DSM modeling in oemof.solph

Introducing the custom component SinkDSM

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Project context

- Research project WindNODE
- Building a regional ESM for Anhalt-Bitterfeld-Wittenberg
- Intended analysis: potential of flexibility options to foster regional energy supply
- Demand-Side Management in households is one option

Code (under development): https://github.com/windnode/WindNODE_ABW

A minimal testing energy system

Household busbar

Assuming we have a household including

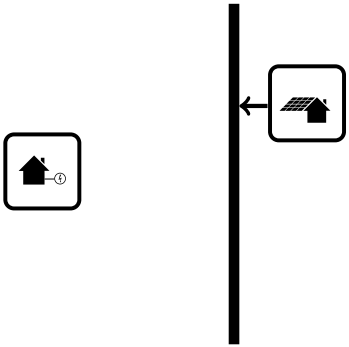
A minimal testing energy system

Household busbar

Assuming we have a household including

- Demand

A minimal testing energy system

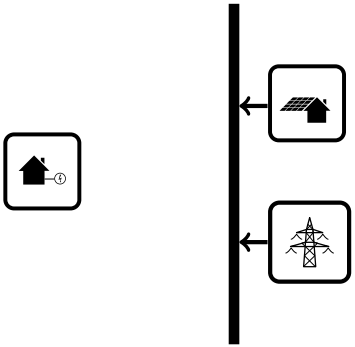


Household busbar

Assuming we have a household including

- Demand
- PV

A minimal testing energy system

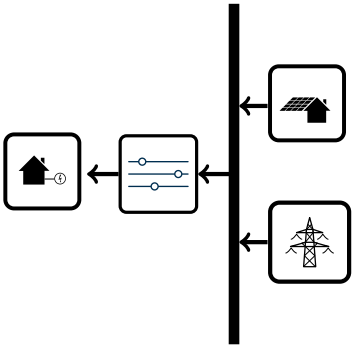


Household busbar

Assuming we have a household including

- Demand
- PV
- Grid connection

A minimal testing energy system



Household busbar

Assuming we have a household including

- Demand
- PV
- Grid connection
- Demand-side management unit

Create some data

```
# Create some data
pv_day = [(-(1 / 6 * x ** 2) + 6) / 6 for x in range(-6, 7)]
pv_ts = [0] * 6 + pv_day + [0] * 6
data_dict = {"demand_el": [3] * len(pv_ts),
             "pv": pv_ts,
             "Cap_up": [0.5] * len(pv_ts),
             "Cap_do": [0.5] * len(pv_ts)}
data = pd.DataFrame.from_dict(data_dict)

# Do timestamp stuff
datetimeindex = pd.date_range(start='1/1/2013', periods=len(data.index),
  freq='H')
data['timestamp'] = datetimeindex
data.set_index('timestamp', inplace=True)
```

Surrounding minimal energy system

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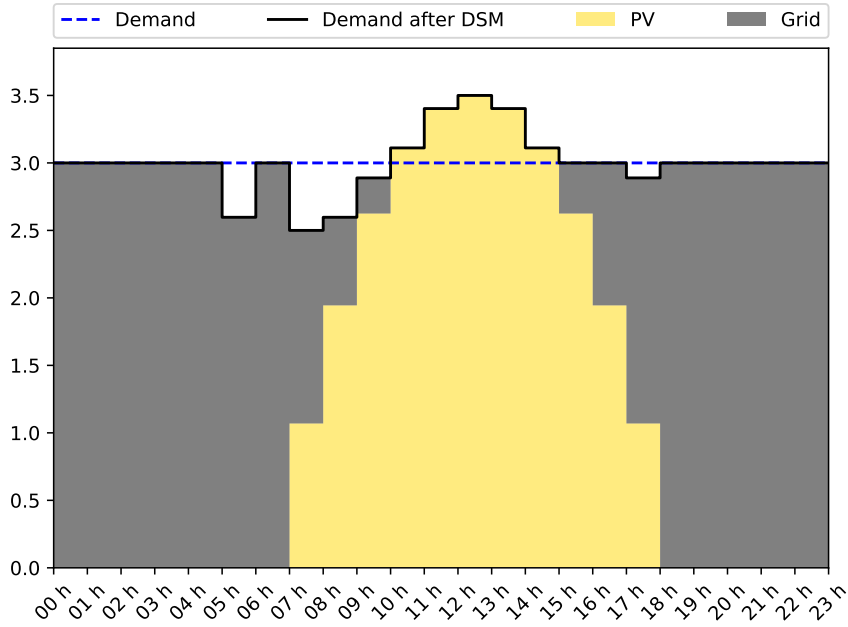
```
es = solph.EnergySystem(timeindex=datetimeindex)
Node.registry = es

b_elec = solph.Bus(label='Electricity bus')

grid = solph.Source(
    label='Grid',
    outputs={b_elec: solph.Flow(nominal_value=10000,variable_costs=50)})

pv = solph.Source(
    label='pv',
    outputs={b_elec: solph.Flow(actual_value=data['pv'], fixed=True,
    nominal_value=3.5)})
```

SinkDSM component

```
# Create DSM Sink
demand_dsm = solph.custom.SinkDSM(label='DSM',
                                  inputs={b_elec: solph.Flow()},
                                  capacity_up=data['Cap_up'],
                                  capacity_down=data['Cap_do'],
                                  delay_time=6,
                                  demand=data['demand_el'],
                                  method="delay",
                                  cost_dsm_down=5)
```


Demand
Demand after DSM
PV
Grid
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
00 h
01 h
02 h
03 h
04 h
05 h
06 h
07 h
08 h
09 h
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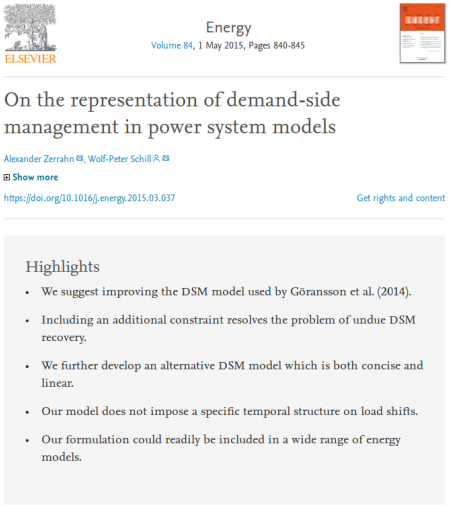
23 h

How to model DSM?



Energy
Volume 84, 1 May 2015, Pages 840-845

On the representation of demand-side management in power system models

Alexander Zerrahn, Wolf-Peter Schill
Show more

https://doi.org/10.1016/j.energy.2015.03.037

Highlights

- We suggest improving the DSM model used by Göransson et al. (2014).
- Including an additional constraint resolves the problem of undue DSM recovery.
- We further develop an alternative DSM model which is both concise and linear.
- Our model does not impose a specific temporal structure on load shifts.
- Our formulation could readily be included in a wide range of energy models.

Abstract

DSM formualtion 1: Zerrahn & Schill (delay)

$$\dot{E}_t = demand_t + DSM_t^{up} - \sum_{tt=t-L}^{t+L} DSM_{t,tt}^{do} \quad \forall t \in \mathbb{T} \tag{1}$$

DSM formualtion 1: Zerrahn & Schill (delay)

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$$DSM_t^{up} = \sum_{tt=t-L}^{t+L} DSM_{t,tt}^{do} \quad \forall t \in \mathbb{T} \tag{2}$$

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$$DSM_t^{up} \leq E_t^{up} \quad \forall t \in \mathbb{T} \tag{3}$$

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$$\sum_{t=tt-L}^{tt+L} DSM_{t,tt}^{do} \leq E_{tt}^{do} \quad \forall tt \in \mathbb{T} \tag{4}$$

DSM formualtion 1: Zerrahn & Schill (delay)

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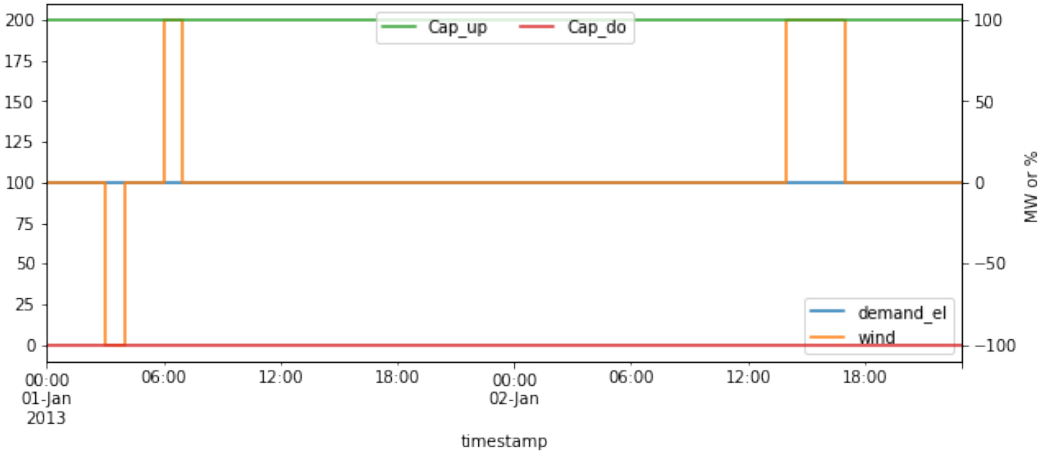
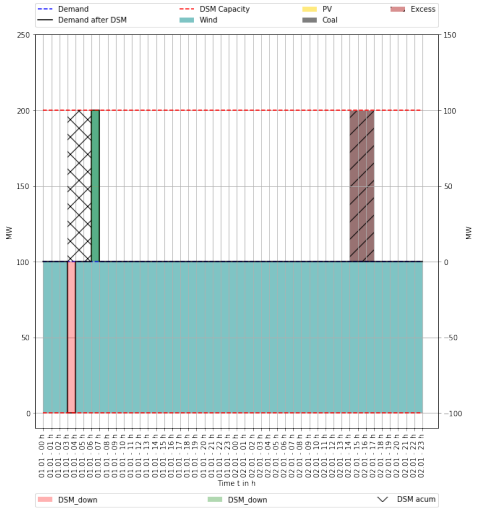
$$DSM_t^{up} + \sum_{t=tt-L}^{tt+L} DSM_{t,tt}^{do} \leq max\{E_{tt}^{up}, E_{tt}^{do}\} \quad \forall tt \in \mathbb{T} \tag{5}$$

Basic testing data



How it works

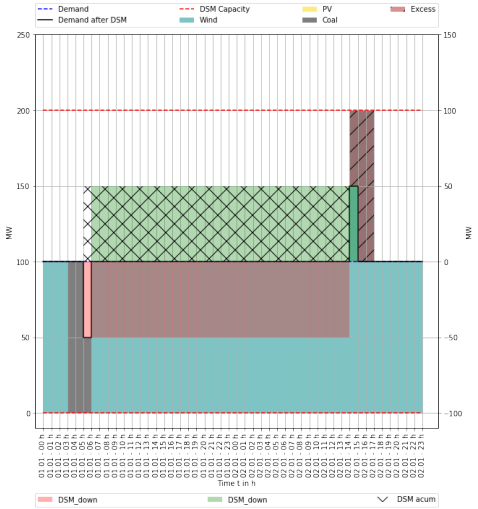


Delay time: 3

What's happening

- Interrupted wind generation in hour 4 set 100 MWh on hold
- Doubled wind generation in hour 7 compensates for demand that is set on hold
- Doubled wind generation around afternoon on the second day goes to excess

Shifting energy exceeding the delay time (basic)

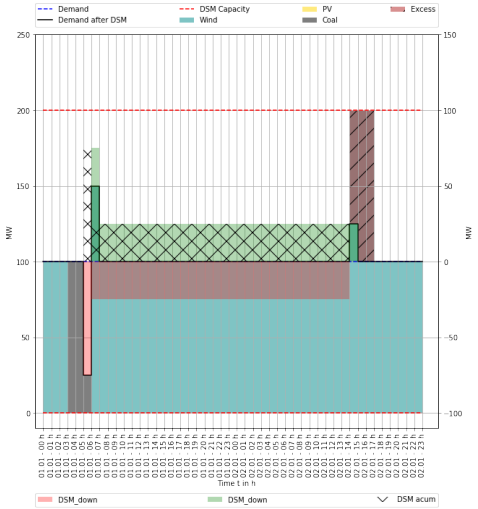


Delay time: 1

What's happening

- DSM allows to shift energy from first day morning to second day afternoon. How is that possible?
- Zerrahn et al.'s (2015) constraints allow to trigger DSM^{up} and DSM^{do} at the same time
- DSM^{up} and DSM^{do} are constrained to the tighter bound (Eq. (5))

Limited by DSM events in between (50 %)



Delay time: 1

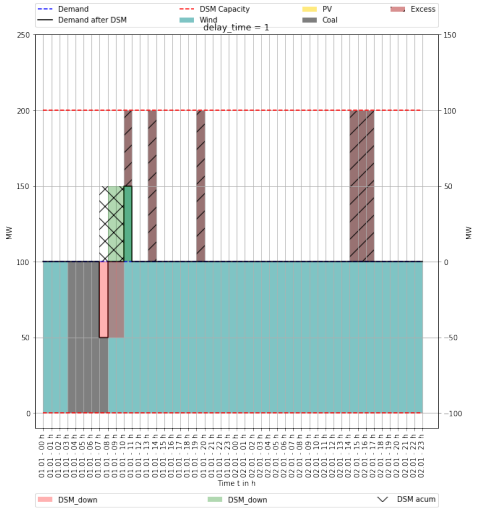
Intermediate DSM trigger:

50 % of DSM_{up}

What's happening

- DSM activity in the morning of the first day: 50 MWh
- DSM shift that exceeds the delay time is limited: 50 MWh $\rightarrow$ 25 MWh

Effect of delay time

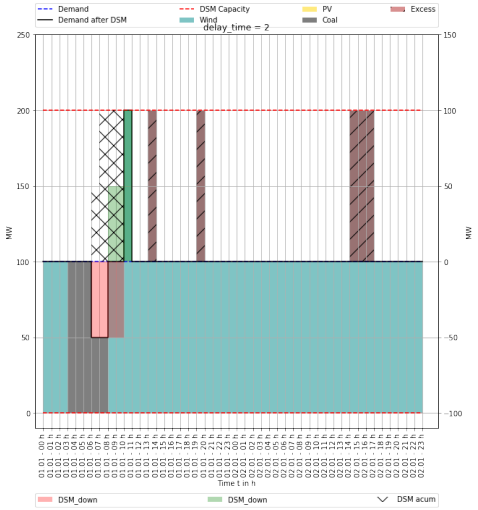


Delay time: 1

What's happening

- DSM shift exceeding the delay of 50 MWh

Effect of delay time

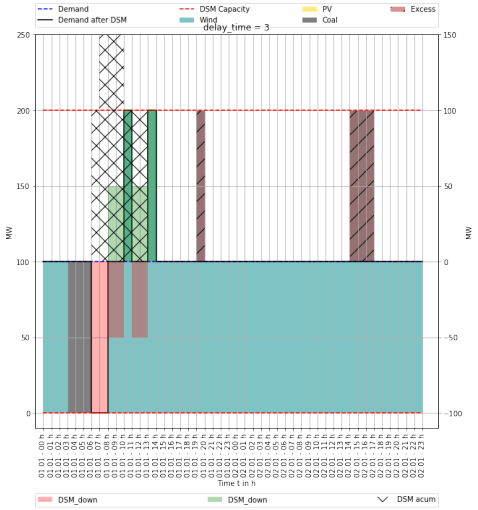


Delay time: 2

What's happening

- Longer delay times allow for more DSM shifts exceeding the delay time

Effect of delay time

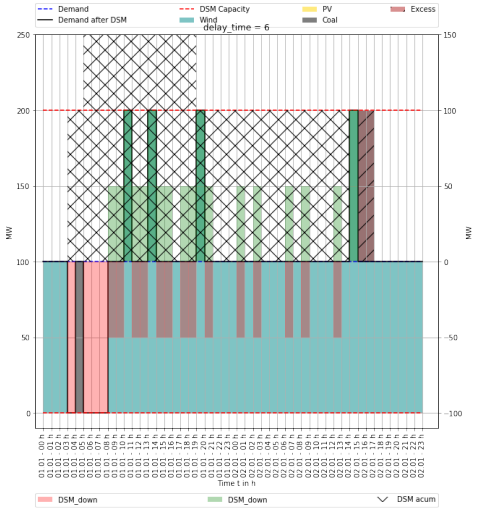


Delay time: 3

What's happening

- ...and more

Effect of delay time

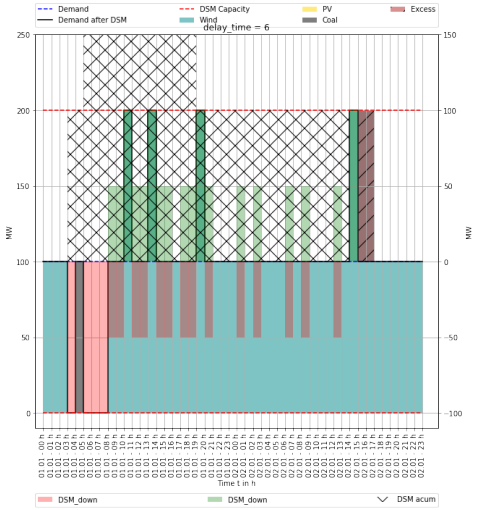


Delay time: 6

What's happening

- and even more

Effect of delay time



Delay time: 6

What's happening

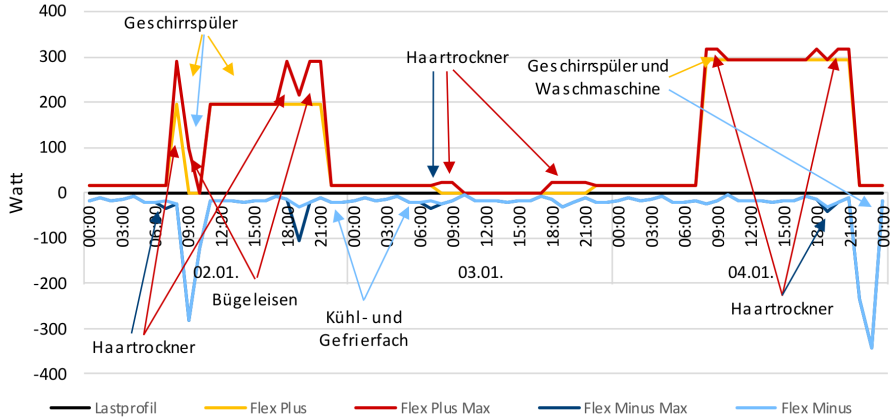
- and even more

But...

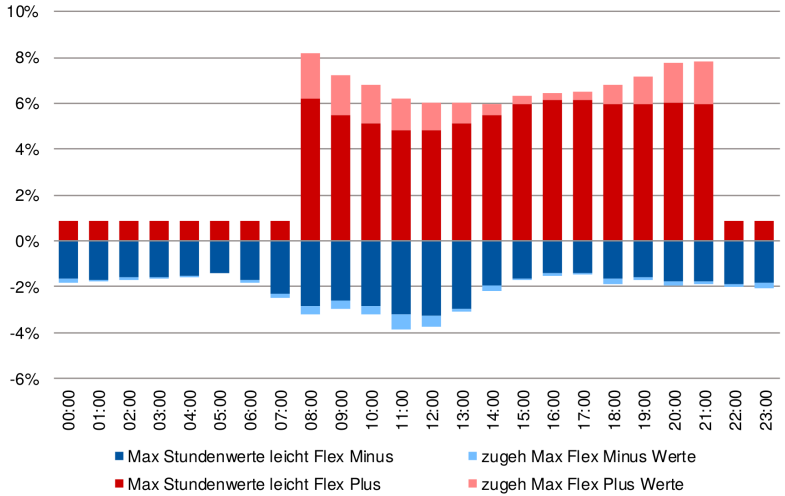
the modeler interprets his/her results!

DSM modeling for households

Available data: technical DSM potential for groups of households



DSM potential



DSM formulation 2: Interval

The dataset for DSM potential does not allow to shift energy across days!

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$$\dot{E}_t = demand_t + DSM_t^{up} - DSM_t^{do} \quad \forall t \in \mathbb{T} \tag{6}$$

DSM formulation 2: Interval

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$$DSM_t^{up} \leq E_t^{up} \quad \forall t \in \mathbb{T} \tag{7}$$

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$$\sum_{t=t_s}^{t_s+\tau} DSM_t^{up} = \sum_{t=t_s}^{t_s+\tau} DSM_t^{do} \quad \forall t_s \in \{k \in \mathbb{T} \mid k \mod \tau = 0\} \tag{9}$$

DSM formulation 2: Interval

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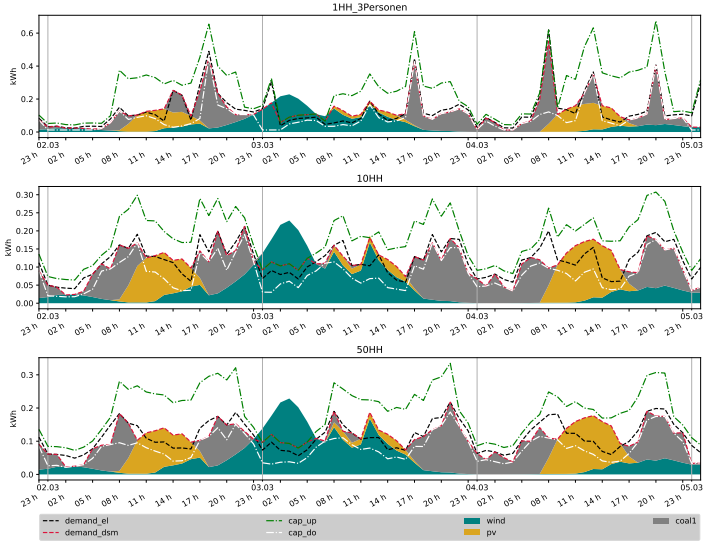
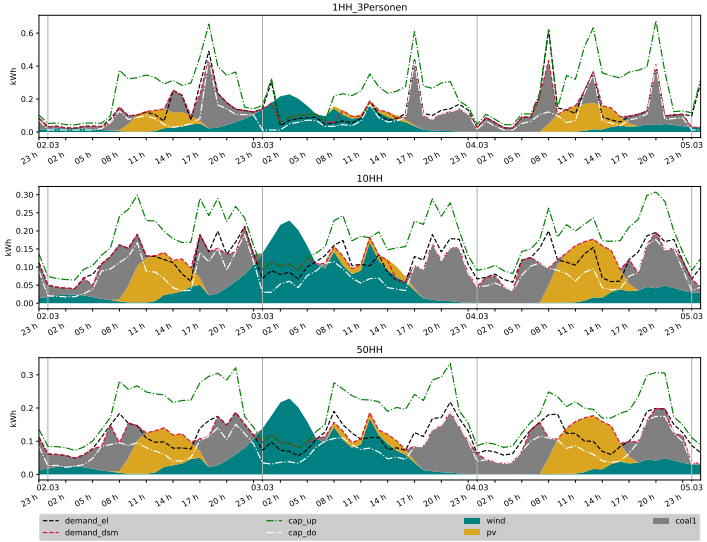
Using $\tau = 1$ sets the window for DSM activity to exactly one day.

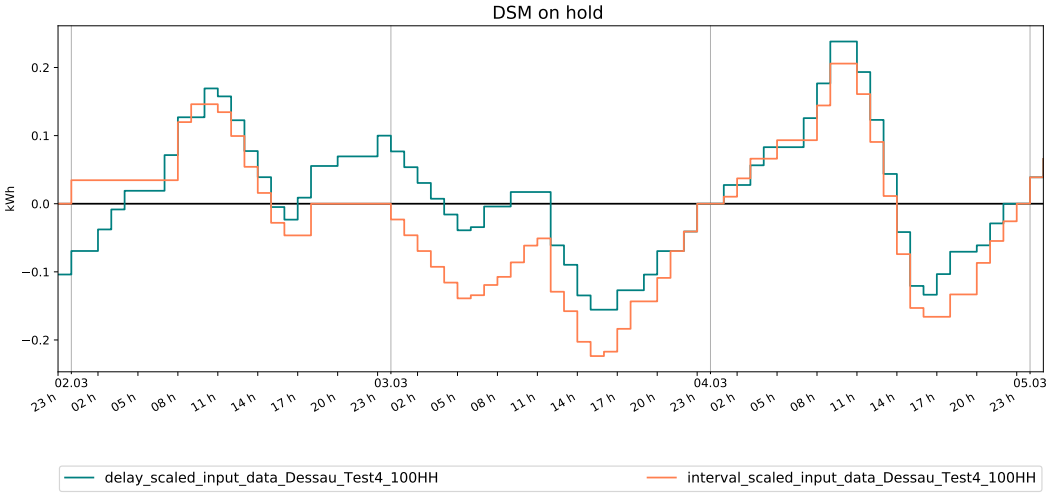
Comparing both formulations – delay method



Comparing both formulations – interval method



DSM energy on hold



Comparison by numbers

	demand_el	dsm_tot	excess	cap_up	cap_do	wind	pv	coal
1 HH 3 P. [delay]	91.0	18.0	43.0	109.0	34.0	96.0	15.0	23.0
10 HH	92.0	14.0	42.0	59.0	27.0	96.0	15.0	22.0
50 HH [delay]	89.0	13.0	43.0	57.0	27.0	96.0	15.0	21.0
100 HH [delay]	88.0	13.0	44.0	53.0	26.0	96.0	15.0	21.0
1 HH 3 P. [interval]	91.0	18.0	44.0	109.0	34.0	96.0	15.0	24.0
10 HH [interval]	92.0	12.0	43.0	59.0	27.0	96.0	15.0	23.0
50 HH [interval]	89.0	11.0	44.0	57.0	27.0	96.0	15.0	22.0
100 HH [interval]	88.0	11.0	45.0	53.0	26.0	96.0	15.0	22.0

Discussion

1. Who plans to model DSM with oemof.solph in the near future?
2. Further development of `SinkDSM`
   - Move to `solph.Components` by v0.4.0?
   - Responsibility for `SinkDSM`?
   - Roadmap

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