Testing strategies for use of an energy store

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Introduction

A fluctuating renewable energy can be smoothed to provide a more constant source of energy by combining with a battery energy store and carefully choosing the strategy by which to charge and discharge it [1]. The aim of my research is to determine this optimal strategy, making the net energy as smooth as possible, and applying this to the battery store at Warwick University (35 kWh capacity, 95.5% efficiency and 50 kW nominal power) to smooth fluctuations of the photovoltaic energy output of the university.

Theory

Working in discrete time, we have a renewable energy output w_t at time t which we wish to smooth using an energy store. The storage operator chooses the amount of energy x_t to take off the grid by the battery at time t subject to rate and capacity constraints. Let X be the set of strategies satisfying these conditions. The optimisation problem is to find a strategy $x^* \in X$ to minimise the measure of variability of $x - w$ given by

$$C(x) = \sum_{t=1}^{T-1} |(x_{t+1} - w_{t+1}) - (x_t - w_t)|$$

over all $x \in X$. Our algorithm computes this optimal strategy.

Results

Without Rate Constraints

Using the parameters of our battery store, the non-rate constrained algorithm was used to smooth the photovoltaic energy of the university over the course of a year. $C(x^*)$ was reduced from 37.8 MWh to 16.6 MWh, and the required power exceeded the nominal power of the battery on only three discrete time steps.

With Rate Constraints

Lower rates are often preferred to prevent battery degradation. Maintaining the parameters, the rate constrained algorithm was used with a rate constraint of 20 kW, which increased $C(x^*)$ by just 8%.

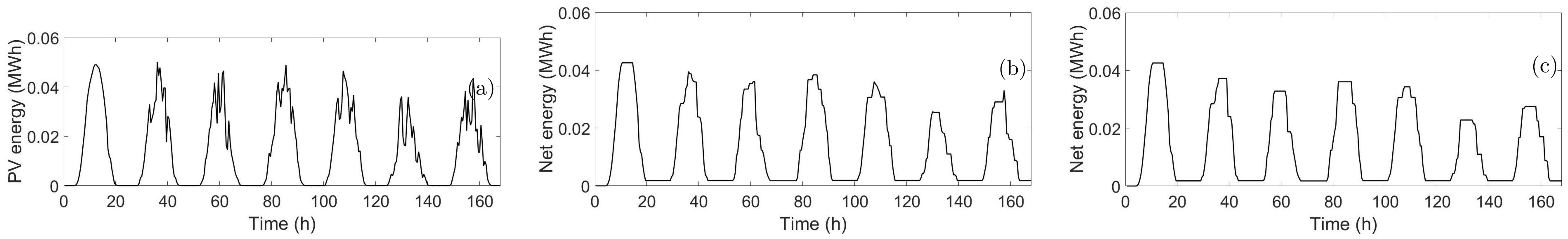

Figure 1: (a) Photovoltaic energy over one week. (b) Net energy due to rate constrained algorithm over one week. (c) Net energy due to non-rate constrained algorithm over one week.

Time Horizons

At each step of the algorithm, predictions of the photovoltaic energy up to some point in time (called the *time horizon*) are required.

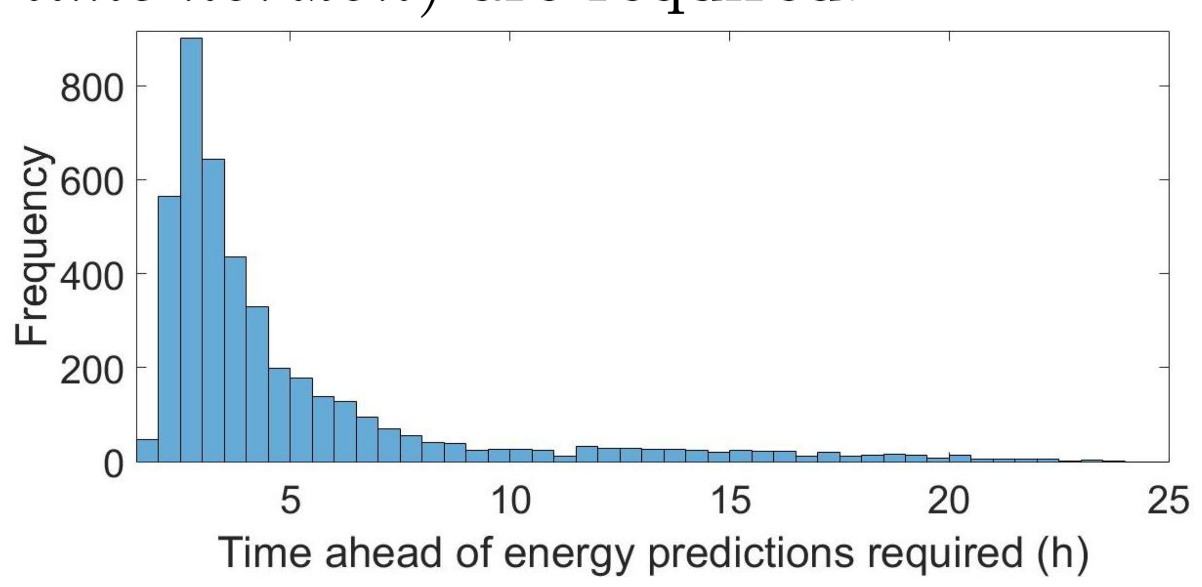

Figure 2: Histogram of time horizons from non-rate constrained algorithm over one year

Future Developments

The cost optimisation of using lower rate constraints could be researched.
Increasing the capacity of the store reduces the total variation, but increases the mean time horizon. To counter this, more research could be made using stochastic energy predictions.

Acknowledgements

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References

[1] L. Flatley, R.S. MacKay, M. Waterson: *Optimal strategies for operating energy storage in an arbitrage or smoothing market*, JDG 3(4) (2016), pp371-398