A Tool for Optimal Operation and Design of Batteries and its Applications to Self-Consumption

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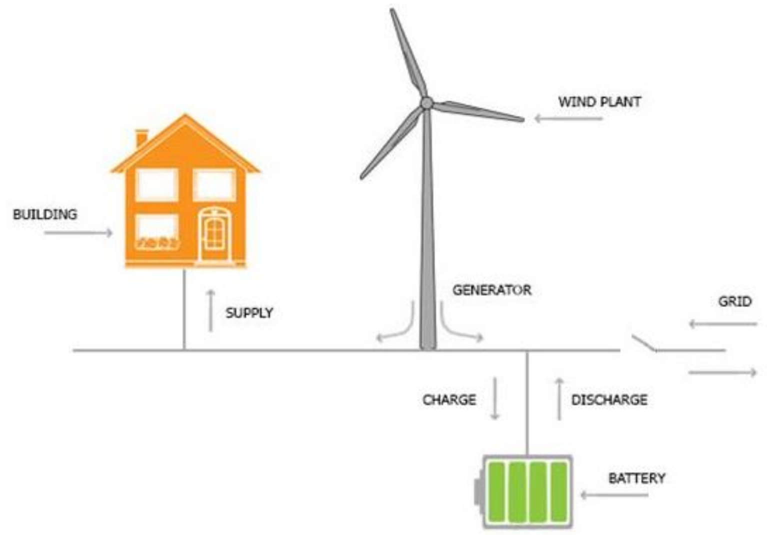
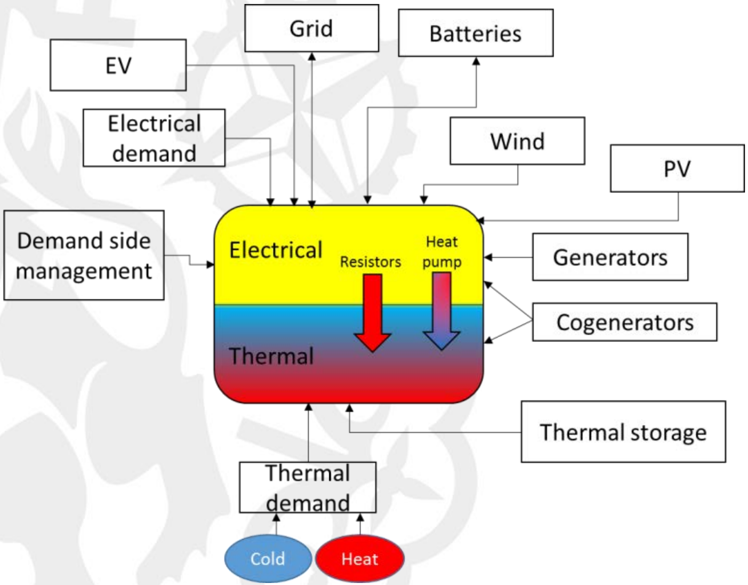
Introduction

- Battery storage is key for off-grid, microgrids and self-consumption systems.



Introduction

- Analyzing profitability requires an appropriate model.



Mathematical formulation

- The objective function is the sum of total costs of the system.

$$\min \sum_{g,ess,h} \left(c_{ren,h} + c_{ess,h} + c_h^{grid} - c_h^{feed} + c_{shed,h} \right)$$

- A mixed-integer linear programming solver is used.

Mathematical formulation

- The cost of operating the batteries is the sum of penalization costs:

$$c_{ess,h} = C_{ess}^{fix} \cdot \delta_{ess,h} + C_{ess}^{lin} \cdot (p_{ess,h}^{gen} + p_{ess,h}^{con}) + \\ + C_{ess,h}^{cycle} + C_{ess}^{SOCpen} \cdot (E_{ess,h}^{outofmargin}), \quad \forall ess, h$$

$$C_{ess,h}^{cycle} = C_{cycle}^{pen} \cdot \left(\delta_{ess,h}^{charge\_end} + \delta_{ess,h}^{discharge\_end} \right)$$

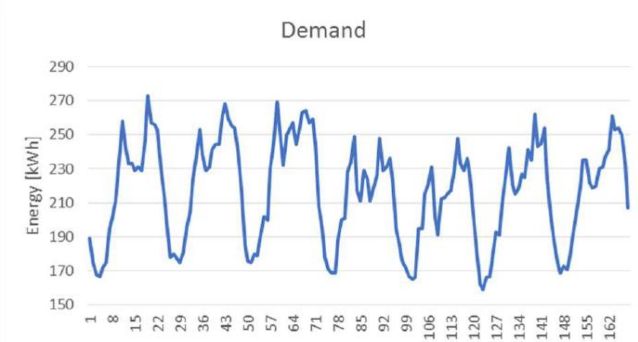
$$E_{ess,h}^{outofmargin} = \begin{cases} E_{ess,h} - E_{ess}^{high} \text{ if } E_{ess,h} > E_{ess}^{high} \\ E_{ess}^{low} - E_{ess,h} \text{ if } E_{ess,h} < E_{ess}^{low} \end{cases}$$

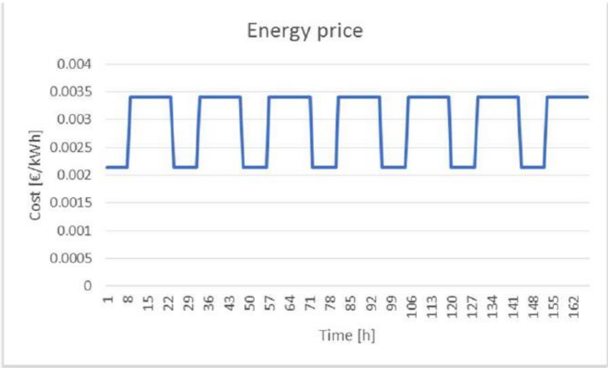
Mathematical formulation

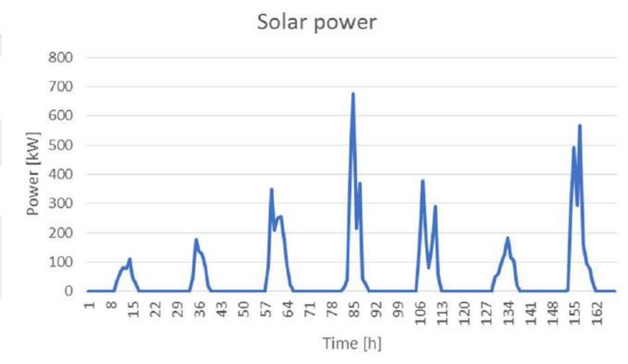
- The connection to the grid has been modelled to allow different configurations:
  - No feed.
  - Feed-in tariff.
  - Net balance:

$$\sum_h (p^{fed}_{grid,h} - p_{feed,h}) = 0$$

Case study: Hotel building







Case study: Hotel building

- Decision elements:

	Max Power (kW)	Max charge (kWh)	High charge (kWh)	Low charge (kWh)	Efficiency
eess1	100	420	420	0	0.94
eess2	200	840	840	0	0.94
eess3	100	500	460	40	0.94
eess4	200	1000	920	80	0.94
eess5	100	1500	1500	0	0.85

	Max Power (kW)	Power term (€/h)
grid1	200	0.27
grid2	300	0.40
grid3	400	0.54

Case study: Hotel building

- Results (no throughput penalization):
  - Low PV:

	Grid 1	Grid 2	Grid 3
No ESS	54927.69	164.29	186.79
ESS 1	4929.46	157.40	178.59
ESS 2	132.30	152.11	172.92
ESS 3	798.14	157.32	179.75
ESS 4	132.31	150.29	173.85
ESS 5	138.29	156.91	179.31

Case study: Hotel building

- Results (no throughput penalization):
  - High PV:

	Grid 1	Grid 2	Grid 3
No ESS	59904.56	165.23	187.73
ESS 1	9192.16	156.84	179.36
ESS 2	129.37	151.21	172.69
ESS 3	6202.17	156.09	178.55
ESS 4	130.82	151.93	172.04
ESS 5	1048.13	156.65	179.93

Case study: Hotel building

- Results (throughput penalization):
  - Low PV:

	Grid 1	Grid 2	Grid 3
No ESS	54927.69	164.29	186.79
ESS 1	4698.58	164.29	186.79
ESS 2	147.94	164.29	186.79
ESS 3	813.91	164.29	186.79
ESS 4	147.95	164.29	186.79
ESS 5	153.31	164.29	186.79

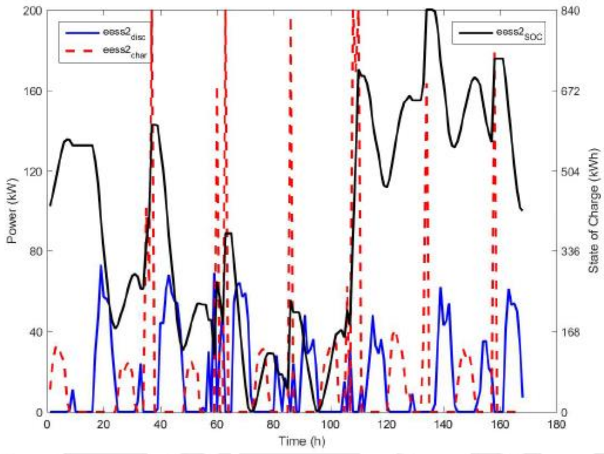
Case study: Hotel building

- Results (throughput penalization):
  - High PV:

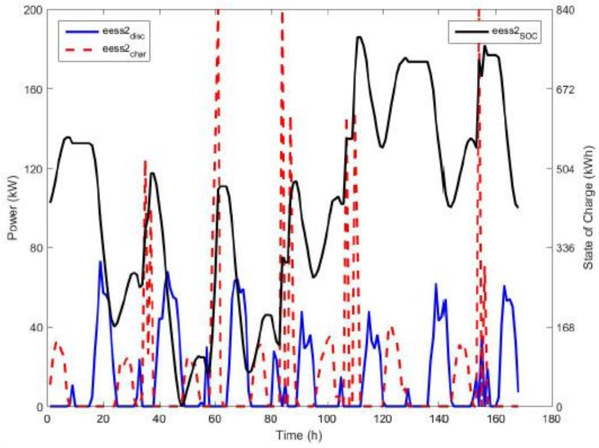
	Grid 1	Grid 2	Grid 3
No ESS	59904.56	165.23	187.73
ESS 1	9179.77	160.06	182.56
ESS 2	146.28	158.49	181.00
ESS 3	6173.48	160.04	182.54
ESS 4	146.28	158.50	181.00
ESS 5	1064.22	159.70	182.20

Case study: Hotel building

- Use of ESS (low PV)
  - No penalization



- Penalization



Conclusions

- A new tool to optimize the size of batteries and maximum power from the grid has been presented.
- A case study has been performed, with the tool determining the best ESS-grid combination for a hotel building.

Thank you!

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