Testing strategies for use of an energy store

Joe Tilley j.tilley@warwick.ac.uk
Supervisor: Robert MacKay
WARWICK
THE UNIVERSITY OF WARWICK
Warwick Mathematics Institute

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.

Method

Suppose we have a renewable resource w_t which we wish to smooth using an energy store. The storage operator chooses the amount of energy x_t to enter the store subject to rate and capacity constraints. Let X be the set of strategies satisfying these conditions. Energy losses due to operational inefficiencies are captured through a function α. The optimisation problem is to find a strategy $x^* \in X$ such that

$$C(x^*) = \min_{x \in X} C(x)$$

where

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

is the discrete analogue of total variation. Our algorithm computes this optimal strategy.

Results

Without Rate Constraints

Using the parameters of the battery store at Warwick University (35 kWh capacity and 95.5% efficiency), the non-rate constrained algorithm was used to smooth the photovoltaic energy of the university over the course of a year. The total variation was reduced from 37.8 MWh to 16.6 MWh, and the required power exceeded the nominal power of the battery (50 kW) on only three discrete time steps.

With Rate Constraints

Lower rates are often preferred to prevent battery degradation. Maintaining the parameters of the battery store, the rate constrained algorithm was used with a rate constraint of 20 kW, which increased the total variation by just 8%.

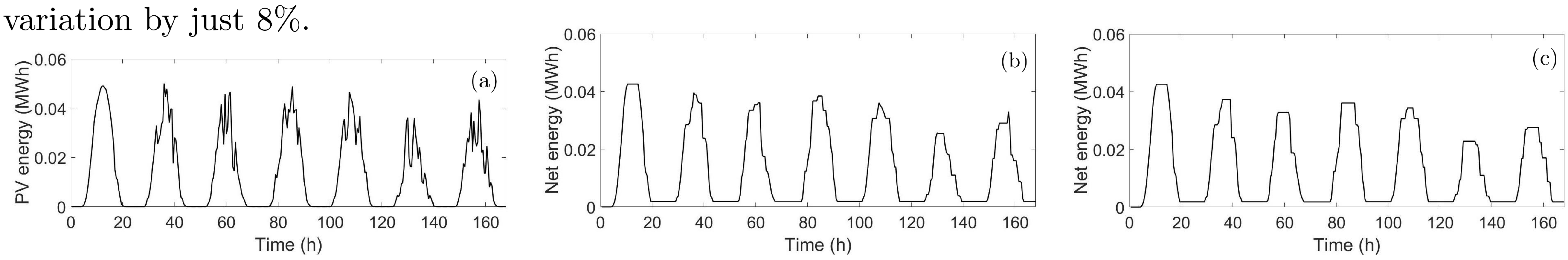

Figure 1: (a) Photovoltaic energy over one week. (b) Net energy due to rate constrained algorithm over one week. (c) Net energy due to non-rate constrained algorithm over one week.

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.

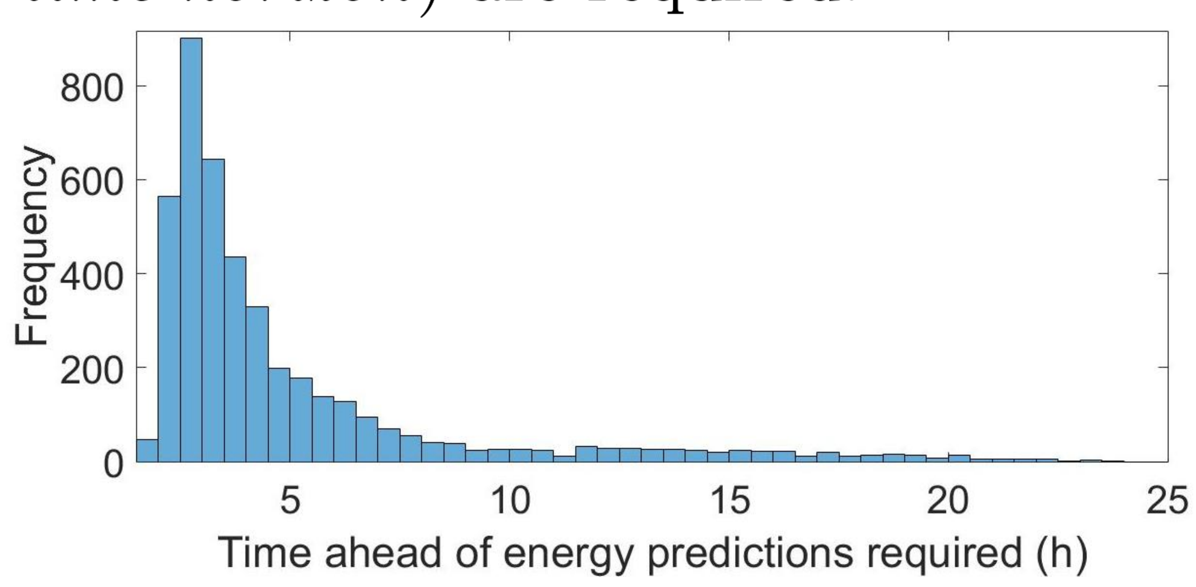

Figure 2: Histogram of time horizons from algorithm over one year

Future Developments

The cost optimisation of using lower rate constraints and higher total variation could be explored. Increasing the capacity of the store reduces the total variation, but increases the mean time horizon. To counter this, more research could be done 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