Scenario Analysis of Battery Storage Technologies for Autarkic Micro-Grids in Rural Energy Distribution Systems

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I. Introduction

Communities possess a high potential for using renewable energies and storage technologies can increase their degree of autarky [1, 2]. The township Bordelum (North Frisia, Germany) aims at both switching completely to renewable energy resources and implementing a self-sufficient electrical supply [3, 4].

Therefore, this study identifies Bordelum's current state of electrical autarky, and suggests scenarios that optimize the level of electrical independence. Furthermore, we calculated the loadflow effect on the grid. An increasing maximum peak load could lead to expensive grid-upgrades. For this purpose, we analyzed seven study cases and compared them to the actual state.

II. Methods

- A developed Matlab/Simulink Model simulated the energy usage of 2015
  - Residential buildings: Local standard load profile [5] based on the Zensus (2011) [6] was constructed by using the load profile generator from the TU Chemnitz [7]
- PV-Plants
  - A local small open field reference-plant delivered weather-influenced energy production data
  - Residential Buildings: 32 plants & 2,340 kW_P [8]
  - several ground-mounted plants: 2,510 kW_P [8]
- Wind data
  - Provided by the DWD [9]

Table 1:Quantity of buildings, used load profiles and amount of electric energy consumption ([A] Others: Shop (G1), hairdresser (G4), physiotherapist (G1), inn (G2), workshop (G1), kindergarten (G1) & 60 street lights á 0.04 kW)

Type of building	Number of sites	Load profile	Consumption [kWh] ([%])
Residential buildings	172	H0-Dörpum	658,385 (67)
Dairy farm	3	L1	125,000 (13)
Sow mast farm	1	L0	120,000 (12)
Others [A]	67	G1, G2, G4, SB0	82,296 (8)
Total	243 (100%)		985,681 (100)

- Quantification of the autarky-degree a by Quaschning's formula
  - Describes the relation between the energy which is covered by self-produced energy ($\bar{P}_{own}$) and the total needed energy of the examined system ($\bar{P}_{cons}$) within Δt [10]

$$a = \frac{\sum \bar{P}_{cons} \cdot \Delta t - \sum \bar{P}_{delivered} \cdot \Delta t}{\sum \bar{P}_{cons} \cdot \Delta t} = \frac{\sum \bar{P}_{own} \cdot \Delta t}{\sum \bar{P}_{cons} \cdot \Delta t}$$

III. Results

- Analysis revealed a current degree of autarky of 47%
- All analyzed scenarios (Tab. 2) lead to enhancements (Fig. 1)
- 100% of autarky is already possible if using existing CHP
- Except two, all scenarios lead to a higher maximum peak load (Fig. 1)

Table 2:Description of all study cases

Study case	Description
I	Refitting all existing PV-plants on residential buildings with a battery storage; 8-10 kWh, 5 kW (in) / 4,6 kW (out)
II-a	All residential buildings: 9.7 kWp PV-plant and 4.9 kWh battery; 5 kW (in) / 4,6 kW (out)
II-b	Same settings, but 9.7 kWh battery;
III	Redox-flow battery for local distribution system; 2,200 kWh, 1 MW in/out
IV	Wind power plant for local distribution grid (1 MW)
V	Small Redox-flow battery (560 kWh, 1 MW in/out) combined with wind power plant (1 MW)
VI	Using existing CHP (875 kW_{el}) for electrical coverage

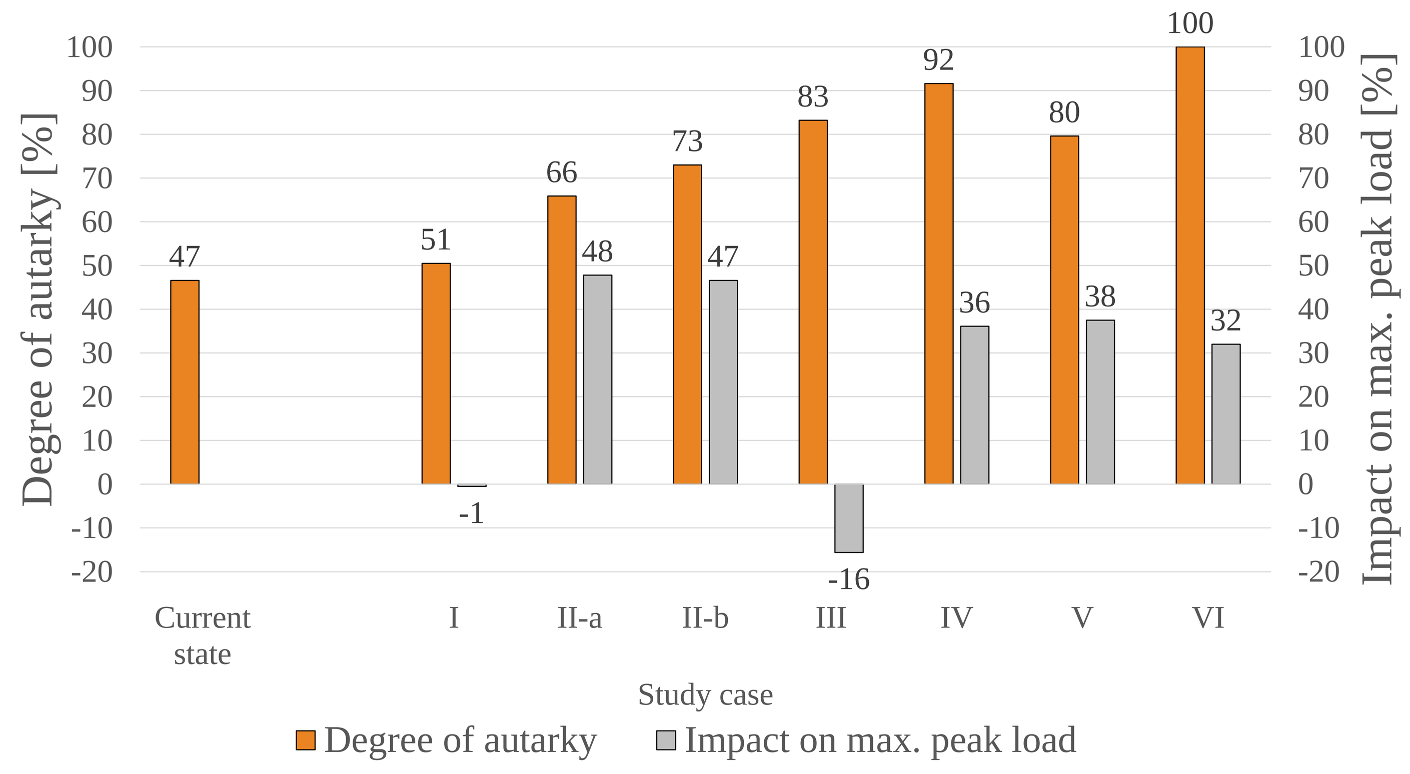

Figure 1: Results for every study case in comparison with the current state

IV. Conclusion

A Redox-Flox battery within the distribution grid leads to a high degree of autarky (83%) and also lowers the maximum peak load (-16%). Considering our analysis, we advise to use central storage technologies.

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V. References

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