IRES 2016 Poster Exhibition
10th International Renewable Energy Storage Conference

Cost-self-sufficiency-tradeoff in a real-life urban microgrid with electric vehicles

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Motivation

The project aims at installing, testing and demonstrating Berlin's third largest train station Berlin Südkreuz as an intelligent, intermodal traffic hub for different transport carriers. The train station is to be used as a case study for intelligently connecting different energy systems with transportation systems in an urban context and to test and demonstrate new strategies, technologies and processes. One of the project's central aims is to identify optimization potential regarding the original topology design of the local energy system with respect to two key performance indicators, levelized cost of energy (LCOE) as well as the system's energetic self-sufficiency ratio (SSR_e).

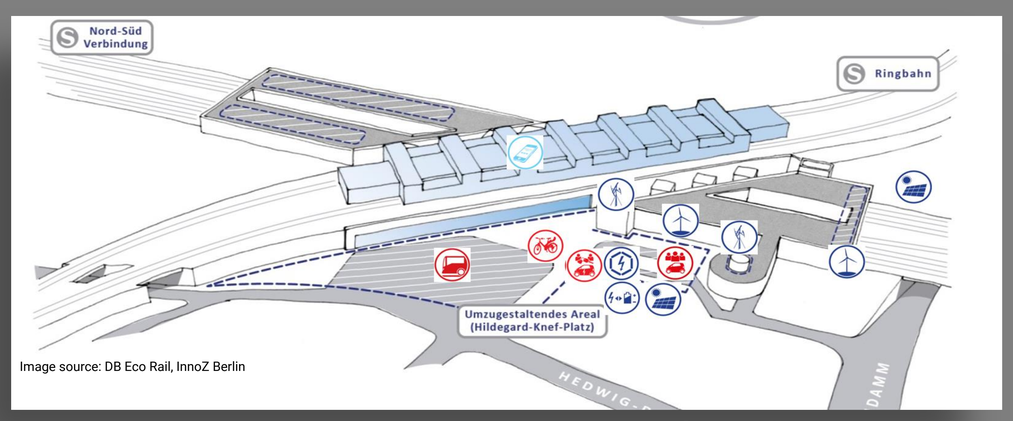


Image source: DB Eco Rail, InnoZ Berlin

Figure 1: microgrid at train station Berlin Südkreuz

Approach and research object

To identify and analyze the optimal tradeoff between LCOE minimization and SSR_e maximization a simulation-based optimization of the component's capacities was conducted using a multi-objective evolutionary algorithm [1]. Techno-economical parametrization of the components is based on the real-life components within the research project.

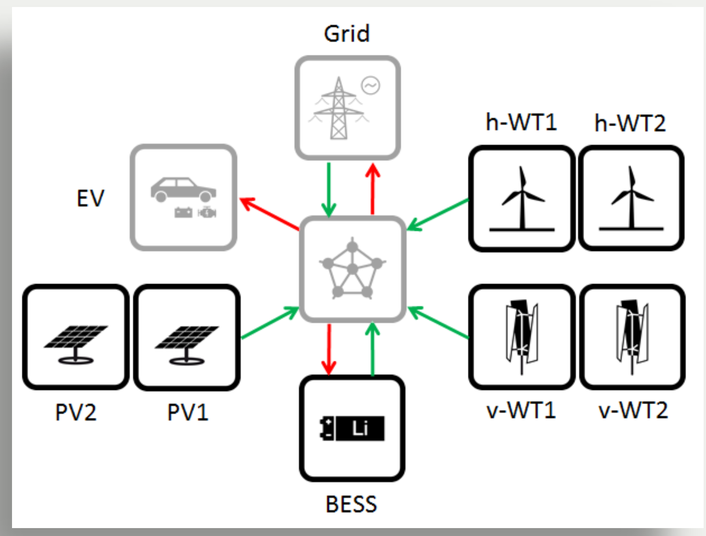
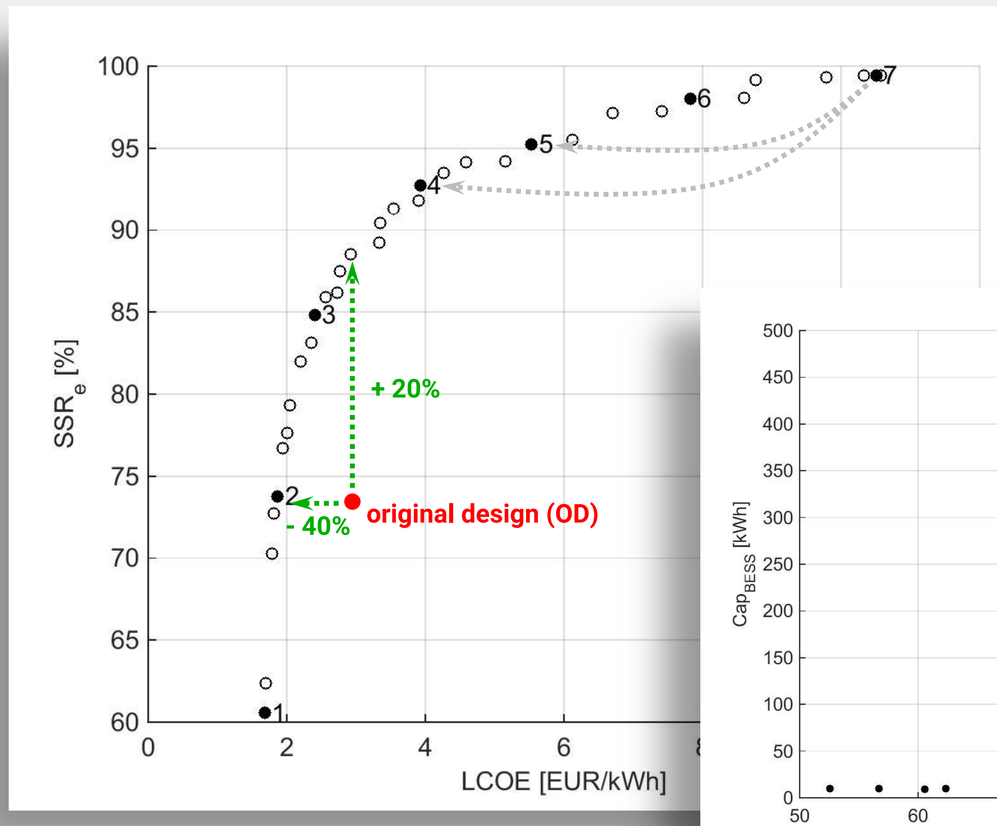


Figure 2: simulation object. microgrid consisting of:

- photovoltaic generators
- horizontal axis wind turbines
- vertical axis wind turbines
- li-ion battery electric storage system
- electrical grid
- electric vehicle fleet

Results



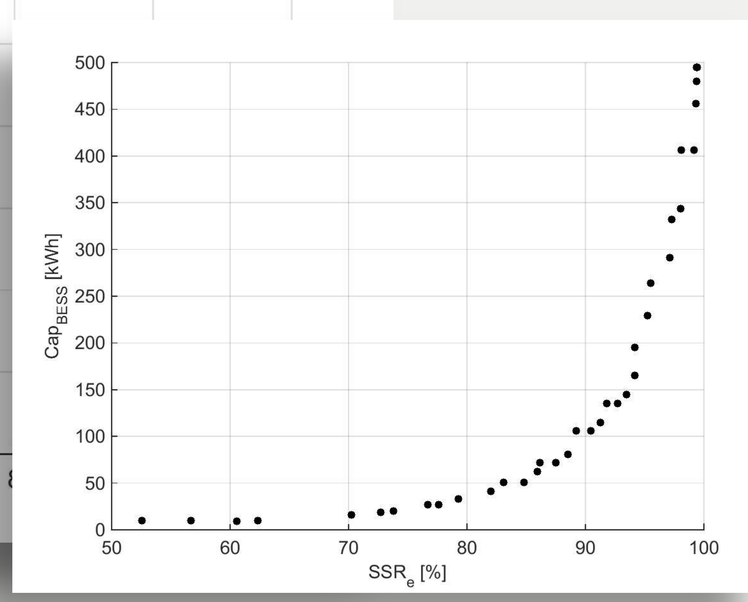


Figure 3: optimal tradeoff between LCOE and SSR_e. Optimziation potential exists for both objecitves (-40% LCOE or +20% SSR_e) compared to the original design. However, ultimate self-sufficiency for the microgrid is overproportionally expensive, with the last 5% of SSR almost doubling LCOE.
Results also indicate that small-scale wind power is less feasible than PV as a renewable source of power within the urban context with regards to cost but may be considered with respect to self-sufficiency.

Figure 4: BESS capacity along pareto. The above described cost increase is largely associated with BESS's capacity, which is largely due to the need for power storage (rather than just energy storage) to achieve higher self-sufficiency ratios.

#	objectives		topology						
	LCOE	SSR	PV1	PV2	v-WT1	v-WT2	h-WT1	h-WT2	BESS
	EUR/kWh	*%*	*kW*	*kW*	*kW*	*kW*	*kW*	*kW*	*kWh*
1	1,7	61	4	4	0	0	6	0	9
2	1,9	74	5	5	0	0	6	0	20
3	2,4	85	8	5	0	0	6	0	51
4	3,9	93	7	12	0	0	6	0	135
5	5,5	95	11	12	0	0	6	0	229
6	7,8	98	9	21	0	0	6	6	344
7	10,5	99	20	21	0	0	6	6	495
OD	3,0	73	7,5	8,5	1	1	6	6	50

Conclusion

Simulation-based optimization of the urban microgrid identified the optimal tradeoff between LCOE and SSR_e, showing potential of improvement for both with regards to the original design.
It could be demonstrated how ultimate self-sufficiency within the urban context is overproportionally expensive and not feasible, due to the need for comparatively large storage capacities.
While small-scale wind turbines seem largely detrimental regarding LCOE, results suggest them as a useful addition for higher self-sufficiencies within the urban context.
In summary, the results exemplify how multi-objective optimization assists the decision maker in gaining better understanding of the objective conflict in order to subjectively choose the best solutions.

References
[1] A. Wanitschke, "Evolutionary multi-objective optimization of micro grids," in Book of Abstracts, EST, Energy Science Technology, International Conference & Exhibition, 20-22 May 2015, Karlsruhe, Germany, 2015.

Funded by:
Die Bundesregierung
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