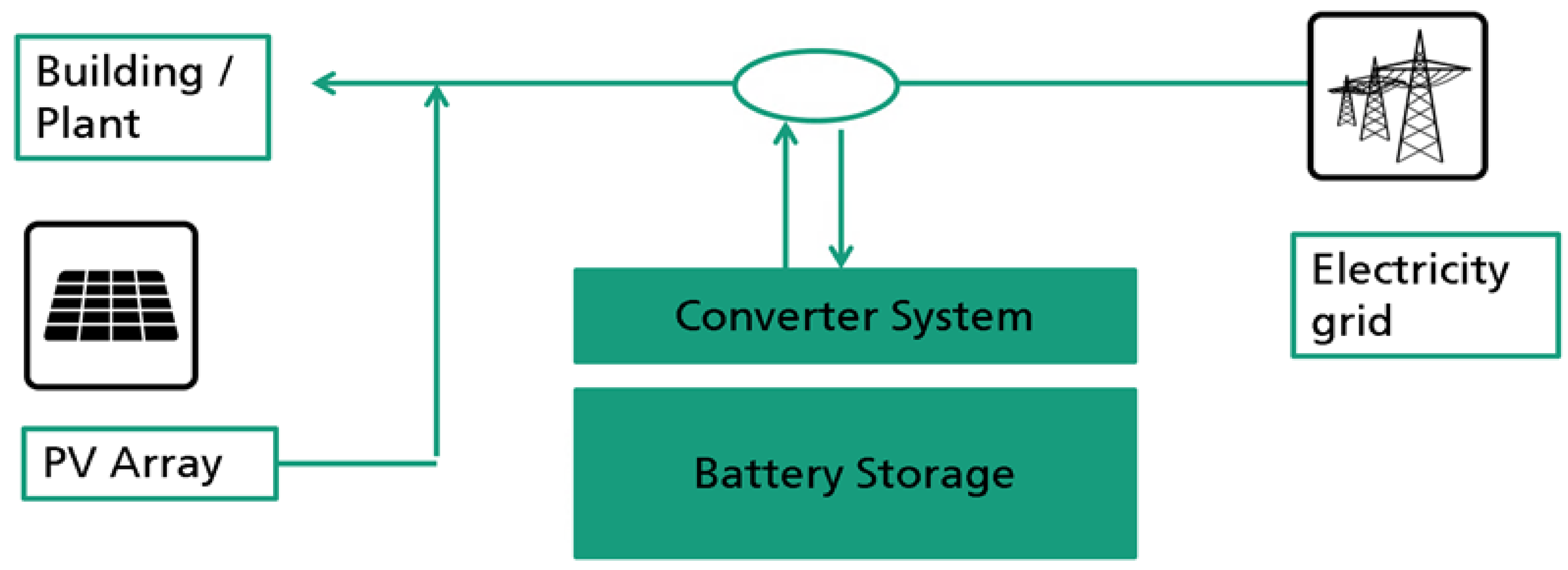
Getting closer to reality? Peak-Shaving with Battery Systems in Commerce and Industry

A. Groß, L. Kreilgaard, B. Köpfer, M. Kühnbach
Corresponding author email: arne.gross@ise.fraunhofer.de

Abstract

In recent years, a battery prices have dropped significantly while electricity prices have increased. This makes battery energy storage systems (BESS) profitable business cases. Various use cases exist such as peak-shaving, PV self consumption or providing frequency containment reserve. In most literature studying these use cases, perfect foresight for future electricity load is assumed, prohibiting real world application. This work aims to investigate this issue by developing methods for load forecast as well as for control using these forecasts.



Schematic Overview of Simulation Model: A BESS is connected to the plant's AC system that includes a PV generator as well. The resulting power at the grid connection point determines the costs

Motivation

PV Battery Systems become more economically attractive in Commerce and Industry

Load Peaks entail Costs

PV generation can exceed load for small companies

Contributions

Forecasting Load Peaks

Defining Economic Objectives

Control Algorithm for Peak-shaving and Self-Sufficiency

Forecasting Peaks of Electric Load

- Load Forecasting is a widely explored topic
- The RMSE is the most common performance criterium
- This can not describe the accuracy with respect to forecasting peaks of electric load

→ Generate and evaluate load forecasts for load peaks

Used metrics

- Root-Mean-Square-Error (RMSE)
- RMSE for energy above a certain threshold
- Peak-Absolute-Percentage Error (PAPE)

Used Forecasting Methods

Supervised Machine learning using explanatory variables of the time series (time of the day, weekday, holidays, …)

- Persistence ("Today is exactly as last week")
- Generalized Linear Model
- Multilayer Perceptron
- K-Nearest-Neighbor

Table 1: Accuracy of Load Forecasts

Metric	Pers.	MLP	GLM	KNN
RMSE / kWh	348.0	348.0	298.1	265.9
PAPE / %	74.6	229.4	254.9	595.6
RMSE[abv] / kWh	322.8	345.2	234.5	234.5

Control Algorithm for Single and Multi-Use

Peak-Shaving

Keep grid power below inteded load peak and recharge from grid below a threshold power

$$u^{ps} = \begin{cases} -\left(p^r - p^{lim}\right) & if\ p^r > p^{\lim} \\ p^{th} - p^r & if\ p^{th} > p^r \\ 0 & else \end{cases}$$

Optimal Self-Sufficiency

Charge PV power into battery, cover load from battery

$$u^{ss}(\hat{p}_k^r) = -\hat{p}^r$$

Adjust control input due to limitations (bat. Power limits, full/empty battery)

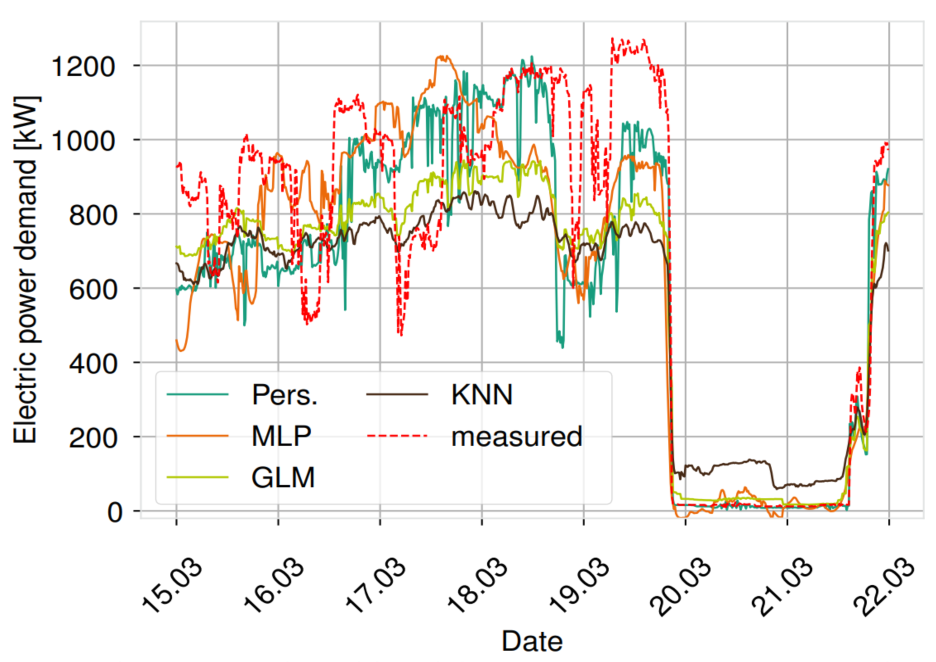
Multi-Use

Forecast residual load above the intended load peak in an 8 h horizon.
Use peak-shaving strategy if load-peak is expected and self-sufficiency strategy otherwise

Evaluation Metrics for Operation

Energy above the intended limit power: E^{abv}

Energy fed to the grid: $E^{pv \to g}$
Max. power drawn from the grid: p^{max}
Self-Sufficiency: Σ^{self}
Idle time while the battery is full: T^{full}



Exemplaric Day-ahead load forecast on 7 consecutive days

Results

Table 2: Results of simulation study

	$E^{pv \to g}$	Σ^{self}	T^{full}	E^{abv}	p^{max}
	[MWh]	%	h	kWh	kW
PS	324.4	15.3	8511.2	0.0	1135.6
SS	270.4	16.7	646.4	6794.0	1265.4
MU Pers	272.2	16.6	1121.8	6618.3	1265.4
MU MLP	272.7	16.6	1240.3	4994.3	1265.4
MU KNN	270.4	16.7	646.4	6794.0	1265.4
MU GLM	270.4	16.7	646.4	6794.0	1265.4
MU Perf	271.4	16.6	870.1	131.8	1135.6

Discussion and Conclusion

Take-Away

- Solely focusing on one business case yields best values regarding that use case
- Using forecasting method, the yearly peak load does not get shaved-off
- Multi-use cases with perfect foresight leads to best values
- Multi-use case reduce idling time at full SOC

Future Research Aspects

- Testing different battery and PV concepts
- Optimizing forecast quality by e.g., customizing loss function
- Generating probabilistic foresights to further reduce unshaveable peaks

Contact

Arne Groß
Data-driven Energy Management for Smart Grids Systems
Fraunhofer institute for Solar Energy Systems
arne.gross@ise.fraunhofer.de