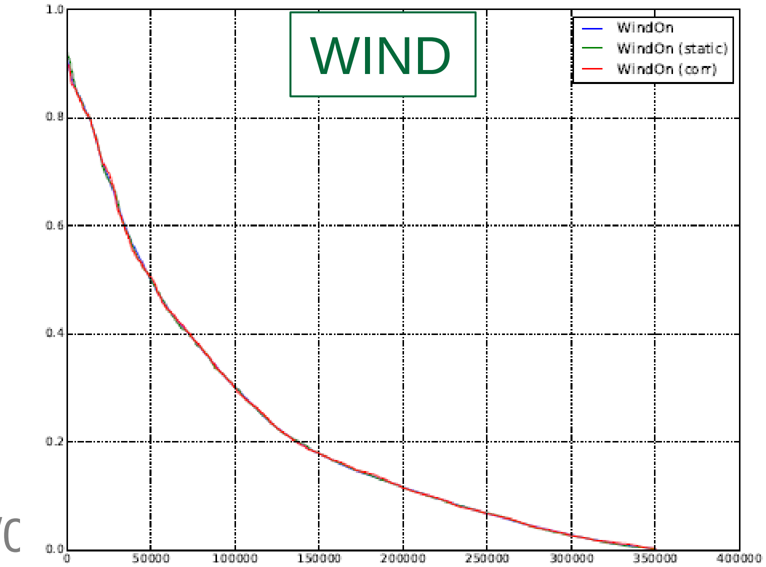


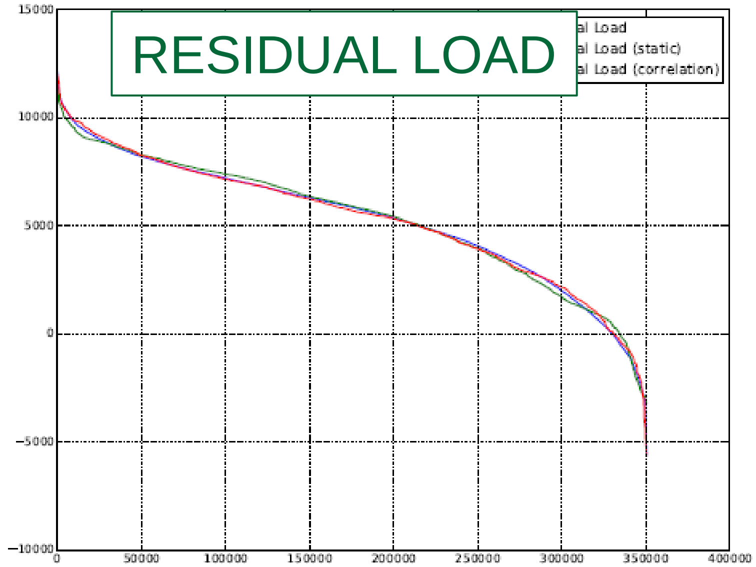


Results – 24 representative days





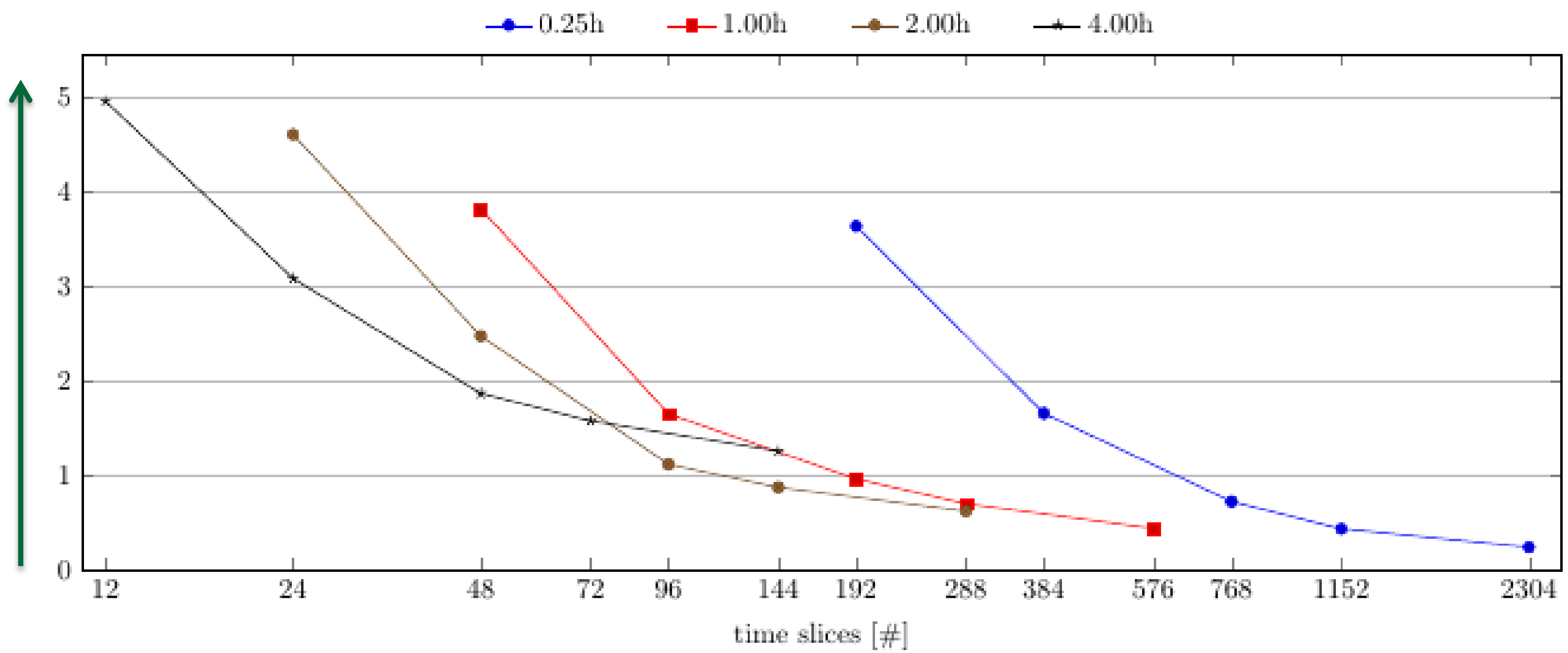




Results – number of days Vs. resolution

- Trade-off # days and resolution (limited # of time slices = # days * # time slices/day)
- Up to now: all selected days with 15min resolution

Error in approximating duration curves of the original time series



Conclusions

- Temporal representation typically used strongly impacts results
  - => Overestimating potential uptake of IRES and baseload generation => underestimating costs
- Improving the temporal representation without strongly increasing the # of time slices possible
  - by using a time slice level for IRES availability
  - by using a set of representative days
- Selecting representative days
  - Developed MILP model for selecting representative days
  - Consider static aspects, dynamic aspects and aspects related to correlation
  - Sufficient #days should be prioritized to using a high resolution

Kris Poncelet, kris.poncelet@kuleuven.be
Hanspeter Höschle, hanspeter.hoschle@kuleuven.be
http://www.mech.kuleuven.be/en/tme/research/energy_environment/